Ownership status influences the degree of joint facilitatory behavior.

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Abstract

When engaging in joint activities, humans tend to sacrifice some of their own sensorimotor comfort and efficiency to facilitate their co-actor's performance. Here, we investigated if ownership - a socio-culturally based non-physical feature ascribed to objects - influences facilitatory motor behavior in joint action. Participants passed mugs that differed in ownership status across a table to a co-actor. Across two experiments, we found that participants oriented the handle less towards their partner when passing their own mug relative to a mug owned by their co-actor (Experiment 1) and a mug owned by the Experimenter (Experiment 2). These findings indicate that individuals plan and execute actions that assist collaborators, but less so if it is the individual's own property that the partner intends to manipulate. We discuss these findings in terms of underlying variables associated with ownership and conclude that a 'self-other distinction' can be instated in the human sensorimotor system.

Keywords: ownership, joint action, beginning state comfort, action prediction, response selection, shared task representation, self-relevance.

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People have sophisticated and flexible internal models of action that allow effective action planning when individuals act alone (Wolpert & Flanagan, 2001). Individuals can also incorporate or adapt internal models to account for other agents (Flanagan & Johansson, 2003; Welsh, Wong, & Chandrasekharan, 2013). This extension or adaptation of individual internal models to "others" allows humans to predict action outcomes on the basis of dynamically unfolding observable events performed by those around them. These internal models of action can also be influenced by shared task representations and goals established prior to action execution (Sebanz, Bekkering & Knoblich, 2006). For example, when passing an object to a partner, knowing the co-actor's intention allows the passer to activate the appropriate internal model to predict the manner in which their co-actor will use the object. Predictions based on the activation of this model in turn leads the passer to spontaneously orient that object to a more comfortable position for their partner (Ray & Welsh, 2011). Known as the 'beginning state comfort effect', this facilitatory behavior can be seen with a range of objects including hammers and calculators (Gonzalez, Studenka, Glazebrook & Lyons, 2011).

Actionable objects, however, are not solely defined by their physical features. They are also defined by non-physical (conceptual) features such as aesthetic qualities, value, and ownership status. In the case of ownership, self-owned objects enjoy elevated importance with regards to a number of psychological variables including attention (Turk et al., 2011) and memory (Cunningham, Turk, MacDonald & Macrae, 2008). Interestingly, ownership has also been shown to influence physical interactions with objects when individuals act alone: 1) actors reach lower peak accelerations when lifting someone else's object than when they lift their own object; and 2) actors' movements are consistent with a general reticence to interact with other people's objects (Constable, Kritikos, & Bayliss, 2011; Constable, Kritikos, Lipp

& Bayliss, 2014). These effects reflect important biases in attachment, preference, and perhaps learned motor programs (see Constable et al., 2014 for a discussion) that alter the manner in which people plan and produce actions toward objects. The present study was conducted to determine if the conceptual feature of object-ownership influences action planning and execution in dyadic interactions.

Given that ownership is socially-based, it stands to reason that the ownership status of an object may shape action planning in social (joint) interactions. This extension is founded on previous work showing that social factors related to the co-actor influence the emergence of joint action effects. For example, joint action effects based on the co-representation of action are stronger when the relationship between two co-acting agents is positive than when the relationship is negative (Hommel, Colzato & van den Wildenberg, 2009). In such joint action studies (Sebanz, Knoblich & Prinz, 2003; Welsh et al., 2005), however, the social environment is incidental to the task because participants perform independent tasks beside another individual. These scenarios may not reflect what occurs in more dynamic and interactive task environments that afford a level of real world applicability and cooperation as rooted in predictions based on internal models of actions. In the present experiments, we investigated how the attribution of ownership status to an object could influence the everyday act of passing that object between two people. In Experiment 1, we determined if an action goal modulates the effect of ownership on joint action performance, and in Experiment 2, we determined if the status of the relationship between the participant and the owner of the object moderates the effect of ownership in joint action.

Experiment 1

Pairs of participants were given a mug to keep prior to the testing session. One-to-two weeks after selecting their mug, participants completed a task in which they passed either their own mug or their partner's mug across a table to their partner. Their partner (co-actor)

then either acted upon the mug (joint action condition) or remained stationary (no action condition). We recorded the angle of the mug's handle relative to the partner's hand to determine (1) how passers would orient the mug based on their partner's task, and (2) if the ownership status of the object modulated any joint action effect.

Given previous findings associated with beginning state comfort (Ray & Welsh, 2011), we expected that an overall facilitatory behavior would emerge in the joint action condition - the handle would be rotated further towards the partner's optimal grasping angle in the joint action condition compared to the no action condition. Further, if ownership modulates all types of actions, then an ownership bias will be present in both the joint action and the no action condition. However, if the context of the action interacts with ownership, the effect of ownership status will only be present in the joint action task in which receiver actually interacts with the object.

Method

Participants.

Thirty-eight right-handed participants (18-25 years old [*M*=21.40, *SD*=2.26], 13 males) were recruited in pairs from the University of Toronto academic community. We set a target of 20 pairs based upon pilot research, however, only 19 of the recruited 20 attended both sessions. One pair dropped out of the study prior to the testing session. All pairs of participants were friends. All participants provided written informed consent prior to testing and received $10 CAD and a mug to keep ($1.50 CAD). The procedures were approved by the Health Sciences Research Ethics Board of the University of Toronto and complied with the ethical standards outlined in the Declaration of Helsinki (1964).

Stimuli and Apparatus.

Owned Objects. Each person in a pair received a different mug to ensure that participants could distinguish between their own mug and their partner's mug. All mugs had

the same shape, and a simple design of lines and a maple leaf (coloured red). The only thing that differed between the mugs was the background colour.

***Motion capture system*.** The location of each participant's hand and the mug was recorded using an 8 camera Qualisys Oqus-1 motion capture system (Qualisys AB, Gothenburg, Sweden). Four infrared reflective markers were attached to each participant's right hand (index finger and thumb tips) and wrist (at the radius and ulna). Four additional markers were attached to the rim of the mug spaced equidistantly.

Procedure and Design.

Participants were tested in pairs and attended the laboratory twice. During the first meeting, each participant was given a mug and asked to take it home or to work and use it on a daily basis. They were specifically instructed that no one else was to use this mug to avoid the possibility of diluting the self-object association or the feeling of psychological ownership. Participants returned to the laboratory 6 - 14 days (M = 9.35, SD = 1.95) later for testing.

During the second session, the pairs sat at a table across from each other with their right hands resting on the table at a marked location approximately 10cm from the edge of the table. Participants were instructed to rest their hands on the table with the thumb and forefinger gently opposing. The experimenter, who was located at the end of the table between the two participants, placed a mug in front of the participant who was acting as the *passer* on a given trial. The mug was oriented parallel to the table edge and with the handle pointing right. When the experimenter said 'go' the passer picked up the mug and placed it in front of their partner (the *co-actor*). The passer was told to pass the mug in a natural manner using their right hand. They were not given any additional instructions on where or how to pass it.

There were two 'partner' conditions. In the action condition, the co-actor (receiver) would pick up the mug using the handle, lift it, and then place it back down on the table. In the no action condition, the co-actor was instructed to remain stationary after the passer placed it on the table. Partners were informed if an action or no action was required prior to the beginning of a block of trials. The participant who acted as the passer randomly varied on a trial-by-trial basis and participants became aware of the role they were playing when the experimenter placed the mug in front of them. The handle always started parallel to the edge of the table and oriented toward the hand. The mug was always empty. Each pair completed two blocks of 120 trials. Action/no action conditions were blocked and the order counterbalanced between participant groups. Passing participant and ownership of the mug were fully randomised within each block.

Data Processing.

The data were processed in Matlab to derive the critical measure of hand-object angle difference. The measure was chosen on the basis of a pilot experiment using a similar paradigm with promising results (n = 39, between subjects design). Hand-object angle difference represents the orientation of the mug handle relative to the receiving participant's hand and was calculated on the basis of the angle of the line made by the index finger marker and the radius marker of the wrist and the line made by the mug handle (Figure 1a; inset panel). The measure can be characterised as a participant-centered measure that incorporates the co-actor's hand orientation. Essentially, the measure represents how much farther the mug would need to be rotated to be perfectly matched with the hand angle regardless of the direction. Note that absolute values were computed. Therefore, the measure would result in the same value when the mug needed to be rotated a further 60° in an anti-clockwise or clockwise direction to match the co-actor's hand. A smaller angle would indicate a greater match between the orientation of the hand and mug (possibly indicating more facilitatory

behavior) than a larger angle. Trials on which data recording was poor or incomplete were removed prior to analysis (9%). Please see supplementary materials for the data submitted to inferential statistics.

Results

A 2(Action Condition) X 2(Ownership) repeated measures ANOVA was conducted on the angle difference measure. This analysis revealed two important observations. First, the main effect of Action Condition, $F(1, 35) = 31.13$, $MSE = 5823$, $p < .001$, $\eta_p^2 = .47$, revealed that the participant placed the mug in front of them such that the line of the handle deviated less from the line of the hand when the co-actor had to act on the object (121°) than when the co-actor was not going to act on the object (192°). This finding indicates that the mug handle was rotated closer to the co-actor's hand when the co-actor was to act on it than when the co-actor was not to act on it – a replication of the 'beginning state comfort' effect (Ray & Welsh, 2011). The second, more theoretically-relevant and novel finding was that, although the main effect of ownership did not reach statistical significance, $F(1, 35) = 1.14$, $MSE = 92$, $p = .293$, $\eta_p^2 = .03$, the interaction between action condition and ownership was statistically significant, $F(1, 35) = 4.32$, $MSE = 65$, $p = .045$, $\eta_p^2 = .11$. Planned comparisons revealed that this interaction emerged because the difference between the angle difference for the passer's owned mug and the mug owned by the co-actor was only statistically significant in the action condition (see Figure 1). Specifically, when the receiver was to act upon the mug, the passer oriented it less towards the co-acting receiver when the mug was the passer's own mug than when the mug was owned by the receiver, $t(35) = 2.10$, $p = .04$, $d_z = .35$, 95% CI[0.16,8.82]. When the co-actor was not going to act on the object, the difference between the orientation of the passer's own mug and the mug owned by the co-actor did not reach significance, $t(35) = -.53$, $p = .60$, $d_z = .09$, 95% CI[-5.20,3.04]. Thus, ownership modulated the passer's behaviour only when the receiving co-actor was to act on the object – the passer placed the

mug on the table with the handle of the co-actor's mug was closer to the co-actor's hand angle than the handle of the participant's own mug. The 'ownership effect', that is the difference in final angle between the own mug and the relevant other mug, is explored further in the supplementary materials at an individual participant level.

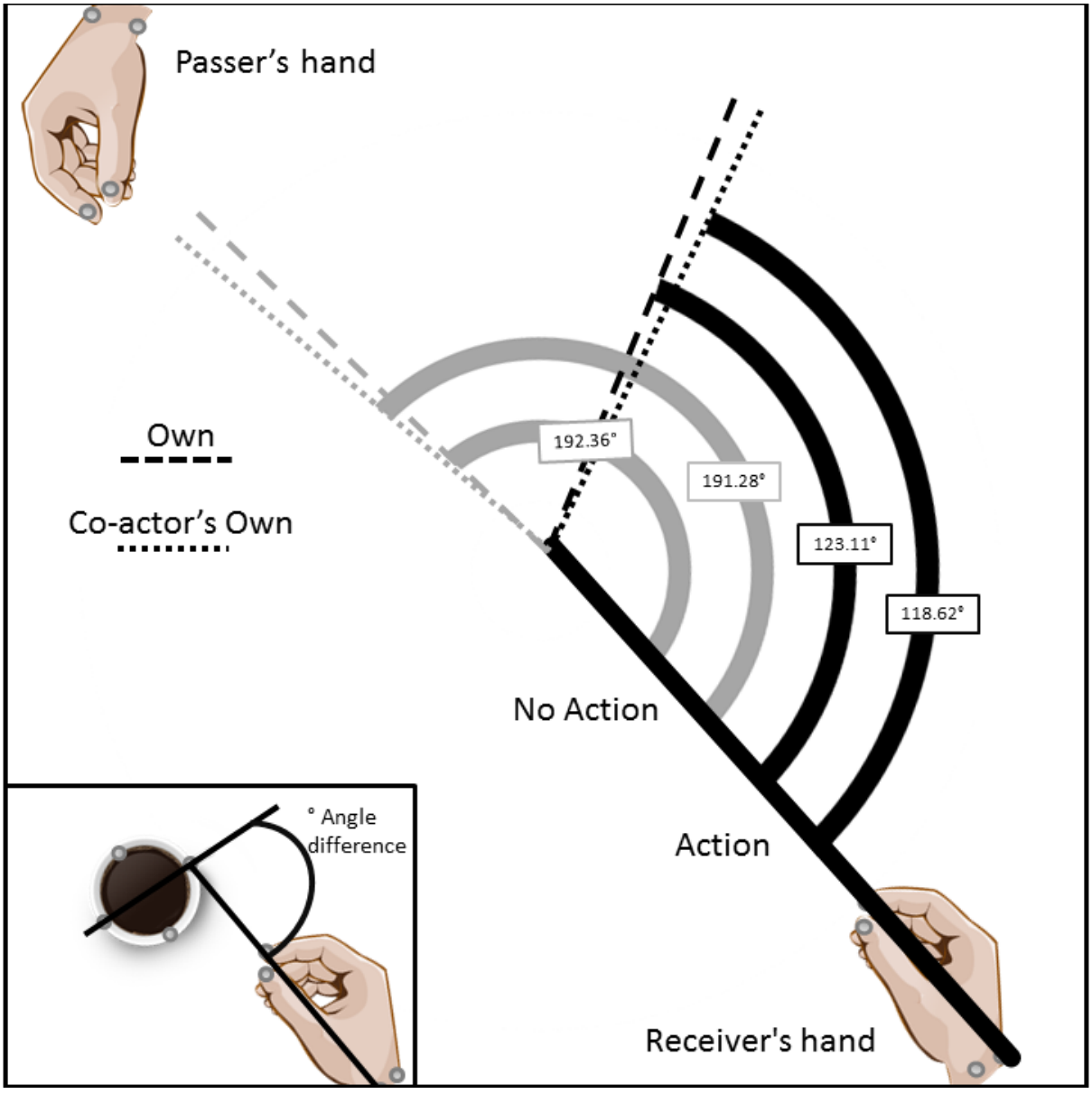

Figure 1. Final angle difference (between mug and receiver's hand) between own mug (or passer's mug) and co-actor's own mug (or receiver's mug) for action and no action is conditions.

Experiment 2

In Experiment 1 our primary finding was that ownership modulated facilitatory behavior in the action condition such that the final position of the co-actor's mug was closer to the co-actor's hand when the co-actor's mug was being passed, as compared to when the participant was passing their own mug. So, do these effects reflect an up-regulation or down regulation of facilitatory behavior dependent on the relative relationship between the owner of the mug and the passer? To this end, a third "experimenter-owned" mug was added to the design because this mug represented an ecologically valid "other-owned" object not owned by the co-actor. Our second question concerned length of ownership because previous research has demonstrated a modulatory effect of time on the ownership effects (Shu & Peck, 2011). In Experiment 2, we retained the longer-term condition but also had participants complete the task immediately after ownership assignment.

Method

Participants.

A total of 46 right-handed participants (18-26 years old (M=20.96, SD=2.34); 13 males) were recruited from the University of Toronto academic community. We aimed to recruit 20 pairs in line with Experiment 1, but eliminated and replaced three pairs of participants because they indicated that they did not believe they were able to keep the mug at the end of the study which invalidated the manipulation of ownership for these individuals. Each participant received $10 CAD per hour in exchange for their time and the mug. All participants provided written informed consent prior to testing. The procedures were approved by the Health Sciences Research Ethics Board of the University of Toronto and complied with the ethical standards outlined in the Declaration of Helsinki (1964).

Owned Objects. Each participant was given a mug to keep (worth approximately $1.50 CAD). The mugs in Experiment 2 were larger (soup) mugs than those used in Experiment 1 because they needed to be wider to accommodate components (battery packs,

wires, and controller) of a different motion tracking system. As such, the mugs were larger and heavier than the mugs used in Experiment 1. All mugs in Experiment 2 were the same size and were distinguishable from each other only on the basis of colour.

Motion capture system. An Optotrak Certus motion capture system (Northern Digital Inc., Waterloo, Ontario, Canada) with a combination of infrared wired and wireless active markers was used for Experiment 2. Two wired markers were attached to the co-actor, one on the tip of their index finger and one at the radial styloid process. A battery pack with three active markers attached to a rigid body was used to record the relative location and orientation of the mug. One marker corresponded to the handle, one to the front of the mug and one to the opposite side of the mug from the handle (see Fig 2 inset). On each trial a total of 5 data points in 3D Cartesian coordinate space were recorded representing one hand and one mug.

Procedure and Design.

The procedure remained the same as Experiment 1 with some slight modifications to the design to account for the different technology used and the specific nature of the research question. First, because we were interested in the effects that the relative relationship between the owner of the mug and the passer had on facilitatory behaviour, we only included the (joint) action condition in which the receiver lifted the mug after it was passed. Second, because were interested in assessing the influences of duration of ownership on the behaviour, the passing task was completed immediately after the participants acquired the mug and again approximately 2 weeks later (12-18 days, M =14.05, SD = 1.05). During the passing task, participants acted as the passer or co-actor for the first 90 trials and then swapped roles for the remaining 90 trials. Within each 90 trial segment, participants passed the Experimenter's mug, their co-actor's mug, or their own mug 30 times each. Unlike

Experiment 1 where ownership and initiator was randomised, both of these conditions were blocked and counterbalanced in Experiment 2.

Data Processing.

The measure used was identical to Experiment 1. One participant broke their mug prior to the second session, and as such, we were unable to collect a complete data set from that pair. As mentioned above, three other pairs did not believe they were able to keep the mug, and as such, they were not included. A further participant who was unable to follow the instruction to place the mug in front of their co-actor was removed. Thus, the final sample included 37 participants. Trials on which data recording was poor, incomplete or divergent from the task were removed prior to analysis (3%). Please see supplementary materials for the data submitted to inferential statistics.

Results.

The 3(Ownership) X 2(Time) repeated measures ANOVA revealed several important findings. First, the main effect of ownership condition, $F(2, 72) = 3.81$, $MSE = 970$, $p = .027$, $\eta_p^2 = .096$, replicated and extended the findings of Experiment 1. Specifically, follow-up comparisons across ownership conditions (collapsed across the time factor) revealed a significant difference between the Experimenter's mug (95°) and the participant's own mug (109°), $t(36) = 2.47$, $p = .02$, $d_z = .41$, 95% CI[2.55,25.81]. The difference between the Experimenter's mug and the co-actor's mug (101°), $t(36) = 1.44$, $p = .16$, $d_z = .24$, 95% CI[-2.56,14.95], and the co-actor's mug and the participant's mug did not reach significance, $t(36) = 1.53$, $p = .14$, $d_z = .25$, 95% CI[-2.60,18.57], respectively (see Figure 2). Second, neither the main effect of time, $F(1, 36) = .001$, $MSE = 3339$, $p = .974$, $\eta_p^2 < .001$, nor the interaction between ownership and time reached statistical significance, $F(2, 72) = 2.13$, $MSE = 437$, $p = .13$, $\eta_p^2 = .06$. Thus, the amount of time owning the object did not modulate the expression of object-ownership in this joint action task. The 'ownership effect', that is the

difference in final angle between the own mug and the relevant other mug, is explored further in the supplementary materials at an individual participant level.

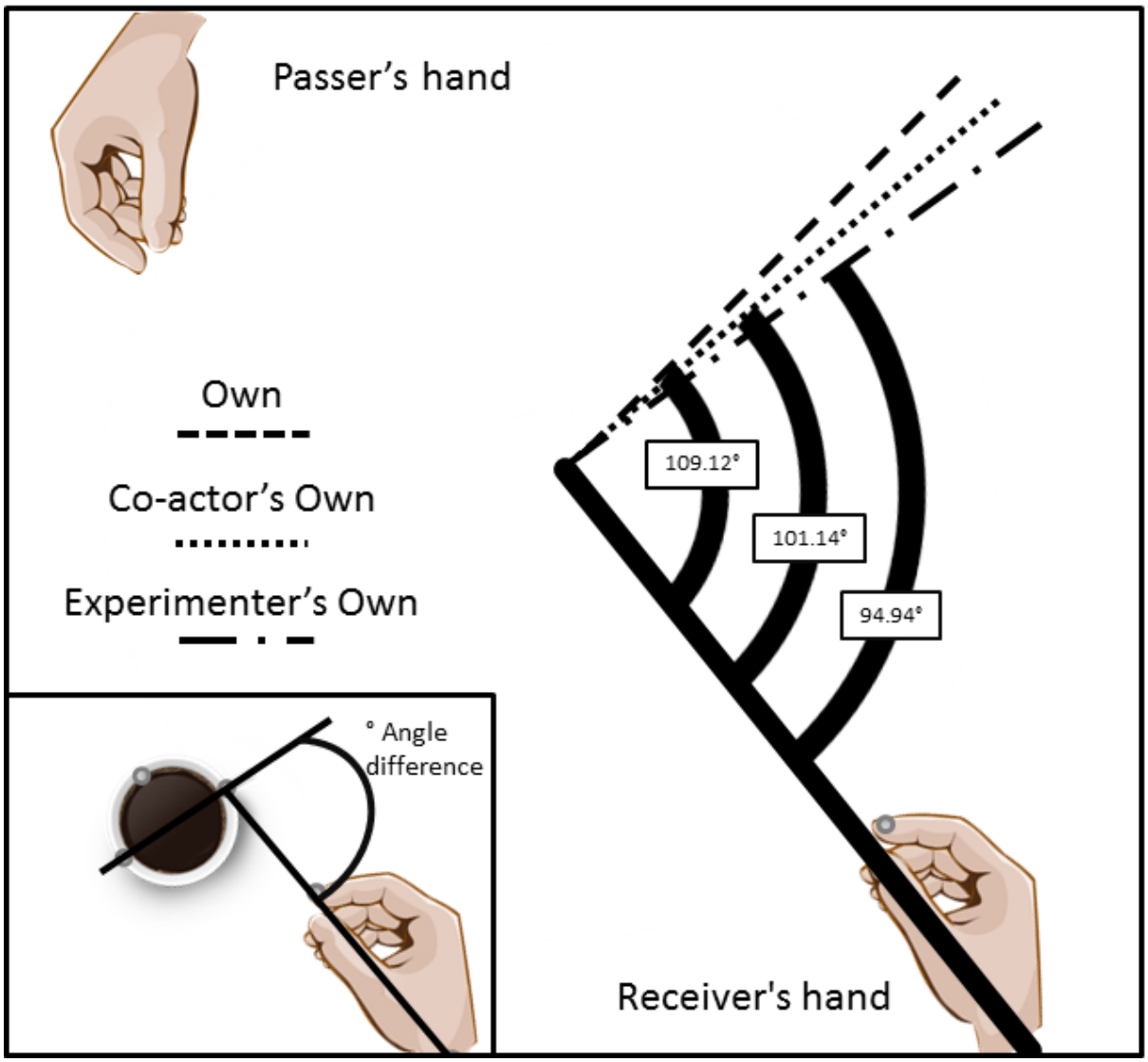

Figure 2. Final angle difference (between mug and receiver's hand) between own mug (or passer's mug), co-actor's own mug (or receiver's mug), and experimenter's mug.

General Discussion

The present study was conducted to investigate if ownership, a socially relevant non-physical feature of objects, can influence joint action behavior. Here, we present two findings: one, a broad replication of a well-documented effect in the joint action literature using a more continuous and precise measure; and two, evidence that ownership influences action planning and execution in a manner that is isolated to a joint action task. Moving

forward we will focus on the critical effects associated with ownership. In Experiment 1, when participants passed the co-actor's mug towards their partner for action, the mug was rotated farther towards the co-actor than when they passed their own mug. In Experiment 2, the aforementioned effect was replicated with the Experimenter's mug and the Participant's own mug. Because the objects were physically identical (aside from colour), the difference in rotation is driven by top-down modulation of motor commands associated with ownership status rather than bottom-up factors associated with the low-level perceptual properties of the mugs. Further, because this effect does not interact with time, familiarity with the mugs is unlikely to play a role.

Given that the facilitatory joint action behavior was expressed for both "own" and the "other's'" mugs, and just the magnitude of that behaviour was altered, we suggest that such high level conceptual knowledge and associated motor programs may implicitly leak into intended movements despite having no functional basis in this particular instance. We propose that, when the concept of ownership is introduced, established prior motor associations with relevant objects change. Although it is difficult to override a facilitatory consideration in joint action, prior associations may be able to modulate the effect. Perhaps it is more common to use your own (and your friend's) possessions and therefore optimise your own comfort (see Rosenbaum, Chapman, Weigelt, Weisse, & van der Wel, 2012, for a review on end state comfort; but see Herbort, 2013). Indeed, prior experience seems to shape response selection when engaging in higher-order planning of sequential action components to both joint and individual situations (individual - Herbort & Butz, 2011; joint and individual – Meyer, van der Wel & Hunnius, 2013). Further, discordant action consequences can influence kinematic parameters (Pfister, Janczyk, Wirth, Dignath, & Kunde, 2014). Therefore, it may be a sensible conclusion that, in the case of the present study, underlying cognitive biases, intentions or prior experience associated with cognitive concepts are

influencing motor programming even though they are discordant with the actual motor intention.

One could also speculate that the effect of ownership may be grounded in embodied mechanisms. For example, it has been reported that it is more natural to make a pushing movement in association with negatively connoted words and a pulling movement in association with positively connoted words (Chen & Bargh, 1999). This effect can then be altered by the target of the verb, indicating a social modulation (Lugli, Baroni, Gianelli, Borghi & Nicoletti, 2012). By this line of reasoning, the passer in the present study may not reach the same level of facilitatory behavior with their own object because the movement of passing the mug, in essence, represents an incongruent condition of pushing or giving a positively connoted object away. Of note, the aforementioned learned associative account does not necessarily conflict with an embodied account. An embodied account may simply represent a higher degree of abstraction in the mechanisms associated with the effect and may eventually prove to be an extension of a learned associative account whereby ownership tends to be confounded with valence (e.g. the mere-ownership effect, Beggan, 1992).

Two additional important insights emerged from Experiment 2. First, facilitatory behaviour in joint action is suppressed when using one's own objects. That is, the 'ownership effect' here represents a reduction of the level of facilitatory behavior associated with the owned mug rather than an enhancement of facilitation associated with the other mugs. This conclusion can be made because the strongest joint action effect was with Experimenter's mug, yet the Experimenter was never the co-actor. Second, it appears that it is necessary to consider both the experimental context (in Experiment 1, the Experimenter's mug was not used) and the relationship to self of the other owners. In the case of Experiment 2, the self-overlap is higher for the co-actor's mug than the experimenter's mug because the co-actor is a friend and thus represents a middle ground. Indeed, the specific numerical pattern of results

in Experiment 2 is consistent with data patterns found in literature concerning self-relevance and perception (e.g., Sui, He & Humphreys, 2012).

In sum, the motor system has developed, both on a collective and individual level, to find elegant solutions to the core problems it faces of efficiently interacting within a social world. The present studies reveal that non-physical features that are culturally- and societally-based can bias the execution of motor plans in previously unreported ways. Although awareness of the ownership status of an object did not interrupt the overarching goal (facilitation of joint behavior) in these naturalistic passing movements, ownership did shape the dyad's joint goals in subtle ways.

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