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Brief article

Adults imitate to send a social signal

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ABSTRACT

Humans frequently imitate each other's actions with high fidelity, and different reasons have been proposed for why they do so. Here we test the hypothesis that imitation can act as a social signal, with imitation occurring with greater fidelity when a participant is being watched. In a preregistered study, 30 pairs of naïve participants played an augmented-reality game involving moving blocks in space. We compared imitation fidelity between trials where the leader watched the followers' action, and trials where the leader did not watch. Followers imitated the trajectory height demonstrated by the leader, and critically, the strength of this correlation was greater in trials where the follower knew the leader was watching them. This suggests that followers spontaneously used imitation as a social signal in a nonverbal interaction task, supporting socio-communicative hypotheses of imitation.

1. Introduction

Humans imitate prolifically, from early childhood through to adulthood, and even when imitation is not strictly necessary (Nadel, 2002; Whiten et al., 2016), but we are yet to fully understand why. A variety of explanations have been advanced to explain imitation, including as a mechanism to learn new skills (Flynn & Smith, 2012), as a by-product of domain-general learning (Heyes, 2017), or as a way to boost social affiliation (Over & Carpenter, 2013; Uzgiris, 1981). This latter theory, also known as the 'social glue hypothesis' (Lakin, Jefferis, Cheng, & Chartrand, 2003), suggests that imitation is a *social signal* which can influence an interaction (Wang & Hamilton, 2012). The aim of the current paper is to test this *social-signalling hypothesis of imitation*, in a robust and ecologically valid fashion.

The genesis of this idea comes from examining how it is possible for imitation to create affiliations between people. Such affiliation could emerge as a lucky side-effect of imitation, but the STORM model (Wang & Hamilton, 2012) makes the more specific claim that imitation is performed in order to affiliate (Farmer, Ciaunica, & Hamilton, 2018). We illustrate this with a scenario in which Alice imitates an action performed by Ben. If imitation influences affiliation, Ben should receive the signal *'I am imitating you'* and change his attitude or behaviour towards Alice in response. This is supported by evidence that being imitated leads to an increase in liking (Lakin & Chartrand, 2003). Further, if Alice imitates in order to send a signal to Ben, she should imitate him with greater fidelity when she knows he is watching her, compared with a time when she knows he is not watching her. Here we consider this latter prediction – that imitation should be produced with greater fidelity when the interaction partner is watching, and can therefore receive the social signal being transmitted.

Previous work testing if imitation increases when a participant is being watched (and can send a social signal) has yielded mixed results. Using video stimuli, Wang, Newport, & Hamilton (2011) showed that imitation is enhanced when a direct gaze cue is present at the time of responding. A study of facial mimicry[1] found stronger imitation of a wince following eye contact, supporting the social-signalling hypothesis (Bavelas, Black, Lemery, & Mullett, 1986). In some studies, children imitate the irrelevant actions performed by a demonstrator only when the demonstrator is present during the child's turn (Diyanni, Nini, & Rheel, 2011; Nielsen & Blank, 2011). However, other studies suggest that children overimitate even when the demonstrator is absent (Lyons, Young, & Keil, 2007), and that both children and adults overimitate when they are not aware of being watched (Whiten et al., 2016). These latter studies argue against imitative behaviour serving as a social signal. However, these may be due to other confounding factors, which overshadow the social-signalling effect. Several of these studies use puzzle-box tasks where learning about a novel object may dominate the response. Many studies use confederates to demonstrate the to-be-

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[1] Mimicry is a subset of imitation referring to copying of actions that are not goal directed. Overimitation, meanwhile, involves copying unnecessary or causally-irrelevant features of a goal-directed action (Hamilton, 2015). In this paper we use the neutral term imitation to refer to all copying behaviour, whether explicitly goal-directed or not.

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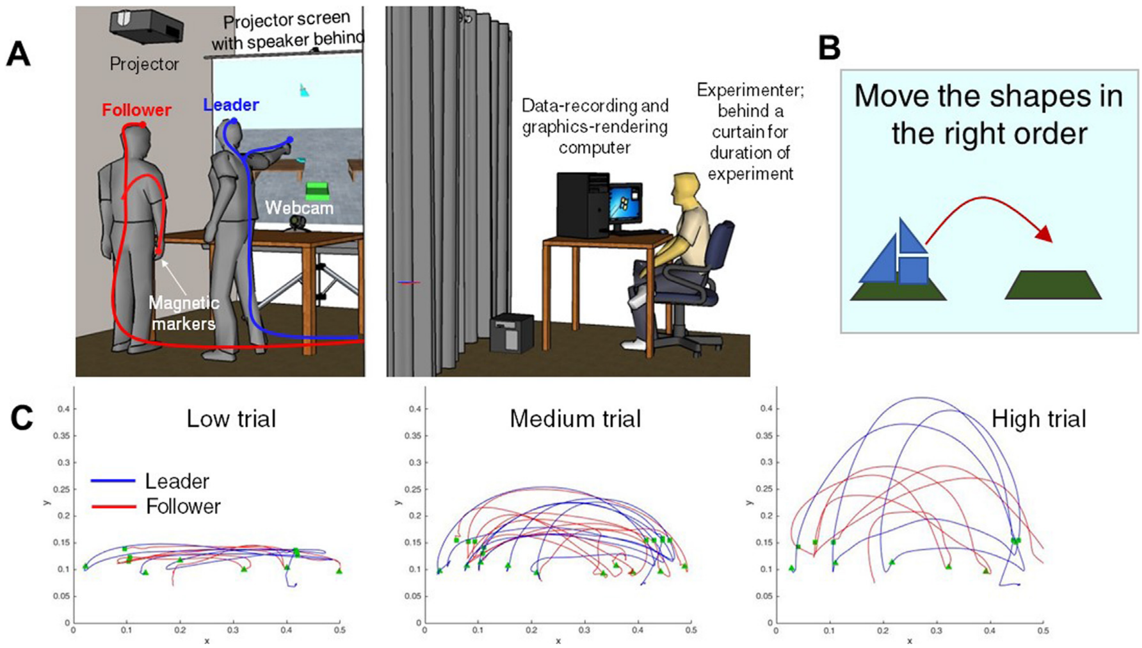

Fig. 1. (A) configuration of the augmented reality lab. Two participants standing side-by-side can see the AR space and are motion tracked. A curtain separated the participants from the experimenter. (B) The task was to move blocks from one table to another in a demonstrated order. (C) Sample trajectories from leader (blue) and follower (red) for trials with different demonstration heights. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

imitated actions, which could lead to an experimenter effect (Gilder & Heerey, 2018; Kuhlen & Brennan, 2013). Other studies use video stimuli where participants know they are not really being watched, compromising ecological validity (Risko, Laidlaw, Freeth, Foulsham, & Kingstone, 2012). Finally, the situations where someone is being watched versus one in which no one is watching can engender several possible cognitive changes (Bond, 1982), including social-facilitation effects, changes in anxiety due to direct gaze and changes in attention. One recent study has suggested that several results showing modulation of imitation by social context arise due to effects of attention or anxiety and are not related to social-signalling (Heyes, 2017). Given that in several extant studies the social context differs significantly between the watched condition and the unwatched condition, it has not so far been possible to explicitly test whether social signalling drives imitative behaviour in adults.

The current study aims to test the social-signalling hypothesis of imitation in a rigorous manner, avoiding confounding factors that have affected previous studies. In this study pairs of naïve adult participants were asked to move blocks from one location to another in a specified order (Oliver, Tachtsidis, & Hamilton, 2017) (Fig. 1). This augmented-reality setup provided a rich interactive context while avoiding experimenter effects. Two independent variables were manipulated: the height of trajectory demonstrated by the Leader, and whether the Leader's eyes were open or closed during the Follower's turn. As the two participants stand side by side throughout there are no changes in eye contact or social facilitation between the two conditions. This is akin to studies of visual perspective taking using 'goggles' (Teufel, Fletcher, & Davis, 2010) which have been accepted as a definitive test of 'social' information processing (Heyes, 2015). Finally, we resolve issues of variance in participant performance by using a simple task with clear rules for excluding non-compliant participants. The study was pre-registered to support a rigorous analysis scheme. This paper presents the results of the pre-registered study, based closely on an exploratory study (see Supplementary Materials).

Based on the STORM model, we predict that (a) participants will imitate the causally-irrelevant kinematic features of their partner's actions without being explicitly instructed to do so, and (b) participants will imitate to a greater extent when they know they are being watched by their partner, compared with a situation where they know their partner cannot see them.

2. Materials and methods

2.1. Participants

The pre-registered study is a replication of an exploratory study (see Supplementary Material and https://osf.io/ezj8g/). A power-analysis in G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) showed that 29 dyads would be sufficient to detect an effect of being watched with a power of 0.9. We therefore planned to collect data from 30 valid dyads. Dyads were excluded for failing pre-analysis quality checks (see Supplementary Material) and a total of 80 participants were tested in 40 pairs to collect data from 30 valid dyads (42 females, 18 males; mean age = 24.17 years; SD = 6.58 years). All were right-handed, had normal or corrected-to-normal vision and hearing, had no history of neurological or psychiatric disorders, and had not previously participated in this experiment. All procedures were approved by the UCL Research Ethics Committee.

2.2. Procedure

Pairs of participants arrived at the same time, and were asked to introduce themselves to each other and choose a 'team name' together; they were told they would be competing against other teams who had previously participated in the experiment. This was done to introduce a prosocial collaborative mind-set during the task. One participant was assigned the role of Leader and the other of the Follower; they stood side-by-side facing the screen (Leader/Follower locations were counterbalanced). Magnetic motion-trackers (Polhemus Liberty, Colchester Vermont) were fixed to the right hand and forehead of each participant. The hand markers allowed participants to control a hand icon in the augmented-reality environment and move objects (akin to a 3D mouse-pointer) (Fig. 1A). Participants were instructed to move blocks from one table to another in a specified order (Fig. 1B). The augmented-reality

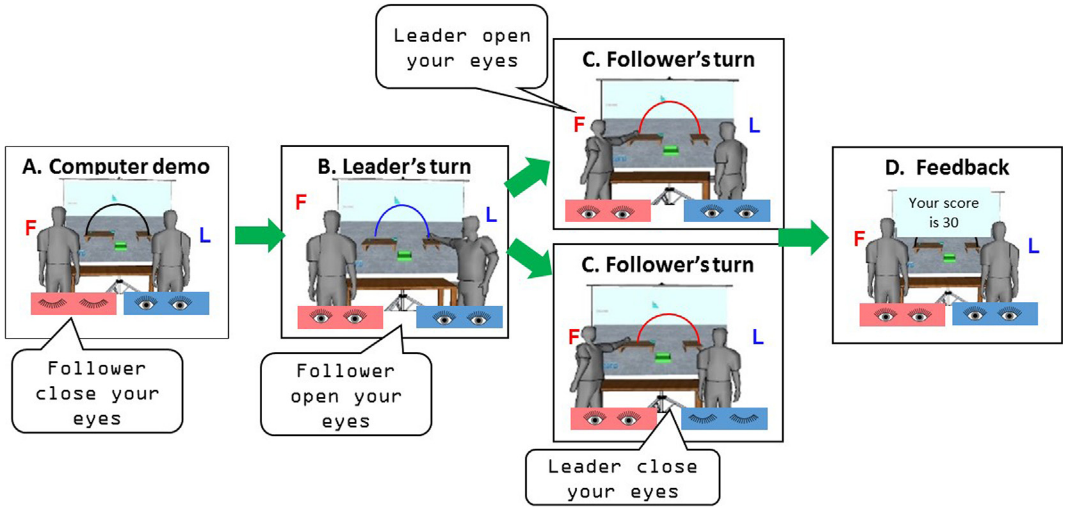

Fig. 2. Trial timeline. (A) The Follower closes their eyes while the Leader watches the computer demonstration. (B) The Leader demonstrates, while the Follower watches. (C) The Follower moves the blocks (The Leader's eyes can be open or closed). (D) Participants see a joint score which rewards accuracy and speed. Speech bubbles throughout show computerised voice commands.

environment and experimental sequence were implemented in Vizard (WorldViz, Santa Barbara, CA).

The study had three phases: familiarisation, full trials and final trials. In the familiarisation phase, participants practiced moving blocks in the augmented-reality environment. At the start of each trial a (computerised) voice command instructed the Follower to close his/her eyes. The Leader then saw a demonstration of 3 or 4 blocks being moved in a specific order from one table to another (Fig. 2A). Then the Follower heard a voice command to open their eyes, and the Leader demonstrated the block-movement task to the Follower (Fig. 2B). Finally, the Follower was asked to move the blocks in the same order to the final table (Fig. 2C). Both participants then saw a joint score based on accuracy (moving blocks in the right order) and timing (moving quickly) (Fig. 2D).

After three familiarisation trials, the experimental phase started. On the first trial, after the Follower closed their eyes, the Leader read an on-screen message with an additional 'secret' instruction to explicitly follow the trajectory demonstrated by the computer.[2] The computer demonstration then showed the blocks moving using a low, medium, or high trajectory, and the Leader was instructed to copy both the block order and the trajectory when demonstrating to the Follower. Leaders who failed to follow these instructions or shared this secret information with the Follower were excluded (see Supplementary Materials). On half the trials, prior to the Follower's turn the Leader was instructed to close their eyes. On the other half the Leader was instructed to keep their eyes open. Thus the ability of the Leader to monitor the Follower's movement was manipulated. All pairs completed 18 experimental trials (with three movement heights and the watched/unwatched conditions, each repeated thrice). The Leader's eyes were open or closed in blocks of three trials (with the order of watched blocks vs unwatched blocks counterbalanced across pairs). Participants then completed the final phase of six trials where both the Leader and Follower were explicitly told to follow the trajectory to enable us to check that they understood this idea. The phases and conditions are summarised in Supplementary Table 1.

Finally, both participants separately completed a series of questionnaires and an open-ended debrief (see Supplementary Materials) to allow for exploratory analyses.

[2] The exact wording of the instruction was as follows: "*You should follow the same PATH as the demonstration. This means you should move the pieces along the same path (reaching the same height) as the demonstration! However, you should NOT share this instruction with your teammate*".

2.3. Data analysis

As specified in the pre-registration our primary analysis focused on a single parameter: the maximum height reached by each participant in each full trial. Since there were multiple pieces moved in each trial (3 or 4 depending on the trial), we believe peak height is the most salient measure of whether a movement trajectory was copied. The correlation coefficient (R) between the maximum heights reached by the Leader and the Follower in the Watched trials and the Unwatched trials were calculated to characterise the level of imitation in a pair. T-tests were used to determine whether these values were greater than zero and if they differed from each other.

3. Results

Our first analysis shows that Followers tended to imitate the Leader's trajectory with high fidelity, despite not being explicitly asked to do so (Fig. 3A). A one-sample *t*-test showed a statistically significant correlation between the height reached by the Follower and the height reached by the Leader [$N = 30$, $M = 0.38$, Std. Dev. $= 0.46$, $p < 0.001$].

Our second analysis tests the core experimental question: do participants imitate more when they know they are being watched, compared to when they are not watched? Fig. 3C shows the peak heights reached by the Leader and the Follower for one sample dyad. Across all participants, we compared the correlation between the peak heights reached by the Leader and the Follower in trials where the Leader was watching the Follower make their movements and the trials where the Leader was not watching. A paired-sample *t*-test [$N = 30$] showed that these R-values were higher when the Leader was watching [$M = 0.48$, Std. Dev. $= 0.45$] than when the Leader was not watching [$M = 0.32$, Std. Dev $= 0.55$] and that this effect was significant [$t(29) = 2.84$, $p = 0.008$].

This supports our hypothesis that participants will imitate to a greater extent when they know they are being watched by their partner when compared with a situation where they know their partner cannot see them. Both these results are similar to results previously seen in the pilot experiment (see Supplementary Materials). Further exploratory analyses of movement timing and multi-level regressions are detailed in the Supplementary Materials.

The results also suggest that there are sizeable individual differences in Followers' propensity to imitate (Fig. 3A). Some Followers imitated Leaders with great fidelity, while others did not. An exploratory

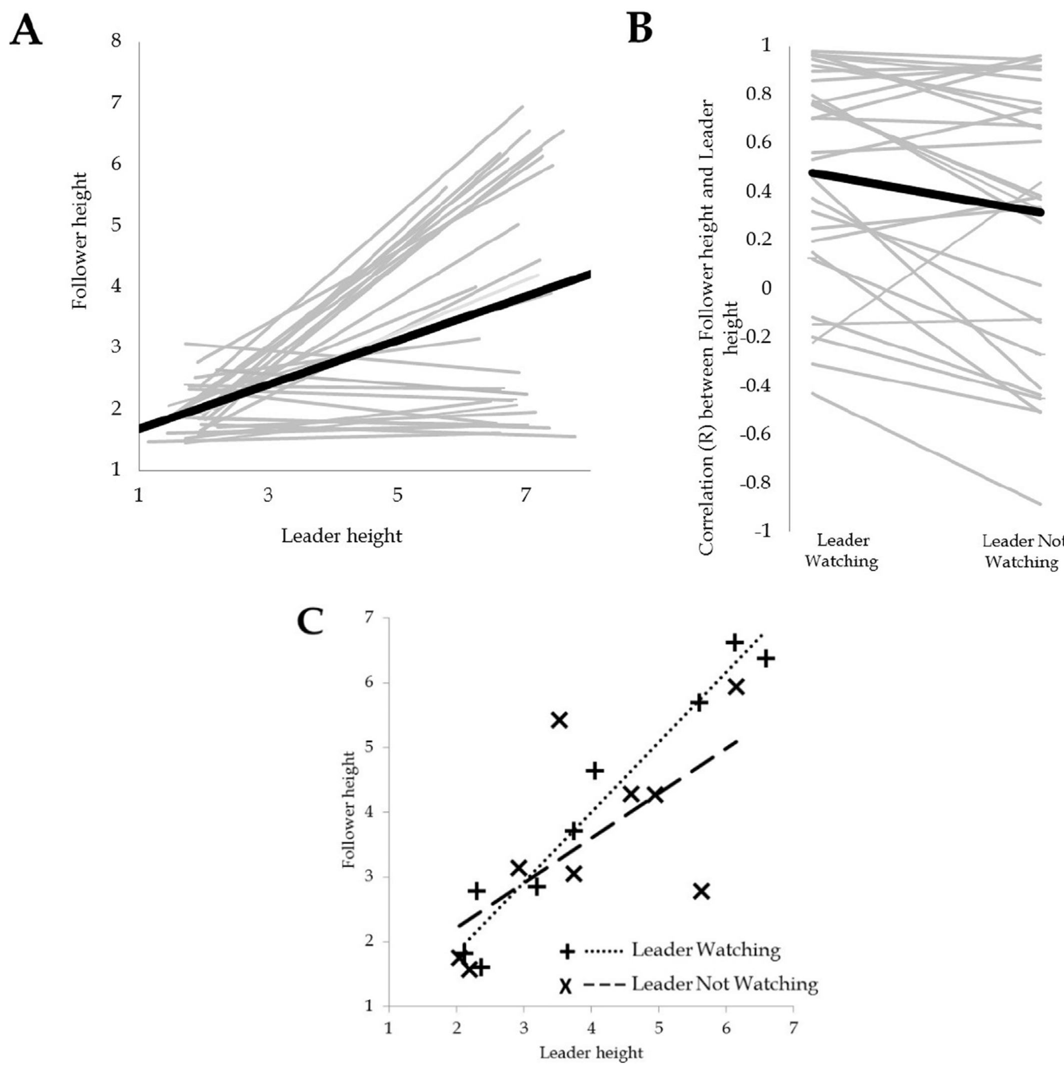

Fig. 3. (A) Overall imitation pattern Line of best-fit for the correlation between Leader heights and Follower heights for each dyad (grey lines) and the group as a whole (heavy black line). (B) Correlations: The R values representing the correlation between the Leader and Follower heights are shown for each dyad and for the whole group (heavy black line) for trials where the Leader watches the Follower make their movements and trials where the Leader does not watch. (C) Results for one sample dyad: The heights reached by the Leader and Follower in one dyad (#20) and respective trendlines across both the Watched and Unwatched conditions.

analysis linking imitative behaviour to traits measured via our questionnaires, namely anxiety, rapport or autistic traits did not suggest any relationships between these self-reported traits and imitative behaviour[3] (See Supplementary Materials).

4. Discussion

This experiment aimed to test the social-signalling hypothesis of imitation that posits that one of the reasons that humans imitate others is to send a social signal. In this study we found clear evidence that adults imitate with greater fidelity when they know they are being watched by an interaction partner.

The current study advances previous work on imitation in several important ways. First, by using two naïve participants (rather than having a confederate or experimenter demonstrate the action sequence) and pre-registering the analyses, we can be confident that our results do not reflect experimenter biases. Second, using augmented-reality allowed for precise capture of motion kinematics while maintaining good ecological validity. Third, the ‘feeling of being watched’ was manipulated at an abstract level by voice signals instructing the Leader to open or close their eyes. This allows us to rule out several alternative interpretations of differences in imitative behaviour being due to arousal from direct gaze (Senju & Johnson, 2009), due to social facilitation (Zajonc, 1965), or due to varying levels of anxiety or attention (Heyes, 2017). In our study both participants stood side-by-side throughout the experiment and therefore differences in eye-gaze and social-facilitation cannot explain the present results. Participants were asked to move quickly and accurately, implying that a straight trajectory was more efficient than using a curved one. Further, if participants felt more anxious during trials when they know they are being watched (Zajonc, 1965), we would expect them to move faster, straighter and lower. Yet, participants actual movements were higher and did not differ in speed. Finally, since the demonstration phases were identical in both the watched and unwatched conditions there cannot be systematic differences in attention during the demonstration phase, allowing us to rule out attentional explanations.

Overall, our experimental design suggests that the ‘being watched’ effect does not arise from differences in arousal, social facilitation, anxiety or attention. The remaining explanation is that participants

[3] It is important to note that this does not mean there is no relationship. Our questionnaires were exploratory in nature and we did not set out to test individual differences. We expect that a much larger study may be more suited to examining these in detail.

imitate with greater fidelity in order to send a signal to their interaction partner. That is, these results support the claim that imitation can serve as a *social signal* (Farmer et al., 2018) and suggests that this signal is enhanced when senders know the recipient can receive it. This is compatible with the STORM model which posits that basic mechanisms for observing and performing actions can be modulated according to the scope and need to strengthen a social connection (Wang & Hamilton, 2012). The current data is also consistent with earlier work on emotion mimicry (Bavelas et al., 1986) and studies using video stimuli (Wang et al., 2011). Note that the claim that imitation can be a social signal does not rule out the possibility that, in other contexts, imitation can also be used for social learning (Lyons, Damrosch, Lin, Macris, & Keil, 2011), as many functions can coincide in this behaviour (Over & Carpenter, 2012).

There are also some limitations to our results. We cannot determine if Followers became consciously aware of the Leader's unusual trajectories at some point prior to being explicitly told about the trajectories (in the final phase).[4] This study, therefore, does not distinguish between conscious and unconscious copying. Future studies could measure when (if ever) Followers become aware of the unusual trajectories and test if awareness modulates imitation fidelity. Second, this study set social imitation of kinematics within the context of a block-order learning task; a potential manipulation for future experiments would be to generate a paradigm without a learning objective, such as a task involving only natural conversation.

Our study also generates several possible directions for future research. First, if imitation is being used as a social signal, what message is being sent? Previous work has suggested that imitation signals a desire to affiliate (Chartrand & Lakin, 2012) but positive effects of being imitated are not always seen (Hale & Hamilton, 2016; Verberne, Ham, & Midden, 2015). Kinematic patterns can also signal informative intentions (McEllin, Sebanz, & Knoblich, 2018) or confidence (Patel, Fleming, & Kilner, 2012) which could be important here. It would also be interesting to understand the neural mechanisms of imitation as a social signal. The STORM model suggests that the interaction between gaze and imitation arises due to influence of medial prefrontal cortex on mirror neuron regions (Wang & Hamilton, 2013; Wang, Ramsey, & Hamilton, 2011). Combining this paradigm with brain imaging techniques such as functional near-infrared spectroscopy (fNIRS) (Pinti et al., 2018), will allow us to test the brain mechanisms involved while preserving the ecological validity of the dyadic interaction. Finally, our results suggest that some Followers imitated with greater fidelity than others, although we did not find links between the self-reported traits and propensity to imitate. Examining these individual differences could also be a productive avenue for further study.

5. Conclusions

We hypothesised that imitation functions as a social signal and would be modulated in line with its expected communicative capacity. A preregistered study of 30 pairs of naïve participants shows that participants tend to imitate the causally-irrelevant kinematic features of their partner's movements, and imitate more when they knew their partner could see them. This provides evidence for top-down social modulation of imitation (Wang & Hamilton, 2012) and for the use of imitation behaviour as a social signal to others.

6. Open practices statement

This study was preregistered at https://osf.io/ezj8g/. Anonymised data will be available on OSF when the paper is published.

[4] We could not explicitly ask about this since we did not want to prime participants with questions about trajectories until the end of the experiment.

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Author contributions

Both authors contributed to the study concept and design. Testing and data collection were performed by SKB. SKB performed the data analysis and interpretation under the supervision of AH. SKB drafted the manuscript and AH provided critical revisions. Both authors approved the final version of the manuscript for submission.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cognition.2019.03.007.

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