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Authors

Jomura, Naohiro
Tamura, Megumi
Sato, Keisuke
et al.

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Sense of Joint Agency: The Role of Prior Partner Information

Naohiro Jomura (jomura-naohiro@g.ecc.u-tokyo.ac.jp)
Graduate School of Arts and Sciences, The University of Tokyo
3-8-1 Komaba, Meguro-ku, Tokyo, 153-8902, Japan

Megumi Tamura (akamy0650@g.ecc.u-tokyo.ac.jp)
Graduate School of Arts and Sciences, The University of Tokyo
3-8-1 Komaba, Meguro-ku, Tokyo, 153-8902, Japan

Keisuke Sato (lesucre326@g.ecc.u-tokyo.ac.jp)
Graduate School of Arts and Sciences, The University of Tokyo
3-8-1 Komaba, Meguro-ku, Tokyo, 153-8902, Japan

Kazuhiro Ueda (ueda@g.ecc.u-tokyo.ac.jp)
Graduate School of Arts and Sciences, The University of Tokyo
3-8-1 Komaba, Meguro-ku, Tokyo, 153-8902, Japan

Abstract

This study examines how prior information about a partner affects the sense of joint agency during a collaborative task. Previous research suggests that perceiving a partner as human enhances this sense. However, the effects of prior instructions remain unclear. We designed a 2 × 2 factorial experiment in which participants were told their partner was human or a program, while their actual partner was either human or a program. In the experiment, each participant and their partner jointly controlled a cursor to trace a circle. Additionally, we measured the sense of agency to compare it with joint agency. The data revealed that the instructional factor only influenced the sense of joint agency, while the actual partner factor solely affected the sense of agency. These findings suggest that beliefs about the partner prior to interaction influence the sense of joint agency, offering insights into the cognitive processes underlying collaborative actions.

Keywords: joint agency; shared agency; prior information; collaborative tasks; partner identity

Introduction

The sense of joint agency refers to the feeling of "we did it" (Pacherie, 2012), indicating how individuals experience co-authorship of actions or outcomes in collaborative contexts. This concept captures the notion that multiple individuals are working toward a shared goal. Previous research has shown that beliefs about a partner significantly affect the sense of joint agency. For example, the human-like appearance of a partner has been shown to enhance the feeling of being part of a coordinated effort (Khalighinejad, Bahrami, Caspar, & Haggard, 2016; Sahaï et al., 2023). Additionally, joint actions with an artificial agent, such as a computer or machine, do not elicit the same level of joint agency as those with human partners (Obhi and Hall, 2011; Sahaï et al., 2019). In problem-solving tasks, performance varies depending on whether the observed agent is instructed to be oneself or another individual (Fireman, Kose, & Solomon, 2003; Osman, 2008; Kotera, Kiyokawa, Ashikaga, & Ueda, 2011). These findings indicate that beliefs about a partner or target significantly affect the interpretation of interactions and subsequent behaviors. However, little is known about how prior information about a partner influences the sense of joint agency, which is crucial for understanding how beliefs about a partner affect this sense.

To assess the effect of instructional influence on the sense of joint agency, this study examined four conditions using a 2 × 2 factorial design. The independent variables were the actual partner's identity (human vs. program, referred to as the partner factor) and the instructions provided about the partner's identity (human vs. program, referred to as the instruction factor).

Participants engaged in a task where they collaboratively traced a circle displayed on a monitor using joysticks. One participant controlled the vertical axis, while the other controlled the horizontal axis, requiring precise coordination to complete the task accurately. After each task, we measured the strength of the sense of joint agency using a questionnaire and evaluated the influence of set factors on this sense. We hypothesize that the condition in which the partner is actually human and is also instructed to be human will result in the strongest belief in the partner's humanity, thereby enhancing the sense of joint agency.

The concept of joint agency is based on the sense of agency, which refers to a person's feeling that they are the cause of their own actions and outcomes (Gallagher, 2000). Although these concepts are distinct, they are believed to be related. Previous studies have shown that strategic cues influence the sense of joint agency, while motor cues more significantly affect the sense of agency (Bars et al., 2020). Based on these findings, we predict that the instructional factor will influence the sense of joint agency while the partner factor that directly affects motor activity will influence the sense of agency. In this study, we examine these relationships by measuring the sense of agency as well as the sense of joint agency.

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Furthermore, we conducted a detailed analysis of temporal changes in the sense of joint agency across the four conditions, examining how this sense evolves over time.

Methods

Experimental Conditions

We manipulated two key independent variables:

1. **Partner Factor:** The actual partner is either a human participant (tested in separate rooms without communication) or a program (Figure 1).
2. **Instruction Factor:** Participants are told that their partner is either human or a program, irrespective of the actual partner condition.

This created four conditions based on a 2 × 2 factorial design (two partner conditions: human vs. program × two instruction conditions: human vs. program). In either of the four conditions, participants are instructed to collaborate with their partner to trace the circle as accurately as possible.

Participants were equally assigned to one of two groups: one group conducted the task under the conditions of Human partner × Human instruction and Program partner × Program instruction. The other group did so under the conditions of Human partner × Program instruction and Program partner × Human instruction. This manipulation was chosen to avoid participants detecting the inconsistency when instructions did not align with the actual partner condition. The two conditions took place on separate days, and the order of conditions was counterbalanced.

In the program partner condition, the cursor movements were pre-recorded using the vertical axis movements from the final trial of the practice phase on the human partner's first experimental day. These pre-recorded cursor movements followed a fixed trajectory and remained consistent across trials for each participant. Participants in this condition had to adapt to their partner's fixed movements. In contrast, in the human partner condition, both participants could mutually coordinate their actions, highlighting a key difference between the two conditions.

Participants

We recruited 34 participants (22 males, 11 females, 1 undisclosed; age range: 18–38 years, mean age = 23.1, SD = 5.15). We calculated the sample size using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) for an ANOVA with repeated measures within-between interaction. We targeted a medium effect size (f = 0.25), set α at 0.05 and *power* at 0.8, with two groups and two measurements (Cohen, 2013). Because there are no prior studies that use a similar experimental task, we preliminarily determined the effect size to be medium, based on an exploratory experiment.All participants provided informed consent and were compensated. The study was approved by the ethics committee of the university to which the authors belong.

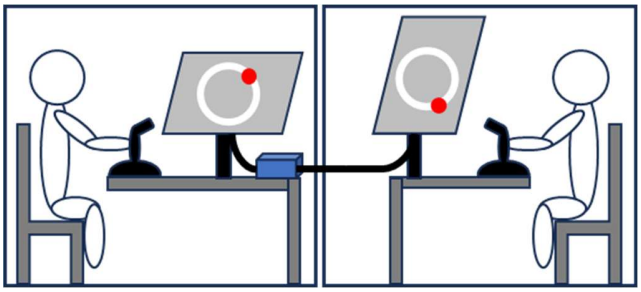

Figure 1: The experimental setup, using the human partner condition as an example. Each participant is assigned to separate rooms for the experiment. In the human partner condition, the control PC, represented by a blue box, displays the screen on monitors in both rooms. In contrast, in the program partner condition, the control PC displays the screen on only one monitor. To standardize the movement directions of joystick operations, the monitor in one room is rotated by 90 degrees.

Experimental Task and Apparatus

The experimental task required participants to collaboratively trace a circle (radius: 250 pixels) on a computer screen, working with either another participant or a program. Participants controlled the cursor movement using a Logitech Extreme 3D Pro joystick. This setup, inspired by Dewey, Pacherie, and Knoblich (2014) and Asai (2015), involved one participant controlling the vertical axis and their partner controlling the horizontal axis, necessitating precise coordination for accurate tracing. The experiment used PsychoPy software on a Mac Studio computer. Participants sat in front of a BenQ GW2480T display (resolution: 1680 × 1050 pixels; refresh rate: 60 Hz) and performed the task as shown in Figure 1. The PsychoPy screen, set to 600 × 600 pixels, was maximized on the display. In the human partner condition, the Mac Studio output was displayed on two monitors to facilitate collaboration, whereas in the program partner condition, it was shown on only one display. To ensure equal roles, one participant's screen was rotated 90 degrees, allowing both participants to perceive their joystick movements as vertical (Figure 1).

Procedure

Participants engaged in a task using joysticks to collaboratively trace a circle displayed on the screen. Each experimental session started with a practice phase, during which participants performed the task individually. A circular dot, representing the starting point, appeared on the circle (radius: 250 pixels) at one of two random positions: $\pi/4$ rad or $5\pi/4$ rad (when using a monitor rotated 90 degrees, $3\pi/4$ rad or $7\pi/4$ rad) (Figure 2-1). During the practice phase, participants controlled both axes to trace the circle. After completing the trace, the screen displayed an error indicator

bar (Figure 2-6), which changed length based on the tracing error. The color of the bar also varied to indicate the error level: green for errors below 10 pixels, yellow for errors between 10 and 15 pixels, and red for errors above 15 pixels. The error was calculated as the average deviation of the cursor's position from the target circle's radius across all frames in a trial. Practice continued until participants achieved three consecutive trials where the error indicator bar turned green. After the practice phase, participants performed 50 trials under one of the experimental conditions. At the start of each trial, the cursor appeared at the center of the screen (Figure 2-1). A circular dot, representing the starting point, was displayed on the circle at one of two random positions: $\pi/4$ rad or $5\pi/4$ rad (when using a monitor rotated 90 degrees, $3\pi/4$ rad or $7\pi/4$ rad). These positions allowed participants to choose their movement direction, unlike a position like π rad, which would restrict one participant's movement direction to only downward.

Participants moved the cursor to the starting point. Once the cursor reached the starting point, a countdown signal transitioned through states every 1000 ms: red, yellow, and then disappeared (Figure 2-2). After the countdown ended, participants traced the circle and returned to the starting point (Figures 2-3, 2-4). Upon returning to the starting point, a 10-second countdown bar was displayed on the task-operating PC (Figure 2-5). During this time, participants completed two questionnaires, on a separate PC, about their sense of agency and joint agency, respectively. The order of the questionnaires was fixed: the sense of joint agency item (Q1) was always presented before the sense of agency item (Q2).

> **Q1. Sense of Joint Agency** (Shiraishi & Shimada., 2021): “To what extent did you feel that we controlled the cursor?” (1: Individual, 5: Neutral, 9: Shared; 9-point Likert scale)
>
> **Q2. Sense of Agency** (Ohata et al., 2020): “To what extent did you feel that you controlled the cursor?” (1: Self, 5: Neutral, 9: Other; 9-point Likert scale)

Once the countdown bar disappeared, the task-operating PC displayed the error indicator bar, providing performance feedback (Figure 2-6). This feedback mechanism was consistent with the error indicator bar used during the practice phase. After completing all trials, participants responded to the following additional questionnaires:

1. Object Impressions (Matsumoto, 2021; Fukuda & Ueda, 2010, modified): Participants rated seven aspects (e.g., ease of operation, boredom, attachment, familiarity, likability, perceived animacy, and perceived purposefulness) on a 7-point Likert scale.
2. Perceived Partner Consideration (Osawa, Kawagoe, Sato, & Kato, 2021): "To what extent did you feel that your partner considered your actions?" (1: Not at all, 4: Neutral, 7: Very much; 7-point Likert scale).

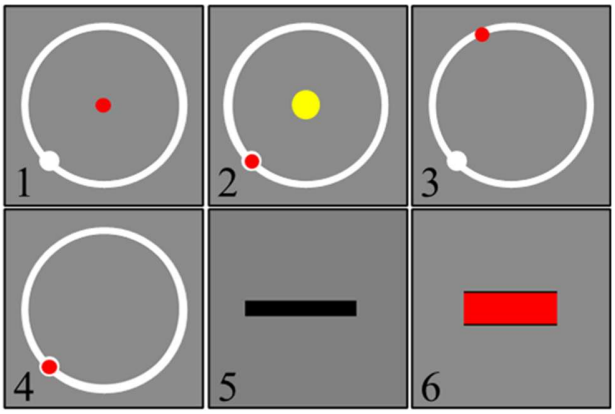

Figure 2: Transition diagram of the experimental screen. The experimental screen transitions through six stages, beginning with the start screen, where a red dot indicates the cursor and a white dot on the edge serves as the starting point. Next, a countdown before task initiation is represented by a yellow circle. The third screen appears during cursor operation, followed by the fourth screen, which signals task completion. A countdown bar, displayed for 10 seconds, is used for responding to the questionnaire on the fifth screen. Finally, the sixth screen shows an error indicator bar.

3. Role Perception: "To what extent did you feel like a leader or follower in operating the object?" (1: Very much a follower, 5: Neutral, 9: Very much a leader; 9-point Likert scale).
4. Perceived Partner Identity (Human-likeness): "To what extent did you feel that your partner was human or a program?" (1: Very much a program, 5: Neutral, 9: Very much human; 9-point Likert scale).
5. Personality Traits (FFPQ-50; Fujishima, Yamada, & Tsuji, 2005): Participants completed 20 items measuring extroversion and attachment traits on a 5-point Likert scale. These data were collected only after the second experimental session.

Following Le Besnerais, Moore, Berberian, and Grynszpan (2024), our experimental setup is designed to ensure equality between partners in terms of both task execution and decision-making related to the cursor movement.

Data Analysis methods

All analyses were performed using R version 4.3.1. This study adheres to the Linear Mixed Model (LMM) analysis framework used in prior research (Bolt, Poncelet, Schultz, & Loehr, 2016). First, we analyze how the instruction factor and the partner factor affect participants' perceptions of their partner, as measured by Questionnaire 4: Perceived Partner Identity (Human-likeness). The model includes fixed effects for the instruction factor and partner factor, and their interaction with participant ID as a random effect. We calculate the significance of the fixed effects and interactions

using a type III analysis of variance (F-test) with Satterthwaite's approximation. Next, to clarify the differences between the conditions, we perform pairwise comparisons on the instruction factor × partner factor interaction using estimated marginal means (EMMs). Each p-value is corrected by a factor of six using the Bonferroni correction.

Next, we examined the effect of the independent variables (sense of joint agency and sense of agency) on the two questionnaires. For Q2, the item was treated as a reverse-scored item. First, we constructed a full LMM model. The fixed effects included partner factor (Human: 0, Program: 1), trial (1–50), error (≥ 0), and instruction factor (Human: 0, Program: 1). The random effects accounted for participant and pair factors, and the order of experimental conditions nested within participants. We identified the final model through backward model selection applied to the full model. Following the same procedure as the analysis for perceived partner identity, we conducted F-tests and pairwise comparisons. Finally, to examine temporal changes in the sense of joint agency across trials in each condition, we calculated and compared trial-by-trial mean predicted values and their 95% confidence intervals based on the LMM.

These analyses were performed using the packages “lme4” (Bates et al., 2015), "lmerTest" (Kuznetsova et al., 2017), and “emmeans” (Lenth, 2022).

Questionnaires that were not collected on a trial-by-trial basis were excluded as independent variables in the LMM analysis of this experiment. Including these questionnaires might introduce effects that remain constant across trials, potentially complicating the interpretation of the model.

Results

Linear Mixed Model for Perceived Partner Identity

An LMM analysis was conducted with Perceived Partner Identity (Human-likeness) as the dependent variable. F-tests revealed significant main effects of partner factor ($F(1, 31.826) = 8.394$, $p < .01$, $\eta p^2 = 0.21$) and instruction factor ($F(1, 31.826) = 15.170$, $p < .001$, $\eta p^2 = 0.32$). Pairwise comparisons indicated significant differences in perceptions of the partner between the human partner × human instruction and program partner × program instruction conditions ($t(32.2) = 4.761$, $p < .001$, $d = 1.66$), as well as between the program partner × human instruction and program partner × program instruction conditions ($t(63.0) = 3.171$, $p < .05$, $d = 1.10$) (Figure 3). These results indicate that both the partner factor and the instruction factor significantly affect the perceptions of partner.

Linear Mixed Model for the Sense of Joint Agency and the Sense of Agency

Table 1 presents the final LMM models for Q1 (sense of joint agency) and Q2 (sense of agency). The optimal models were selected through backward model selection (Q1 model: initial AIC = 12125, final AIC = 12076; Q2 model: initial AIC = 12655, final AIC = 12506.1). The random effects revealed meaningful variability across pair factors and the order of experimental conditions nested within participant factors in both models. In contrast, variability across the participant factor was not significant in either model and was therefore removed from the random effects structure.

Table 1: Summary of Final LMM Model for Q1 and Q2

Predictor	Q1: Sense of Joint Agency				Q2: Sense of Agency			
	β	*SE*	*t-value*	*p-value*	*β*	*SE*	*t-value*	*p-value*
(Intercept)	6.939	0.368	18.857	< .001	6.662	0.325	20.527	< .001
Partner Condition	-0.041	0.435	-0.093	0.925	-1.616	0.370	-4.364	< .001
Trial	-0.007	0.008	-0.902	0.367	0.004	0.008	0.497	0.619
Instruction Condition	-1.208	0.446	-2.708	0.008	-0.594	0.298	-1.991	0.051
Error	-0.062	0.029	-2.111	0.035	-0.165	0.026	-6.494	< .001
Partner Condition × Trial	0.021	0.008	2.664	0.008	-0.001	0.008	-0.121	0.903
Partner Condition × Instruction Condition	-0.093	0.565	-0.164	0.870	0.939	0.403	2.331	0.024
Trial × Instruction Condition	-0.010	0.006	-1.696	0.090	0.007	0.003	2.071	0.038
Partner Condition × Error	0.075	0.030	2.465	0.014	0.072	0.027	2.697	0.007
Trial × Error	0.001	0.001	1.719	0.086	-0.002	0.001	-2.105	0.035
Partner Condition × Trial × Error	-0.003	0.001	-3.240	0.001	0.002	0.001	2.320	0.020
Instruction Condition × Error	0.139	0.034	4.093	< .001	-	-	-	-
Partner Condition × Instruction Condition × Error	-0.105	0.034	-3.075	0.002	-	-	-	-
Trial × Instruction Condition × Error	0.001	0.001	2.065	0.039	-	-	-	-

For Q1 (Sense of Joint Agency), the main effect of the partner factor was not significant, showing that the identity of the actual partner, whether human or program, did not directly affect the sense of joint agency. However, the instruction factor had a significant effect ($F(1,116) = 16.481$, $p < .001$, $\eta p^2 = 0.12$), with participants reporting a stronger sense of joint agency when they believed their partner was human rather than a program. *F*-tests also showed significant main effects of error and significant interactions between partner factor and error, partner factor and trial, and a three-way interaction among partner factor, trial, and error. However, all effect sizes (ηp^2) were below 0.01, indicating that these effects were smaller than the effect of the instruction factor.

For Q2 (Sense of Agency), the main effect of the partner factor was significant ($F(1,245.1) = 13.605$, $p < .001$, $\eta p^2 = 0.05$). Participants reported a lower sense of agency in the program partner condition than in the human partner condition. Unlike the sense of joint agency, Q2 was not affected by the instruction factor. However, the interaction between partner factor and instruction factor was significant ($F(1,47.7) = 5.434$, $p < .05$, $\eta p^2 = 0.1$). Error also showed a significant main effect ($F(1,3342.8) = 2.629$, $p < .001$, $\eta p^2 = 0.03$), where a higher error was associated with a reduced sense of agency. Additionally, *F*-tests revealed that the Trial × Instruction Factor, Partner Factor × Error, and the three-way interaction (Partner Factor × Trial × Error) were significant. However, all effect sizes (ηp^2) were below 0.01, showing that their influence was smaller compared to the effects of partner factor, and error.

The LMM analysis showed that the instruction factor mainly influenced the sense of joint agency, whereas the partner factor, error and the interaction between partner factor and instruction factor primarily affected the sense of agency.

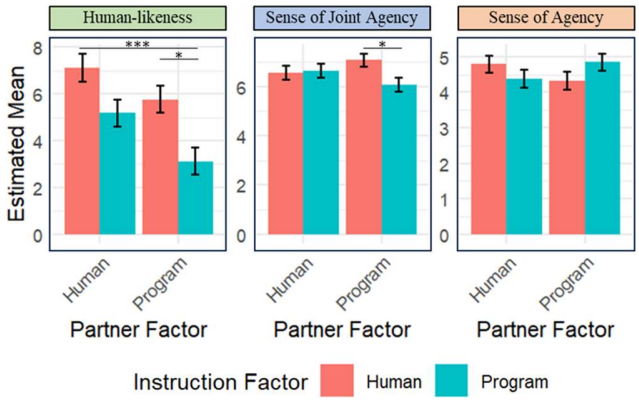

Figure 3: Estimated marginal means (EMMs) of human-likeness, sense of joint agency, and sense of agency based on the LMM model (error bars refer to *SE*). Significant differences are indicated by the results of pairwise comparisons. *** $p < .001$, * $p < .05$.

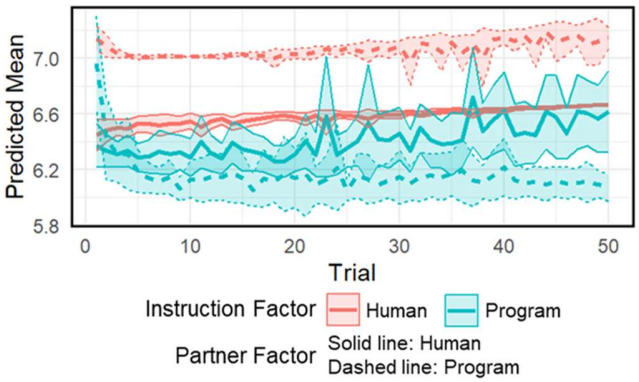

Figure4: Time-series changes in the predicted mean sense of joint agency for each partner condition × instruction condition, as predicted directly from the LMM model (shaded areas represent the 95% CI).

Pairwise Comparisons for the Sense of Joint Agency and the Sense of Agency

To identify differences between conditions, pairwise comparisons were conducted for the interaction term of partner factor × instruction factor.

For Q1 (sense of joint agency), a significant difference was found between the program partner × human instruction condition and the program partner × program instruction condition ($t(48) = 2.814$, $p < .05$, $d = 0.72$) (Figure 3). However, no significant differences were observed for other combinations (Figure 3).

For Q2 (sense of agency), no significant differences were observed for any combination of conditions (Figure 3).

These results of the pairwise comparisons show that in the program partner condition, the sense of joint agency was affected significantly by differences in instruction.

Time-Series Analysis of the Sense of Joint Agency

A time-series analysis was conducted to examine the sense of joint agency in detail. We plotted predicted Q1 values from the LMM model for each trial (Figure 4). The results show that in the program partner condition, the initial level of sense of joint agency was higher compared to the human partner condition (Figure 4). Additionally, in the program partner condition, joint agency decreased within approximately 10 trials when the instructions identified the partner as a program. In contrast, no such decrease occurred when the instructions identified the partner as human. Furthermore, no such changes were observed under any instructional condition in the human partner condition.

The time-series analysis revealed a decrease in the sense of joint agency during the initial phase under the program partner × program instruction condition.

Discussion

Influence of Instruction and Partner Factors on the Sense of Joint Agency and the Sense of Agency

In this study, we aimed to examine how instructions affect the sense of joint agency. We focused on the main effect of the instruction factor, where participants informed that their partner was a program reported a lower sense of joint agency compared to those told their partner was human. This finding suggests that top-down cues, such as verbal instructions, significantly influence perceptions of coordination, even without direct physical or visual observation of the partner. The alignment between the instructions provided and human-likeness scores further supports the robustness of these instructional effects. This highlights the capacity of simple verbal cues to modulate the sense of joint agency, particularly in how beliefs about a partner influence this sense, extending prior research that focused on partner appearance (Khalighinejad et al., 2016; Sahaï et al., 2023).

The results of pairwise comparisons (Figure 3) show that in the program partner condition, telling participants their partner was human significantly increased their sense of joint agency compared with when they were told their partner was a program. This finding suggests that even with artificial agents, such as computer programs, instructions can enhance the sense of joint agency.

The results showed that the instruction factor did not significantly affect participants' sense of agency. Instead, whether the partner was human, or a program played a more significant role. The sense of agency is based on the relationship between participants' actions and the cursor's movements, which the partner factor affects directly, but the instruction factor does not. These findings align with Bars et al. (2020), who found that self-agency relies heavily on motor cues, unlike joint agency, which depends on strategic cues. In contrast, the instruction factor did not affect the sense of agency, because it does not change the cursor's movements, but only influences participants' perceptions of the partner.

Additionally, error was associated with lower ratings of both sense of joint agency and sense of agency. This finding is consistent with previous studies (e.g., van der Wel, Sebanz, & Knoblich, 2012) demonstrating that task performance influences the subjective experience of agency.

The Relationship Between the Perceived Partner Identity and the Sense of Joint Agency

The results of pairwise comparisons (Figure 3) show that human-likeness scores are significantly higher in the human partner × human instruction condition than in the program partner × program instruction condition. However, a similar trend was not observed in the sense of joint agency between the same conditions. On the other hand, within the program partner condition, both human-likeness and sense of joint agency were significantly higher in the human instruction condition than in the program instruction condition. This suggests that perceiving a partner as human and the strength of the sense of joint agency do not always align.

In the program partner condition, the effect of instruction on the sense of joint agency was stronger than in the human partner condition, suggesting that factors other than perceiving the partner as human may influence joint agency. Two possible explanations are proposed for this finding.

First, the predictability of the partner's movements may have been higher in the program partner condition than in the human partner condition. Research shows that greater predictability in a partner's movements increases the sense of joint agency (Sebanz, Bekkering, & Knoblich, 2006; Saad, McCurry, & Trafton, 2024). In the program partner condition, the cursor's movements were pre-recorded and consistent across trials, likely making the partner's movements more predictable compared with those in the human partner condition. As a result, participants in the program partner × human instruction condition may have perceived the partner as more human-like as well as predictable, which could have led to an increased sense of joint agency.

Second, the time-series analysis (Figure 4) shows that in the program partner condition, the initial sense of joint agency was high, possibly because the cursor operated independently along the horizontal axis, enhancing the early sense of the partner's presence. However, when participants learned that the partner was a program, their sense of joint agency decreased within about 10 trials, whereas it remained stable when they believed the partner was human. This finding suggests that telling participants the partner is human helps maintain the initial strength of joint agency. While this indicates that instructions affect the sustainability of initial impressions, the underlying reasons are still unclear and require further investigation.

Conclusion and Future Directions

This study experimentally demonstrated the effect of prior instructions regarding the partner on the sense of joint agency. It was shown that joint agency was significantly higher when participants were instructed that the partner was human compared to when they were instructed otherwise. Furthermore, the study suggests the possibility of enhancing joint agency, even with artificial agents, such as computer programs, using simple instructions. These findings reveal the cognitive processes underlying the sense of joint agency, including beliefs about the partner, and extend previous studies on the sense of joint agency with artificial agents.

Further research is necessary to clarify the direct relationship between perceptions of partners and the sense of joint agency, as well as how instructions affect temporal changes in this sense of joint agency. In particular, it is important to disentangle the effects of specific behavioral features of the partner, such as predictability, responsiveness from the effects of instruction. Exploring these aspects will lead to a more comprehensive understanding of the cognitive processes that underlie joint action.

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