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Interpersonal Approach-Avoidance Actions Modulate the Joint Flanker Effect

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Abstract

This study aims to investigate the regulatory role of interpersonal embodied actions on joint action in social contexts. Previous research has primarily focused on embodied effects at the individual level, lacking investigation into the role of interpersonal embodiment in social contexts. This study combines interpersonal approach-avoidance actions with a joint Flanker task to systematically examine the regulatory effects of interpersonal embodied actions on joint action effects through a series of experiments, and to test the roles of partner' s social attributes and interaction effectiveness. Experiments 1a and 1b demonstrate that interpersonal approach actions can significantly shorten interpersonal distance perception and enhance joint action effects, whereas avoidance actions increase distance perception and eliminate joint action effects. Experiments 2a and 2b further reveal that the regulatory effects of embodied actions only emerge when the partner possesses social attributes and the two parties establish effective interaction. In summary, interpersonal approach-avoidance actions can regulate joint action effects, with interpersonal distance being an important influencing factor, but the embodied effects depend on the partner' s social attributes and interaction effectiveness. This study reveals the important role of interpersonal embodied effects in joint action and provides an embodied theoretical framework for further understanding joint action.

Full Text

Preamble

The Modulation Effect of Interpersonal Approach-Avoidance Actions on the Joint Flanker Effect

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Abstract

This study investigated how interpersonal embodied actions modulate joint action in social contexts. While previous research has predominantly focused on individual-level embodiment effects, few studies have examined the role of interpersonal embodiment in social interaction settings. By integrating interpersonal approach-avoidance actions with a joint Flanker task, this research systematically examined the modulatory effects of interpersonal embodied actions on joint action performance and tested the influence of a partner' s social attributes and interaction effectiveness. Experiments 1a and 1b demonstrated that interpersonal approach actions significantly shortened perceived interpersonal distance and enhanced the joint action effect, whereas avoidance actions increased distance perception and eliminated the joint action effect. Experiments 2a and 2b further revealed that these modulatory effects only emerged when the partner possessed social attributes and when effective interaction was established between both individuals. In summary, interpersonal approach-avoidance actions can modulate joint action effects, with interpersonal distance serving as a crucial mediating factor; however, these embodiment effects depend on the partner' s social attributes and interaction effectiveness. This study reveals the important role of interpersonal embodiment in joint action and provides an embodied theoretical framework for further understanding collaborative behavior.

Keywords: joint action; embodied cognition; interpersonal distance; approach-avoidance actions

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In social interaction contexts, individuals' behaviors are significantly influenced by the presence of others. Even without shared goals, performance typically differs systematically from solitary conditions (Mundy & Newell, 2007; Sebanz et al., 2006). For instance, compared with performing the Flanker task alone, partner-related flanker stimuli in joint Flanker tasks elicit more pronounced flanker interference effects—known as the joint Flanker effect (Atmaca et al., 2011; Dolk et al., 2014). To explain these phenomena, researchers have proposed cognitive frameworks such as the co-representation account and referential-coding account. The co-representation account suggests that individuals can comprehend a partner' s intentions (Milward et al., 2014; Tsai et al., 2008) and tend to integrate the partner' s task information into their own task representation to facilitate social collaboration (Beaurenaut et al., 2021; Sebanz et al., 2003, 2005). The referential-coding account emphasizes that individuals' cognitive action representations comprise a coding network that represents all perceived action effects (Hommel et al., 2001); when spatial coding is shared with another stimulus, stimulus processing activates this spatial code and subsequently triggers the action (Hommel, 2007). Despite their different explanatory orientations, both theories indicate that representing the partner and their task is crucial in joint action. However, these cognitive frameworks have not adequately incorporated another widely discussed perspective—embodied cognition. This limitation is particularly evident in methodological approaches, as previous joint action research has primarily relied on simple button-press responses (Campos-Moinier et al., 2023; de la Asuncion et al., 2015; Song et al., 2024), largely neglecting the potential influence of bodily actions in real interactive contexts. This is precisely the core tenet of embodied cognition theory, which posits that the body and its interactions with the environment play a vital role in shaping cognitive processes. Bodily actions not only influence individuals' perception of the environment (Simons, 2011) and shape fundamental thinking patterns (Lakoff, 2012) but also profoundly constrain emotional experiences, social attitudes, and interpersonal interactions (Tversky & Hard, 2009). Numerous empirical studies have confirmed the significant impact of bodily actions on higher-level cognition, including social cognition. For example, participants who maintained an upright posture reported stronger pride after receiving positive feedback compared to those in a slumped posture (Stepper & Strack, 1993). Nevertheless, in collaborative joint action contexts involving dyads, whether and how embodied actions modulate joint task performance remains unexplored systematically.

Individual-level embodied cognition research has demonstrated that approach and avoidance bodily actions can significantly influence individuals' perceptions and evaluations of others or objects (Kawakami et al., 2007; Van Dessel et al., 2020). For instance, individuals trained to perform specific reactive actions (e.g., approaching images of outgroup members) showed significantly reduced implicit social bias toward outgroup members and exhibited more intimate physical behaviors in subsequent real interactions, such as closer interaction distances and more direct body orientation. In social contexts, although some studies have found effects of bodily experiences on social cognition (e.g., individuals holding hot coffee tend to perceive others as "warmer people"), further research is still needed to extend this core embodied mechanism of "approach-avoidance" from the individual level to social interaction settings. In joint action contexts, there is no direct evidence yet whether interpersonal approach-avoidance actions can similarly regulate the intimacy or distance of interpersonal behavior, thereby affecting interpersonal distance. Meanwhile, interpersonal distance has been shown to be a key variable that modulates joint action effects; research indicates that closer or more distant interpersonal distances can regulate the level of self-other integration among interacting members and consequently influence joint action task performance, regardless of whether this distance manipulation stems from social relationship closeness or physical spatial proximity. For example, the joint Simon effect was significantly larger for friend dyads than for stranger dyads (Song et al., 2024); when two participants performed a joint Simon task outside each other' s personal space (i.e., beyond arm' s reach), the joint Simon effect disappeared (Guagnano et al., 2010). Thus, the question of whether interpersonal approach-avoidance actions can modulate joint action effects warrants further investigation.

Furthermore, compared to individual-level approach-avoidance actions, interpersonal approach-avoidance actions possess two key characteristics: the social attributes of the interaction partner and the effectiveness of interindividual bodily interaction—that is, the mutual influence of each other' s actions, where each person is both a giver and a receiver, forming a continuously iterative action-perception-action chain (Goffman, 1959). First, individuals show significant performance differences when facing partners with different social attributes. For instance, individuals perceive closer spatial distances when judging avatars facing them versus facing away (Jung et al., 2016), an effect that does not occur with non-social objects (Vestner et al., 2019). Spatial navigation tasks also show that position judgment errors are significantly smaller when targets are humans (social objects) compared to non-human objects (non-social objects) (Kuehn et al., 2018). These findings suggest that the facilitative effect of embodiment on task information processing depends on the social attributes of the interaction partner. Second, the effectiveness of interindividual bodily interaction is crucial for maintaining high-quality interactions between individuals. For example, in ball-tossing games, manipulating the frequency with which individuals receive passes (affecting their sense of participation and interaction effectiveness) can induce feelings of social exclusion (Williams et al., 2000), disrupting interpersonal interaction. During partner communication, face-to-face dialogue elicited significantly greater neural synchronization in the left inferior frontal cortex (associated with understanding others' intentions) compared to back-to-back dialogue, face-to-face monologue, or back-to-back monologue conditions (Jiang et al., 2012). These studies highlight the central role of effective bodily interaction in shaping social bonds and promoting cognitive synergy.

In summary, this study aims to investigate whether and how interpersonal embodied actions modulate joint action task performance, with a particular focus on examining how the partner' s social attributes and interaction effectiveness influence this modulatory effect. Specifically, this research employs interpersonal approach-avoidance actions as the interpersonal embodied manipulation and uses the joint Flanker paradigm as the joint action task. The advantage of this paradigm is that the task itself does not rely on external spatial relationships (Iani et al., 2014), effectively controlling for potential interference from spatial factors on embodied action effects. Experiments 1a and 1b aim to examine whether interpersonal approach-avoidance actions can modulate the joint action effect. Experiment 1a is a joint context where two human participants perform the joint Flanker task together; Experiment 1b is an individual context where participants perform the same task alone as a baseline control. The experiments include three embodied action manipulation conditions: approach, neutral, and avoidance. In the approach condition, the left participant pushes the joystick to the right and the right participant pushes it to the left, creating a mutual approach bodily experience; in the avoidance condition, the left participant pushes left and the right participant pushes right, creating a mutual avoidance bodily experience; in the neutral condition, both participants push the joystick forward or backward, an action that does not convey specific interpersonal approach-avoidance meaning. Experiments 2a and 2b further examine whether social attributes and interaction effectiveness are necessary prerequisites for the modulatory effect of interpersonal approach-avoidance actions on joint action. Experiment 2a replaces the real human partner with a conspicuous non-social object (e.g., a maneki-neko, Dolk et al., 2013, 2014) to explore whether the modulatory effect depends on the partner' s social attributes. Experiment 2b fixes one participant to always perform neutral actions while the other performs approach/neutral/avoidance actions, blocking the interactivity between both parties to simulate ineffective or unidirectional interaction, and investigates whether the modulatory effect depends on the effectiveness of interindividual bodily interaction.

Experiment 1

Experiment 1 preliminarily investigated whether interpersonal approach-avoidance actions can modulate the joint action effect. The experiment included two contexts: a joint context (Experiment 1a) and an individual context (Experiment 1b), and manipulated three types of interpersonal embodied actions: approach, neutral, and avoidance. We hypothesized that among the three conditions, interpersonal approach actions would lead participants to perceive closer interpersonal distances and produce more significant joint action effects.

2.1.1 Method

(1) Participants. This experiment adopted a 3 (Embodied Action Type: approach, neutral, avoidance) × 2 (Stimulus Type: baseline, incompatible) within-subjects design. Given the absence of similar embodiment research in the joint action domain, this study used a relatively conservative medium effect size (f = 0.2) for sample size calculation. Based on analysis using G*Power 3.1.9.7 (Faul et al., 2007), to achieve 95% statistical power at a significance level of 0.05, this experiment required at least 43 participants. Since the joint context required dyadic pairing, the final sample comprised 44 female university students (mean age = 20.50 years, SD = 1.36 years, range = 18–24 years) with normal or corrected-to-normal vision and no color blindness. Random grouping ensured that each pair of participants were strangers before the experiment. This study was approved by the institutional ethics committee. Participants signed informed consent before the experiment and received compensation afterward.

(2) Materials. The experiment was programmed using E-Prime 3.0 to control stimulus presentation and data collection. Stimuli were presented on a Dell LCD monitor (resolution: 1920$×$1080, refresh rate: 60Hz) against a black background. Participants responded to stimuli using a flight simulator joystick (PXN-2113PRO). The viewing distance was approximately 56 cm.

During the experiment, four letters (H, K, S, C) served as target stimuli, with two flanker stimuli on each side of every target letter. Two participants collaborated on the task: one responded to two letters (e.g., H and K) while the other responded to the remaining two letters (e.g., S and C). Based on the relationship between targets and flankers, experimental stimuli were divided into three types: (1) compatible trials, where flankers and targets belonged to the same participant' s response set; (2) neutral trials, where flankers belonged to neither participant' s response set; and (3) incompatible trials, where flankers and targets belonged to different participants' response sets. Each stimulus subtended approximately 3.1° × 1.1° of visual angle. Specific experimental stimuli are shown in Table 1 .

Table 1 Examples of experimental stimuli

(3) Procedure. In each trial (Figure 1 [Figure 1: see original paper]), a central fixation point was presented for 500 ms, followed by a 500 ms blank screen. The experimental stimulus then appeared at the center of the screen and remained visible for 2000 ms or until a response was made. Subsequently, feedback was presented for 1000 ms: "Correct!" for correct responses, "Error!" for incorrect responses, and "No Response" for trials without timely responses. The inter-trial interval was 1000 ms.

Figure 1 Experimental flowchart

When the target stimulus appeared, participants made different responses under the three experimental conditions (approach, neutral, avoidance). In the approach condition, the left participant was instructed to push the joystick to the right upon seeing their target stimulus, while the right participant pushed left, together creating an embodied approach meaning. In the neutral condition, both left and right participants pushed the joystick forward or backward upon seeing their target stimuli, an action that conveyed no specific interpersonal meaning between the two individuals. In the avoidance condition, the left participant pushed the joystick left while the right participant pushed right, together creating an embodied avoidance meaning. Different experimental orders (approach-neutral-avoidance, avoidance-neutral-approach) were counterbalanced across participants. The neutral condition was included to eliminate potential residual embodiment effects from preceding conditions. Each experimental condition comprised two phases: a practice block of 12 trials and a formal experimental block of 192 trials. The practice block presented only neutral trials to help participants familiarize themselves with the response requirements of the current experimental condition. During the formal experimental block, the three stimulus types (compatible, neutral, incompatible) were presented randomly, with a optional break after 96 trials.

(4) Interpersonal distance measurement. To verify that interpersonal approach-avoidance actions modulated interpersonal distance between participants while ensuring implicit measurement, this study did not use questionnaires. Instead, we used the physical distance between chairs that participants adjusted autonomously as a quantitative index. The specific procedure was as follows: after completing each experimental condition (e.g., the approach condition), the experimenter guided both participants to another room to complete a questionnaire (five brief questions unrelated to the experiment content or participants' privacy, such as "What superpower would you most like to have?"). In this room, two adjacent chairs were placed by a table; participants needed to move the chairs themselves to sit down and complete the questionnaire. After finishing, participants returned to the original experimental room to continue the experiment, and the experimenter subsequently measured the physical distance between the chairs.

2.1.2 Results

Following previous joint Flanker research (Dolk et al., 2014), since the influence of a partner' s presence on individual task performance is primarily manifested in incompatible conditions, the average reaction time of compatible and neutral trials was used as the baseline for comparison with incompatible conditions in the reaction time analysis. To investigate the effect of interpersonal approach-avoidance actions on the joint Flanker effect, this study conducted a repeated-measures ANOVA on reaction times with 3 (Embodied Action Type: approach, neutral, avoidance) $\times$ 2 (Stimulus Type: baseline, incompatible). Additionally, to examine changes in interpersonal distance across the three experimental conditions, a one-way repeated-measures ANOVA was performed on interpersonal distance with Embodied Action Type as the factor. To explore the relationship between joint action performance and interpersonal distance changes, we conducted Pearson correlation analyses. Considering that neutral actions lacked embodied meaning, we analyzed neutral condition data separately. Specifically, we performed correlation analyses separately for conditions with embodied meaning (approach and avoidance) and for the neutral condition lacking embodied meaning. Data analysis retained only correct-response trials; 0.17% of trials were excluded due to incorrect responses in this experiment.

The reaction time repeated-measures ANOVA results (Figure 2 [Figure 2: see original paper]A) showed a significant main effect of Stimulus Type, $F(1,43) = 75.283$, $p < 0.001$, np 2 = 0.636. Reaction times in incompatible conditions ($M = 619.415$ ms, $SE = 10.505$ ms) were significantly longer than in baseline conditions ($M = 598.016$ ms, $SE = 10.197$ ms), mean difference = 21.399 ms, 95% CI = [16.425, 26.373], $SE = 2.466$ ms, $t(43) = 8.677$, $p < 0.001$, Cohen' s $d = 0.280$. The interaction between Embodied Action Type and Stimulus Type was significant, $F(2,86) = 7.800$, $p < 0.001$, np 2 = 0.154. Follow-up simple effects analysis revealed that the difference in reaction times between incompatible and baseline conditions (i.e., the Flanker effect) was significant across all interpersonal embodied action types: approach condition, mean difference = 31.623 ms, 95% CI = [21.395, 41.851], $SE = 3.291$ ms, $t(43) = 9.609$, $p < 0.001$, Cohen' s $d = 0.414$; neutral condition, mean difference = 18.879 ms, 95% CI = [6.077, 31.681], $SE = 4.119$ ms, $t(43) = 4.584$, $p < 0.001$, Cohen' s $d = 0.247$;

avoidance condition, mean difference = 13.695 ms, 95% CI = [2.804, 24.586], SE = 3.504 ms, t(43) = 3.908, p = 0.005, Cohen' s d = 0.179.

Subsequent polynomial contrast analysis revealed a significant increasing linear trend in Flanker effects from avoidance to neutral to approach conditions, F(1,43) = 13.723, p = 0.001, ηp 2 = 0.242. These results indicate that interpersonal embodied actions can effectively modulate the Flanker effect, with more approach-oriented embodied actions producing larger Flanker effects. The main effect of Embodied Action Type was not significant, F(2,86) = 1.799, p = 0.179.

The interpersonal distance repeated-measures ANOVA results (Figure 2B) showed a significant effect of Embodied Action Type, F(2,42) = 17.076, p < 0.001, ηp 2 = 0.448. Bonferroni-corrected post-hoc tests revealed significant differences in interpersonal distance between any two embodied action type conditions: interpersonal distance in the approach condition (M = 13.473 cm, SE = 0.918 cm) was closer than in the neutral condition (M = 16.182 cm, SE = 0.836 cm), mean difference = -2.709 cm, 95% CI = [-5.240, -0.178], SE = 0.973 cm, t(21) = -2.785, p = 0.033, Cohen' s d = -0.662; approach condition distance was closer than in the avoidance condition (M = 18.655 cm, SE = 0.859 cm), mean difference = -5.182 cm, 95% CI = [-7.825, -2.538], SE = 1.016 cm, t(21) = -5.099, p < 0.001, Cohen' s d = -1.267; neutral condition distance was closer than in the avoidance condition, mean difference = -2.473 cm, 95% CI = [-4.079, -0.867], SE = 0.617 cm, t(21) = -4.005, p = 0.002, Cohen' s d = -0.605. These results demonstrate that interpersonal embodied actions effectively modulated participants' perceived interpersonal distance.

Figure 2 Results of reaction times and interpersonal distance in Experiment 1a

Pearson correlation analysis revealed a significant negative correlation between interpersonal distance and Flanker effect under embodied approach and avoidance action conditions, r = -0.326, p = 0.031, indicating that as interpersonal distance increased, the Flanker effect decreased (Figure 3 [Figure 3: see original paper]). However, under the neutral action condition lacking embodied meaning, the correlation was not significant, r = 0.098, p = 0.663.

Figure 3 Relationship between joint action effect and interpersonal distance in Experiment 1a

2.1.3 Discussion

Consistent with our predictions, when dyadic participants produced avoidance, neutral, and approach embodied actions by pushing joysticks in different directions, we observed progressively shorter interpersonal distances accompanied by more pronounced joint Flanker effects. Moreover, Pearson correlation analysis showed that under embodied action conditions, closer interpersonal distance was associated with stronger joint Flanker effects; no such pattern was observed in the neutral condition lacking embodied meaning. These results indicate that interpersonal approach-avoidance actions indeed influence joint task performance, and that interpersonal distance is an important factor in this process.

2.2 Experiment 1b

In joint action research, a single-person context is typically established as a baseline to compare with joint context performance and assess the degree of influence from the partner's presence (Sebanz et al., 2003). Therefore, Experiment 1b was conducted in a single-person context.

2.2.1 Method

(1) Participants. This experiment used the same design as Experiment 1a. Referring to the sample size of Experiment 1a, we recruited 44 female university students (mean age = 20.94 years, SD = 1.65 years, range = 19–25 years). In the single-person context, each participant completed the experiment alone. All other settings were identical to Experiment 1a.

(2) Materials and Procedure. The experimental materials, equipment, and procedure were essentially the same as in Experiment 1a. The difference was that this experiment was conducted in a single-person context, with one participant completing the task alone. Stimuli that would have been responded to by a partner in the joint context disappeared automatically after 2000 ms without feedback. Different experimental orders and participant positions (left or right) were counterbalanced across participants. Since only one participant was present in each session, interpersonal distance data were not collected.

2.2.2 Results

Data processing and analysis methods were identical to Experiment 1a. In this experiment, 0.19% of trials were excluded due to incorrect responses.

The reaction time repeated-measures ANOVA results (Figure 4 [Figure 4: see original paper]) showed a significant main effect of Stimulus Type, $F(1,43) = 16.490$, $p < 0.001$, ηp 2 = 0.277. Reaction times in incompatible conditions (M = 662.333 ms, SE = 14.276 ms) were significantly longer than in baseline conditions (M = 649.055 ms, SE = 15.023 ms), mean difference = 13.277 ms, 95% CI = [6.683, 19.871], SE = 3.270 ms, $t(43) = 4.061$, $p < 0.001$, Cohen's d = 0.127. The main effect of Embodied Action Type was not significant, $F(2,86) = 1.089$, $p = 0.335$; the interaction between Embodied Action Type and Stimulus Type was not significant, $F(2,86) = 1.127$, $p = 0.285$.

Figure 4 Reaction time results of Experiment 1b

2.2.3 Joint Analysis Results: Experiments 1a & 1b

To investigate the degree to which individual task performance was influenced by the partner' s presence, we conducted a mixed ANOVA on reaction times from Experiments 1a and 1b, including two within-subjects factors (Embodied Action Type, Stimulus Type) and one between-subjects factor (Social Context: joint context, single-person context). Results showed a significant main effect of Stimulus Type, $F(1,86) = 71.691$, $p < 0.001$, np 2 = 0.455, with faster responses in baseline conditions, mean difference = 17.338 ms, 95% CI = [13.267, 21.409], SE = 2.048 ms, $t(86) = 8.467$, $p < 0.001$, Cohen' s d = 0.190. The main effect of Social Context was significant, $F(1,86) = 6.946$, $p = 0.010$, np 2 = 0.075, with faster responses in the joint context (i.e., Experiment 1a), mean difference = 46.978 ms, 95% CI = [11.544, 82.413], SE = 17.825 ms, $t(86) = 2.636$, p = 0.010, Cohen' s d = 0.514. The three-way interaction between Embodied Action Type, Stimulus Type, and Social Context was significant, $F(2,172) = 4.795$, p = 0.009, np 2 = 0.053.

To directly compare Flanker effects, we calculated the difference in reaction times between baseline and incompatible conditions for each participant. Accordingly, a 3 (Embodied Action Type: approach, neutral, avoidance) × 2 (Social Context: joint context, single-person context) repeated-measures ANOVA was performed on Flanker effects. Results showed a significant main effect of Embodied Action Type, $F(2,172) = 3.811$, $p = 0.024$, np 2 = 0.042. Bonferroni-corrected post-hoc tests revealed that the Flanker effect in the approach condition (M = 21.463 ms, SE = 3.010 ms) was significantly larger than in the avoidance condition (M = 12.174 ms, SE = 2.843 ms), mean difference = 9.289 ms, 95% CI = [0.443, 18.134], SE = 3.623 ms, $t(86) = 2.564$, $p = 0.036$, Cohen' s d = 0.348. All other pairwise comparisons between embodied action types were not significant, largest t = 1.720, smallest p = 0.267. The interaction between Embodied Action Type and Social Context was significant, $F(2,172) = 4.795$, p = 0.009, np 2 = 0.053. Simple effects analysis revealed that in the joint context, the Flanker effect in the approach condition (M = 31.623 ms, SE = 3.291 ms) was significantly larger than in the avoidance condition (M = 13.695 ms, SE = 3.504 ms), mean difference = 17.928 ms, 95% CI = [2.459, 33.397], SE = 5.123 ms, $t(86) = 3.499$, $p = 0.011$, Cohen' s d = 0.671. In the single-person context, no significant differences were found between embodied action types, $t(86) <$ 1.541, $p > 0.05$.

Experiment 1b found a main effect of Stimulus Type, consistent with previous research (Atmaca et al., 2011; Dolk et al., 2014), indicating that conflict between relevant and irrelevant stimuli persists in single-person conditions, leading to significantly longer reaction times in incompatible versus baseline conditions. Further mixed ANOVA revealed a main effect of Social Context, with participants responding faster when another person was present. This phenomenon may be explained by social facilitation theory (Zajonc, 1965), which posits that the presence of others can influence individual task performance, facilitating simple tasks while potentially inhibiting complex ones (Bond & Titus, 1983). The Flanker task used in this experiment required participants to respond only to specific letters, constituting a simple Go/No-Go task; thus, shorter reaction times in the joint context than in the single-person context align with social facilitation predictions. Critically, the three-way interaction and post-hoc analyses indicated that in the single-person context, no significant differences in Flanker effects existed across the three embodied conditions; however, in the joint context, the effect varied significantly across embodied conditions. This demonstrates that joint task performance is only modulated under interpersonal embodied action conditions.

Experiments 1a and 1b demonstrated that interpersonal approach-avoidance actions modulate joint action performance. Experiment 2 further examined whether this modulatory effect is constrained by two factors: (1) the partner' s social attributes, and (2) interaction effectiveness. Experiment 2a replaced the human partner with a maneki-neko (non-social object) to test whether the modulatory effect depends on the partner' s social attributes. Experiment 2b blocked interaction effectiveness by fixing one participant to always perform neutral actions while the other performed approach/neutral/avoidance actions, simulating ineffective or unidirectional interaction to examine whether the modulatory effect depends on the effectiveness of bodily interaction between social partners. We hypothesized that the modulation of joint action by interpersonal approach-avoidance actions requires both social attributes and effective interaction; therefore, we expected no modulation of the joint action effect by embodied actions in Experiments 2a and 2b.

3.1.1 Method

(1) Participants. This experiment used the same design as Experiment 1a and recruited 44 female university students (mean age = 20.50 years, SD = 1.46 years, range = 19–24 years). All other settings were identical to Experiment 1a.

(2) Materials and Procedure. The experimental materials, equipment, and procedure were essentially the same as in Experiment 1a. The difference was that one participant in each dyad was replaced by a maneki-neko measuring 12.5 cm in height, 9 cm in width, and 7 cm in thickness. Throughout the experiment, the maneki-neko' s left arm waved continuously at a frequency of 0.4 Hz at a 50° angle from vertical (Dolk et al., 2013). Different experimental orders and maneki-neko positions were counterbalanced across participants.

3.1.2 Results

Data processing and analysis methods were identical to Experiment 1a. In this experiment, 0.18% of trials were excluded due to incorrect responses.

The reaction time repeated-measures ANOVA results (Figure 5 [Figure 5: see original paper]) showed a significant main effect of Stimulus Type, $F(1,43) = 21.408$, $p < 0.001$, ηp 2 = 0.332. Reaction times in incompatible conditions (M = 678.253 ms, SE = 15.083 ms) were significantly longer than in baseline conditions (M = 666.477 ms, SE = 14.725 ms), mean difference = 11.777 ms, 95% CI = [6.644, 16.910], SE = 2.545 ms, $t(43) = 4.627$, $p < 0.001$, Cohen' s d = 0.111. The main effect of Embodied Action Type was not significant, $F(2,86) =$

0.312, $p = 0.733$; the interaction between Embodied Action Type and Stimulus Type was not significant, $F(2,86) = 0.272$, $p = 0.763$.

Figure 5 Reaction time results of Experiment 2a

3.1.3 Joint Analysis Results: Experiments 2a & 1b

To compare task performance between the maneki-neko context and the single-person context, we conducted a mixed ANOVA on reaction times including two within-subjects factors (Embodied Action Type, Stimulus Type) and one between-subjects factor (Social Context: maneki-neko context, single-person context). Results showed a significant main effect of Stimulus Type, $F(1,86) = 36.561$, $p < 0.001$, ηp 2 = 0.298, with faster reaction times in baseline conditions, mean difference = 12.527 ms, 95% CI = [8.408, 16.645], SE = 2.072 ms, $t(86) = 6.047$, $p < 0.001$, Cohen' s d = 0.119. All other main effects and interactions were not significant, largest F = 1.372, smallest p = 0.256.

3.1.4 Discussion

Consistent with our hypothesis, when the partner (maneki-neko) lacked social attributes, Experiment 2a observed no modulatory effect of embodied actions on the joint action effect. Further mixed ANOVA showed no significant difference in Flanker effects between the maneki-neko context and the single-person context, indicating that no joint Flanker effect emerged. This result is inconsistent with previous research showing that joint Flanker effects can be observed as long as the partner has physical salience (i.e., can attract participants' attention, Dolk et al., 2014). Our findings suggest that compared to general cognitive factors, the modulatory mechanism of interpersonal approach-avoidance actions may have higher dependence on the partner' s social attributes.

3.2.1 Method

(1) Participants. This experiment used the same design as Experiment 1a. Due to increased between-subjects counterbalancing factors (i.e., the position of the participant performing neutral embodied actions) and because only data from participants who completed all three embodied action types were included in the analysis, this experiment recruited 96 female university students (mean age = 20.69 years, SD = 2.09 years, range = 18–26 years). All other settings were identical to Experiment 1a.

(2) Materials and Procedure. The experimental materials, equipment, and procedure were essentially the same as in Experiment 1a. The difference was that one participant in each dyad performed embodied actions under three different conditions, while the other member performed only neutral embodied actions throughout the entire experiment. Different experimental orders and positions of the neutral-action participant were counterbalanced across participants.

3.2.2 Results

Data processing and analysis methods were identical to Experiment 1a. In this experiment, 0.15% of trials were excluded due to incorrect responses.

The reaction time repeated-measures ANOVA results (Figure 6 [Figure 6: see original paper]A) showed a significant main effect of Stimulus Type, $F(1,47) = 36.916$, $p < 0.001$, np 2 = 0.440. Reaction times in incompatible conditions (M = 607.415 ms, SE = 9.201 ms) were significantly longer than in baseline conditions (M = 589.840 ms, SE = 9.305 ms), mean difference = 17.188 ms, 95% CI = [11.497, 22.879], SE = 2.829 ms, $t(47) = 6.076$, $p < 0.001$, Cohen' s d = 0.236. The main effect of Embodied Action Type was not significant, $F(2,94) = 2.254$, $p = 0.124$; the interaction between Embodied Action Type and Stimulus Type was not significant, $F(2,94) = 0.728$, $p = 0.486$.

The interpersonal distance repeated-measures ANOVA results (Figure 6B) showed a significant effect of Embodied Action Type, $F(2,94) = 14.914$, $p < 0.001$, np 2 = 0.241. Bonferroni-corrected post-hoc tests revealed significant differences in interpersonal distance between any two embodied action type conditions: interpersonal distance in the approach condition (M = 13.135 cm, SE = 0.549 cm) was closer than in the neutral condition (M = 14.773 cm, SE = 0.563 cm), mean difference = -1.638 cm, 95% CI = [-2.984, -0.291], SE = 0.543 cm, $t(47) = -3.018$, $p = 0.012$, Cohen' s d = -0.400; approach condition distance was closer than in the avoidance condition (M = 16.263 cm, SE = 0.656 cm), mean difference = -3.127 cm, 95% CI = [-4.567, -1.687], SE = 0.580 cm, $t(47) = -5.393$, $p < 0.001$, Cohen' s d = -0.763; neutral condition distance was closer than in the avoidance condition, mean difference = -1.490 cm, 95% CI = [-2.966, -0.013], SE = 0.595 cm, $t(47) = -2.505$, $p = 0.047$, Cohen' s d = -0.364. These results indicate that unidirectional embodied actions also effectively modulated participants' perceived interpersonal distance.

Figure 6 Reaction time and interpersonal distance results of Experiment 2b

3.2.3 Joint Analysis Results: Experiments 2b & 1b

To compare task performance between the neutral-condition joint context and the single-person context, we conducted a mixed ANOVA on reaction times including two within-subjects factors (Embodied Action Type, Stimulus Type) and one between-subjects factor (Social Context: joint context, single-person context). Results showed a significant main effect of Stimulus Type, $F(1,90) = 50.094$, $p < 0.001$, np 2 = 0.358, with faster responses in baseline conditions, mean difference = 15.233 ms, 95% CI = [10.957, 19.508], SE = 2.152 ms, $t(90) = 7.078$, $p < 0.001$, Cohen' s d = 0.171. The main effect of Social Context was significant, $F(1,90) = 11.484$, $p = 0.001$, np 2 = 0.113, with faster responses in the joint context, mean difference = 57.260 ms, 95% CI = [23.691, 90.828], SE = 16.897 ms, $t(90) = 3.389$, $p = 0.001$, Cohen' s d = 0.641. All other main effects and interactions were not significant, largest F = 2.700, smallest p = 0.070.

3.2.4 Discussion

Consistent with our hypothesis, when participants could not establish effective interaction, Experiment 2b observed no modulatory effect of embodied actions on the joint action effect. Further mixed ANOVA showed that, similar to Experiment 1a, the main effect of Social Context was significant, with participants responding faster when another person was present, consistent with social facilitation effects. Critically, there was no significant difference in Flanker effects between the joint context and the single-person context, indicating that no joint Flanker effect emerged. Combined with the joint analysis from Experiments 2a and 1b, these results suggest that for interpersonal approach-avoidance actions to exert their modulatory effect, the partner' s social attributes alone are insufficient; effective interaction between both participants is also required. Although the modulatory effect of interpersonal embodied actions was not significant, Experiment 2b found a significant main effect of Embodied Action Type on the interpersonal distance measure, indicating that unidirectional embodied actions still affected interpersonal distance between dyads. This result was likely driven by the action-initiating participant (i.e., the participant performing approach, avoidance, or neutral actions). Previous research has shown that physical contact with others or objects can enhance perceived intimacy (Kawakami et al., 2007; Stepper & Strack, 1993; Van Dessel et al., 2020). Therefore, despite the absence of bidirectional embodied interaction, approach or avoidance actions may still alter the action initiator' s perception of intimacy toward their partner, resulting in interpersonal distance differences across embodied conditions.

4 General Discussion

This study is the first to introduce an embodied cognition perspective into the joint action paradigm, systematically examining whether interpersonal approach-avoidance embodied actions can modulate joint action task performance and the potential role of interpersonal distance, thereby advancing the integration of embodied cognition theory and joint action research. Building on this foundation, the study further reveals the necessary prerequisites and boundary conditions for interpersonal embodiment effects. Experiments 1a and 1b combined interpersonal embodied action manipulations with the joint Flanker task, finding that in the approach condition, participants formed mutual approach bodily representations, significantly shortening interpersonal distance perception and enhancing the joint action effect; conversely, in the avoidance condition, mutual avoidance bodily representations significantly increased interpersonal distance perception and eliminated the joint action effect. Experiments 2a and 2b manipulated the partner' s social attributes (human vs. non-social object) and bodily interaction effectiveness (interactive actions vs. unidirectional actions), revealing that interpersonal approach-avoidance actions only modulated joint Flanker task performance when the partner possessed social attributes and established effective interaction with the individual.

In the field of embodied cognition, existing research has primarily focused on the individual level, demonstrating that action training using joysticks to approach or avoid images of people can effectively change individuals' implicit social attitudes and subsequent interactive behaviors (e.g., seating distance, body orientation, Kawakami et al., 2007; Van Dessel et al., 2020). However, systematic research on the "approach-avoidance" embodied mechanism in social interaction contexts remains lacking. This study extends such embodied manipulations to interpersonal joint contexts, not only continuing the research tradition of action metaphors shaping social cognition but also constructing a novel interpersonal approach-avoidance paradigm (Experiment 1a). This paradigm requires participants to move the joystick toward or away from their partner to respond to target stimuli. Results showed that in the approach condition, participants perceived significantly closer interpersonal distances, while in the avoidance condition, this distance increased significantly. This finding confirms the mapping mechanism between bodily actions and conceptual metaphors at the interpersonal level (moving the joystick toward the partner signifies "distance shortening," while moving it away signifies "distance increasing"), and demonstrates that metaphor processing based on dyadic coordinated actions can reshape interpersonal distance cognition, thereby expanding the explanatory scope of embodied cognition theory in interactive contexts. In the joint action domain, this study further reveals the modulatory effect of interpersonal embodied actions on joint action task performance. Specifically, individuals in the approach condition showed stronger flanker interference effects in the joint Flanker task, while the avoidance condition weakened or eliminated this effect. Previous research has indicated that closer interpersonal distance can promote perceived similarity, blur self-other boundaries (Parkinson et al., 2018), and enhance self-other integration (Song et al., 2024). Consistently, this study found that interpersonal distance shaped by bodily actions directly influenced the level of self-other integration between individuals and their partners, thereby systematically modulating joint action performance. In summary, this study innovatively introduces an embodied cognition paradigm into joint action research, not only verifying the plastic effect of bodily actions on interpersonal distance at the interpersonal level but also revealing for the first time the modulatory effect of such actions in joint action, providing new experimental evidence and research pathways for understanding the coupling mechanisms among bodily actions, interpersonal distance, and cognitive systems in real social interactions.

Building on these findings, this study further reveals two key prerequisite conditions for the modulatory effect of interpersonal approach-avoidance actions on joint action effects: (1) the partner' s social attributes, and (2) the effectiveness of bodily interaction. Experiment 2a introduced a non-social partner (e.g., maneki-neko) and found that it could not support the modulatory effect of embodied actions on joint action effects. Previous research has shown that physically salient objects (e.g., maneki-neko, metronomes) can elicit joint action effects similar to human partners (Dolk et al., 2013, 2014; Wang et al., 2025), a mechanism explainable by referential-coding theory—physical stimuli activate action representations through shared spatial coding, causing response conflict due to irrelevant information coding (Dolk et al., 2014; Hommel et al., 2001; Hommel, 2007). However, this study found that embodied actions were ineffective under these conditions, suggesting that their modulatory effect depends on social processing pathways; non-social partners cannot provide social cues such as intentions, leading to disruption of social cognitive pathways. This result supports the "multidimensional representation model" perspective, indicating that embodied actions have specificity for social dimension representations (Song & Dong, 2023), with mechanisms independent of general spatial coding. On the other hand, Experiment 2b disrupted bodily interaction effectiveness by fixing the partner to perform neutral actions, similarly observing the disappearance of the embodied action modulatory effect. This result suggests that unidirectional actions are insufficient to produce modulatory effects; embodied actions must be based on bidirectional, reciprocal action-response cycles (e.g., A approaches → B responds with approach) to be effective. This finding aligns with social exchange theory (Homans, 1958), which posits that interpersonal behavior is essentially a reciprocal exchange, and only bidirectional responses can effectively shorten interpersonal distance and increase intimacy (Sprecher et al., 2013). Cognitive neuroscience research further supports this view, showing that effective bodily interaction can induce interbrain synchronization, including resonance in the putative mirror neuron system (pMNS) involved in motor planning and the ventromedial prefrontal cortex (vmPFC) involved in thinking about others' mental states, with information flow transmitted bidirectionally between interacting partners (Schippers et al., 2010). For example, face-to-face interaction between couples significantly enhanced synchronization in the left inferior frontal cortex (Jiang et al., 2012), indicating that the body serves as a neural interface for social meaning, and its modulatory function must be realized through real-time interaction. This study clarifies the boundary conditions for interpersonal approach-avoidance actions to exert their modulatory effect in joint action from the dimensions of social attributes and interaction effectiveness, providing new empirical evidence for understanding the mechanism of embodied actions in joint action.

Moreover, this study provides an important supplement to understanding joint action mechanisms from an embodied interaction perspective, bridging gaps in previous purely cognitive theories in explaining bodily coordination phenomena. While co-representation and referential-coding theories have revealed how individuals represent others' tasks and responses at the mental level, they struggle to fully explain the rapid, spontaneous, and unconscious action coordination in joint contexts. This study found that even when individuals' action intentions and physical spatial references remained constant, interpersonal approach-avoidance actions could still significantly modulate joint action effects. This result suggests that social interaction based on the body may constitute a modulatory pathway independent of cognitive representation, directly influencing coordinated behavior between individuals through real-time coupling of action-perception loops and metaphorical mapping. Therefore, the embodied perspective does not negate the role of cognitive representation but rather emphasizes that bodily interaction and social cognition have synergistic or even complementary functions in joint action, thereby refining the existing theoretical framework for explaining interpersonal coordination mechanisms.

In conclusion, this study reveals the modulatory effect of interpersonal approach-avoidance actions on joint action and its prerequisite conditions, providing a new perspective for understanding embodied cognition in joint action research. However, this study has several limitations: First, although using a joystick to complete tasks is embodied, its action complexity is insufficient compared to real social interactions (e.g., partner dancing, collaborative heavy lifting). Future experiments could increase ecological validity by adding haptic feedback or multimodal embodied action designs. Second, this study used a relatively low-level task paradigm, though previous research has demonstrated that joint action effects can also be validated in high-level, abstract task stimuli (Zhao et al., 2025; Zheng & Wang, 2023). Therefore, future experiments could investigate the generality of embodied action effects using abstract-level paradigms. Additionally, future research should employ neuroimaging techniques to further explore the neural basis of embodied actions in joint action.

This study systematically reveals the modulatory effect of interpersonal approach-avoidance actions on joint action task performance through a series of experiments and further clarifies the key prerequisite conditions for this effect. The results demonstrate that interpersonal approach-avoidance actions can effectively modulate joint Flanker task performance, with interpersonal distance being an important influencing factor. However, this modulatory effect only occurs when the partner possesses social attributes and establishes effective interaction with the individual. This study not only expands the applicability of embodied cognition theory in the joint action domain but also provides empirical evidence for elucidating the mechanism of embodied actions in joint action.

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