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Implicit priming of embodied cognition on human motor intention understanding in dyads in love

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Abstract

Recent theories of embodied cognition suggest that congruence between observed actions and integrated templates of self-related motor experiences facilitates intention understanding of significant others. We tested this hypothesis in 60 participants using response latency measures and a motor intention inference task, which involved video clips of actions performed either by themselves, their beloved partner, or by acquaintances or strangers (as controls). Results show significantly faster reaction times when participants had to understand the intentions of themselves and their significant others, especially if they reported being passionately in love with their significant others. These findings provide an account for facilitation effects of embodied cognition on intention understanding among dyads in love.

Keywords

embodied cognition, love, dyads, intention understanding, mirror neuron system

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Couples in passionate love often refer to each other as the 'better half' or 'soul mate', suggesting that self-expansion occurs in the relationship (Aron & Aron, 1996; Hatfield & Walster, 1978; James, 1950). This quest for union among couples passionately in love is consistent with evolutionary theory's claim that intense emotional experiences during a lifetime (e.g., passionate love) may be a central human motivation to *expand one's self* (Barkow, Cosmides, & Tooby, 1992; James, 1950).

On a cognitive level, self-expansion suggests that each partner makes a decision (conscious or not) to include the significant other in his or her own self representation (Aron & Aron, 1996), allowing the creation of a shared mental representation of the self and partner, especially in love relationships. For instance, when an individual forms a love relationship, her/his own sense of self assimilates some of her/his partner's characteristics. In the past two decades, behavioral and neuroimaging evidence appeared consistent with the self-expansion model, including the activation of self-related brain areas in people passionately in love and yearning for union (Aron & Aron, 1996; Bianchi-Demicheli, Grafton, & Ortigue, 2006; Ortigue, Bianchi-Demicheli, Hamilton, & Grafton, 2007).

Passionate love: A quest for union between self and other

From a phenomenological viewpoint, passionate love involves a yearning, or intense longing, for union with another (Hatfield & Rapson, 1993). Passionate love is complex, including appraisals or appreciations, subjective feelings, expressions, patterned physiological processes, action tendencies, and instrumental behaviors (Hatfield & Rapson, 1993). Reciprocated love (union with the other) is associated with fulfillment and ecstasy, while unrequited love (separation) is associated with feelings of emptiness, anxiety, and despair.

Couples passionately in love do, indeed, yearn for union and act to secure it. For instance, lovers often use 'we' instead of 'I' or 'you' (Aron & Aron, 1996; Hatfield & Rapson, 1993; Hatfield & Sprecher, 1986); they tend to gaze at one another (Hatfield & Rapson, 1993; Hatfield & Sprecher, 1986; Williams & Kleinke, 1993), stand close to one another, and consider themselves as 'one' such that the usual give and take of relationships does not apply (Clark & Grote, 1998; Hatfield & Rapson, 1993; Hatfield, Rapson, & Aumer-Ryan, 2008).

Some signs of love are obvious and explicit. Lovers kiss, hold hands, and embrace (Andersen, Guerrero, & Jones, 2006; Lockard & Adams, 1980). Other signs that people are passionately in love are more subtle, automatic, and sometimes implicit (non-conscious). For instance, individuals engaged in mutual gaze reported greater romantic love, attraction, interest, warmth, and respect for one another than did control participants (Kellerman, Lewis, & Laird, 1989). People in love have automatic motor 'inclination' toward one another (e.g., visibly incline when sitting side by side, as at a dinner table; Galton, 1884).

Modern research supports Galton's postural hypothesis and emphasizes the role of embodied cognition in couple relationships (Cacioppo, Petty, Losch, & Crites, 1994; Mehrabian, 1968; Niedenthal, Barsalou, Winkielman, & Ric, 2005). Investigating embodied cognition in loving relationships may provide a scientific account of common knowledge describing lovers' ability to automatically infer the significant other's mental states and motor intentions (i.e., the facilitation effect). For lovers, the facilitation effect

should be far stronger when observing the beloved partner's tasks than those of strangers (Ortigue & Bianchi-Demicheli, 2008).

In romantic love relationships, mutual understanding of motor intentions may occur, for example, when a spouse anticipates a beloved's intention before s/he even entirely completes the action (Ortigue & Bianchi-Demicheli, 2008). More precisely, a husband may immediately understand his wife's intention to drink based on the way she grasps a glass. Because mutual understanding is critical to love relationships, it is hypothesized that this phenomenon is facilitated in couples in passionate love (Ortigue & Bianchi-Demicheli, 2008). This hypothesis, however, is untested for embodied cognition. We specifically address this question in the present study by evaluating automatic intention understanding in dyads who were in passionate love (when compared with dyads not in passionate love as controls).

Facilitation effects of embodied cognition on intention understanding

Recent theories of embodied cognition suggest new approaches to individuals' processing and understanding of others' intentions. Although embodied cognition is not a prerequisite to act or to understand the kinematics of an action, simulation theories assume that individuals understand others' actions through direct matching between observed and performed actions, and reactivation (or reenactment) of past self-related bodily experiences (Niedenthal, 2007; Niedenthal et al., 2005).

Comprehension of others' actions involve perceptual, somato-visceral, and motor re-experiencing of the acts in one's self (i.e., embodiment; see Niedenthal, 2007; Niedenthal et al., 2005). The embodiment of action automatically affects how others' actions and intentions are perceived and understood. Congruence between observed actions and integrated templates of stored motor experiences facilitates understanding of observed actions (Niedenthal, 2007; Niedenthal et al., 2005). For instance, imitation of an other's emotional motor expressions is part of the bodily reenactment of the other's experience, and facilitates emotional understanding (Niedenthal, 2007). In another instance, a functional magnetic resonance imaging (fMRI) study revealed similar changes in female participants' brain activity when painful stimulation was applied to her hand and her partner's hand (Singer et al., 2004). This suggests that an observational mechanism is supported by reenactment of the emotional and physical experience in the observer.

Recent research provides insight into people's ability to infer others' intentions from stored self-related motor experiences (Aglioti, Cesari, Romani, & Ugesi, 2008; Grafton, Schmitt, Van Horn, & Diedrichsen, 2008; Rizzolatti & Sinigaglia, 2008). Understanding intent, however, has not been tested in couples, nor as a function of the partners' relationship.

Cognitive facilitation effects in dyads in passionate love

Passionate love and companionate love have different effects on cognition latency measures specific to the implicit presentation of emotional words (Bianchi-Demicheli

et al., 2006; Ortigue et al., 2007). Participants in passionate love, when subliminally exposed to their partner's name before a word detection exercise, perform faster than when they are subliminally exposed to an acquaintance's name. This is consistent with the notion that exposure to attachment figures' (versus acquaintances') names, as well as mental representations of attachment figures, is associated with self-related attachment-related goals (Gillath, Mikulincer, Birnbaum, & Shaver, 2008; Mikulincer & Florian, 1999).

Neurologically, fMRI recordings during behavioral tasks (including subliminal stimuli; Ortigue et al., 2007) reveal strong activation of the angular gyrus, a brain area critically involved in self-related information integration and associative mechanisms, strategically located at the crossroads of brain regions involved in multimodal integration (e.g., Blanke, Ortigue, & Landis, 2002; Ortigue & Bianchi-Demicheli, 2008). This brain region is activated (with the caudate nucleus and ventral tegmental areas of the dopaminergic system) when a person falls in love (Ortigue et al., 2007). This phenomenon, affective priming, indicates that passionate love facilitates cognition of words using some top-down influences from the angular-centered network. Those passionately in love perform quicker because their beloved's name is implicitly stored in mental representations. Therefore, passionate love is not only an emotion, but is also a dopaminergic-related motivation that may call for integrated representation of positive reinforcement.

Although a growing literature suggests this mechanism, it is not clear whether it will generalize to pictures of actions performed by the beloved. The current research proposal focuses specifically on this question. This is based, first, on theories that assume that embodiment includes automatic reenactment of past motor experiences (rather than the agents' perceptual familiarity), and that others' observed actions are more quickly processed when they have been previously performed by the participant or a significant other (e.g., (Aziz-Zadeh, Wilson, Rizzolatti, & Iacoboni, 2006; Cross, Hamilton, & Grafton, 2006; Cutting & Kozlowski, 1977). In addition, the self-expansion theory of intention understanding suggests similar mechanisms between the mental representations of the self and a significant other (Ortigue & Bianchi-Demicheli, 2008). Therefore, we assumed that embodied cognition mechanisms (including the mirror neuron system) might be associated with passionate love mechanisms. More precisely, given that the same brain areas mediate love and embodied cognition, we expected that embodied cognition would be facilitated by passionate love (Aron et al., 2005; Beauregard, Courtemanche, Paquette, & St-Pierre, 2009; Ortigue et al., 2007).

Both the subcortical and cortical brain areas mediate love. Subcortical brain areas are also involved in reward, motivation, and emotion regulation while cortical brain areas (e.g., inferior frontal gyrus, or parietal lobe) are involved in more abstract and cognitive processes such as bodily-self representation. Brain network mediating embodied cognition involves a broad network in the mirror neuron system (including the action observation network, and the so-called social network), which may involve a broad variety of cognitive functions such as theories of mind (e.g., inferior frontal gyrus, superior temporal sulcus, anterior inferior parietal lobule, and dorsal and ventral premotor cortex; see Grafton, 2009 for further details).

Goals of the present study

We predict, first, that dyads will exhibit faster reaction times in inferring an other's intentions when they are in passionate love with the target, when compared with strangers' intentions (Hypothesis 1). Second, we predict that participants in passionate love understand intentions performed by themselves equally fast as intentions performed by their beloved partner (Hypothesis 2). Third, we predict that facilitation effects would be specific to participants who yearn for union with their partner (Hypothesis 3).

Moreover, we predict that interpersonal closeness would correlate positively with the ease of understanding intentions. Finally, we hypothesize that facilitation effects on intention understanding would not be sensitive to perceptual familiarity (Hypothesis 4). If perceptual familiarity drives facilitation effects, faster reaction times are expected for agents that were presented frequently (versus rarely). If facilitation effects are a function of embodied cognition, similar reaction times are expected to be independent of exposure frequency.

General procedure

We tested our hypotheses among 60 participants performing a standardized motor intention inference task (Ortigue, King, Gazzaniga, Miller, & Grafton, 2009). We investigated the extent to which facilitation effects occur in response latency measures among 10 dyads in a passionate love relationship (Study 1); 10 dyads in a companionate relationship (Study 2); and 10 pairs of strangers (Study 3).

Participants' feelings of passionate love for their partner were assessed in detailed interviews using the Passionate Love Scale (PLS; Hatfield & Sprecher, 1986). Feelings of companionate love with their partner were assessed in detailed interviews using the Companionate Love Scale (Hatfield & Sprecher, 1986). The one-item Inclusion of Other in Self scale; (IOS; Aron, Aron, & Smollan, 1992) was included as a measure of interpersonal closeness.

Prior to the motor intention inference task, all participants provided general personal information (e.g., anxiety or depression; Zigmond & Snaith, 1983). Participants provided written informed consent. All participants were right-handed (Oldfield, 1971), and had normal or corrected to normal vision. Participants were not taking anti-depressant medication nor did they have neurological illnesses as ascertained by a detailed medical anamnesis.

Study I

Method

Participants. Participants were recruited via advertisements seeking individuals passionately in love. Ten heterosexual couples (aged 18–29 years, $M = 20.3$, $SD = 2.9$), who were dating, or engaged, participated.

Materials. Stimuli included, first, photographs of participants performing six different actions combined into a video clip. Pictures were taken with non-directional lighting

against a green background to facilitate later digital editing. The camera was positioned on a tripod and angled downward (approximately 30 degrees from horizontal) to capture the forearm and hand reaching for an object from a first person perspective. The first image, an establishing shot, depicted the stimuli (frame #1), followed by the participant's right forearm touching an object (frame #2), and finally the hand performing one of six intentional actions or six non-intentional actions (frame #3). Sets of pictures were considered intentional if they carried out a common and consistent action. Similar pictures were then taken with their beloved partner and two control persons (one male and one female stranger in the same age range and skin color as participants). To control for distinguishing signs, participants removed any jewelry or piercings. (Given their recognizability, participants with tattoos were not included in the task). The advantage of the three-frame video clip is the tight control of the kinematics, task duration and timing. After pictures were taken, participants returned to the laboratory the next day to complete the computer-based motor intention inference task.

To check that participants were not aware of the category membership of the acting agent, we used an extensive debriefing procedure in which participants were asked increasingly specific questions about the study. This procedure revealed that all participants reported that they had seen different types of arms. However, no participant could report on the specific category of the arms.

Procedure. In the motor intention inference task, video clips displayed an agent (i.e., the participant, their partner, and a stranger) performing different types of actions. These agents created three conditions: the self condition, the beloved condition, and a control stranger condition. Conditions were intermixed and presented randomly. In total, six blocks (three with the left hand, and three with the right hand) took 40 minutes to perform, including breaks. A total of 48 video clips per block (288 total video clips) were presented on a computer monitor located 75 cm from participants. Video clips included six different scenes that could have either a correct or an incorrect intention. The six scenes included: (i) writing with a pen on paper/on table, (ii) cutting/painting with scissors, (iii) ironing a piece of cloth/holding an iron's tip on a piece of cloth, (iv) hammering a nail onto a flat surface/hammering a table, (v) turning on a lamp/knocking it over, and (vi) answering a telephone/placing the phone receiver on the table.

Participants indicated as rapidly and accurately as possible whether the outcomes were intentional or non-intentional. Participants were not explicitly asked to judge category membership of the acting agent (i.e., self, beloved, or stranger), so they were unaware that the motor intention inference task included their own, their beloved's or a stranger's forearm.

To control for any hand effects, participants alternated between using their left or right hand to make responses. Hand use was randomized and predetermined within participants using an ABBABA design across blocks. Respondents pressed the letter K on a computer keyboard for intentions and M for non-intentions using their right hand (and D and C when using left hand). Response keys were randomized between and within participants.

Design. During the computer-based motor intention inference task (run using JAVA), participants observed a series of three-frame video clips presented centrally on a monitor screen. The first 500 ms frame depicted two objects (e.g., a pen and a piece of paper) positioned on an empty, neutral, background. The second 1000 ms frame depicted a hand grasping one object (e.g., the pen) and appeared immediately following the first. The third 1000 ms frame followed immediately and displayed either a correct (write with the pen on paper) or incorrect (write with pen on table) intention. Each trial began with a 150 ms fixation cross. A 2000 ms maximum inter-trial interval separated the onset of each movie presentation.

Mean reaction time and percent of correct response were calculated for each participant and condition. Participants' reaction times were analyzed using a one-way repeated measure ANOVA (analysis of variance) as participants performed all the three conditions (self; beloved; stranger). Correlations were calculated between scales (e.g., IOS) and reaction times. No accuracy analyses were performed due to the ceiling effect in participants' performance.

Results and discussion

Participants reported being passionately in love with their partner from 6 to 23 months, $M = 9.50$, $SD = 60$. On average, participants reported being very close to their partner, IOS $M = 5.30$, $SD = .24$. Participants reported high levels of passionate, $M = 7.31$, $SD = .75$ and companionate love, $M = 7.90$, $SD = .88$. On average, participants indicated thinking about their partner about 60% of their waking hours, $M = 60$, $SD = 15.97$.

Reaction times. Reaction time analyses revealed a significant condition effect ($F[2, 38] = 4.03$, $p < .03$, $d = 2.10$) and post-hoc comparisons indicated that participants were significantly faster in understanding their own ($M = 845$ ms, $SE = 43.67$) and their beloved's ($M = 842$ ms, $SE = 38.09$) intentions than a stranger's ($M = 882$ ms, $SE = 40.59$; $d = .30$ for both self and partners; non-overlap = 21.3%). Self and partner reaction times did not differ. No gender or hand differences were observed. An extremely strong positive correlation between reaction times for understanding self and partners' intentions ($r = .94$, $p < .0001$) suggests similar automatic mechanisms between these judgments.

Correlation with reaction times. Consistent with Hypothesis 1, a negative correlation was found between passionate love scores and reaction times ($r = -.53$; $p < .03$), which suggests that the more passionate love participants reported for their partner, the faster their ability to understand their partner's intention. Correlations with reaction times for understanding strangers' intentions were not significant.

There was also a significant negative correlation between duration of the love relationship and reaction times. The longer the passionate love with their partner; the faster partners decided their own intentions, $r = -.70$; $p = .003$. Correlations between companionate love and reaction times, though not substantial, were not significant, self: $p = .54$; beloved: $p = .37$; control: $p = .34$. The correlation with percent of thoughts was not significant.

These results are consistent with our first two hypotheses, which predicted that participants in passionate love are faster in detecting both their own and their partner's intentions, as compared to strangers. We attribute these effects to implicit priming because participants were not explicitly asked to judge category membership (i.e., self, beloved, or stranger) and were unaware who would appear in the task.

Participants in passionate love can understand intent faster when primed by specific agents (self or significant other) and are not fast for all people. Consistent with other studies on affective priming, the specificity of facilitation priming effects demonstrates that it occurs at an associative level, rather than a perceptual level (Bianchi-Demicheli et al., 2006). That these facilitation effects occur for self-related stimuli is also consistent with previous research on implicit affective priming (Bianchi-Demicheli et al., 2006; Ortigue et al., 2007). In this sense, these effects can be explained by automatic spreading activation from stored self-related representations associated with a beloved partner and their close interpersonal interaction (Bianchi-Demicheli et al., 2006; Ortigue et al., 2007).

Correlation between performance and passionate love scores, and the absence of significant correlation with companionate feelings, suggest that the present facilitation priming may be primarily related to the love relationship. Response latency generally results from the activation of a neural network in response to associative concepts (e.g., affective categories) that are linked and stored in memory. The activation of such a network generally facilitates the activation of related targets in a hierarchical manner, such that closely related concepts are activated more quickly and strongly than are distal targets (Bianchi-Demicheli et al., 2006). Furthermore, activation of a particular neural concept can inhibit, or not influence, responses to incongruent or neutral concepts, such that the self-concept activation does not facilitate responses to non-self-related targets (Bianchi-Demicheli et al., 2006).

Study 2

Method

Participants. Participants were solicited via advertisement seeking friends for an experiment. Ten pairs of same-sex friends (healthy adults ranging in age between 18 and 21 years; $M = 20.10$, $SD = 1.13$; 10 men, 10 women) signed up for this study.

Materials. The six scenes (e.g., writing with a pen) were identical to those used in Study 1. Only condition 2 differed between Studies 1 and 2 (significant other versus friend). Photographs were taken of actions performed by participants (condition 1) and the friend (condition 2). Condition 3 (a male and a female stranger of the same age range, skin color and gender as the participant) was identical to Study 1. All conditions were intermixed and presented randomly to avoid any variability effects. Procedure, design, apparatus, and statistical analyses were identical to Study 1.

Results and discussion

Participants were friends from 1 to 26 months ($M = 12.88$, $SD = 8.47$) at time of the data collection. On average, participants' closeness scores ($M = 3.30$, $SD = .25$) were

significantly lower than from Study 1, $p < .001$. On the other hand, companionate love scores ($M = 6.90$, $SD = .29$) did not differ significantly from Study 1, $p = .07$. This is consistent with our intent to investigate two groups with equivalent companionate love, but which are different in closeness.

Reaction time. No significant reaction time difference appeared between the three conditions, $F(2, 38) = .82$, $p > .05$, $d = .26$; $M_{self} = 962.24$ ms, $SE = 88.71$; $M_{friend} = 979.6$ ms, $SE = 83.60$; $M_{stranger} = 990.9$ ms, $SE = 78.43$. No significant correlations were observed between participants' reaction times and friendship measures such as companionate love ($r = -.14$ for self; $r = -.05$ for friend; $r = -.14$ for others) or closeness, $r = -.17$ for self; $r = -.14$ for friend; $r = -.18$ for others, $p > .05$. No gender or hand differences were observed.

Study 2 investigated the extent to which the facilitation effects of embodied cognition on understanding the intentions of significant others occur with companionate love. Results suggest that being in a friendship is likely an insufficient condition to induce a strong facilitation effect. Although the present facilitation effects of embodied cognition in friends were not statistically significant, we cannot totally exclude them. Future studies assessing embodied cognition in the different relationship and love types (e.g., compassion, unconditional love, maternal love, and fraternal love) should be performed.

Study 3

Study 3 investigated the extent to which facilitation effects from Study 1 may be due to perceptual familiarity. To test this notion, another group of participants with no relationship with agents performed the motor intention inference task.

Method

Participants. Participants were recruited via advertisement seeking individuals to perform a motor intention inference task. Twenty healthy participants (10 women, 10 men, aged 18–35 years; $M = 19$, $SD = 0.90$) signed up for this study.

Materials. The same set of six scenes was used (e.g., writing with a pen on paper/on table). As in Study 1, participants watched a total of 288 video clips (six sets of 48). Nevertheless, in Study 3, participants had no relationship with agents (i.e., strangers) performing actions in these video clips. Agent perceptual frequency was divided into three conditions. For 108 of the 288 video clips, the *same* male stranger performed actions (frequent male stranger, condition 1); a second subset of the 108 of 288 clips depicted the *same* female stranger performing actions (frequent female stranger, condition 2); the remaining 72 clips presented 36 *different* male strangers and 36 *different* female strangers performing the actions (rare strangers, condition 3). Thus, frequent stimuli constituted 75% of video clips and rare stimuli constituted the remaining 25%. Selection of frequency categories was based on previous pilot studies. Video clips were chosen from the stimuli set from Study 1. Procedures and design were identical to Study 1.

Results and discussion

As expected, no facilitation effect was found. Participants' reaction times did not differ across conditions, $F(2, 38) = .46, p > .05, d = .15$; condition 1: $M = 973.77$ ms, $SE = 72.81$; condition 2: $M = 983.10$ ms, $SE = 77.34$; condition 3: $M = 995.96$, $SE = 68.22$. Thus, perceptual familiarity does not induce faster reaction times. These findings reinforce the specificity of the facilitation effects from Study 1 by demonstrating that automatic priming effects on action anticipation and intention understanding likely occurs at an associative, rather than a perceptual level (Bianchi-Demicheli et al., 2006).

Comparisons among self, partner and stranger

A one-way repeated measure ANOVA for the self condition revealed that participants in passionate love were slightly faster in understanding intentions performed by themselves than friends or strangers, $F(1, 19) = 4.69, p = .04$. This is consistent with recent findings suggesting faster cognitive processes in passionate love dyads, as compared to controls (Bianchi-Demicheli et al., 2006; Ortigue et al., 2007). In addition, consistent with predictions, a one-way repeated measure ANOVA also revealed a significant difference between groups for the partner condition, such that participants in passionate love were faster in understanding intentions implicitly performed by their beloved partner than by friends or strangers, $F(1, 19) = 5.18, p = .03$.

A lack of difference between the means for self and beloved partner indicates that these facilitation effects are limited to self-related stimuli, consistent with research on implicit affective priming (Bianchi-Demicheli et al., 2006; Ortigue et al., 2007). As demonstrated in Bianchi-Demicheli et al. (2006), passionate love's priming effects on intention understanding may be explained by automatic spreading activation accounts from stored self-related representations associated with the beloved partner and close interpersonal interaction (Bianchi-Demicheli et al., 2006; Ortigue et al., 2007). This is consistent with the correlation between closeness and partner-related reaction times, suggesting that the greater the closeness between partners, the more similar self and partner conditions will be.

This is consistent with self-expansion and intention understanding theories, suggesting that being in love expedites the self–other inclusion process. The self-expansion model assumes that individuals form relationships to facilitate growth and progress (see Aron & Aron, 1996; Aron, et al., 2005). That is, when individuals form a love relationship, their self concept assimilates some of the partner's characteristics: the self encompasses the partner's characteristics. Theories of embodied cognition suggest that individuals understand others' actions and intentions based on their own body movements and motor memory of past bodily experiences (Grafton, 2009). Self-expansion (Aron et al., 1996) suggests that it is easier to embody others' actions when they are mentally included in the self representation (Aron et al., 1996; Ortigue and Bianchi-Demicheli, 2008).

Finally, a one-way repeated measure ANOVA for the stranger condition revealed no difference between groups, suggesting that participants in passionate love were no faster

than other participants, $F(1, 19) = 3.7, p = .07$. This reinforces the specificity of the facilitation effect to people in passionate love. It is interesting to note that the present marginally significant result suggests that participants in love tend to be faster than the other groups at identifying strangers' intent. This highlights our explanation that those in love have increased processing speed.

Closeness and reaction times

Variability of closeness within and between groups was consistent with predictions. First, friends in Study 2 were significantly less close than lovers in Study 1, suggesting that closeness between partners may play a crucial role in the ease of understanding others' intentions. More critically, when combined, data from Studies 1 and 2 indicate a significant negative correlation between closeness and self-related reaction times, $r = -.36, p < .01$, 2-tailed. We also found a significant negative correlation between closeness and partner-related reaction times, ($r = -.36, p = .03$, 2-tailed). Consistent with self-expansion and intention understanding theories (Aron et al., 1996; Ortigue & Bianchi-Demicheli, 2008), the greater the closeness between participant and agent, the faster participants are able to detect the agent's intentions.

General discussion

Results indicate that facilitation effects of embodied cognition on intention understanding are influenced in participants in passionate love. Implicit facilitation effects for intention understanding were observed in couples in passionate love when actions were performed by their beloved partner, but not when performed by acquaintances or strangers.

The facilitation effect between passionate love, embodiment, and mutual understanding stems from how humans encode and represent interpersonal relationships (Niedenthal, 2007). That these implicit facilitation effects occur for some agents (self and significant others) but not others (e.g., strangers) indicates that embodiment occurs automatically at a high cognitive level via related associations integrated over time in the observer's cognitive structures. Implicit associations are sufficient to lead to automatic conceptual priming on the basis of associative relatedness between agent and observer (Bianchi-Demicheli et al., 2006; Ortigue & Bianchi-Demicheli, 2008; Ortigue et al., 2007).

The present results are consistent with theoretical accounts of facilitation effects that highlight automatic self-related associative priming (Bianchi-Demicheli et al., 2006; Ortigue et al., 2007). Thus, the present data reinforce the notion that implicit facilitation effects of passionate love may stem from automatic associations rather than pure reflex emotional feelings, as have been suggested for other facilitation priming effects (Bianchi-Demicheli et al., 2006; Ortigue et al., 2007). Along with studies on the implicit effect of love on decision making (Bianchi-Demicheli et al., 2006; Ortigue et al., 2007), the present results reinforce the assumption that passionate love is a cognitive state that includes self-related cognitive motivations in interpersonal interactions, rather than simply a basic emotion (Aron et al., 2005; Bianchi-Demicheli et al., 2006; Ortigue et al.,

2007). Further studies need to specify these implicit facilitation effects within a variety of interpersonal relationships to determine whether it is possible to generalize to other intense love states (e.g., maternal love or compassionate love) and other relational stages (early or late).

Limitations and future research directions

Because few studies focus on implicit facilitation effects of embodied cognition on intention understanding, and none of them directly investigate mutual understanding in close relationships, our study constitutes a first step with limitations. One limitation concerns the small sample sizes in the present study. Replications of this facilitation effect of embodied cognition should use much larger samples and assess relationships of various length (early versus late relationship stages) and across the lifespan. Such studies would provide valuable information on the evolution of embodied cognition in love relationships and its functional dynamics on mutual understanding. Future research should also investigate implicit cognitive effects across socio-cultural contexts.

Another limitation concerns the difficulty of assessing objectively perceptual familiarity in partners in love as it may include visual and tactile familiarity. In Study 3, perceptual familiarity was only visual. Future research should examine other types of perceptual familiarity (e.g., tactile) on intention understanding. For a deeper understanding of how close couples form shared self-representations and develop embodied mechanisms, further studies need to assess familiarity in dyads of varied relationship length, familiarity, strength of feelings, and self-other inclusion, closeness, and love.

Also, longitudinal assessment in dyads would allow greater understanding of the development of embodied mechanisms in dyads. Questions might include how long and how close do relationships need to be for facilitation effects on mutual intention understanding to occur. Finally, future studies should pursue objective assessment of implicit mechanisms during mutual understanding, including a combination of behavioral and high spatio-temporal resolution neuroimaging techniques (e.g, fMRI and high-density electroencephalographic [EEG] recordings with brain source localization algorithms). EEG recordings could provide significant information about the functional temporal dynamics of facilitation effects of embodied cognition on intention understanding within interpersonal relationships.

We expect these facilitation effects to correlate positively with activity in at least one brain area involved in embodied cognition (Bianchi-Demicheli et al., 2006; Ortigue et al., 2007). Notably, brain network mediating embodied cognition recruits brain areas within the mirror neuron system, the action observation network, and the so-called social network, which may include a broad variety of cognitive functions such as theories of mind (e.g., inferior frontal gyrus, superior temporal sulcus, anterior inferior parietal lobule, and dorsal and ventral premotor cortex; Grafton, 2009).

Finally, we suggest that reduced recruitment of brain areas involved in embodied cognition may be inhibited among people in unsatisfying love relationships (Ortigue & Bianchi-Demicheli, 2008). A systematic study of this hypothesis of mutual understanding is needed to better understand the temporal course of dyadic mutual understanding.

Conclusion

Implicit facilitation effects on understanding others in passionate love dyads fit with current theories of close relationships, and explain the ease of anticipating and predicting spousal actions and intentions via embodied cognition and self-expansion models. Our findings offer a new avenue to better grasp the mechanisms underlying dyadic mutual understanding.

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