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REVIEW

Embodied self-other overlap in romantic love: a review and integrative perspective

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Abstract

Romantic love has long intrigued scientists in various disciplines. Social-cognitive research has provided ample evidence for overlapping mental representations of self and romantic partner. This overlap between self and romantic partner would contribute to the experience of love and has been found to be a predictor of relationship quality. Self-partner overlap has been mainly documented at the level of conceptual or narrative self, with studies showing confusion between one's own and partner's identity aspects, perspectives, and outcomes. But the self is not restricted to abstract, conceptual representations but also involves body-related representations, which, research has revealed, are linked to social-cognitive processes. In this article, we review the emerging evidence that romantic love involves not only a blurring of conceptual selves but also a reduction of the distinction between self and romantic partner at a bodily level. We discuss the potential function(s) of self-other overlap in romantic relationship at the level of body-related representations and consider possible mechanisms. We conclude with possible future directions to further investigate how romantic love engages embodied self-other representations involved in social interactions.

Introduction

Romantic or passionate love has attracted attention from scholars in various disciplines, including anthropology, biology, neurosciences and psychology. Romantic love, defined as "a state of intense longing for union with another" (Hatfield & Rapson, 1987), differs from other kinds of love, such as companionate love or maternal love (Hatfield & Rapson, 2005; Sternberg, 1986). Romantic love is associated with specific behavioral and psychological traits, such as an intense focusing on a specific individual, obsessive thoughts directed toward the partner (intrusive thinking), euphoria, craving, and it is tightly related to—though independent from—sexual desire (Fisher et al., 2002; Hatfield & Rapson, 2005; Tennov, 1979). Anthropological investigations indicate it is a human cross-cultural phenomenon that plays a crucial role in mate preference (Jankowiak & Fischer, 1992). Furthermore, evolutionary and biological approaches suggest that romantic love is an evolved form of a mammalian mating system, designed to motivate pair-bonding (Fisher, Aron, & Brown, 2006; Walum & Young, 2018). Consistent with this view, neuroimaging studies in humans have linked romantic love to activations in brain reward and motivation systems (Aron et al., 2005; Scheele et al., 2013). Love is thus a powerful emotion–motivation system that can have a strong influence on people's social life and thoughts.

Psychological research has explored various aspects of love, from feelings associated with the experience of love to factors influencing relationship quality (e.g., O'Leary, Acevedo, Aron, Huddy, & Mashek, 2012). A particular line of research, focusing on self-representation, has revealed a key psychological feature of romantic love. This work indicates that being in love involves overlapping mental representations of self and romantic partner (Agnew, Van Lange, Rusbult, & Langston, 1998; Aron, Aron, Tudor, & Nelson, 1991; Mashek, Aron, & Boncimino, 2003). This self-partner overlap is thought to play a functional role in romantic feelings and has been found to predict various positive relationship outcomes (for a review, see Branand,

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Mashek, & Aron, 2019). So far, self-other overlap in romantic relationships has been documented mostly at the level of conceptual or narrative self, which refers to an abstract, higher-level representation of the self, shaped by social interactions, associating information such as personality traits, beliefs, preferences and autobiographical memories (Gallagher, 2000; Schechtman, 2011). However, the self is not restricted to conceptual self-representations. Body-related representations and sensorimotor processing form the basis of another dimension of the self, referred to as bodily self (Dieguez & Lopez, 2017; Farmer & Tsakiris, 2012; Gallagher, 2000). Self-other overlap at this bodily level has been well documented and is thought to play a causal role in social cognition (de Vignemont, 2014; Gallese, 2014; Keysers & Gazzola, 2009). Remarkably, there is accumulating evidence that romantic love involves not only a blurring of conceptual selves but also a reduced distinction between self and romantic partner at the level of bodily self. The present article reviews this line of research and discusses the potential function(s) of self-partner overlap in the bodily domain. We also consider possible basic mechanisms underlying self-partner confusion and, lastly, offer possible future directions. Our ambition is to further delineate how the core of the self is modified in romantic love and provide a better understanding of how partners process information about each other in romantic relationships.

Overlapping (conceptual) selves in romantic love

Social-psychological research has provided various conceptualizations and models of romantic love (e.g., Berscheid & Walster, 1978; Sternberg, 1986). Among these, the self-expansion model of love is a process-oriented model conceiving romantic love as the cognitive inclusion of the (cognitive representation of) romantic partner in the self (Aron & Aron, 1996; Aron, Aron, & Norman, 2004). This model first posits a central human motivation to extend the self, in the sense that people seek to enhance their perspectives, resources, and identities, to improve their potential efficacy (i.e. their ability to accomplish goals) (Aron & Aron, 1986; Maslow, 1967). Second, close relationships, especially romantic relationships, are assumed to provide self-expansion through the inclusion of other in the self, a process by which partners become closer and develop overlapping self representations (Aron & Aron, 1996; Aron, Mashek, & Aron, 2004). Accordingly, the self is expanded in romantic relationships by including aspects of the other in the self: the partner's resources, perspectives, and characteristics are to some extent treated as one's own (Aron & Aron, 1996). The experience of self-expansion is rewarding and positive, in that it broadens one's own potentialities. It is assumed that the exhilaration associated with romantic love would be related to the experience of such self-expansion through the inclusion of partner's characteristics into one's self content (Aron, Norman, Aron, McKenna, & Heyman, 2000). Consistent with this view, self-expansion has been linked to positive outcomes in romantic relationships, such as admiration for the romantic partner, greater levels of satisfaction, commitment, and passion (Aron et al., 2000; Fivecoat, Tomlinson, Aron, & Caprariello, 2015; Mattingly, Lewandowski, & McIntyre, 2014; Reissman, Aron, & Bergen, 1993; Schindler, Paech, & Löwenbrück, 2015). Moreover, to the extent romantic partner's perspectives and identities are experienced as one's own, these partner's characteristics thus turn out to be cognitively linked to one's sense of self, leading to an overlap of representations of self and other (Aron & Aron, 1986). Being in love thus entails a reduced distinction, or a greater confusion, between the self and the romantic partner (Aron et al., 1991; Mashek et al., 2003; Rusbult, Martz, & Agnew, 1998).

In line with the idea of self-expansion through the inclusion of the romantic partner in the self, people involved in a romantic relationship report more and wider domains (i.e. an increased diversity in self-descriptive terms) in the contents of the self-concept than singles (Aron, Paris, & Aron, 1995). This result attests to an expansion of the self-concept which is thought to arise from the inclusion of romantic partner's characteristics into one's own self-representation. Furthermore, consistent with the view that love involves overlapping representations of self and partner, research based on the Inclusion of the Other in the Self (IOS) scale, a pictorial measure supposed to capture self-other overlap (Aron, Aron, & Smollan, 1992), showed that participants report more overlap with their romantic partner compared to with a close friend or a family member (Acevedo, Aron, Fisher, & Brown, 2012; Quintard, Jouffre, Croizet, & Bouquet, 2018). Importantly, comforting the idea that self-other overlap plays a significant role in romantic relationships, IOS scores are predictors of relationship stability over 3 months, the degree of overlap being negatively related to the likelihood of relationship dissolution (Le, Dove, Agnew, Korn, & Mutso, 2010).

A key prediction of the self-expansion model is that overlapping representations of self and romantic partner elicit self-other confusion. Consistent with this prediction, studies have shown confusion between partner's and one's own traits (Aron et al., 1991; Mashek et al., 2003), interests, or attitudes (Aron, Steele, Kashdan, & Perez, 2006). For example, Aron et al. (1991) found slowed response times in a "me/not me" decision task (i.e., does the trait describe me?) when romantically involved participants had to evaluate traits that were relevant only for self or partner, compared to shared traits, suggesting blurred self-other boundaries in romantic love (see also Smith, Coats, & Walling, 1999). Also, the typical drop of self-esteem

observed when one experiences upward social comparison is no longer present when people are outperformed by their romantic partner, especially for those reporting a high level of closeness (Lockwood, Dolderman, Sadler, & Gerchak, 2004). Thus, people do seem to experience their partner's outcomes as their own.

Results from neuroimaging studies also suggest overlapping representations of self and romantic partner. Cerebral regions known to be involved in the processing of self-related information, such as anterior cingulate cortex, fusiform and angular gyri, are activated by the presentation of the beloved's name or face (Aron et al., 2005; Ortigue, Bianchi-Demicheli, Hamilton, & Grafton, 2007). Moreover, these cerebral activations triggered by the evocation of the beloved are positively correlated with the IOS-scores reported by participants with respect to their partner (Acevedo et al., 2012).

To sum up, several lines of evidence show a blurring of the distinction between self and romantic partner, in line with the model of romantic love as an inclusion of the partner in the self. A large part of this work dealt with individuals' traits, interests or attitudes (Aron et al., 1991, 2006; Mashek et al., 2003), that is, abstract, conceptual forms of self-representation (Gallagher, 2000; Smith, 2008). However, romantic, intimate relationships involve embodied cues such as touch, physical proximity, and shared bodily experiences (Fiske, 2004). Moreover, as speculated in early formulations of the self-expansion model of love, "in close relationships one's body also behaves as if it is the other's body" (Aron & Aron, 1996, p. 50), implying that the inclusion of the romantic partner in the self encompasses the body. Self-partner processing at a bodily level may be an important aspect to consider in romantic relationships in the light of empirical and theoretical research suggesting that self-other representations and social relationships are grounded in sensorimotor processing and body-related representations (e.g. Barsalou, 2010; Smith, 2008). In the next section, we provide an overview of this line of work, focusing on self-other overlap at a bodily level and its potential role in social cognition. Then, we explain why it is relevant to approach romantic love from this perspective, addressing why romantic love would affect the overlap between self and romantic partner at the bodily level.

Embodied approach to self-other overlap and romantic love

Theories of embodiment postulate that representational codes that are specific to the body, including sensorimotor, somatosensory, and visceral codes, play an important role in human cognition and may even account for language comprehension and abstract, conceptual thinking (Barsalou, 2010; Goldman & de Vignemont, 2009). Embodied accounts of social cognition suggest that the bodily self shapes our perception and understanding of others (Gallagher, 2000; Gallese, 2003, 2014; Hommel, 2018). Before considering self-other overlap at a bodily level in romantic relationships, it is important to mention key phenomena that have driven embodied theories of self-other interactions: mirroring and behavioral mimicry.

Mirroring and behavioral mimicry

Several embodied theories of social cognition build on the existence of overlapping, or shared, representations of self and other's bodily states. This idea has received important support from research on mirror neuron systems, which suggests that parts of the brain areas coding for our own actions, sensations and emotions, are also activated while perceiving the actions, emotions and sensory experiences of other individuals (Hardwick, Caspers, Eickhoff, & Swinnen, 2018; Iacoboni, 2009; Keysers & Gazzola, 2009). Various scholars have proposed that these shared neural substrates between the representations of self and other enable an *embodied simulation process* whereby the observer uses his own bodily experience to derive hidden internal states from the observable behaviors/experiences of others, providing a rudimentary form of empathy (e.g., Bastiaansen, Thioux, & Keysers, 2009; Gallese, 2003; Keysers & Gazzola, 2009). In the action domain, other authors have speculated that mirror systems might play a role in predicting and coordinating actions with others (e.g., Brown & Brüne, 2012; Wilson & Knoblich, 2005).

Another body of research has focused on behavioral mimicry, i.e. the spontaneous—often unconscious—tendency to imitate others' behaviors. For example, it is well known that people tend to automatically imitate (or mimic) facial expressions displayed by others (Niedenthal, 2007). Research shows that people also tend to mimic others' gestures, postures and mannerisms (for a review, see Chartrand & Lakin, 2013). Unsurprisingly, behavioral mimicry has been linked to mirror systems activity, which would automatically map observed action onto a corresponding motor representation (Iacoboni, 2009). Irrespective of the neural circuitry underlying this phenomenon, behavioral mimicry involves two individuals making similar movements, hence sharing bodily states (and thus corresponding representations) between the mimicker and the mimickee. Studies have investigated the social consequences of behavioral mimicry; that is, how the occurrence of this type of behavior—where the mimicker and the mimickee share bodily states—can affect social interactions. This line of work has shown that being mimicked by another individual is accompanied by several positive outcomes, including greater feelings of closeness, trust, helping behavior, and liking (Chartrand & Lakin, 2013). Conversely, it has been found that participants instructed to imitate (vs. not to imitate) the behavior of an

interaction partner reported greater closeness toward this partner (Stel & Vonk, 2010). These results suggest that during behavioral mimicry, shared bodily states between self and other act as a social embodied cue creating a social bond between individuals (Lakin & Chartrand, 2003; Smith, 2008). Blurred self-other boundaries created by shared movements, as well as detection of similarity and better prediction of perceived behaviors (which would be rewarding), have been proposed as related to possible mechanisms underlying the positive outcomes of mimicry (Hale & Hamilton, 2016; Smith, 2008). In conclusion, there is ample evidence for the existence of self-other bodily overlap which, research indicates, may help us to understand and/or relate to others.

Cognitive models of perception–action links

Two major theories of action–perception links have been applied to explain the cognitive mechanisms of self-other overlap at a bodily level: the Theory of Event Coding (TEC; Hommel, Müsseler, Aschersleben, & Prinz, 2001; Hommel, 2019) and the Associative Sequence Learning (ASL) model (Brass & Heyes, 2005; Cook, Bird, Catmur, Press, & Heyes, 2014; Heyes, 2011). More specifically, these theories explain how a visual description of other's bodily states can be mapped onto (or transformed into) corresponding sensorimotor representations in the observer (Iacoboni, 2009).

According to TEC, which is an extension of ideomotor accounts of action control (Greenwald, 1970; James, 1890), actions are represented by codes of features of their sensory consequences. More precisely, TEC assumes that actions are represented by networks of codes (so-called event files) of all the perceived effects of an action (e.g., proprioceptive feedback, sounds, visual description of the moving effector, concerned objects, etc.) and the motor patterns underlying the action (Hommel et al., 2001). Hence, TEC is based on the ideomotor core assumption that repeatedly performing a movement and perceiving its effects results in the integration of an action's motor codes and the effects the action generates, and that action selection consists in the activation of codes of the desired effect. A critical assumption of this theory is that action and perception share a common representational format, which in turn facilitates the translation of perceived actions into one's own actions (Hommel et al., 2001).

The ASL model, which aims to account for mirroring and imitation of actions, also assumes that sensorimotor experience shapes action–perception links (Cook et al., 2014). Contiguous experience of seeing and executing one's own actions establishes associations between 'sensory' (visual, auditory) representations of action and 'motor' representations (see also Keysers & Perrett, 2004). Once established, these links allow activation of the visual representation of an observed action to be propagated to the motor representation. Note that, in contrast to TEC, the ASL model assumes that separate sensory and motor representations exist, which, however, become linked through experience.

While both theories have been developed originally to account for representations of self and others' actions, they have been extended to somatic and emotional processing (Heyes, 2018; Hommel, Lippelt, Gurbuz, & Pfister, 2017; Press, Heyes, Haggard, & Eimer, 2008). Importantly, while the two approaches differ with respect to a number of assumptions, they both imply that action–perception links support shared self-other body representations and that social interactions are grounded in sensorimotor experience.

An embodied perspective on romantic love

The role of self-other overlap at a bodily level in constructing romantic relationships has been largely ignored so far. However, because the bodily self is thought to play a role in constructing our relationships with others, a prominent overlap between bodily representations of self and romantic partner may contribute to romantic love, paralleling the well documented role of self-partner overlap at the level of conceptual self (see previous section). There are a priori arguments suggesting such a possibility. Studies show that the social or affective relationship existing between individuals influences the overlap of bodily representations between self and other (Avenanti, Sirigu, & Aglioti, 2010; Hein & Singer, 2008; Singer et al., 2006). Moreover, both TEC and ASL suggest that experience shapes the perception–action links supporting this embodied self-other overlap. Thus, both the positive link and shared bodily experiences between romantic partners may favor self-partner overlap at the bodily level. Moreover, embodied cues of self-other overlap, such as behavioral mimicry, can foster a positive affective relationship between individuals.

Hence, the body of work on romantic love offers an opportunity to conceptualize causes and consequences of embodied self-other overlap within a specific relationship characterized by closeness and intimacy. In the present paper, we review evidence suggesting that romantic love is associated with a prominent overlap between self and romantic partner at a bodily level. We focus on phenomena that have been largely connected to self-other bodily overlap (e.g., imitation, joint action, action prediction) and we systematically address the potential consequences for the relationship between partners. Furthermore, although current models (e.g., Chartrand & Lakin, 2013; Heyes, 2011; Liepelt, von Cramon, & Brass, 2008; Wang & Hamilton, 2012) postulate or acknowledge that a close, intimate relationship between individuals may be associated with a greater overlap of body-related representations of self and other, these models remain relatively silent about the

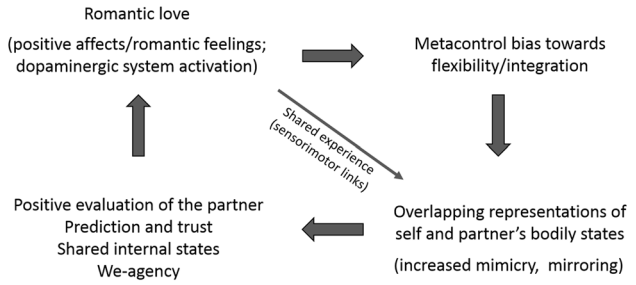

Fig. 1 Causes and consequences of embodied self-other overlap in romantic love

cognitive mechanisms by which such a modulation operates. Here, we aim to offer a complementary view by addressing these mechanisms. We will proceed in two steps. First, by building on models of action–perception links (especially TEC), we consider the role of experience in fostering greater overlap, or reduced distinction, between self and romantic partner at the level of bodily self. Second, by considering another (though limited) body of literature on the cognitive consequences of romantic love, we propose to apply a recent extension of TEC, the metacontrol state model (MSM; Hommel, 2015, 2019), to explain how potential positive effects of self-other overlap may promote a mode of cognitive processing that in return would favor integration of self-other representations. Our objective is thus to offer an integrative view of the causes and consequences of self-other bodily overlap in romantic love (Fig. 1) and to describe the cognitive mechanisms that are involved at a level that is more mechanistic than previous accounts (Kim & Hommel, 2019, 2019).

Embodied self-partner overlap in romantic love: empirical evidence and potential functions

Imitation

According to TEC and the ASL model, sensorimotor learning plays an important role in the development of shared bodily representations. Importantly, while both theoretical views suggest that the main source of learning is through execution and perception of one's own movement, the perception of others' movements may also contribute to the development of perception–action links (Heyes & Ray 2000; Hommel, 2018). These links can be created through the establishment of associations between self-produced and others' perceived actions, during the experience of synchronous action or when being imitated (accounting for example for mirroring of opaque actions such as facial expression—self-produced actions that one cannot see, except in a mirror). Therefore, these models predict that perception of others' actions that often co-occur with self-performed action is more likely to trigger a perception-compatible action than other possible actions. Accordingly, people spending more time together and sharing activities, like romantic partners, should show more imitation of each other's actions.

Consistent with this proposal, in a now famous study, it was revealed that romantic partners tend to become physically similar after twenty years of marriage (Zajonc, Adelmann, Murphy, & Niedenthal, 1987). Such similarities may be explained by reciprocal imitation of the partner's facial and other bodily expressions over time, leading partnered individuals to incorporate the bodily expressions of the other in their own body representation.

A recent study by Maister and Tsakiris (2016) has more directly investigated automatic imitation (as a behavioral index of embodied self-other overlap) in romantic relationships. In their study, romantically involved participants were instructed to open or close their mouth depending on the color of a target dot while viewing pictures of their partner vs. a friend who produced either the same or a different action. The interference between observed and executed action (automatic imitation) was found to be larger when participants were exposed to pictures of their romantic partner's actions compared to pictures of their friend's actions. This may indicate greater overlap in embodied representations between romantic partners as compared to friends, even though attentional effects (more attention being drawn to pictures of the romantic partner) cannot be excluded.

Increased automatic imitation of the beloved may have important consequences, as it potentially implies greater reciprocal imitation between romantic partners. Indeed, given the well documented positive outcomes of behavioral mimicry (such as liking, trust, and closeness; Chartrand & Lakin, 2013), increased imitation of the beloved may play a significant role in romantic relationships by fostering liking and connection between lovers. In line with this, studies based on naturalistic observation of interacting individuals have demonstrated that the amount of rapport individuals feel with each other is correlated with the assessment of the amount of posture sharing during their interactions (Lafrance, 1979; Lafrance & Broadbent, 1976).

It is interesting to note that people involved in a romantic relationship are less prompt to imitate an attractive alternative, especially when passionately in love (Karremans & Verwijmeren, 2008). From this reduced mimicry of attractive alternatives, which might contribute to relationship maintenance, it is tempting to conclude that imitation has a special status within the romantic relationship.

Prediction of action

Theoretical frameworks suggest that shared mental representations between perceived and executed actions allow one to predict the future outcomes of others' actions (e.g., Wilson & Knoblich, 2005). Moreover, according to TEC, the ability to predict the outcomes of another's action is modulated by the degree of self-other overlap (Hommel, 2015, 2018). The idea here is that prediction relies on past experience, which should be the largest for oneself: given that I am the person that I have experienced most often and in the most various circumstances, my expertise in predicting my own actions should be particularly high (Hommel & Colzato, 2015). If so, one's expertise in predicting other people's actions should rely on self-other overlap, because increasing overlap implies an increasing amount of past information that can be generalized to predict the behavior of the other person (Hommel, 2018; Hommel & Colzato, 2015). Thus, the overlap between self and romantic partner would improve one's ability to predict outcomes of the beloved one's actions.

Ortigue, Patel, Bianchi-Demicheli, and Grafton (2010) reported finding in line with this hypothesis. Romantically involved participants were required to judge the outcomes of motor actions performed either by themselves, their partner or by friends or strangers. Results showed that participants were faster when they had to judge their partner's and their own actions, as compared to that of a friend or a stranger, which was especially true for participants who were passionately in love.

Better prediction of the beloved one's actions may have several positive consequences. It may facilitate the processing of interpersonal, affective touch (Gallace & Spence, 2010) and increase mutual trust[1] (Hommel & Colzato, 2015). It may also be crucial to coordinate and synchronize joint action (Doerrfeld, Sebanz, & Shiffrar, 2012). Better coordination and synchronization would, in turn, be expected to promote closeness and intimacy between partners and create a sense of "oneness" (Sharon-David, Mizrahi, Rinott, Golland, & Birnbaum, 2018; Smith, 2008; Vacharkulksemsuk & Fredrickson, 2012). Whether these effects are independent from or interact with those stemming from conceptual self-other overlap remains an open question.

Joint action

The studies reviewed above are consistent with the idea that romantic partners exhibit an increased overlap between bodily representations. A potential consequence of increased self-other overlap is a reduced ability to discriminate between self and other. This has indeed been demonstrated at the level of conceptual selves (Aron et al., 1991), but empirical and theoretical work suggests this is true also of bodily selves (e.g., Hommel, 2018; Lindner, Echterhoff, Davidson, & Brand, 2010; Tajadura-Jiménez & Tsakiris, 2014). According to TEC, action control consists in discriminating between alternative representations, and the more features shared between these representations, the greater the discrimination problem should be. Because we represent our own actions the same way that we represent other's actions, one also faces a discrimination problem between self and other's action representations (Hommel, 2018; Dolk et al., 2014).

Self-other distinction at a bodily level has been recently investigated in the context of joint action, using a paradigm introduced by Sebanz, Knoblich and Prinz (2003). These authors had participants carry out a Simon task (Simon & Rudell, 1967), in which participants respond to a non-spatial stimulus attributes, such as color or shape, by pressing the left and right keys. The important manipulation consists in the fact that the stimuli randomly appear on the left or right side of a display, thereby creating stimulus–response correspondence or compatibility in some trials (e.g., if the stimulus appears on the left and calls for a left keypress) but stimulus–response non-correspondence or incompatibility in other trials (e.g., if the stimulus appears on the right and calls for a left keypress). The standard Simon effect consists in the observation that this task-irrelevant compatibility matters: people are faster if stimulus and response correspond than if they do not. The key manipulation of Sebanz et al. (2003) was to distribute the responses that amount to participants so that one participant only responded to one of the relevant stimulus attributes by pressing the left key and the other participant responded to the other stimulus attribute by pressing the right key. If such a task is carried out by only one participant at a time, the Simon effect disappears or is drastically reduced (Hommel, 1996; Sebanz et al., 2003). If another person is operating the alternative key, however, the Simon effect comes back—a phenomenon known as joint Simon effect (JSE). While the JSE does not necessarily rely on the other person being a human (Dolk, Hommel, Prinz, & Liepelt, 2013), it does indicate that the presence of another responding agent influences our own action selection process. Several interpretations of this effect[2] have

[1] Such an effect might occur because, as suggested by Hommel and Colzato (2015), a core aspect of interpersonal trust would be the ability to predict the behavior of the trustee.

[2] Note that the JSE involves processes that go beyond the direct action–perception links that trigger automatic imitation, since this phenomenon is still present even when the two actors cannot see each other (Quintard et al., 2018; Vlainic, Liepelt, Colzato, Prinz, & Hommel, 2010).

been proposed (Sebanz et al., 2003; Guagnano, Rusconi, & Umiltà, 2010). The referential coding hypothesis (Dolk et al., 2014) offers a comprehensive explanation for various effects reported in the context of the joint Simon task[3] (e.g., Ruissen & de Bruijn, 2015). This hypothesis, which is rooted in TEC, suggests that in a joint Simon task, not only representations or codes concerning the perceptual features of our own action are activated, but also codes of perceptual features of any other salient object or event, including the interaction partner and his/her action (Dolk et al., 2013; Klempova & Liepelt, 2016). This creates a self-other discrimination problem which is assumed to trigger mechanisms at the origin of the JSE.[4] Therefore, the JSE is considered as an index of self-other discrimination processes at the bodily level (Dolk et al., 2014; Milward & Sebanz, 2016).

Using the amplitude of the JSE as an index of self-other discrimination at a bodily level, Quintard et al. (2018) tested the hypothesis that increased bodily self-other overlap between romantic partners would result in a greater action discrimination problem in the context of the joint Simon task. They had both members of romantically involved couples perform the joint Simon task either with their romantic partner or with an opposite-sex friend. A stronger JSE was found when the task was shared with the romantic partner, compared to with a friend. Furthermore, the magnitude of the JSE during joint action with the romantic partner was positively correlated with the strength of romantic feelings. These findings thus support the idea that love blurs the boundaries between self and romantic partner at a bodily level.

Related findings have been reported in a recent study (Giesen, Löhl, Rothermund, & Koranyi, 2018), in which participants alternated between performing a speeded stimulus categorization task and observing their romantic partner vs. a stranger perform the same task. The results showed that after seeing their romantic partner give a response to a specific stimulus, participants' reaction times (RTs) were subsequently slowed when they had to give a different (vs. identical) response to this stimulus (a sign of observationally acquired S-R bindings). However, this compatibility effect was absent following the observation of a stranger. Thus participants acquired S-R binding through observation of their romantic partner, but not through observation of a stranger. In line with the results reported by Quintard et al. (2018), this shows that the partner's actions (vs. non-significant others') have a stronger impact on people's own action control, comforting the idea of reduced bodily boundaries between self and romantic partner.[5]

Interestingly, recent work has assessed how engaging in joint action may involve a transformation of agentive identity, with a shift from a sense of self-agency to a sense of we-agency, or experience of shared control (Pacherie, 2014; Sahaï, Desantis, Grynszpan, Pacherie, & Berberian, 2019). The sense of agency refers to the experience of generating and controlling one's own actions (Haggard & Chambon, 2012). It is proposed that during joint action or cooperative tasks, where each individual contributes to a joint goal, self-boundaries and sense of self-agency would decrease while a sense of we-agency would emerge (Pacherie, 2014). This sense of we-agency may expand the scope of one's agency (i.e., the range of possible outcomes one can bring about) because outcomes caused by the dyad or group are experienced as one's own (Doerrfeld et al., 2012; Pacherie, 2014; van der Wel, Sebanz, & Knoblich, 2012). Several factors favoring the emergence of we-agency have been identified, including the ability to represent the other's action, reduced self-other distinction, and positive relationships (as a motivation to engage in joint action) (Bolt, Poncelet, Schultz, & Loehr, 2016; Pacherie, 2011). In the light of the research we have reviewed, a sense of we-agency is thus more likely to arise when acting jointly with one's romantic partner. Consistent with this view, recent research (Sahaï et al., 2019) has shown that the emergence of we-agency was associated with

[3] The original action/task co-representation account proposed by Sebanz et al. (2003) explains the JSE by the social dimension of joint action, such that individuals automatically represent the other's task. This interpretation however fails to account for the occurrence of similar effects in non-social contexts (Dolk et al., 2013). The referential coding account applies to any event (be it social or not) and thus can explain why JSE occurs in non-social contexts (Dolk et al., 2014).

[4] More precisely, it is assumed that the discrimination problem can be resolved by emphasizing feature codes that discriminate between (relevant) self-related representations and (irrelevant) other-related ones. In the context of the joint Simon task, such a feature is the spatial response location (left or right). Participants would thus give more weight to the spatial dimension, allowing to differentiate the alternative representations of self and other. Giving more weight to the spatial dimension reintroduces effects of spatial correspondence between response and stimuli, hence the JSE (Dolk et al., 2014).

[5] This echoes with Burris and Rempel's (2008) work, which is built on the idea that the physical body plays a crucial role in psychological boundaries between self and not-self. Accordingly, a reduction of self-partner boundaries in romantic relationships should lead romantically involved individuals to be less focused on themselves as separate entities, and thus to feel less constrained by their physical body. In line with this, Burris and Rempel (2008) found that romantically involved individuals, compared to single individuals, reported to feel less separate and constrained by their physical body. Partnered individuals also demonstrated less sensitivity to bodily threat, suggesting that romantic love decreases the salience of the bodily domain of self-boundary. Thus, being in love affects how people process their own body in a way that is compatible with an embodied self-other overlap.

the occurrence of the JSE (which is increased with one's romantic partner; Quintard et al., 2018). A sense of we-agency, favored by reduced bodily boundaries between self and romantic partner, may thus contribute to the experience of shared outcomes among romantic couples.

There is no direct evidence in favor of this view, which renders it rather speculative. However, it is interesting to link we-agency to experiments aiming to test the self-expansion model of love and which have examined the impact of engaging in novel, challenging activities with the partner on romantic relationships (Aron et al., 2000). In one of these studies, couples engaged in a joint action task where the partners had to move together a cylinder using only their heads (while their hands and feet were tied together) (Aron et al., 2000). Compared to couples in a control condition, the couples who experienced this shared bodily activity subsequently reported both greater relationship satisfaction and love feelings. The emergence of we-agency, increasing agency scope, may contribute to such benefits, suggesting an embodied expansion of the self which may strengthen romantic feelings.

Shared internal states

The ability to share and understand the internal states of the romantic partner might be of crucial importance for relationship well-being and satisfaction (Sened et al., 2017). In this context, it is relevant to consider the possible consequences of embodied self-overlap in the ability to understand the beloved.

As seen above, TEC explains how representations coding for our own bodily experiences are activated when perceiving others' bodily states, and it further suggests this embodied self-other overlap may be strengthened by shared mutual experiences. The same way TEC predicted an increased imitation and better prediction of the romantic partner's actions, it can predict greater self-other overlap when perceiving the partner's affective states and somatosensory experiences, as compared to seeing another individual (Hommel, 2018; for a similar prediction based on ASL, see Heyes, 2018).

Results from studies investigating the neural correlates of the perception of pain in the romantic partner may be consistent with this view. Singer et al. (2004) reported that similar brain regions belonging to the pain matrix were activated when painful stimuli were applied on the participants' hand and when participants watched the same stimuli applied on their romantic partner's hand. More importantly, in a study by Cheng, Chen, Lin, Chou, and Decety (2010), participants observed hands or feet in painful situations from either their own perspective, from the perspective of their loved-one, or the perspective of a stranger. Adopting the perspective of the romantic partner, as compared to adopting the perspective of a stranger, was associated with greater involvement of the pain matrix activated in the self-perspective condition. This neural overlap between self- and partner-perspective attests to some shared processes between the coding of our own bodily experiences and that of our romantic partner. Moreover, there was a greater overlap with the partner than with a stranger. In the light of embodied simulation theories suggesting that shared bodily representations contribute to understand others' mental states (e.g., Keysers & Gazzola, 2009), it is tempting to speculate that such a prominent embodied self-other overlap may help partners to understand each other's affective states.

However, the potential benefit of a prominent overlap between self and partner at a bodily level remains uncertain. Indeed, theoretical and empirical works suggest that a full merging of self and others may be detrimental for social interactions and empathy. Shared body representations without clear self-other distinction would result in emotional contagion or affect-sharing, without discrimination between one's feelings and those of the other (Decety & Jackson, 2006). In contrast, empathy—when defined as a capacity to both share and understand the affective states of others—requires one to distinguish the representations of one's own actions, sensations, and emotions from that of others, to avoid personal distress or egocentric bias (Decety & Jackson, 2006; de Vignemont & Singer, 2006). Supporting this view, research suggests that self-other distinction processes are crucial for social cognition (Brass, Ruby, & Spengler, 2009; Liepelt et al., 2016; Milward & Sebanz, 2016). Therefore, one might wonder if, beyond a given level, reduced boundaries between the self and the romantic partner at a bodily level (Maister & Tsakiris, 2016; Quintard et al., 2018) could interfere with mutual understanding.

There is some evidence consistent with this possibility. For instance, it has been shown that partnered individuals who are happiest in their relationship are those who think they found someone they can be understood by and with whom they can share their experiences with (Murray, Holmes, Bellavia, Griffin, & Dolderman, 2002). Yet, romantically involved individuals who experience stable and satisfactory relationships assimilate their partner to themselves (egocentric bias) and tend to overestimate similarities with the partner (Byrne & Blaylock, 1963; Murray et al., 2002). This illusion predicts the feeling of being understood by the romantic partner as well as relationship satisfaction (Acitelli, Douvan, & Veroff, 1993). Ultimately, embodied (as well as conceptual?) self-other overlap might thus contribute to create an illusion of "we-ness" (Agnew et al., 1998) that would promote the feeling of being understood rather than actual understanding of the partner. Consequences would be positive since both actual and perceived understanding are beneficial for relationships (Murray et al., 2002; Reis, Lemay, & Finkenauer, 2017).

Functional mechanisms underlying self-other confusion

Theoretical frameworks have successfully predicted that romantic love increases self-other overlap and the sense that representations of oneself and representations of the beloved one becomes less discriminable. While the social effects and implications of this increase in representational overlap are varied and substantial, it is not yet well understood how it actually works.

On the basis of ASL and TEC frameworks, we argued above that shared bodily experiences with the romantic partner may partly explain stronger bodily self-other overlap, in that it would promote the development of sensorimotor links between, or integration of, self and partner actions. But romantic love does not only, or necessarily, involve shared bodily experiences, it also entails a strong affective component and social evaluation and attitudes, which are further potentially important modulatory sources of self-other overlap.

Although models acknowledge that action–perception links can be modulated by factors such as social distance or attitudes, through top-down modulation (e.g. Heyes, 2011; Chartrand & Lakin, 2013; Wang & Hamilton, 2012), they remain relatively silent regarding the cognitive mechanisms involved. However, there are first indications that romantic love might be systematically related to, and perhaps trigger a particular cognitive-control style that favors the integration of representations, be they social or not, over discrimination.

The general idea that interpersonal relations might be systematically associated with particular styles of information processing has received quite some support in recent years. For instance, high (vs. low) social power has been suggested to lead to more abstract information processing (Smith & Trope, 2006) and, conversely, abstract thinking has been shown to raise one's subjective sense of power (Smith, Wigboldus, & Dijksterhuis, 2008). More specifically, it has been reported that love priming (via imagination instructions), as compared to sexual priming, promotes a global, integrative processing of information in a classical local/global processing task (Förster, Özelsel, & Epstude, 2010; see also Förster, 2009).

The idea that romantic love is associated with a global processing bias, accompanied by reduced attentional selectivity (de Fockert, Caparos, Linnell, & Davidoff, 2011), is consistent with the outcomes of a recent study investigating the link between romantic love and sensitivity to irrelevant information (van Steenbergen, Langeslag, Band, & Hommel, 2014). Romantically involved participants were first required to imagine or write about a romantic event and listen to their favorite love-related music. Then they completed two conflict tasks (a Stroop and a flanker task) indexing the ability to regulate interference from irrelevant information according to situational demands. The results showed a positive association between the intensity of passionate love (as reported on the Passionate Love Scale) and the degree of interference control: more intense loving was associated with reduced selectivity, leading to a stronger impact of irrelevant information. In other words, romantic love is accompanied by a global/integrative mode of cognitive processing, which would indeed be expected to reduce self-other discrimination. This observation raises the questions (1) how the hypothetical global/integrative mode reduces discrimination between self- and other-representations, (2) why this reduction covaries with the kinds of effects and behaviors that were found to accompany romantic love, and (3) why this mode is sensitive to romantic love. Even though none of these questions has been investigated in the context of romantic love already, available findings suggest a preliminary scenario.

With respect to the first question, general models of cognitive control have suggested that adaptive behavior requires a dynamic balance between two conflicting cognitive control states, persistence/selectivity and flexibility/integration (Cools & D'Esposito, 2011; Goschke, 2003; Hommel & Wiers, 2017)—a process that has been called metacontrol (Hommel, 2015). According to a recent formulation of this view (Hommel & Wiers, 2017), a metacontrol bias toward persistence/selectivity strengthens the top-down influence of the current goal, which focuses the system on relevant information and creates a strongly selective processing state reinforcing mutual competition between alternative representations. Conversely, a metacontrol bias toward flexibility/integration is characterized by the weak top-down influence of the current goal and weak mutual competition between alternative representations, which widens the focus and creates a more integrative processing mode. Furthermore, the individual pattern of persistence/flexibility tradeoff would emerge from an interaction between various factors known to bias cognitive control, such as genetic predisposition (Colzato, Waszak, Nieuwenhuis, Posthuma, & Hommel, 2010), cultural learning (Hommel & Colzato, 2017), task constraints (Bonnin, Gaonac'h, & Bouquet, 2011; Mekern, Sjoerds & Hommel, 2019), and affect (Dreisbach & Goschke, 2004). Various findings have provided evidence that participants biased towards persistence/selectivity outperform others in tasks that require the exclusion of irrelevant information but perform more poorly than others in tasks that require the conjoint processing of different kinds of information, while participants biased towards flexibility/integration show the exact opposite pattern (for reviews, see Hommel, 2015; Hommel & Colzato, 2017). From this theoretical perspective, it would make sense to assume that romantic love induces a bias towards flexibility/integration.

According to this metacontrol approach, and now we turn to the second question, romantic love should reduce the impact of the current goal on information processing, which is consistent with the observation that viewing a picture of the romantic partner is associated with a deactivation of brain areas involved in the representation of task intentions (Bartels & Zeki, 2000, 2004; Zeki & Romaya, 2010). The approach would also predict more conflict between alternative representations, given that mutual inhibition is reduced, which accounts for van Steenbergen et al.'s (2014) observation that the intensity of romantic love is accompanied by a loss of conflict control.

Converging evidence comes from studies in which metacontrol biases towards flexibility/integration were experimentally induced by having participants engage in a divergent thinking task, which is taxing people's flexibility (Guilford, 1967). This manipulation has been found to evoke behavior that is very similar to that evoked by romantic love: it promotes interpersonal trust (Sellaro, Hommel, de Kwaadsteniet, van de Groep, & Colzato, 2014) and the integration of the others' actions into one's own task representation (Colzato, van den Wildenberg, & Hommel, 2013). Hence, romantic love may generate a similar bias towards flexibility/integration, which would account for the blurring of boundaries between the self and the romantic partner, at both conceptual and bodily levels.

But why would romantic love do this? This brings us to our third question. Metacontrol biases have been shown to depend on genetic predisposition and cultural molding—two factors that are rather permanent and stable—but also on situational factors (Hommel & Colzato, 2017). The best-investigated situational factor is mood, which in the case of positive mood has been demonstrated to promote metacontrol flexibility at the cost of persistence (Dreisbach, 2006; Dreisbach & Goschke, 2004). This is interesting for our purposes for no less than four interconnected reasons. First, positive mood has also been consistently found to improve divergent thinking (Baas, de Dreu & Nijstad, 2008), the task that apparently induces similar kinds of behavior than romantic love does. Second, inducing positive mood was found to reduce interference control in conflict tasks in similar ways than romantic love does (van Steenbergen, Band, & Hommel, 2010). Third, both positive mood (Akbari Chermahini & Hommel, 2012; Dreisbach et al., 2005) and divergent thinking (Akbari Chermahini & Hommel, 2010, 2012) have been shown to rely on (presumably striatal) dopamine, the neurotransmitter that is assumed to underlie metacontrol (Cools & D'Esposito, 2011; Hommel & Colzato, 2017). And, fourth, romantic love has been linked to dopaminergic transmission (Fisher et al., 2006). Taken altogether, this picture implies that engaging in romantic love and similar positive emotions are neurally represented as and/or accompanied by tonic increases of (presumably striatal) dopamine. Given that metacontrol biases are assumed to emerge from the interaction of frontal and striatal dopaminergic activity, and that increases of striatal dopamine are related to a stronger bias towards flexibility (Hommel & Colzato, 2017), this means that romantic love and flexibility biases are sharing a neuromodular mechanism that is known to generate behavior that has been observed in romantic lovers.

Conclusion and future directions

In this paper, we combined theories and empirical work from contemporary social cognition, experimental psychology and neurosciences, to address the outstanding question of self-other processing in the bodily domain within romantic relationships. Extending previous research on conceptual self-other representations, the reviewed empirical findings suggest a prominent overlap between self and partner at a bodily level in romantic love. Moreover, this bodily overlap has been repeatedly found to be related to the intensity of romantic feelings. Thus, the two forms of selfhood—bodily self and conceptual self—seem to be engaged in the creation of the unique, intimate link between lovers.

Building on models of perception–action links (TEC and ASL), we propose an integrative view of causes and consequences of embodied self-other overlap in romantic relationships. We suggest that the ability to share partner's bodily states facilitates interactions and promotes behaviors strengthening the affective bond between self and partner. Hence, this view highlights the key role of shared bodily states in social functioning as embodied cues of connectedness (Smith, 2008). Furthermore, an important and original aspect of our proposal is that it articulates the role sensorimotor and affective experiences in self-other processing. We argue that bodily experiences shared with the romantic partner and affective states may play a role in promoting the integration of self and partner bodily representations.

Our proposal, which is rooted in TEC, is partly consistent with other models suggesting that action–perception links acquired through sensorimotor experience may be sufficient to explain the development of social cognitive abilities such as imitation and/or empathy (e.g. Brass & Heyes, 2005; Heyes, 2018; Keysers & Gazzola, 2009). Here we suggest that to fully account for the impact of these links on social cognition, it is necessary to assume regulatory processes (metacontrol states) biasing the discrimination between self- and other-representations. By the same token, these regulatory processes allowed us to explain how affective states associated with romantic love may contribute to the reduction of bodily boundaries between self and romantic partner.

Yet, the potential role of self-partner bodily merging and the underlying mechanisms are far from being understood. Future directions can be identified to further investigate how romantic love engages embodied self-other representations involved in social interactions.

Conceptual self-other overlap (as indexed for instance by IOS-scores) in the romantic context has been found to correlate with intimacy, relationship commitment and satisfaction, and to be a predictor of long term relationship stability and quality (Agnew et al., 1998; Aron et al., 1991; Le et al., 2010). Much less is known however regarding self-other overlap in the bodily domain. Future research should explore the links between embodied self-other overlap and different aspects of the relationship (satisfaction, self-disclosure, emotional expression, level of intimacy…). Another valuable direction would be to test how bodily self-other overlap with the romantic partner, as indexed for instance by behavioral mimicry, in the early stage of the relationship is a predictor of future relationship outcomes. More broadly, further work should examine the association between embodied self-other overlap and social cognition processes associated with the beloved.

Studies already found a positive association between the intensity of romantic feelings and self-partner overlap at a bodily level (Ortigue et al., 2010; Quintard et al., 2018). This brings about the exciting question of the causal role of blurred self-other bodily boundaries to romantic feelings or attraction. A promising direction would be to test whether imitation of the beloved or procedures creating confusion between one's own and other's body (such as interpersonal multisensory stimulation; Tajadura-Jiménez & Tsakiris, 2014) can affect self-partner relationship.

Another interesting future direction is to explore the impact of reduced bodily boundaries between self and romantic partner on the representation of peripersonal space (i.e., the space within reach). This space, which is crucial for our interaction with objects and others, has been proven to be very plastic. It is expanded in presence of another person—especially if the person is cooperative (Teneggi, Canzoneri, di Pellegrino, & Serino, 2013) and it is updated following physical changes in one's own body (Cardini, Fatemi-Ghomi, Gajewska-Knapik, Gooch, & Aspell, 2019). Interestingly, recent work using interpersonal multisensory stimulation has demonstrated that experimentally induced reduction of self-other bodily boundaries modifies the representation of the other's peripersonal space—in the sense of a remapping onto one's own space (Maister, Cardini, Zamariola, Serino, & Tsakiris, 2015). Such a modification of the representation of the other's peripersonal space may affect the way one processes events related to the other and his/her behaviors. This calls for future investigations of whether peripersonal space boundaries between romantically involved individuals may be modified and how this may relate to reduced bodily boundaries between self and romantic partner. A first step to address this fascinating question may be to test whether the presence of the romantic partner modifies our representations of peripersonal spaces differently from other individuals.

An important, yet relatively unexplored, possible effect of self-other overlap is a transfer of (usually) positive self-evaluations to the other. This kind of transfer would explain why physically touching objects triggers ownership effects (i.e. the fact that we value more objects that we own; Beggan, 1992): owned/touched objects would be valued because of their association with the (positive) self. An outstanding question is to what extent this transfer applies to one's romantic partner, and whether self-other bodily merging may sustain such an effect.

Finally, as stressed earlier, only a few studies have been devoted to the examination of basic, domain-general cognitive processes in the context of romantic love. Cognitive skills such as self-regulation and self-control (i.e. cognitive skills related to cognitive control) have been connected with relationship maintenance (Finkel & Campbell, 2001; Ritter, Karremans, & van Schie, 2010). Recent work also suggests that romantic love involves particular cognitive control states (van Steenbergen et al., 2014). Identifying potential modes of cognitive processing associated with romantic love and specifying their links with both conceptual and embodied self-other overlap is thus another crucial direction for research on romantic cognition.

We hope considering these future directions will shed some new light on cognition and behaviors associated with romantic love.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

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