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Cooperative Tool-Use Reveals Peripersonal and Interpersonal Spaces are Dissociable

Ivan Patané[1,2,3*], Alessandro Farnè[2,3,4§], Francesca Frassinetti[1,5§]

[1] Department of Psychology, University of Bologna, Bologna, Italy;

[2] ImpAct Team, Lyon Neuroscience Research Centre, INSERM U1028, CNRS UMR5292, Lyon, France;

[3] UCBL, Lyon I University, Lyon, France;

[4] Hospices Civiles de Lyon, Neuro-immersion & Mouvement and Handicap, Lyon, France

[5]Fondazione Salvatore Maugeri, Clinica del Lavoro e della Riabilitazione, IRCCS – Istituto Scientifico di Castel Goffredo, Mantua, Italy

*Corresponding author: Ivan Patané

Department of Psychology, University of Bologna,

Viale Berti Pichat, 5 - 40127 Bologna, Italy.

Tel.: +39 051 209 1841.

Fax: +39 051 243086.

E-mail address: ivan.patane2@unibo.it

[§]Authors contributed equally to this work.

Abstract

The space surrounding people is often termed Interpersonal (IPS) in social psychology and Peripersonal (PPS) in neuroscience. In the current debate about their origin, the prevalent opinion is they share common functional characteristics. Bucking the trend, here we report a dissociation between PPS, operationalized as reachable space, and IPS, operationalized as comfort space. To probe their plasticity we introduced a novel type of cooperative long-tool-use that would modify both spaces. Results showed the estimated IPS referred to another individual was reduced, as expected following a positive social interaction. In sharp contrast, the estimated PPS toward the very same cooperative person was actually extended after use of the same long-tool. Control short-tool-use selectively reduced IPS, but not PPS, when performed in the same cooperative set or had no effect on either space estimation, when performed in a neutral set where the other person is not interacting cooperatively, but simply observing. The use of tools to perform actions in social settings allows us to report the first strong evidence that PPS and IPS underlie dissociable plastic representations: the former representation is sensitive to long-tool-dependent plasticity, whereas the latter representation, independently of use of a short or long tool, is sensitive to cooperation-dependent plasticity.

Highlights:

1. We assessed the relation between peripersonal (PPS) and interpersonal space (IPS).
2. We instigated plasticity of PPS and IPS due to a novel cooperative tool-use task.
3. After having used a long tool to cooperate, PPS expanded and IPS contracted.
4. Only IPS decreased following the cooperative use of a short tool.
5. PPS and IPS can be functionally dissociable.

Keywords: Peripersonal space, Interpersonal space, tool use, social interaction, space perception, cooperation

1. Introduction

Our sensorimotor and social interactions mostly occur within a limited area around the body. Although scholars from different fields had various visions about how this space is coded, the area surrounding our bodies is framed around two main representations: peripersonal space (PPS) and interpersonal space (IPS). PPS arises from the activity of multimodal neurons encoding the space surrounding different body-parts (Rizzolatti, Scandolara, Matelli, & Gentilucci, 1981; Brozzoli, Ehrsson, & Farné, 2014). Crucial for sensorimotor guidance of actions (Makin, Holmes, Brozzoli, Rossetti, & Farnè, 2009; Serino, Annella, & Avenanti, 2009; Avenanti, Anella & Serino, 2012), PPS is a plastic space, which may be extended by tool-use to the point where an individual is able to act (Berti & Frassinetti, 2000; Farnè & Ladavas, 2000; Maravita, Husain, Clarke, & Driver, 2001; Cardinali, Frassinetti, Brozzoli,, Urquizar et al., 2009; Cardinali, Jacobs, Brozzoli, Frassinetti,, et al., 2012), also referred to as the reachable space (Maravita & Iriki, 2004; Occelli, Spence, & Zampini, 2011). However, human beings commonly perform actions in social contexts, where others are present and interacting to various degrees. Individuals reliably regulate a socially appropriate distance between each other, termed IPS, which typically extends to a point that, if crossed, causes discomfort (Hall, 1966; Sommer, 2002).

Several recent studies revealed that PPS is not only modified by using a long-tool, but also by social factors (Heed, Habets, Sebanz, & Knoblich, 2010; Teneggi, Canzoneri, Di Pellegrino & Serino, 2013), supporting the idea that PPS and IPS are tightly interwoven. Adopting an embodied perspective (Ferguson & Bargh, 2004), some scholars suggested these systems share common mechanisms regulating space around the body (Lloyd, 2009; Iachini, Ruggiero, Ruotolo, Schiano di Cola, & Senese, 2015). Within this debate, we previously hinted at the possibility that there may not be full overlap between action and social space: the tool-use-dependent changes of the peer-referred PPS, as indexed by a Reaching-distance task, do not modify the IPS toward the same peer, as indexed by a Comfort-distance task (Patané, Iachini, Farnè, & Frassinetti, 2016).Yet, one may argue that IPS modulation was not observable because the classical tool-use manipulation was not “social” enough, since participants were left alone and required to reach for objects by themselves (Farnè, Iriki, & Ladavas, 2005). Stressing the sensorimotor body-objects interaction might have thus endorsed only PPS plasticity, whereas IPS plasticity may require a more social context to emerge.

Here we have overcome this limitation to more directly address the question of whether PPS and IPS may be considered as the two faces of the same coin, or not. As we frequently engage in cooperative behavior to coordinate our actions in space with those of conspecifics, we introduced a “social” tool-use setting, in which tools are not only bodily extensions, but become instruments for social cooperation. If PPS and IPS represent the same psychological entity, then cooperative tool-use should similarly impact reachable (PPS) and comfort space representations (IPS). More specifically, since the classical long-tool-use manipulation, by extending one’s range of action, increases the PPS, by adding to long-tool-use a social dimension of the most typically employed could “elongate” not only the reachable, but also the comfort space.. The finding of a similar tool-use dependent remapping of both spatial representations would thus support the idea that PPS and IPS share common functional mechanisms. Alternatively, if the social dimension of long tool-use triggers plasticity of two functionally distinct representations, a different scenario would be predicted: PPS estimates should increase because of tool-use dependent sensorimotor plasticity, whereas IPS estimates should decrease because of tool-use dependent social plasticity. This finding would instead support the alternative hypothesis that two spatial representations are independent from each other.

We tested these predictions in Experiment 1. Participants were engaged in a Reaching-distance and a Comfort-distance task to estimate respectively their PPS and IPS toward a male confederate, before and after having used a 70 cm-long tool to cooperate with the confederate. After finding evidence for differential changes of PPS and IPS following the use of a long tool in a social context, in Experiment 2 we investigated the effects induced by the use of a short tool in the same cooperative set. We predicted that plasticity due to the cooperative use of a short tool, which does not expand one's action capability, should affect perceived IPS, but not perceived PPS. Finally, to further assess the selectivity of social-tool-use effects, we also ran a control experiment. The question we addressed in Experiment 3 was whether cooperative interaction with another person is critical for any sensorimotor or social modulations of spatial representations. In particular, neither PPS nor IPS changes were expected to occur when short tool-use is not cooperative.

A final goal of the present study was to explore the relationships between PPS and IPS and a series of factors potentially involved in the sensorimotor and social regulation of the space surrounding the body. The parallel reading of cognitive neuroscience and social psychology literature led us to select two variables of interest: actual length of the arm (Longo & Lourenco, 2007; Linkenauger, Bülthoff & Mohler 2015) and familiarity with the other individuals (Hayduk, 1983, Pedersen & Shears, 1974). Based on this literature, we hypothesized the perception of PPS to be influenced by actual arm's reach, whereas the perception of IPS should be influenced by the degree of perceived familiarity of the interacting person.

2. Experiment 1

The first experiment was conducted to assess the plastic effects of a novel version of a long-tool-use paradigm from a more social perspective. To this aim, we adopted two tasks to measure the individual-to-individual spatial relationships before and after a cooperative long-tool-use session. Participants were therefore engaged in a Reaching-distance and a Comfort-distance task, administered in two separate blocks, to estimate respectively their PPS and IPS toward a male confederate, before and after having used a 70 cm-long tool to cooperate with the confederate.

2. 1. Method

2.1.1. Participants

Twenty healthy volunteers (9 women) were recruited for this study (mean age=23 years, SD=2.03 years, education=15.90, SD=1.17, see supplemental material for sample size estimation). They were all right-handed but three ambidextrous as assessed by the Edinburgh Handedness Inventory (mean = 58.72; SD = 20.24), and provided written informed consent before participating. The protocol was approved by the institutional ethics review board and conformed to the principles of the Declaration of Helsinki.

2.1.2. Procedure

All participants were tested individually in the same room. They performed a Reaching- and a Comfort-distance task to measure the estimated PPS and IPS between the participant and a male confederate actor. Next, participants underwent a cooperative tool-use session by using a 70-cm long rake, hereafter *long-tool,* to perform a task with the confederate. Then, the Reaching- and the Comfort-distance tasks were repeated with the same confederate. After completing the experimental post tool-use tasks, participants were asked to rate their perception of the tool-use session on several dimensions (i.e., easiness, pleasantness, positivity, cooperation, competition) and the perceived familiarity with the confederate. Moreover, the experimenter recorded the participant’s length of the right arm (acromion to middle fingertip) with arms outstretched at shoulder height. At the very end of the experiment, subjects were debriefed and thanked. None of the participants was suspicious about the real goal of the study.

A standardized appearance of the confederate was ensured across all sessions and all participants: the confederate had to wear the same neutral casual clothes and to maintain a neutral expression. Subjects and the confederate were not allowed to speak to each other for the whole experiment.

2.1.3. Experimental tasks

At the beginning of each trial, participants were positioned at a starting position with their toes on a line that was marked on the floor, while the confederate was located in front of them. The confederate looked straight at the participant's chin, avoiding any direct eye contact. Through the experimental tasks, participants stood with their arms extended along their trunk and were instructed to close their eyes between each trial. In the Reaching-distance task, participants were required to move at a natural gait speed toward the confederate and stop themselves at the distance they thought they could reach the other person by extending their arm. Instead, in the Comfort-distance task they were asked to move toward the confederate and to stop themselves at the shortest distance they would feel comfortable with the other's proximity. In either task, subjects could fine-tune the distance by moving slightly further backward or forward. Finally, they closed their eyes and the chest-to-chest distance at the sternum level was measured with a digital laser meter (Agatec, model DM100, error ±0.3 cm). Then participants opened their eyes and came back to their initial position for the following trial. The Reaching- and Comfort-distance tasks were administered in separate blocks of 10 trials per task. The order of blocks was counterbalanced between participants. Within each task, the initial distance between the two partners varied randomly across trials. In half of the trials the confederate was located at a distance of 3.5 metres from participant, whereas in the remaining half of the trials the confederate was positioned at a distance of 4 metres (see Figure 1A). This experimental manipulation served to prevent the use of any response strategy based, at least partly, on non-spatial cues in both tasks. Participants completed a practice trial before starting each task.

2.1.4. Cooperative tool use session

During long-tool-use session, both the participant and the confederate, facing each other, stood still along either side of a table (60 x 180 cm). As a cover story, the experimenter justified the presence of the same confederate during the long-tool-use session by explaining that the study aimed at demonstrating how collaborating with another person enhances the motor performance in speed and accuracy of both agents. Participants were indeed informed that, compared to their performance when alone, individuals tend to perform better when working in pairs. They were instructed to retrieve all the objects placed on the table (i.e., plastic poker chips and domino tiles) by means of the long rake and put them, one at a time, into a basket located along either the right or the left side of the table, according to the participant's position. The right and the left basket position were alternated across subjects. Notably, both the participant and the confederate had to collect together all the items, regardless of the type and position on the table. The plastic chips and domino tiles were randomly located by the experimenter outside the reaching space, at a distance of ≈90 cm from the participant' and confederate's trunks (see Figure 1B). Participants were also required to be as accurate as possible and there was no other constraint. Moreover, in order to promote the joint completion of the task, from time to time the confederate would encourage cooperative play by facilitating the task, passing or moving some items closer to the participant to engage her in cooperative activities. As a stopping rule for deciding whether to continue or stop the tool-use session, we decided to end the session when one of the two following criteria was met: the participants performed 250 movements, even before 15 minute of tool-use, or the participants used the long tool for 15 minutes, even before performing 250 movements. These two criteria were established on the basis of data from a pilot study to have comparable amount of movements performed, as well as comparable time spent with tools and the confederate across experiments.

2.1.4. Ratings

In order to assess how participants perceived both the long-tool-use session and the confederate himself, we administered several questionnaires at the end of the experiment. Participants were asked to rate the tool experimental session using a 7-point bipolar scale on the following dimensions: easy versus difficult (1 = easy, 7 = difficult), pleasant versus unpleasant (1 = pleasant, 7 = unpleasant), positive versus negative (1 = positive, 7 = negative), not cooperative versus cooperative (1 = not cooperative at all, 7 = highly cooperative), and not competitive versus competitive (1 = not competitive at all, 7 = highly competitive). Finally, participants rated the familiarity perceived throughout the experiment with the other person on a 7-point scale (1=not familiar to me, 7=very familiar to me). To avoid potential test-retest effects, all the questionnaires were collected only after the end of the post-tool experimental tasks.

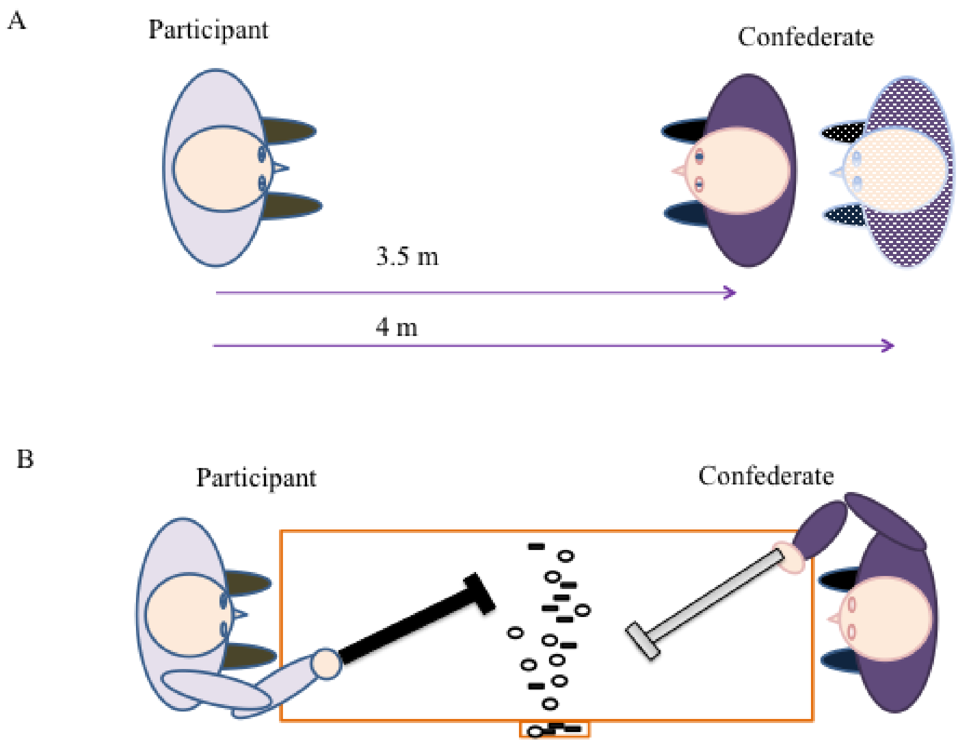

Fig. 1 A) Experimental Tasks: Participants performed Reaching-distance and Comfort-distance tasks, designed to respectably measure PPS and IPS. Participants approached the confederate and had to either: “stop yourself at the distance you think you can reach the other person” (Reaching-distance) or “stop yourself at the shortest distance you feel comfortable with the other person" (Comfort-distance). Across trials, the confederate was randomly positioned at 3.5 m or 4 m from participant. **B)** Long-tool-use session: The participant and the confederate, facing each other, stood still along either side of a table (60 x 180 cm). They were instructed to retrieve plastic all the poker chips and domino tiles (depicted by circles and rectangles) by means of a 70 cm-long rake and put them, one at a time, into a basket located to the left or to the right according to the participant ’s position (here depicted on the right). Plastic chips and domino tiles were randomly presented outside the reaching space, at a distance of ≈90 cm from the participants’ trunk.

2.2. Results and discussion

For all mean values reported, standard error and the 95% confidence intervals are indicated. Partial eta-squared and Cohen’s *d* were calculated as measures of effect size. The mean distances in cm recorded in each condition were contrasted by analysis of variance (ANOVA) with Task (Reaching- and Comfort-distance) and Session (pre- and post-tool) as within-subject factors. Significant interactions were followed by Bonferroni post-hoc test. A significant main effect of Task, $F(1,19)=6.73$, $p=.018$, $\eta^2_p=.26$, showed generally larger distance in the Reaching-distance (M=67.87, SE=2.02, 95% CI=[63.64, 72.11]) than in the Comfort-distance task (M=57.80, SE=4.71, 95% CI=[47.94, 67.65]). The main effect was qualified by its interaction with Session, $F(1,19)=60.76$, $p<.001$, $\eta^2_p=.76$. Bonferroni post-hoc comparisons revealed the Reaching-distance was significantly extended after cooperative long-tool-use, as compared to before ($p<.001$, $d=0.87$), whereas the Comfort-distance following the cooperative use of long-tool was reduced with respect to before ($p<.001$, $d=1.19$). In addition, before tool-use no significant difference between Reaching and Comfort-distance amplitudes appeared ($p=.09$, $d=0.19$, see Table 1). Yet, such difference was found to be significant after cooperative tool-use (p<.001, d=0.91, see Table 1 and Figure 2).

As complementary evidence for the efficacy of the cooperative interaction, participants reported that long-tool-use session was easy, pleasant, positive, cooperative and not competitive. Furthermore, the confederate was rated as mildly familiar (See Table 2).

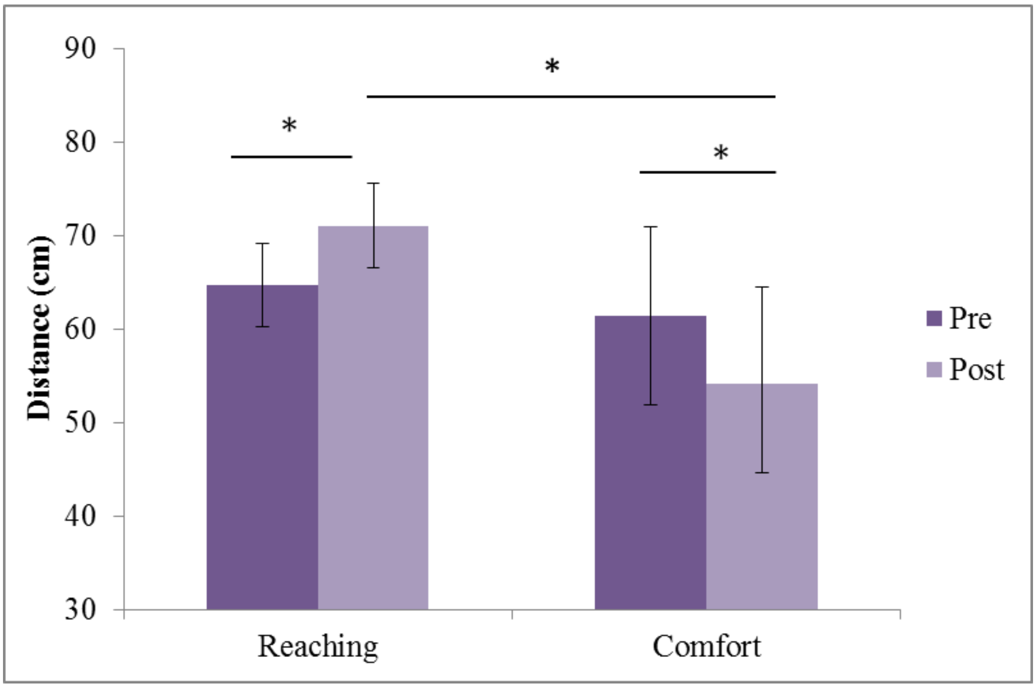

Fig. 2 The graph shows the average distance (in cm) as a function of task (Reaching- and Comfort-distance) and session (prior to and following cooperative long-tool-use session). Error bars indicate 95% confidence intervals. Asterisks indicate significant differences in Reaching and Comfort-distance estimates before (PRE, dark purple) and after (POST, light purple) long tool-use.

In line with previous studies (e.g., Iachini, Coello, Frassinetti, & Ruggiero, 2014), before long-tool-use reachable and comfort space estimates did not differ, supporting the idea that PPS and IPS could refer, in some circumstances, to a similarly sized sector of space. More interestingly, despite the fact that the reaching and comfort pre-tool amplitudes were comparable, the cooperative long-tool manipulation revealed an opposite pattern in the plastic properties of PPS and IPS. Indeed, we observed a plastic change of PPS representation in the direction of <u>extension</u>, due to the tool-use effects on the perceived reachable distance. This is of particular interest in light of the plastic contraction of IPS representation, due to the cooperative social interaction on the perceived comfort distance between conspecifics.

Although several studies have shown tool-use effects to vary with the functional length of the tool, it could be argued that the mere act of reaching repetitively for objects, regardless of the length of the tool used to retrieve them, may alter the PPS estimation. In addition, it has been shown that social interactions (i.e., an economic exchange) may expand one's own PPS boundaries to incorporate the space surrounding the cooperative confederate (Teneggi et al., 2013). Thus, either repeated reaching movements or the cooperative interaction per se could have affected the PPS estimates. In order to control for these alternative hypotheses, we conducted a control study using a short tool, which did not increase action potentialities and, thereby, should not impact on PPS estimates. Nonetheless, short-tool-use in a cooperative context should still reduce the IPS estimates.

3. Experiment 2

The second experiment was run to further explore the role of tool-use-dependent plasticity in a social setting by measuring the perceived PPS and IPS before and after a cooperative short-tool-use session.

3. 1. Method

3.1.1. Participants

Twenty new healthy adults (10 women) were recruited (mean age=22.75 years, SD=2.57 years, education=15.95, SD=1.32). They were all right-handed but four ambidextrous as assessed by the Edinburgh Handedness Inventory (mean = 62.20; SD = 20.41), and provided written informed consent. The protocol, approved by the institutional Ethics Committee, was performed in accordance with the standards of the Declaration of Helsinki.

3.1.2. Procedure and tasks

The procedure was the same as in Experiment 1, except that in the tool-use session participants used a short tool to cooperate with the confederate. Both the participant and the confederate used a rake with a 10 cm-long handle (i.e., not extending the sensorimotor representation of the arm length) to reach and move the same objects into the same basket. The distance at which target objects were placed was adapted at around ≈30 cm from either member of the dyad (see Figure 3A)

3.2. Results and discussion

The mean distances were entered in a two-way ANOVA with Task (Reaching- and Comfort-distance) and Session (pre and post-tool) as within-subject factors. A significant main effect of Session appeared, F(1,19)=21.86, $p< .001$, η^2_p=.54, with participants keeping a shorter distance in the post (M=58.15, SE=2.74, 95% CI=[52.42, 63.89]) than in the pre tool-use session (M=65.53, SE=3.54, 95% CI = [58.12, 72.93]). Also, a significant interaction between Task and Session emerged, F(1,19)=7.93, p=.011, η^2_p=.29), due to the fact that the distance was reduced in the Comfort-distance task after as compared to before cooperative short-tool-use session (p<.001, d=0.92). In contrast, no significant difference between before and after tool-use estimates was found in the Reaching-distance task (p=.187, d=0.89). Furthermore, at baseline Comfort- and Reaching-distance amplitudes prior to cooperative short-tool-use did not differ from one other (p=0.99, d=0.07). However, after tool-use distance amplitudes were significantly smaller in the Comfort- than in the Reaching-distance task (p<.001, d=0.41, see Table 1 and Figure 3A).

Moreover, participants perceived the cooperative short-tool-use session as being easy, pleasant, positive, cooperative, but not competitive. They also rated the confederate as moderately familiar (see Table 2).

Consistent with previous studies, at baseline no difference in terms of distance emerged between the two tasks designed to measure the PPS and IPS. Once again, the cooperative interaction was effective in reducing the comfort distance from the confederate after the short-tool-use session. By contrast, no significant difference in pre vs. post-tool estimates was observed in the reachable distance toward the confederate.

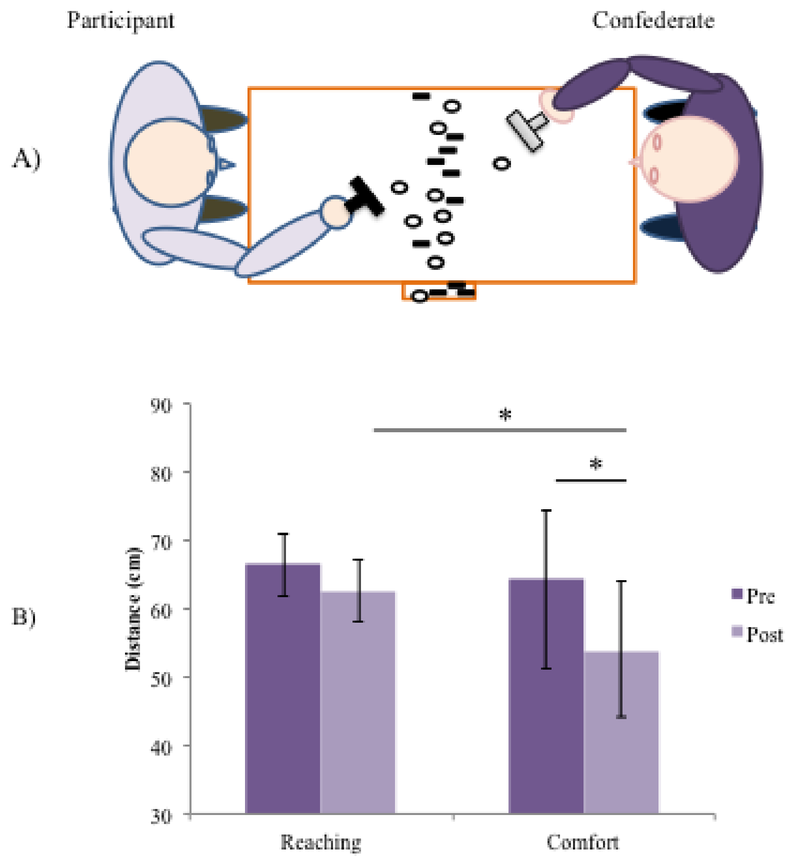

Fig 3 A) Short-tool-use session: The participant and the confederate used two 10 cm-long rakes to retrieve plastic poker chips and domino tiles randomly located by the experimenter at ≈30 cm from both the confederate and the participant. The goal of the task was to put the objects into the same basket, located at the right or left edge (randomly varied across subjects) of the table. B) The graph shows the average distance (in cm) as a function of task (Reaching- and Comfort-distance) and session (prior to and following short-tool-use session). Error bars indicate 95% confidence

intervals. Asterisks indicate significant differences in Comfort distance estimates before (PRE, dark purple) vs. after (POST, light purple) short-tool-use and in Reaching vs. Comfort distances estimates after short-tool-use. .

Experiment 1: Cooperative Long-tool-use	Pre Reaching-distance M= 64.78 SE=2.12 95% CI=[60.34, 69.22]	Post Reaching-distance M= 70.97 SE=2.22 95% CI=[66.32, 75.62]
	Pre Comfort-distance M=61.49 SE=4.56 95% CI=[51.95, 71.03]	Post Comfort-distance M=54.11 SE=4.95 95% CI=[43.74, 64.47]
Experiment 2: Cooperative Short-tool-use	Pre Reaching-distance M= 66.55 SE=2.25 95% CI= [61.84, 71.26]	Post Reaching-distance M= 62.56 SE=2.10 95% CI= [58.17, 66.98]
	Pre Comfort-distance M = 64.51 SE=6.35 95% CI = [51.21, 77.80]	Post Comfort-distance M = 53.73 SE=4.69 95% CI = [43.91, 63.55]
Experiment 3: Test-retest control	Pre Reaching-distance M = 64.12 SE=1.73 95% CI = [60.26, 67.98]	Post Reaching-distance M = 64.80 SE=2.12 95% CI = [60.07, 69.53]
	Pre Comfort-distance M = 67.04 SE=6.56 95% CI = [52.43, 81.65]	Post Comfort-distance M = 64.78 SE=4.78 95% CI = [54.12, 75.44]

Table1. Descriptive statistics for the participant-confederate distances obtained in the experimental conditions.

	Familiarity with the candidate: 1=not familiar to me, 7=very familiar to me	M = 3.95 SE = 0.25 95% CI=[3.44,4.46]
	Easiness of tool-use session: 1 = easy 7 = difficult	M = 2.65 SE = 0.24 95% CI=[2.14, 3.16]
	Pleasantness of tool-use session: 1 = pleasant 7 = unpleasant	M = 3.35 SE = 0.24 95% CI=[2.84, 3.86]

Experiment 1 Cooperative long-tool-use	Positivity of tool-use session: 1 = positive 7 = negative	M = 2.50 SE = 0.21 95% CI=[2.06, 2.94]
	Cooperation of tool-use session: 1 = not cooperative at all 7 = highly cooperative	M = 5.15 SE = 0.17 95% CI=[4.80, 5.50]
	Competition of tool-use session: 1 = not competitive at all 7 = highly competitive	M = 1.15 SE = 0.08 95% CI=[0.98, 1.32]
Experiment 2 Cooperative short-tool-use	Familiarity with the candidate: 1=not familiar to me, 7=very familiar to me	M=3.85 SE=0.26 95% CI=[3.30, 4.40]
	Easiness of tool-use session: 1 = easy 7 = difficult	M = 2.50 SE = 0.28 95% CI= [1.92, 3.08]
	Pleasantness of tool-use session: 1 = pleasant 7 = unpleasant	M = 2.60 SE = 0.20 95% CI= [2.19, 3.01]
	Positivity of tool-use session: 1 = positive 7 = negative	M = 2.30 SE = 0.22 95% CI= [1.84, 2.76]
	Cooperation of tool-use session: 1 = not cooperative at all 7 = highly cooperative	M = 5.40 SE = 0.21 95% CI= [4.62, 5.84]
	Competition of tool-use session: 1 = not competitive at all 7 = highly competitive	M = 2.00 SE = 0.29 95% CI= [1.39, 2.61]

Table 2. Descriptive statistics for rating scores.

Overall, these results indicate that the use of a short tool to collaborate with another individual did not modify the estimated reachable distance. At the same time, the very same manipulation selectively shrank the estimated comfort distance. Thus, by replicating previous work showing the lack of effect of short-tool-use on reachable space (Bourgeois, Farnè, & Coello, 2014; Costantini, Ambrosini, Sinigaglia, & Gallese, 2011), the results of this second investigation provide strong support to the finding the PPS and IPS representations can be shaped differently and, more importantly, they may be even directionally dissociated.

4. Relationships between participant-confederate distances, arm length and familiarity

Finally, we tested for the relationships that may exist between the distance at which the participants stopped themselves according to the task (Reaching- or Comfort-distance) in Experiment 1 and 2 and some independent variables of interest. In particular, we focused on the actual arm's reach (here measured in terms of arm length) and the degree of familiarity with the other person (here assessed by judging on a Liker-like scale the perceived familiarity with confederate during the whole experiment).

Preliminary analyses revealed a linear relationship between the reachable or comfort distances and the two additional measures, which are not part of the main experimental manipulation but have an influence to some extent on the distances being measured. To assess the influence of arm's length and familiarity on PPS and IPS estimates before and after the social tool manipulations, we pooled the data of all the experimental conditions from the two experiments in a single analysis. We thus fitted a linear model (ANCOVA) to submit the pooled data to inferential analysis. Assumptions for an ANCOVA model were met. A Repeated Measures ANCOVA was conducted for extension of reachable and comfort distances prior and following the two cooperative tool-use sessions taking Task and Session as within subject factors and Tool (short and long) as between subject factor. To control for the influence of the actual arm's reach and the perceived familiarity, we entered arm's length and scores of the familiarity rating as covariates. Finally, we also included in the model the appropriate two-way and three-way interactions. Results revealed a significant main effect of Task, $F(1,35)=6.50$, $p= .015$, $\eta^2_p=.15$, and a significant interaction Session by Tool, $F(1,35)=10.91$, $p=.002$, $\eta^2_p=.23$. More relevant to the purpose of the present study, these three factors (i.e., Task, Session, Tool) interacted, $F(1,35)=5.09$, $p= .030$, $\eta^2_p=.12$, even after taking into account the effect of the covariates. As far as the arm's length, the analysis found only a significant interaction with Task, $F(1,35)=4.26$, $p= .046$, $\eta^2_p=.11$ (Figure 4A and 4B display the effect of the covariate against the Reaching and Comfort-distances amplitudes). Finally, there also was a significant main effect of familiarity, $F(1,35)=10.28$, $p= .003$, $\eta^2_p=.22$, qualified by its interaction with Task, $F(1,35)=13.35$, $p= .001$, $\eta^2_p=.27$ (see Figure 4C and 4D). To summarise, this analysis fully replicated the pattern of results described above, with the additional benefit of offering a more powerful and stringent approach. The critical Task x Session x Tool interaction witnesses again the differential changes induced by the cooperative use of a long or short tool on reachable space and the comfort space estimations. Here we wish to emphasize that this effect is significant even after controlling the influence of the covariates being considered. Most interestingly, specific correlations of the arm's length and familiarity rating were observed with the Reaching and Comfort-distance tasks, respectively. The positive relation between the arm length and the reaching estimates revealed that participants with longer arm kept a larger distance in the Reaching-distance task, whereas no influence of the arm length was found on the comfort estimates. When looking at the perceived familiarity with the confederate, the negative relation between this covariate and the comfort estimates indicates that the more participants perceived the other individual as familiar, the shorter the distance they kept with him. By contrast, no influence of the familiarity rating was found on the reaching estimates. Therefore, these findings support the view that PPS and IPS can be specifically influenced and functionally dissociated.

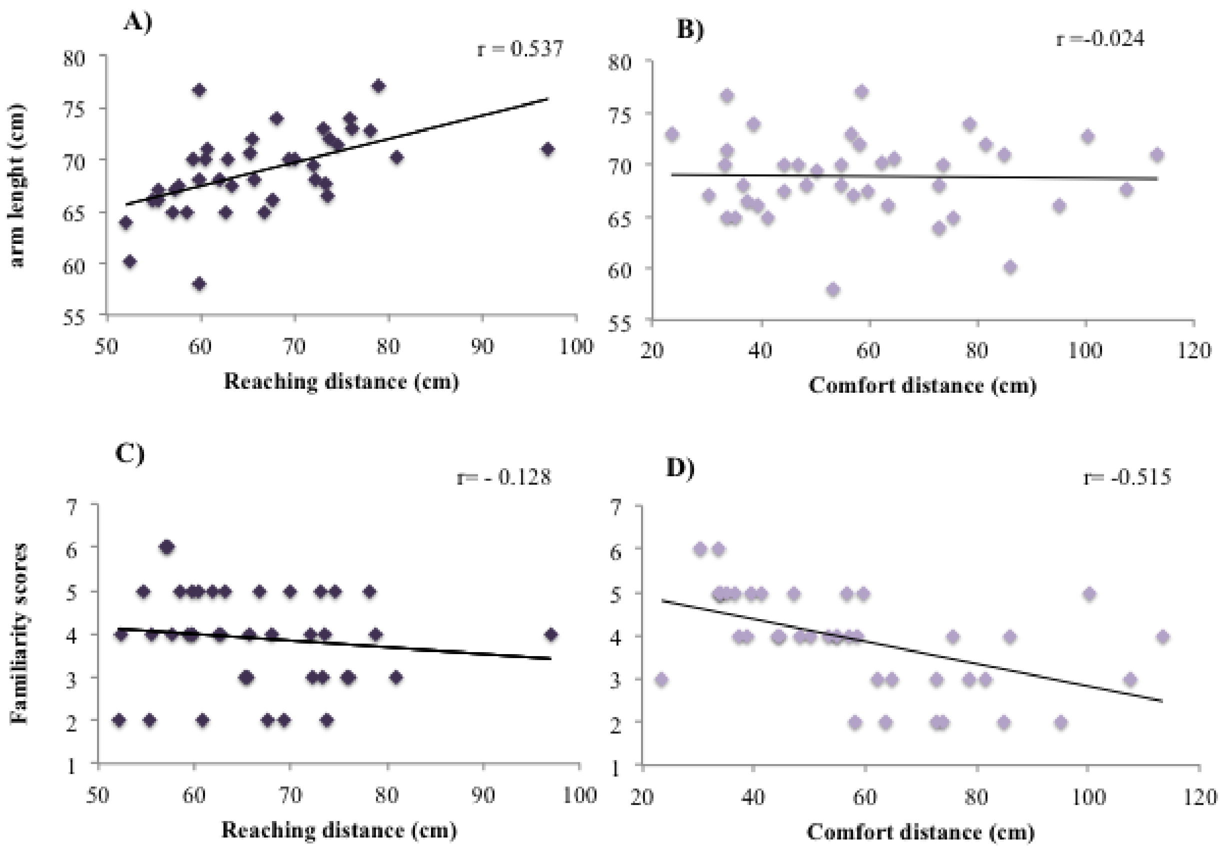

Figure 4 Scatter plots (with best-fitting regression lines) showing confederate-participant distances, separately for the Reaching- (A and C) and Comfort-distance tasks (B and D), as a function of the length of the participants' arm (upper panels) and as a function of the ratings of perceived familiarity with the confederate (lower panels).

5. Experiment 3

Taking into account the evidence that familiarity with another person is associated with the extent of the estimated IPS, one could wonder whether the mere fact of being exposed to the same social stimulus (i.e., the confederate) throughout the experiment can have an effect either on reachable or comfort distance. It is indeed important that the results of the two experiments are controlled for potential confounds, such as the repeated contact with the other, familiarization with the tasks, or any test-retest effects. As a control, novice participants (n=11) were submitted to the same procedure previously described in Experiment 2 with the only difference that during the short-tool-use session they simply performed the classical (i.e., non-cooperative) task while the confederate was observing the participants using the short rake. Participants therefore underwent the Reaching- and Comfort-distance tasks prior to and following a classical tool-use session in the presence of the confederate, who was simply observing the completion of tool session.

The mean distances were contrasted by a Repeated Measures ANOVA with Task (Reaching- and Comfort-distance) and Session (pre and post tool) as within-subject factors. Results from this additional experiment showed no significant difference in pre vs. post estimates (all Fs<1, all ps $\geq$.386, $\eta^2_p \leq$.08, see Table 1 for descriptive statistics and supplemental materials for sample size estimation, detailed procedure and data), ruling out any role for unspecific effects potentially coming from repeated administration of the tasks, habituation of the experimental context, or increased contact with the confederate. Although the interaction with the confederate was not cooperative in the control tool-use experiment, the ratings of perceived familiarity with the confederate during the whole study did not differ across experiments (see Manipulation check questionnaires in the supplemental materials). This interesting comparison reveals that the mere presence of the same individual throughout the experiment cannot account for the selective modulations induced by cooperative tool-use. These findings therefore suggest that the differences in reachable and comfort distance estimates observed after cooperative tool-use in Experiment 1 and 2 reflect genuinely our variables manipulation.

6. General discussion and conclusion

The eventuality of a multiplicity of the spaces surrounding the body becomes increasingly debated (see, for a review, de Vignement & Iannetti, 2015). We suggest a fruitful strategy to inform theoretical models of near space representation would consist in testing PPS and IPS for their dynamics. As a first contribution, we recently reported that a classic tool-use session enlarged the action-related PPS representation, but not the social-related IPS representation (Patané et al., 2016). Here we make a substantial step forward: by transforming the most typically employed tool-use paradigm into a socially cooperative tool-use paradigm, we disclose a full dissociation between IPS and PPS. The findings of Experiment 1 reveal that a completely opposite modulation of the extent of IPS (reduced) and PPS (enlarged) may result when introducing a social dimension to an otherwise classical tool-use task.

Experiment 2 and 3 showed the selectivity of this dissociation: social cooperative use of a short tool, which provides no functional extension of the individual's arm reach, shaped the IPS estimates only, while the same short tool used in a neutral, non-cooperative setting had no effect in modulating either spatial representation. It should yet be noted that the distance at which the participants and the confederate performed the social tool-use tasks varied across experiments. Indeed, that distance was larger in Experiment 1 than Experiment 2 and 3 because both members of the interacting dyad had to use a 70 cm-long rake in the cooperative long-tool-use session. Since IPS is, by definition, sensitive to the distance at which the social stimulus is located, the different location of the confederate could differently affect the perceived comfort space after tool-use. One may predict that the closer the confederate is facing the participants during the cooperative interaction, the shorter comfort distance they maintained with him. In spite of such a possibility, when comparing results from the two experiments we observed similar Comfort-distance estimates after cooperative long and short tool-use ($t(38)=.05$, $p=.957$). As a consequence, we consider unlikely that the different confederate-participant distance during social tool-use session could have an important effect on our measures. To corroborate this point, one must also consider that the reduction of IPS after cooperative tool session is comparable, as indicated by the effect size of the contrasts pre vs. post Comfort-distance estimates in the first and the second experiment.

Results from questionnaires importantly add to these behavioral findings, in that they support the effectiveness of the novel social version of our tool-use task. The ratings administrated to assess perception of tool-use manipulations indicated that, when comparing the three experiments, participants explicitly judged the quality of the tool sessions as different (see Manipulation check questionnaires in the supplemental materials). Indeed, the social tool-use paradigm in Experiment 1 and 2 was perceived as more cooperative and more positive than the “less social” manipulation in the control Experiment 3. Conversely, the social perception of the other individual in terms of familiarity appeared comparable: familiarity ratings collected in Experiment 1 and 2 were not significantly different from those collected in third control experiment. Hence, as the familiarity of the social stimulus (i.e., the confederate facing the participants throughout the study) was similarly perceived across experiments, we deem unlikely that the results of the present study could be explained in terms of different degree of familiarity with the confederate. We suggest instead that the crucial variable that selectively affected spatial regulation is the social dimension (cooperative vs. non-cooperative) of tool-use (see also Candini, Giuberti, Manattini, Grittani et al. 2016 for a recent study showing a differential modulation of IPS depending on the type (cooperative or non-cooperative) of interaction in children).

Before arguing the theoretical implications of these findings, we would like to point out that our design was aimed at controlling for potentially confounding variables, such as gender effects, that could account for the potentially different modulations of cooperative tool-use on the social space representation. A wealth of studies from social psychology have indeed shown the influence of gender on interpersonal spatial relationships (Aiello, 1987; Hayduk, 1983 and Sommer 2002 for reviewers). In this regard, a recent study investigating how reachability and comfort distances were moderated by gender differences reported that the critical determinant of the effect of this social variable was not the participants’, but the confederate’s gender: larger distances were indeed chosen in front of a male than a female confederate (Iachini, Coello, Frassinetti, Senese et al., 2016). In the light of these findings, here participants were exposed to the same male confederate. In addition, to limit potentially spurious effects driven by participants’ gender, we recruited balanced samples. Thus, even if gender was not the focus of our investigations, care was taken to ensure that this variable could have not masked the effects being assessed in our study.

When considering the other social variables influencing the representation of the space around the body, previous work (Teneggi et al., 2013) reported a PPS modulation as a function of the interaction with a partner. By using an audio-tactile paradigm to estimate the PPS boundary, the authors showed there was no longer detectable PPS boundary between the participant and the confederate when the latter had behaved cooperatively. This finding was thus interpreted as a social extension of PPS. This interpretation, however, may be not in full agreement with a social-related function of the PPS representation. Indeed, as we disclose here by jointly assessing the IPS, one would expect the social space to be reduced after a socially positive interaction (Sensenig, Reed, & Miller, 1972; Tedesco & Fromme, 1974; Candini et al. 2016). In other words, if one perceives the interacting peer as cooperative, the social space should not enlarge but shrink, inasmuch as the other person is experienced as more positive. Paraphrasing Heed et al.'s speculation (Heed et al., 2010) on the potential causes of the social modulations of PPS, the fair interaction may have simply increased the relevance of stimuli coming from the space occupied by the cooperative partner, thus resulting in a PPS extension to include her. As suggested by an anonymous reviewer, if we consider the differences between previous and the present results one could argue that they may emerge from different definitions/functions of PPS. In their work, Teneggi et al (2013) relied on the audio-tactile facilitation effect as a proxy for the location of the PPS boundary from the participants' face, while here we used the perceived reachability toward another person as a proxy of PPS. These two different paradigms to assess PPS extent could therefore focus on two different metrics of the same representation: on the one hand PPS as the portion of space where multisensory integration is facilitated; on the other hand PPS as reachable space where hand-object interactions occur. In the light of this definition, one may argue the perceived reachability as an index of the extent of PPS could be less sensitive to social factors. Following this alternative account, one might think that we disclose a dissociation between PPS and IPS because the reachable space is modulated only by low level sensorimotor manipulations such as tool-use. However, several reports concur in demonstrating that PPS, as operationalized by reachability measures, is actually affected by social and emotional factors (e.g., perceived morality and facial expressions, Iachini et al., 2015; Ruggiero, Frassientti, Coello, Rapuano et al., 2016). For instance, when participants are being approached by a confederate they perceive as immoral, both comfort and reaching distances were modulated. Although this impact of the (im)moral evaluation was more prominent on IPS, there was a significant expansion not only of the comfort zone, but also of the perceived reachable space, allowing to dismiss an alternative account of the present findings in terms of resilience of reachability to social modulations.

Before concluding, another point we would like to mention here is that the same direction of the PPS modulation (i.e., expansion) might be driven by the different functional features of the PPS. Even when PPS is assessed by audio-tactile interaction tasks to capture its multisensory nature, the same directional effect can observed after manipulations of seemingly opposite emotional valence. Unlike the reaching estimates (Iachini et al., 2015), the audio-tactile paradigm as a proxy of PPS might not differentiate between the positive and negative valuation of social-emotional factors: a larger PPS was found after both *positive* valuation of a fair confederate (Teneggi et al., 2013) and *negative* valuation of sound-mediated emotions (Ferri, Tajadura-Jiménez,, Väljamäe, Vastano, & Costantini, 2015). These apparently conflicting results might be reconciled if interpreted in the light of the different functions of PPS recently proposed by de Vignemont and Iannetti (2015). They suggested a distinction between PPS functions defining a protective space and a working space: the former functional role would be protection of the body, while the latter would serve goal-directed actions. Each function would correspond to a specific set of actions: appetitive and protective actions. Indeed, working space interface is more often associated to voluntary movements, and the protective space interface to automatic movements. Following this suggestion, we would argue that the same outcome (i.e., expansion) can be elicited by opposite functions subserved by PPS and that the different nature of the interactions with the surroundings would privilege one target function over the other. Positive valence of the interaction may induce an “extension” of PPS, an effect compatible with the appetitive function of the working space interface, while negative valence may induce an extension, compatibly with the defensive function of the protective space interface. As quality or valence of body-objects interactions might represent a possible confounding variable, we wish to emphasize that here we investigated PPS and IPS plasticity within the same (positive) social context: the use of a tool to cooperate. To this aim, we capitalized on reaching estimates as a measure of PPS, which are selectively and reliably sensitive to social variables (Iachini et al., 2015; Ruggiero, et al., 2016). The double dissociation reported here emerged from a social set with a similar positive valence, but only following cooperative use of a long tool. In sharp contrast, the neutral nature of the non-cooperative tool-use turned out to have no effect on IPS and IPS plasticity.

In line with the hypothesis that the functional properties of PPS and IPS may differ, the complementary pooled analysis indicated that reachable and comfort space are based upon different action-related (i.e., the actual arm's length) and socio-emotional (i.e., the perceived familiarity) factors, respectively. Indeed, the results revealed that perception of the space between conspecifics is selectivity influenced by different factors (namely, the arm length and the familiarity with the other) according to the spatial representation examined (namely PPS and IPS, respectably). It is reasonable to expect that body-related factors, and thereby possibilities for reaching, may modulate PPS extent, which in some situations may remain immune to some social-related factors, such as the perceived familiarity with the person facing us. If the arm length role in modulating the perceived reachable distance fits with previous findings and confirms a close relationship between body-action capabilities and PPS (e.g., Longo & Lourenco, 2007), one may have expected this factor to be involved also when regulating interpersonal social distances. On the contrary, here we disclose that only the perceived familiarity with the confederate correlated with IPS, a result consistent with prior evidence reporting that stimulus familiarity can influence social distance (e.g., Pedersen & Shears, 1974). This is particularly interesting given that PPS and IPS were measured from a social perspective by asking to estimate the reachable and comfort distance toward the same peer. Indeed, one important difference with respect to our previous study (Patané et al, 2016) is that here participants were being exposed to the same person in the session prior to and following tool-use. Nonetheless, the feeling of familiarity with the interacting individual influenced differently the extents of PPS and IPS: another important piece of evidence indicating that the two spatial representations are not completely overlapping dimensions.

To summarize, these findings converge in bringing support to our suggestion that the putative role of PPS for the guidance of interpersonal motor interactions (e.g., Brozzoli et al., 2014; Ambrosini, Blomberg, Mandrigin and Costantini, 2014) does not legitimate the assumption of its functional identity with IPS. In conclusion, we would like to remark that although PPS and IPS can be influenced similarly by some high-order social manipulations, our results based upon testing for their potential dissociation calls for a distinction between them. While it is certainly possible that new associations and mutual influences between PPS and IPS will be reported in the future, they do not imply that PPS and IPS share a common representation, nor that they are the same nosological entity.

References

1. Aiello, J. R. (1987). Human spatial behavior. In D. Stokols & I. Altman (Eds.), Handbook of environmental psychology, 505–531. New York: Wiley Interscience

2. Aron, A., Aron, E., & Smollan, D. (1992). Inclusion of Other in the Self Scale and the structure of interpersonal closeness. *Journal Of Personality And Social Psychology*, *63*(4), 596-612. http://dx.doi.org/10.1037//0022-3514.63.4.596

3. Avenanti, A., Annela, L., & Serino, A. (2012). Suppression of premotor cortex disrupts motor coding of peripersonal space. *Neuroimage*, *63*(1), 281-288. http://dx.doi.org/10.1016/j.neuroimage.2012.06.063

4. Berti, A. & Frassinetti, F. (2000). When Far Becomes Near: Remapping of Space by Tool Use. *Journal Of Cognitive Neuroscience*, *12*(3), 415-420. http://dx.doi.org/10.1162/089892900562237

5. Bourgeois, J., Farnè, A., & Coello, Y. (2014). Costs and benefits of tool-use on the perception of reachable space. *Acta Psychologica*, *148*, 91-95. doi:10.1016/j.actpsy.2014.01.008

6. Brozzoli, C., Ehrsson H., & Farnè, A. (2014). Multisensory representation of the space near the hand: From perception to action and interindividual interactions. *The Neuroscientist*, *20*(2), 122-135. doi:10.1177/1073858413511153

7. Candini, M., Giuberti, V., Manattini, A., Grittani, S., di Pellegrino, G. and Frassinetti, F. (2016), Personal space regulation in childhood autism: Effects of social interaction and person's perspective. Autism Res. doi: 10.1002/aur.1637

8. Cardinali, L., Frassinetti, F., Brozzoli, C., Urquizar, C., Roy, A. C., & Farnè, A. (2009). Tool-use induces morphological updating of the body schema. *Current Biology*, *19*(12), R478-R479.

9. Cardinali, L., Jacobs, S., Brozzoli, C., Frassinetti, F., Roy, A., & Farnè, A. (2012). Grab an object with a tool and change your body: tool-use-dependent changes of body representation for action. *Experimental Brain Research*, *218*(2), 259-271. http://dx.doi.org/10.1007/s00221-012-3028-5

10. Costantini, M., Ambrosini, E., Sinigaglia, C., & Gallese, V. (2011). Tool-use observation makes far objects ready-to-hand. *Neuropsychologia*, *49*(9), 2658-2663. http://dx.doi.org/10.1016/j.neuropsychologia.2011.05.013

11. De Vignemont, F., & Iannetti, G. (2015). How many peripersonal spaces?. *Neuropsychologia*, *70*, 327-334. doi:10.1016/j.neuropsychologia.2014.11.018

12. Farnè, A. & Làdavas, E. (2000). Dynamic size-change of hand peripersonal space following tool use. *Neuroreport*, *11*(8), 1645-1649. http://dx.doi.org/10.1097/00001756-200006050-00010

13. Farnè, A., Iriki, A., & Làdavas, E. (2005). Shaping multisensory action–space with tools: evidence from patients with cross-modal extinction. *Neuropsychologia*, *43*(2), 238-248.

14. Ferguson, M. & Bargh, J. (2004). How social perception can automatically influence behavior. *Trends In Cognitive Sciences*, *8*(1), 33-39. http://dx.doi.org/10.1016/j.tics.2003.11.004

15. Ferri, F., Tajadura-Jiménez, A., Väljamäe, A., Vastano, R., & Costantini, M. (2015). Emotion-inducing approaching sounds shape the boundaries of multisensory peripersonal space. *Neuropsychologia*, *70*, 468-475.

16. Hall, E. T. (1966). The hidden dimension. Doubleday, New York

17. Hayduk, L. A. (1983). Personal space: Where we now stand. *Psychological bulletin*, *94*(2), 293.

18. Heed, T., Habets, B., Sebanz, N., & Knoblich, G. (2010). Others' actions reduce crossmodal integration in peripersonal space. *Current Biology*, *20*(15), 1345-1349. doi:10.1016/j.cub.2010.05.068

19. Iachini, T., Coello, Y., Frassinetti, F., & Ruggiero, G. (2014). Body space in social interactions: A comparison of reaching and comfort distance in Immersive Virtual Reality. *Plos ONE*, *9*(11), e111511. doi:10.1371/journal.pone.0111511

20. Iachini, T., Coello, Y., Frassinetti, F., Senese, V. P., Galante, F., & Ruggiero, G. (2016). Peripersonal and interpersonal space in virtual and real environments: Effects of gender and age. *Journal of Environmental Psychology*, *45*, 154-164.
21. Iachini, T., Pagliaro, S., & Ruggiero, G. (2015). Near or far? It depends on my impression: Moral information and spatial behavior in virtual interactions. *Acta Psychologica*, *161*, 131-136. http://dx.doi.org/10.1016/j.actpsy.2015.09.003
22. Linkenauger, S. A., Bülthoff, H. H., & Mohler, B. J. (2015). Virtual arm′ s reach influences perceived distances but only after experience reaching. *Neuropsychologia*, *70*, 393-401.
23. Lloyd, D. (2009). The space between us: A neurophilosophical framework for the investigation of human interpersonal space. *Neuroscience & Biobehavioral Reviews*, *33*(3), 297-304. doi:10.1016/j.neubiorev.2008.09.007
24. Longo, M. & Lourenco, S. (2007). Space perception and body morphology: extent of near space scales with arm length. *Exp Brain Res, 177*(2), 285-290. http://dx.doi.org/10.1007/s00221-007-0855-x
25. Makin, T., Holmes, N., Brozzoli, C., Rossetti, Y., & Farne, A. (2009). Coding of Visual Space during Motor Preparation: Approaching Objects Rapidly Modulate Corticospinal Excitability in Hand-Centered Coordinates. *Journal Of Neuroscience*, *29*(38), 11841-11851. http://dx.doi.org/10.1523/jneurosci.2955-09.2009
26. Maravita, A., & Iriki, A. (2004). Tools for the body (schema). *Trends In Cognitive Sciences*, *8*(2), 79-86. doi:10.1016/j.tics.2003.12.008
27. Maravita, A., Husain, M., Clarke, K., & Driver, J. (2001). Reaching with a tool extends visual–tactile interactions into far space: evidence from cross-modal extinction. *Neuropsychologia*, *39*(6), 580-585. http://dx.doi.org/10.1016/s0028-3932(00)00150-0

28. Occelli, V., Spence, C., & Zampini, M. (2011). Audiotactile interactions in front and rear space. *Neuroscience & Biobehavioral Reviews*, *35*(3), 589-598. http://dx.doi.org/10.1016/j.neubiorev.2010.07.004

29. Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia*, *9*(1), 97-113.

30. Patané, I., Iachini, T., Farnè, A., & Frassinetti, F. (2016). Disentangling Action from Social Space: Tool-Use Differently Shapes the Space around Us. *PloS one*, *11*(5), e0154247. http://dx.doi.org/10.1371/journal.pone.0154247

31. Pedersen, D. & Shears, L. (1974). Effects of an interpersonal game and of confinement on personal space. *Journal Of Personality And Social Psychology*, *30*(6), 838-845. http://dx.doi.org/10.1037/h0037533

32. Rizzolatti, G., Scandolara, C., Matelli, M., & Gentilucci, M. (1981). Afferent properties of periarcuate neurons in macaque monkeys. II. Visual responses. *Behavioural Brain Research*, *2*(2), 147-163. http://dx.doi.org/10.1016/0166-4328(81)90053-x

33. Ruggiero, G., Frassinetti, F., Coello, Y., Rapuano, M., di Cola, A. S., & Iachini, T. (2016). The effect of facial expressions on peripersonal and interpersonal spaces. *Psychological Research*, 1-9.

34. Sensenig, J., Reed, T., & Miller, J. (1972). Cooperation in the prisoner's dilemma as a function of interpersonal distance. *Psychonomic Science*, *26*(2), 105-106. http://dx.doi.org/10.3758/bf03335449

35. Serino, A., Annella, L., & Avenanti, A. (2009). Motor Properties of Peripersonal Space in Humans. *Plos ONE*, *4*(8), e6582. http://dx.doi.org/10.1371/journal.pone.0006582

36. Sommer, R. (2002). From personal space to cyberspace. *Handbook of environmental psychology*, *2*.

37. Tedesco, J. & Fromme, D. (1974). Cooperation, Competition and Personal Space. *Sociometry*, *37*(1), 116. http://dx.doi.org/10.2307/2786471

38. Teneggi, C., Canzoneri, E., di Pellegrino, G., & Serino, A. (2013). Social modulation of peripersonal space boundaries. *Current Biology*, *23*(5), 406-411. doi:10.1016/j.cub.2013.01.043

Author Contributions

All authors contributed to the study design. Testing, data collection and analysis were performed by I.P. All authors contributed to writing the manuscript and approved the final version.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.