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ORIGINAL ARTICLE

Cues of control modulate the ascription of object ownership

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Abstract Knowing whether an object is owned and by whom is essential to avoid costly conflicts. We hypothesize that everyday interactions around objects are influenced by a minimal sense of object ownership grounded on respect of possession. In particular, we hypothesize that tracking object ownership can be influenced by any cue that predicts the establishment of individual physical control over objects. To test this hypothesis we used an indirect method to determine whether visual cues of physical control like spatial proximity to an object, temporal priority in seeing it, and touching it influence this minimal sense of object ownership. In Experiment 1 participants were shown a neutral object located on a table, in the reaching space of one of two characters. In Experiment 2 one character found the object first; then another character appeared and saw the object. In Experiments 3 and 4, spatial proximity, temporal priority, and touch are pitted against each other to assess their relative weight. After having seen the scenes, participants were required to judge the sensibility of sentences in which ownership of the object was ascribed to one of the two characters. Responses were faster when the objects were located in the reaching space of the character to whom ownership was ascribed in the sentence and when ownership was ascribed to the character who finds the object first. When contrasting the relevant cues, results indicate that touch is stronger than temporal priority in modulating the ascription of object ownership. However, all these effects were also influenced by contextual social cues like the gender of both characters and participants, the presence of a third-party observer, and the co-presence of characters. Consistent with our hypothesis, our results provide evidence that many different cues of physical control influence the ascription of ownership in daily social contexts.

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Introduction

Knowing that someone owns a particular object is a crucial piece of information when interacting in social contexts. Quite predictably, disregarding the ownership status of an object (i.e., whether that object is owned and by whom) gives rise to costly conflicts with rightful owners and, at least in humans, also with third parties who might be willing to intervene and enforce owners' rights. Given the ubiquity of object-centered interactions in our daily life, knowing their ownership status is thus essential to deal with others successfully.

Presumably, the easiest way to acquire this information is by simply being told who the owner is. Consider, however, the common experience of having dinner at a restaurant. Even if you are missing a fork, you are able to quickly establish that the one in front of a nearby stranger "belongs" to her, and will refrain from taking it. Clearly, the ownership status of forks, knives, and glasses in a restaurant is only rarely established via verbal testimony, and is often resolved with direct observation alone. By

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observing, for instance, that someone else is in possession of an object, you can usually predict who the owner is, what she expects from you, how the other bystanders will behave if you act contrary to shared expectations.

Legal scholars, however, have long warned against collapsing “possession”, a mere physical relation between a person and a thing, on “ownership”, which is viewed as a social relationship between people that is created and protected by the law itself: the legal right to control an item without the need to have it in one’s possession (see for instance Merrill, 1998). In this perspective, prior possession, at most, might be the sensorial “root” (Epstein, 1979), i.e., the perceptual basis we use—somewhat arbitrarily—to assign ownership over previously un-owned objects.

Empirical research has provided evidence that mere visual cues like possession do influence successive judgments on who the owner is. Beggan and Brown (1994) investigated, for instance, how different visual associations between a person and an object influence the attribution of ownership of an object to a person. Subjects were asked to judge on a 7-point scale how much they agree with different ascriptions of ownership after having read a story in which the two characters enter into a dispute about who the owner is. Mere exposure to a picture of one character using the disputed object (e.g., a woman watching TV; see Experiment 1) influenced later judgments on who should get the object. In another experiment, reading a story of a boy who is the first to find or to invest effort in modifying a neutral object (e.g., a tree branch; see Experiment 2) influenced ownership attributions when somebody else subsequently challenged the boy. With a similar paradigm, Friedman (2008) has asked adults to judge who the owner of an object is after seeing a cartoon in which first a character and then another character is in physical contact with the object (e.g., first a boy plays with a ball and then a girl plays with the same ball). Results indicate that, even if either character could in principle be the legitimate owner, ownership judgments are influenced by a “first possession” bias: the tacit assumption that the first one who is known to possess the object is probably the owner.

It is generally accepted that this evidence points to a connection between possession and ownership that is only inferential. Starting from the premise that ownership is a prototypical abstract concept (Miller & Johnson-Laird, 1976; Jackendoff, 1992, 2002; Friedman & Ross, 2011), which is not readily available to the senses, it is contended that possession can at most provide defeasible evidence about who the owner is. In particular, possession is usually informative of ownership because it is coupled with the additional assumption that the current possessor has previously acquired ownership in some other legitimate way, e.g., by purchasing the object or receiving it as a gift (Friedman, Neary, Defeyter & Malcolm, 2011). If people come to know about the ownership status of objects via reflective reasoning, i.e., by reconstructing the history of its legitimate acquisition in the past (Friedman, Van de Vondervoort, Defeyter & Neary, 2013), then observed possession is just one premise among others for this reasoning process.

The inferential link between knowledge about possession and knowledge about ownership is typically explored by directly measuring the ownership judgments of experimental participants. After being exposed to short stories or vignettes of two characters interacting around an object, participants are asked to resolve an imaginary dispute when both claim ownership over the desired object. This direct method to measure the explicit ownership judgments of participants has been useful to uncover the unspoken principles that orient our reasoning. These principles might influence the process by way of which we offer public justifications for one decision rather than another (Beggan & Brown, 1994; Friedman, 2008, 2010; Palamar, Le & Friedman, 2012; Kanngiesser & Hood, 2014; DeScioli & Karpoff, 2015). After all, in these experiments, participants are typically tasked with the third-party role of “judges” who are required to solve property disputes.

In our everyday interactions, like in the restaurant example, such disputes, however, are rare. Indeed, when deciding how to act in social contexts, people tend to take the ownership status of objects into account without awareness. It has been shown, for instance, that verbally acquired knowledge that a cup is owned by someone else directly modulates its affordances. This might occur, for instance, eliminating the automatic potentiation of action towards a graspable object (Experiment 2 in Constable et al., 2011), and thus making the motor system “blind” to the affordances of graspable objects owned by others (see also Turk, van Bussel, Waiter, & Macrae, 2011 for evidence on the neural basis of these effects).

More generally, if one is interested in how we take ownership into account during our everyday interactions with objects, the received distinction between possession—the mere holding of an object in one’s hand—and its legally acknowledged ownership is misleading because it obscures the relevance of a crucial behavioral pattern lying in between: respect of possession established by others (Merrill, 2015). In the restaurant example, for instance, what is actually relevant to facilitate social interaction is to respect possession of others, since legal ownership of the cutlery clearly lies elsewhere.

On the basis of the seminal work of evolutionary biologists (Sherratt & Mesterton-Gibbons, 2015 for a review), it has been, in fact, suggested that humans might be naturally reluctant to intrude and challenge prior possessors who are, in turn, prepared to defend a resource they

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physically control (Gintis, 2007; Eswaran & Neary, 2014, Pietraszewski & Shaw, 2015). Crucially, this behavioral pattern can only ground a minimal sense of object ownership with a marked temporal dimension: it is a form of "temporary" ownership that is acknowledged (and respected) as long as one keeps being in possession of the item.

This temporary form of ownership is in contrast with a more flexible one that is "permanent"—the owner keeps her property even if it is in possession of someone else. While temporary ownership is the kind of ownership that we share with the rest of the animal kingdom (Brosnan, 2011), permanent ownership is what makes human property unique (Kummer, 1991). Full human property (permanent ownership) enables more complex patterns of social interaction, like for example that of allowing third parties to settle property disputes once they have arisen.

Here we hypothesize that a minimal sense of object ownership grounded on respect of possession (temporary ownership) is potentially independent from understanding and reflectively reasoning about permanent ownership (legal property), and could rely on processing of sensory cues alone. Permanent ownership, on the other hand, requires an increasingly sophisticated and flexible cognitive system to be represented, i.e., some form of detached cognition (Pezzulo & Castelfranchi, 2007). To be able to represent and sustain permanent ownership, which is crucial to solve disputes, the availability of explicit representations upon which public justification can be based could be necessary. The use of public symbols like language might be required, and would help to explain the extension of ownership across space and time. Importantly, however, the use of symbolic systems can increase behavioral flexibility without necessarily severing the connection with their perceptual origins, as the modern embodied and grounded approach to cognition, language and abstract thought suggests (Barsalou, 2008; Borghi, Binkofski, Cimatti, Scorolli & Tummolini, 2017).

The temporary ownership hypothesis: tracking of ownership via cues of possession

Notwithstanding what is often assumed, possession of an object is not as self-evident as it seems (see Rose, 1985 for the subtleties of what counts as possession). Just touching an object accidentally, for instance, is not sufficient to have it in one's possession but having it at home when one is outside could be (Heine, 1997). To account for these complexities, we argue that possession amounts to having control over the object. Control is here intended as always relative to a goal-oriented process, and reflects the ability to maintain a goal in face of possible interferences (Elgesem, 1997). In this control view, possession of an object amounts to having control over the object in face of physical interferences. We hypothesize that, if one is concerned with temporary ownership only, having a full blown conceptual understanding of ownership is not needed to track the ownership status of objects. To track temporary ownership, and thereby ascribing objects to people implicitly, cues of possession or physical control can be sufficient, i.e., all those cues that predict physical control like being spatially close to the object or touching it, for instance.

Indeed, as suggested above, evolutionary models have shown that prior possession can be a conventional cue for (temporary) ownership. This means that tracking that one has established possession over an object can work as an arbitrary signal to induce the appropriate behavioral dispositions in all the relevant participants like that of refraining from taking the object or challenging the current possessor (i.e., respect of possession). From our perspective, this entails that an individual who is tracking the cues that predict who is going to be in control of the item would also be in the position to track who the (temporary) owner is. As a consequence, spatial proximity (being spatially close to the object), temporal priority (being the first to find it), and touch (being in bodily contact with it) can all be used, possibly with different reliability, as cues of possession and thus to predict whom to respect (temporary ownership). Within this view, understanding who the (temporary) owner of an object is and what the relevant consequences are does not need to be supported by a full-fledged conceptual understanding of ownership.

On the other hand, since permanent ownership endures even when an organism is not in possession of the object (i.e., lack of physical control), a more flexible process is required to take this kind of ownership into account, one in which a conceptual understanding of ownership, supposedly, would play a role. We hypothesize, however, that the concept of ownership is also—at least partially—grounded on the same sensory-motor experiences that are sufficient to grasp temporary ownership. Indeed, grounded approaches to cognition maintain that conceptual understanding is enabled by simulation mechanisms that recruit the same perception, action and emotional networks that are activated during actual experience of a stimulus (e.g., Barsalou, 1999, 2003; Glenberg & Robertson, 2000; Zwaan, 2004). A simulation mechanism is the re-enactment of past experiences (Barsalou, 1999) and is an unconscious, non-deliberate, process that it is aimed at prediction and action preparation (Gallese & Sinigaglia, 2011). With respect to the problem of understanding the ownership status of objects, such simulative mechanisms would work by re-enacting the visuomotor, affective and social experiences one has when observing instances of physical possession. Visuomotor experiences could consist, for example, in a

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facilitation to interact with objects owned by the self and an induced inhibition to undertake physical control of objects owned by others; affective experiences would increase the motivational salience of objects owned by the self and would facilitate defensive behaviors or an anticipation of the emotional consequences of taking control of objects owned by others. Finally, social experiences could consist in the mirroring of these processes in others. As we have suggested, these are the experiences that are behind the minimal sense of object ownership.

In sum, according to our hypothesis, the conceptual understanding needed to enable permanent ownership is (at least partially) grounded in the same cognitive resources employed to track temporary ownership.

Present study

The main prediction that follows from our hypothesis is that tracking temporary object ownership can be influenced by any cue that predicts the establishment of individual physical control over objects. As mentioned above, the cues of possession that we consider are spatial proximity, temporal priority and touch. Experiments 1 and 2 are designed to test possible effects of the first two cues while Experiments 3 and 4 are designed to contrast the (verified) effects of temporal priority with the effects of spatial proximity and touch, respectively. Our hypotheses, as well as the rationale of each experiment, are summarized in Table 1 and detailed in the following section.

As shown in Table 1, to test our hypotheses we have employed a sensibility judgment task in which participants are asked to judge whether a sentence is semantically sensible or not by pressing a different key on a keyboard. Since sensibility judgments require relative deep semantic processing of a sentence, they have been extensively used to investigate how concepts, words and sentences are mentally represented. For instance, Kaschak et al. (2005) have found that participants' sensibility judgments on sentences describing events involving movement (e.g., "The car approached you") are influenced by the concurrent perception of visual stimuli that match or mismatch the movement implied in the sentences, thereby indicating that conceptual understanding of motion recruits the same mechanisms used in visual perception of motion itself (for other studies employing sensibility judgment paradigms see Scorolli & Borghi, 2007; Borghi & Scorolli, 2009; for a review see Scorolli 2014).

Similarly, participants in our study are first briefly presented with a picture in which cues predicting physical control over an object are shown. In each visual scene there are at least two characters, either of whom can be either near the object (spatial proximity: Experiment 1, Experiment 3), or the first to find the object (temporal priority; Experiment 2, Experiment 3, Experiment 4), or in physical contact with it (touch; Experiment 4). Each scene is followed by a sentence on which participants have to provide sensibility judgments. Sensible sentences are all instances of predicative possessive constructions in which ownership of the object is ascribed to someone (e.g., "The [person] owns the [object]; The [object] belongs to the [person]"; see below for details). Trials can either be matching or mismatching, conditional on whether the person who is close to the object, or the first to find it, or is touching it in the picture, "matches" the person to whom the object is ascribed in the sentence (in the sense that he or she "owns" it). If the linguistic content of the sentence overlaps with the perceptual experience of the visual scene, then we expect a difference in response times between matching and mismatching trials. The presence of a matching effect indicates that the visual percept can be easily integrated with the content of the sentence and is interpreted as evidence that participants ascribe ownership to the character who is going to establish control over the object, thereby tracking the ownership status of objects in the visual scene.

Similar methods have also been used in research on theory of mind (TOM). Wertz and German (2007) asked participants to read a scenario in which, for instance, a character placed an object in a location, then in his/her absence the object was placed somewhere else. The object was then either substituted by a distractor object or the location was left empty. Participants were then required to interpret the character's mental states by choosing among possible explanations. The explanation task used in these experiments was explicitly related to the story that participants read before, and these explanations could either be consistent (correct explanations) or inconsistent (incorrect explanations) with the information presented in the story. The number of errors made by participants was used as evidence of activation of conflicting mental representations spontaneously generated by participants reading the story. Differently from this explanation task, however, in our sensibility judgment task the image viewed before the sentence was irrelevant for the task since the participants had to decide on the basis of the sentence only. Facilitation\interference effects at this level are thus exploited as an indirect measure of ownership ascription.

To facilitate discrimination between the two characters, each image displays both a male and a female, while ownership of the object is ascribed either to a male or to a female in each sensible sentence (e.g., "The ball belongs to the boy/girl"). We also manipulate the presence and the age (peer vs. senior) of a bystander to understand the influence of third parties on tracking object ownership, which plays a distinctive role in human property. Since both gender cues and the presence and age of bystanders can potentially influence who is going to gain control over the object, it is also possible that these cues modulate the

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Table 1 Summary of the rationale and the paradigms of the overall study—four experiments

N°. exp	Visual cue/s of control			Rationale		Cue operationalization	Displayed characters		Operationalization of the Protagonist	Sensibility Judgment Task	
	Spatial proximity	Temporal priority	Touch	Predictions			Potential owners	Bystanders		Sensible sentences on ownership	Non-sensible sentences
1	√			If the target cue affects ownership ascription	>Faster responses to sentences ascribing ownership to the character closest to the object	Neutral object on the table, at one of two extremes	Female, male, robot	Absent, peer (boy), senior (female)	Character sharing participant's perspective	Describing, in turn, the Protagonist and the Other as owners of the object	-Ownership of an object ascribed to inanimate artifacts, e.g., "The table owns the blackboard;
2		√ No co-presence; Partial co-presence; Full co-presence			>Faster responses to sentences ascribing ownership to the character seeing the object first	Neutral object at the center of the Table; in the 2nd picture one character appears; he/she is the first to see the object. Then the other character appears and sees the object	Female, male	Absent, female (peer or senior), male (Peer or Senior)	Correspondence between finder's and participant's gender	Two kinds of sentences:—focusing on the agent: "The [person] owns the [object]"; - focusing on the agent: "The [object] belongs to the [person]"	-Other topics, e.g., "The hill marries the case"
3	√	√ Partial co-presence; Full co-presence		Depending on the cue having relatively more weight on ownership ascription	>Faster responses to sentences ascribing ownership to the closest vs. first finder character	In the 2nd picture one character appears: he/she is the first to see the object. Then the other character appears and sees the object: she/he is the closest to the object			The first finder: the character shares both perspective (as in Exp. 1) and gender (as in Exp. 2) with the participant		
4		√ Partial co-presence; Full co-presence	√		>Faster responses to sentences ascribing ownership to first finder vs. touching character	In the 2nd picture one character appears: he/she is the first to see the object. Then the other character appears and sees the object: she/he touches the object			Gender correspondence between the character and the participant (as in Exp. 2)		

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tracking of object ownership and could be reflected in the presence or absence of the matching effect. The potential effect of both gender and bystander on sentence sensibility judgments was investigated across the four experiments.

A crucial advantage of this design is that it also allows the investigation of the relative weight of different cues in influencing the ascription of object ownership. While other studies have tried to identify the specific visual cue on which judgments on the acquisition of ownership are based (Friedman, 2010), or to contrast cues in visual and linguistic modalities (Blake, Ganea & Harris, 2012), our hypothesis suggests that all cues that predict the establishment of physical control over an object can be potentially relevant to track temporary ownership. Though such cues are typically convergent in most contexts—the one who is the first to find an object is usually the one who is able to get closer to it and to grab it—a given cue might be more or less reliable than another one in different contexts, hence each cue might have different weight. We focus, in particular, on the role of three main cues: spatial proximity, temporal priority and touch. We predict that they might have different weights in function of their reliability in predicting agent's control: touch is more reliable than spatial proximity, which in turn is more reliable than being the first in time to find an object. Hence, in Experiment 3 (spatial proximity vs. temporal priority) we contrast the spatial cue with the temporal one, while in Experiment 4 (temporal priority vs. touch) we contrast the temporal cue with physical contact with the object. Unfortunately, given the constraints of our design we could not dissociate spatial proximity from touch, which are thus not pitted against each other in this study.

Experiment 1: spatial proximity

In the first experiment we focused on the spatial proximity cue: participants were shown a virtual room with an object located on a table and placed in the reaching space of one of two main characters.

Method

Participants

Thirteen pre-adolescents (mean age 12.92, SD = 1.08; 7 female) and twelve adults (mean age 41.67, SD = 13.20; 4 women) took part in the experiment.

All participants were right-handed, except one preadolescent and one adult; all were Italian speakers with normal or corrected-to-normal vision and were naive as to the purpose of the experiment. The study was carried out along the principles of the Helsinki Declaration and was approved by the local ethics committee.

Visual stimuli

Participants viewed pictures of a room with a rectangular table in the center. An object was positioned on the table, at one of the two extremes. We selected six different everyday objects, chosen among those of potential interest for both pre-adolescents and adults: a flute, a mobile, a mask, a pencil case, a diary, and a ball.

At each side of the table there were two characters: a character seen from behind by participants and a character seen frontally (see Fig. 1). We will define the *Protagonist*

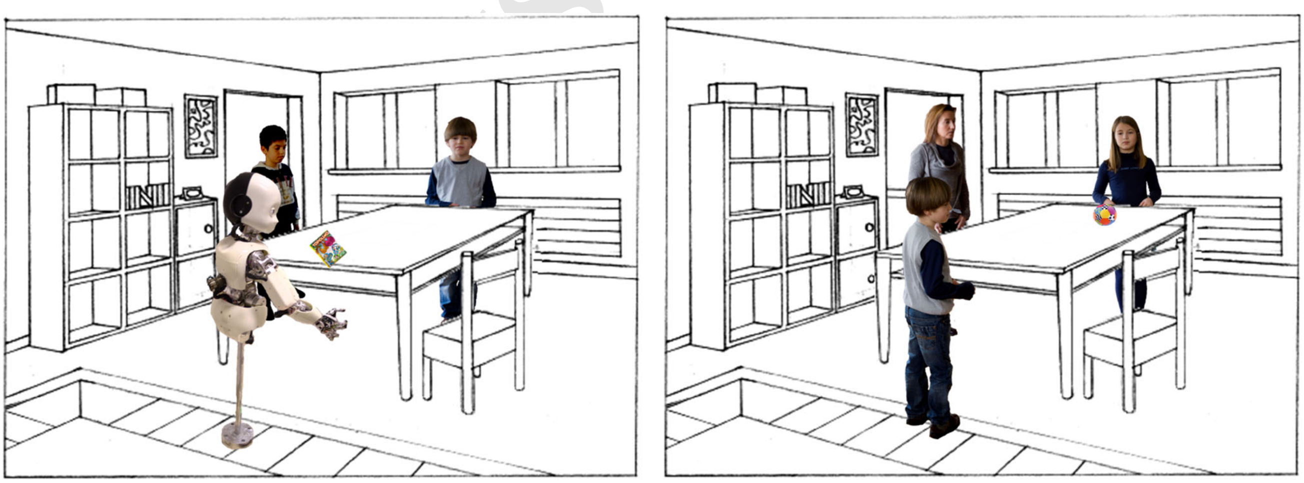

Fig. 1 Participants viewed pictures of a room with a table in the center: on the table there was an object. At each side of the table there were two characters: the Protagonist and the Other (a boy, a girl, or a robot). A Bystander could be present: when present, he/she could be either a peer (see figure on the *left*) or a senior (see figure on the *right*). The crucial manipulated variable was the match–mismatch between physical proximity to the object (object close to the Protagonist, see figure on the *left*, or far from the Protagonist and close to the Other, see figure on the *right*) and ownership of the object as expressed by the sentence (e.g., "The ball belongs to the girl"). Participants were presented with 6 repetitions of the relevant variables combinations

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as the character seen from behind and who shares the perspective of the participant, and the *Other* as the character in front view. We assume that participants would preferentially identify with the Protagonist on the basis of previous evidence on perspective taking showing an advantage of the egocentric over the allocentric perspective while processing potential hand actions (Bruzzo, Borghi, & Ghirlanda, 2008), when imagining actions by others (Marzoli et al., 2011), and when imitating (Jackson, Meltzoff, & Decety, 2006). Thus, the Protagonist is here considered as a proxy for the participant observing the visual scene (self-protagonist equivalence).

Moreover, the Protagonist and the Other could be either humans or robots. We selected humans and robots because we were interested in verifying whether ownership ascription during observation of potential actions was influenced by motor resonance effects. Studies have indeed demonstrated reduced motor resonance (Calvo-Merino, Glaser, Grezes, Passingham, & Haggard, 2005; Calvo-Merino, Grezes, Glaser, Passingham, & Haggard, 2006) or reduced automatic imitation effects (Heyes, 2011) when observing hands of humanoid robots than when observing biological hands (Anelli et al., 2012; Ranzini et al., 2011). Consistently, we expected slower responses when the Protagonist was a robot. To verify whether motor resonance or automatic imitation effects based on gender arise, we manipulated the gender of the human characters, while the gender of the humanoid robot was not manipulated. To facilitate age resonance for pre-adolescents we selected the pictures of a boy or of a girl (Liuzza, Setti & Borghi, 2012; Pollux, Hermens, & Willmott, 2016). Overall, we had six possible Protagonist–Other combinations: Girl–Boy; Boy–Girl; Girl–Robot; Robot–Girl; Boy–Robot; Robot–Boy.

Because we aimed to investigate the influence of a third party on ownership tracking, in some conditions a third-party bystander was present. We manipulated the age of the bystander, to verify whether his/her influence depended on his/her potential social role; hence, the bystander was either a peer boy (same age of the main characters) or an adult woman (older than the main characters, i.e., senior). Overall, then, the Bystander could be Absent, and, when present, Peer or Senior.

The object on the table was always close to the Protagonist or to the other and far from the Bystander (if present). With "close" we intend that it was on the same side of the rectangular table as the Protagonist or as the Other, thus it was clearly easy to reach. The object was never close to the Bystander, since he/she was not standing at one of the extremes of the rectangular table. An example of the pictures is shown in Fig. 1.

We selected 216 pictures resulting from all possible combinations between the critical factors ('Protagonist–Other combination': Girl–Boy; Boy–Girl; Girl–Robot; Robot–Girl; Boy–Robot; Robot–Boy; 'Kind of object': flute, mobile, mask, pencil case, diary, ball; 'Bystander': Absent, Peer, Senior; 'Spatial proximity to the object': close to the Protagonist, close to the other). The pictures were kept constant across participants to permit comparison between the two groups.

Linguistic stimuli

Ownership is typically expressed in languages using two main kinds of possessive constructions: "attributive" and "predicative" possession (Heine 1997). Attributive possession corresponds to noun phrases like "her house" or "the girl's house", while predicative possession is exemplified by "the girl has a house", "the girl owns the house" or "the house belongs to the girl". Since in the attributive construction possession is only presupposed, attributive possession is often considered to be more polysemous, e.g., "the girl's house" could refer to the house the girl has designed, or to the house where she lives, or to the house she was referring to in previous discourse (Herslund & Baron, 2001). Predicative constructions are instead less ambiguous since possession is encoded in a two-place predicate such as 'has', 'own' or 'belong'. All languages, moreover, have some conventionalized means to distinguish between HAVE-constructions and BELONG-constructions (Heine, 1997). This distinction is quite similar to a voice distinction: by focusing on the agent, transitive HAVE-construction is similar to the active voice, while the intransitive BELONG-construction is similar to the passive voice in that it focuses on the object (Herslund & Baron, 2001). Finally, while HAVE-constructions are used to express also notions of possession other than object ownership (e.g., "the girl has two legs" or "the girl has a brother"), the predicate "own" seems to be limited to ascription of ownership ("the girl owns two legs" and "the girly owns a brother" are not acceptable; Heine, 1997).

As we do not have specific hypotheses as far as the linguistic constructions are concerned, we created 216 sensible sentences balancing the OWN- and the BELONG-constructions (i.e., 108 OWN-constructions in which the owner appears as the clausal subject and the owned item as an object or complement, e.g., "The boy/girl/robot owns the diary", and 108 BELONG-constructions in which the owned item appears as the clausal subject and the owner as the object, e.g., "The ball belongs to the boy/girl/robot"). In addition, we created 70 non-sensible sentences: 30 sentences in which ownership of an object is ascribed to inanimate artifacts that are typically rejected by speakers (Noles, Keil, Bloom, & Gelman, 2012) (15 OWN-constructions, e.g., "The table owns the blackboard", and 15 BELONG-constructions "The window belongs to the table") and 40 sentences referring to other topics using the

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voice distinction, which is analogous to the two possessive constructions (20 active sentences, e.g., "The hill marries the case" and 20 passive sentences, e.g., "The lion is eaten by the ant").

Procedure

Participants were tested individually in a quiet laboratory room. They sat on a comfortable chair in front of a computer screen and were instructed to look at a fixation cross (+) that remained on the screen for 500 ms. When the fixation cross disappeared, a picture (80 × 80 visual angle degree) appeared on the screen for 1000 ms. Then the target-sentence was displayed on the screen until a response was given or until 2000 ms had elapsed. The timer started operating when the sentence appeared on the screen. All the stimuli were displayed centrally on the monitor and randomized. The experiment was programmed using E-prime2 software (Psychology Software Tools).

Participants viewed 216 target pictures (i.e., each picture was seen at least once by each participant) followed by 216 target sentences, thus they were presented with 6 repetitions of the relevant variable combinations. Half of the sentences in the OWN-construction (108/2) were paired with pictures depicting Spatial Proximity to the Protagonist; the other half were paired with pictures depicting Spatial Proximity to the Other. Sentences in the BELONG-construction were similarly balanced across Spatial Proximity to the Protagonist (108/2) vs. to the Other (108/2).

For half of the trials, the character who was close to the object in the picture, e.g., the boy, matched the person to whom the object was ascribed in the sentence, e.g., "the ball belongs to the boy" (matching trials); for the other half of the trials, the character who was close to the object in the picture, e.g., the boy, was different from the person to whom the object was ascribed in the sentence, e.g., "the ball belongs to the girl" (mismatching trials).

In addition to the 216 target sentences, participants were also shown 70 randomly selected non-sensible sentences, preceded by 70 pictures (each of them was randomly selected from the 216 pictures and presented only once), and 24 randomly selected sensible and non-sensible sentences preceded by 24 pictures with a red detail (catch trials). Thus, participants completed 310 trials in total.

For each trial, half of the participants were instructed to press the right key with the right hand if the sentence was sensible, and the left key with the left hand if the sentence was not sensible. The other half of participants performed the same task with the opposite hand mapping. If in the picture there was a red triangle, circle or square (catch trial), they had to refrain from responding. Participants received feedback for both correct and wrong responses. All participants were informed that their response times would be recorded and were invited to respond as quickly as possible while still maintaining accuracy.

The experimental trials were preceded by 12 practice trials (different from the experimental ones) to allow participants to familiarize with the procedure.

Analyses

We conducted the analyses with participants as a random factor. After eliminating all incorrect responses, we focused on response times (RTs) analysis to sensible sentences only. RTs were submitted to a 2 (Participants' Age: children, adults) × 2 (Participants' Gender: female, male) × 3 (Protagonist: boy, girl, robot) × 3 (Bystander: absent, peer, senior) × 4 (Spatial Proximity: MATCHING, sentence referring to the Protagonist; MATCHING, sentence referring to the Other; MISMATCHING, sentence referring to the Protagonist, MISMATCHING sentence referring to the Other) ANOVA. The factors Protagonist, Bystander and Spatial Proximity were manipulated within participant. The crucial variable we manipulated was Spatial Proximity, i.e., the match–mismatch between the character who was closer to the object, as shown in the picture, and ownership ascription as expressed by the sentence.

Results

There was no main effect of our main variable of Spatial Proximity but an interaction between Bystander and Spatial Proximity, F (2, 18) = 4.23, MSe = 47116,20, $p < 0.05$, $\eta_p^2 = 0.12$. Without any third-party observer depicted in the scene, as expected participants were faster to respond to sentences in matching trials (the character spatially closer to the object matched the owner as described by the sentence) than in mismatching ones (sentences referring to the Protagonist: $M = 1285$ ms vs. $M = 1371$ ms; sentences referring to the Other: $M = 1290$ ms vs. $M = 1346$ ms, post hoc LSD: $ps < 0.05$). However, with a bystander whose age was similar to the characters (a peer), participants responded faster to sentences that ascribed ownership to the character far from the object and in frontal view, i.e., the Other (mismatching trials with sentences referring to the Other: $M = 1263$ ms), than to sentences that ascribed ownership to the character close or far from the object, but in back view, i.e., Protagonist (matching trials with sentences referring to the Protagonist, $M = 1371$ ms; mismatching trials with sentences referring to the Protagonist, $M = 1353$ ms, $ps < 0.05$). Consistent with our predictions on the third-party presence, we found that when a senior bystander was looking at the scene, there was no difference between matching vs. mismatching trials (sentences referring to the Protagonist: matching: $M = 1295$ ms,

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mismatching: $M = 1326$ ms; sentences referring to the Other, matching: $M = 1338$ ms, mismatching: $M = 1315$ ms, post hoc LSD: $ps \geq 0.22$; see Fig. 2).

Analyses also showed a main effect of Participants' Gender, F (1, 19) = 9.70, $MSe = 2023327{,}88$, $p < 0.01$, $\eta_p^2 = 0.34$: male participants were faster ($M = 1165$ ms) than female ones ($M = 1483$ ms). We also found a main effect of the Protagonist, F (1, 19) = 9.84, $MSe = 47116{,}02$, $p < 0.01$, $\eta_p^2 = 0.29$: when the Protagonist, i.e., the character sharing the same perspective with the participant, was the artificial agent (robot), participants' responses to sentences were slower ($M = 1364$ ms) than with male ($M = 1291$ ms) or female ($M = 1316$ ms) protagonists. These two main effects, however, should be considered in light of the significant interaction between Participant's Gender and the Protagonist of the scene, F (2, 18) = 4.29, MSe = 47116,01, $p < 0.05$, $\eta_p^2 = 0.18$, as female participants were faster when the character sharing their perspective was a boy ($M = 1420$ ms) rather than a girl ($M = 1481$ ms) or a robot ($M = 1548$ ms, post hoc LSD: $ps < 0.05$). On the other hand, there was no modulation by the Protagonist for male participants (boy: $M = 1162$ ms, girl: $M = 1152$ ms, robot: $M = 1180$ ms; post hoc LSD: $ps \geq 0.25$, see Fig. 3).

Consistently, we also found a significant interaction between Protagonist and Spatial Proximity, F (6, 14) = 2,37, MSe = 40630,02, $p < 0.05$, $\eta_p^2 = 0.11$. Post hoc LSD showed that this interaction was basically due to the pattern obtained in case of the boy protagonist. Responses to sentences ascribing ownership to a boy when the character who was close to the object was also a boy were faster (matching trials with sentence referring to the Protagonist: $M = 1232$ ms) than to all sentences referring to the girl ($M = 1344$) and to the robot ($M = 1374$, LSD, $ps < 0.05$); responses to these sentences were also faster than sentences ascribing ownership to the boy in trials in which he was far from the object (mismatching trials with sentence referring to the Protagonist: $M = 1343$ ms; mismatching trials with sentence referring to the Other: $M = 1305$ ms, $ps < 0.05$), but did not differ from

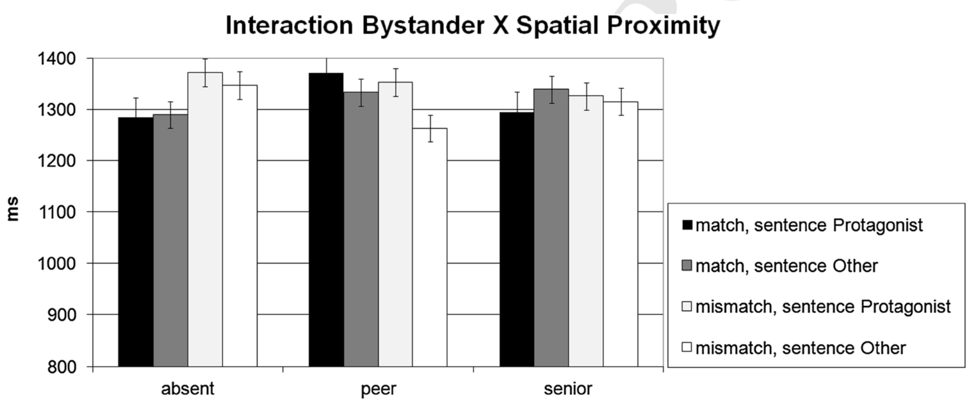

Fig. 2 Without bystanders, participants were faster in matching trials in which there was a match between the character spatially closer to the object and the owner as described by the sentence, both for sentences referring to the character who shared the perspective with the participant (the Protagonist) and sentences referring to the character in front view (matching effect). When a peer bystander was present, there was an advantage of mismatching sentences referring to the character in front view. When the senior bystander was present, we did not find any advantage for the matching vs. mismatching conditions. *Error bars* represent the standard error

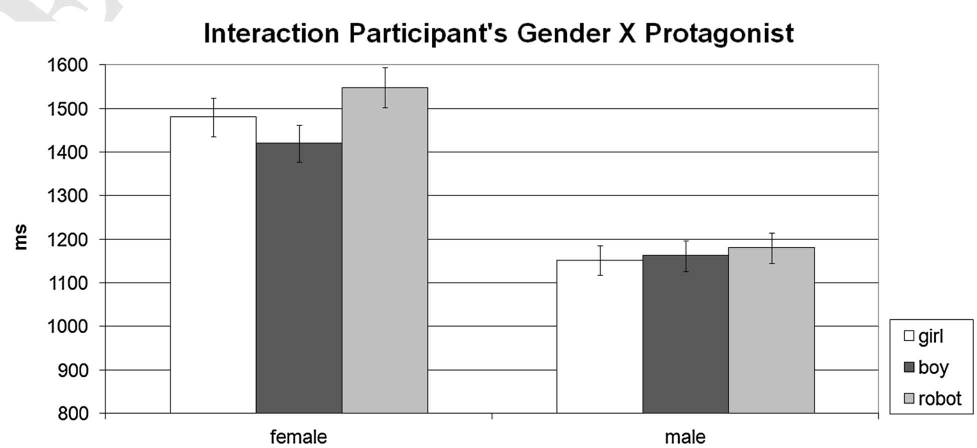

Fig. 3 Significant interaction between Participants' Gender and Protagonist: females were faster in their sensibility judgments when ownership of the object was ascribed to boys rather than to girls; they were slower in case of robots. With male participants there was no modulation determined by the robot, nor by the other's gender. *Error bars* represent the standard error

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responses to sentences ascribing ownership to the boy when he was close to the object but did not share the participant's perspective (matching trials with sentence referring to the Other: $M = 1282$). Thus, the matching effect, an advantage of matching trials over mismatching ones, was modulated by gender cues in the image.

Finally, we found no significant effect of Participants' Age, but an interaction between Participants' Age, Protagonist, and Bystander, $F\ (4,16) = 3.66$, $\text{MSe} = 35310$, $p < 0.05$, $\eta_{\text{p}}^2 = 0.16$, which shows that pre-adolescents' responses to sentences were slower when the Protagonist was a robot and the bystander was a peer. We also found an interaction between Gender, Protagonist, and Bystander, $F\ (4,16) = 3.23$, $\text{MSe} = 35310$, $p < 0.05$, $\eta_{\text{p}}^2 = 0.15$, which shows that overall male participants were faster than female participants. With female participants responses were slower when the Protagonist was a robot, in particular when the bystander was absent, and when the protagonist was a female with a senior bystander.

Discussion

The interaction between Bystander and Spatial Proximity reveals the existence of a matching effect when no third-party is involved. This result is consistent with our hypothesis that spatial proximity to an object influences ownership ascription when this cue is sufficiently reliable to predict who will establish control over the object. The matching effect is present when there is no bystander and this effect is eliminated when there is a third party who is older than the characters. This result indicates that the more the cue of spatial proximity is predictive of who is going to establish physical control over the object, the more it is effective. When no other character is present on the scene, proximity to the object is highly predictive of who is going to gain control over the object. However, when a third character is present, proximity is less effective and ownership ascription becomes more uncertain. When a peer is shown, participants were particularly slow when sentences ascribed ownership to the character sharing the perspective with the participant, regardless of the location of the object. Actually, in this condition, the Protagonist is perceived alone in the scene, while the Other and the Bystander are close to each other; in case of peers, both can desire the object (e.g., the ball) to play together. Alternatively, since in this experiment the peer third-party observer was always a boy and closer to the object than the Protagonist, it might also be that ownership was ascribed to him in these trials.

Conversely, the presence of an older character eliminates the matching effect possibly because age as a cue might contrast with spatial proximity: the older character can be viewed as an authority figure (e.g., a parent) whose typical role in contexts of possible conflicts over object is to promote sharing behavior, i.e., to trump ownership considerations (Ross 1996).

Given their possible relevance in predicting who is going to establish control, it is also important to discuss the role of gender and gender cues in ownership ascription.

Indeed, the interaction between Participant's Gender and Protagonist suggests that only in case of female participants we found a significant effect of perspective-based resonance, which indicates that ascription of ownership to males is favored (for a similar complementarity effect in females, see Lugli et al., 2016). Consistently, the interaction between Protagonist and Spatial Proximity suggests that, independent of possible identification with the self, spatial proximity modulates ownership ascription favoring males.

Due to their complexities, the interaction between Participants' Age, Protagonist and Bystander, showing that adult participants are fastest when the Protagonist is male and the Bystander is a senior, and the interaction between Gender, Protagonist and Bystander are difficult to interpret. On the one hand, the motor resonance explanation highlights the relevance of gender and the difficulty of ascribing ownership to robots. With female participants, responses are slower when the Protagonist is a robot, in particular when the bystander is absent, but also when the protagonist is a female with a senior bystander. This suggests that ownership tends to be preferentially ascribed to male protagonists also by female participants, and that it less easily ascribed to robots. Taken together, also these two interactions seem to point to a subtle role of cues of gender in ownership ascription which seem to favor males also by female participants (see the "General discussion" and Table 2).

On the other hand, a possible alternative explanation of the slower response times we obtained with robots is that robots are not able to own things because they are not viewed as cognizant beings. Thus, responses could be slower with robots possibly because the trials involving the robot were perceived as nonsensical statements. Our data do not allow us to disentangle between the motor resonance explanation and this alternative explanation.

Experiment 2: temporal priority

In the second experiment we tested the effects of the cue of temporal priority (i.e., being the first in time to find an object) on ownership ascription. The paradigm was the same of Experiment 1, but we have changed the design and factors (see below). Moreover, we presented a sequence of four or five—depending on the condition—pictures instead of a single picture. In the first and in the last picture

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Table 2 Summary of the findings from the overall study: target cues effects as well as modulation determined by further variables are highlighted

N°. exp	Visual cue/s of control			Main hypotheses and results		Further variables and possible effects					
	Spatial proximity	Temporal priority	Touch			Participants' Age	Robot	Bystanders	Participant's Gender	Protagonist's Gender	Interaction between Participant's and Protagonist's Gender
1	√			>Faster answers for sentences ascribing ownership to the character closest to the object	Yes Without any third-party observer, faster responses in the matching conditions (the character spatially closer to the object matched the owner as described by the sentence) $p < 0.05$	No	No Slower responses when the protagonist is a robot rather than a male or a female $p < 0.01$	Yes When a bystander is present (and she is not a peer), no difference in matching vs. mismatching conditions	Yes Males faster than female $p < 0.01$	Yes Faster answers in matching condition for sentences referring to boy as protagonist than to girl and robot $p < 0.05$	Yes Females faster when the protagonist is a boy rather than a girl or a robot $p < 0.01$
2		√ No co-presence; Partial co-presence; Full co-presence		>Faster answers for sentences ascribing ownership to the first character to see the object	YES, for Full co-presence condition: advantage of matching over mismatching trials in case of gender correspondence between the finder and the participant $p < 0.001$			Partial No	Yes	No	Yes * Males faster in matching trials when the finder is a male $p < 0.05$ * Females faster in matching than in mismatching trials only if the sentence refers to the ownership of a male $p < 0.05$
								Full No	Yes Only females are faster when the owner as described by the sentence matches the finder, than when they mismatch $p < 0.01$	No	Yes In matching conditions, participants are faster in case of gender correspondence than when there is not $p < 0.01$

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Table 2 continued

N°. exp	Visual cue/s of control			Main hypotheses and results		Further variables and possible effects					
	Spatial proximity	Temporal priority	Touch			Participants' Age	Robot	Bystanders	Participant's Gender	Protagonist's Gender	Interaction between Participant's and Protagonist's Gender
3	√	√ Partial co-presence; Full co-presence		>Faster answers for sentences ascribing ownership to the closest vs. discovering character	Relatively more weight of spatial proximity on ownership ascription. But the effect is modulated by other contextual social cues like gender and the presence/absence of a bystander			Yes*	Yes*	No	Yes * Females, when the bystander is a female peer or is absent, are sensitive to spatial proximity: they are faster when the character spatially closer to objects is the same to whom ownership is ascribed by the sentence $p < 0.05$
4		√ Partial co-presence; Full co-presence	√	>Faster answers for sentences ascribing ownership to the closest vs. touching	Relatively more weight of touch the effect is sensitive to contextual cues as it is found 1. for females, regardless of the kinds of co-presence and characters' gender 2. for both females and males, for the Full Co-presence condition, but only when participants' gender corresponds to the discoverer's gender			No	Yes Females are faster than males $p < 0.05$	Yes Males always ascribe ownership to the male character, regardless of whether he is the first finder or touches the object (judgment entirely driven by gender cue) $p < 0.05$ For females touch is more important than temporal priority both for correspondence of gender ($p < 0.05$) or not ($p = 0.07$)	Yes For the Full co-presence, as in case of gender correspondence between the first finder and the participant (i.e., no correspondence between the gender of the touching character and the one of the participant), touching the object is more relevant than temporal priority $p = 0.05$

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participants saw the objects in the center of the table. In the second picture one character appeared: he/she was the first to see the object (the first finder). Then, in the following picture/s, the other character appeared and saw the object as well.

Results of Experiment 1 suggest that the spatial proximity cue influenced ownership ascription especially when it was highly predictive of control. Accordingly, in this experiment we have created three different contexts in which the two characters could be more or less co-present in each scene. Thus, depending on the kind of context, the first finder disappeared or remained with the other on the scene.

Method

Participants

Since in "Experiment 1" we did not find relevant differences between pre-adolescents and adults, in the second experiment we tested twenty-six adults (mean age 25.12, SD = 3.34; 13 female). All were right-handed, except for four participants. Participants were Italian speakers with normal or corrected-to-normal vision and were naive as to the purpose of the experiment; the experiments were carried out along the principles of the Helsinki Declaration and approved by the local ethics committee.

Stimuli

Differently from Experiment 1, participants viewed four or five sequences of pictures: the first and the last image showed a room with a table. One of six everyday objects was located in the center of the table (a pouch, a CD case, a book, an alarm clock, a pair of glasses, a mobile; see Figs. 4, 5, 6). The Protagonist and the Other did not appear simultaneously: they appeared one at a time, and remained for two or three further pictures, depending on the condition. In the second picture the first character appeared: he/she was conceived as the first finder, the first to see the object (see Figs. 4, 5, 6, image on the left). Then we designed the three following conditions that were manipulated between participants: (1) no co-presence—in the third picture the first finder disappeared and the other character appeared (see Fig. 4); (2) partial co-presence: in the third picture another character appeared, alongside the first finder; in the fourth picture the first finder disappeared and only the other character remained on the scene (see Fig. 5); (3) full co-presence: in the third picture the other character appeared, alongside the first finder, and in the fourth picture both remained on the scene (see Figs. 6). The characters could be a female or a male (about 25 years old) and the object was always equally distant from both. Since both characters shared the perspective of the participant, we could not define the Protagonist on the basis of perspective, as in Experiment 1. Thus in this experiment the Protagonist was defined by gender correspondence between the character and the participant (gender resonance: see Calvo Merino et al., 2005, 2006; see also Anelli et al., 2012), while we defined the Other as the character whose gender did not match that of the participant. We decided to focus only on human characters and to avoid the additional complexity of finding two humanoid robots differing in gender and similar in all other characteristics. Since in Experiment 1 there was a significant effect of the third-party observer, in Experiment 2 we manipulated the presence as well as the gender and the age of the bystander. When present, the bystander could be a female or a male (about 25 years old: same age as the participants, peer) or an older woman or man (about 60 years old: older than the participants, senior).

We selected 180 pictures resulting from all possible combinations between the critical factors ('First Finder': female, male; 'Co-presence': no co-presence, partial co-presence; full co-presence; 'Kind of object': a pouch, a CD case, a book, an alarm clock, a pair of glasses, a mobile; 'Bystander': absent, female peer, male peer, female senior, male senior; see Figs. 4, 5, 6). For each of the three variants of the experiment, we randomly selected 24 sets of pictures, composed by 4 or 5 sequences, and added a red detail (a circle, a triangle, or a square) in the third or fourth scene of the set, in a random position. These pictures were used as catch trials.

Finally we created 180 sensible sentences referring to the ownership of the object (90 OWN-constructions, e.g., "The boy owns the book", and 90 BELONG-constructions, e.g., "The glasses belong to the girl") and 72 non-sensible sentences, 30 referring to ownership ascribed to artifacts and 42 not referring to ownership (for examples of both passive and active sentences see Experiment 1 and Table 1).

Procedure

The procedure was same as Experiment 1. When the fixation cross disappeared, the four **or** five pictures in sequence appeared on the screen for 500 ms each. The last picture (showing only the table and the object) was substituted by a sentence (2000 ms). The timer started operating when the sentence appeared on the screen. All the stimuli were displayed centrally on the monitor and randomized.

Participants were presented with 180 sequences of target pictures (i.e., each set was seen once by each participant) followed by 180 target sentences ascribing the ownership of the object to a girl or to a boy, thus they were presented

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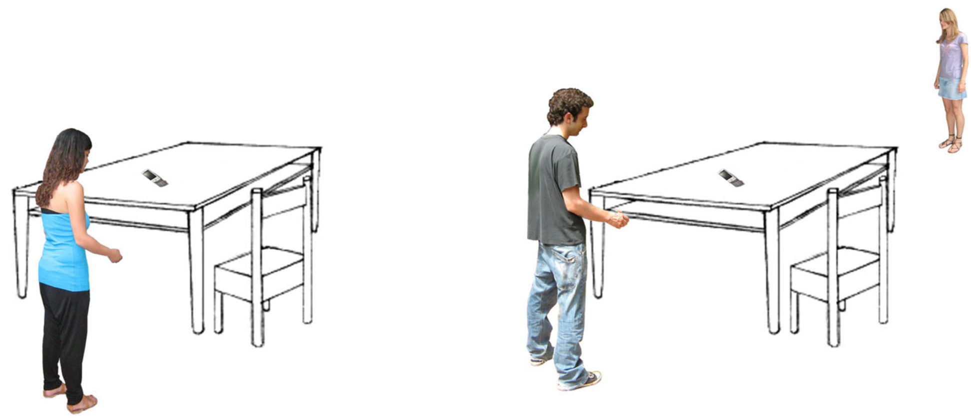

Fig. 4 In the NO CO-PRESENCE condition a female/male was the first to find the object; then he/she disappeared and the other character appeared

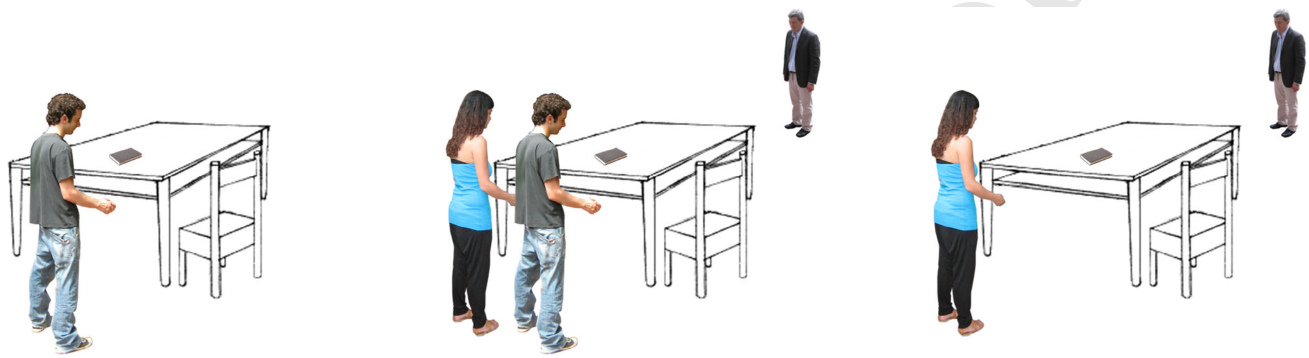

Fig. 5 In the PARTIAL CO-PRESENCE condition a female/male was the first to find the object; then the other character appeared, on the same side of the table as the finder. Finally the finder disappeared

Fig. 6 In the FULL CO-PRESENCE condition a female/male was the first to find the object; then the other character appeared, on the same side of the object as the finder. Both characters remained on the scene

with three repetitions of the relevant variables combinations. Half of the sentences in the OWN-construction (180/2) were paired with the Gender correspondence condition; the other half with the No-Gender correspondence condition. Symmetrically, sentences in the BELONG-construction were balanced across the two levels of the variable Gender correspondence.

Ownership was ascribed to the first to find the object in half of the combinations; for the other half of the combinations ownership was ascribed to the other character. As for the previous experiment, participants were also presented with 72 non-sensible sentences, preceded by 72 randomly selected sets of pictures (each of them was randomly selected from the 180 sets of pictures and presented only once) and 24 catch trials, thus participants completed 276 trials in total.

For each trial, half of the participants were instructed to press the right key with the right hand if the sentence was

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sensible, and the left key with the left hand if the sentence was not sensible. The other half of participants performed the same task with the opposite hand mapping. In case of catch trials, participants had to refrain from responding. The experimental trials were preceded by 12 practice trials.

Analyses

We conducted the analyses with participants as a random factor. After eliminating all incorrect responses, we focused the analysis on response times (RTs) to sensible sentences. The crucial variable we manipulated was Temporal Priority, which concerned the match–mismatch between the character who was the first to find the object as shown in the picture and the ownership ascription as expressed by the sentence.

RTs were submitted to a 3 (Co-presence: no; partial; full) × 2 (Participants' Gender: female, male) × 5 (Bystander: absent, same age female, same age male, older female, older male) × 2 (Gender correspondence, i.e., correspondence between First Finder's and participant's gender: yes; no) × 2 (Temporal Priority: matching sentence—finder; mismatching sentence—finder) ANOVA. The factors Bystander, Gender correspondence and Temporal Priority were manipulated within participants.

Results

Analyses did not show significant main effects. However, we found a three-way interaction between Co-presence, Gender correspondence (First Finder–Participant), and Temporal Priority, F (2, 20) = 4.94, MSe = 4198,84, $p < 0.05$, $\eta^2_p = 0.33$. Crucially, in the FULL CO-PRESENCE condition, we found the predicted advantage of matching over mismatching trials in case of gender correspondence between the finder and the participant (matching: $M = 857$ ms; mismatching: $M = 911$ ms, post hoc LSD, $p < 0.001$), but not without gender correspondence (matching: $M = 897$ ms; mismatching: $M = 881$ ms, post hoc LSD, $p = 0.28$). Post hoc LSD showed that in no other condition matching and mismatching trials were significantly different. In the NO CO-PRESENCE condition, matching and mismatching trials did not differ, neither in case of correspondence (matching: $M = 935$ ms; mismatching: $M = 937$ ms) nor of no correspondence (matching: $M = 932$ ms; mismatching: $M = 942$ ms) between the gender of the finder and that of the participant (post hoc LSD, $ps \geq 0.45$). Similarly, in the PARTIAL CO-PRESENCE condition there was only a slight difference between the matching and mismatching trials in case of no gender correspondence (matching: $M = 978$ ms; mismatching: $M = 1007$ ms, $p = 0.06$), while there was no difference in matching ($M = 954$ ms) and mismatching conditions ($M = 976$ ms; $p = 0.14$) when gender was correspondent.

We also found a four-way interaction between Participants' Gender, Co-presence, Gender correspondence between first finder and participant, and Temporal priority, F (2, 20) = 7.52, MSe = 4198,84, $\eta^2_p = 0.43$, $p < 0.01$. To understand the pattern of results we performed separate analyses for each experiment, in which RTs were submitted to a 2 (Participants' Gender: female, male) × 2 (Bystander: absent, peer female, peer male, senior female, senior male) × 2 (Gender correspondence, i.e., gender correspondence between first finder and participant: yes; no) × 2 (Temporal priority: MATCHING sentence—finder; MISMATCHING sentence—finder) ANOVA.

a. No co-presence condition: results We found no significant effects.

b. Partial co-presence condition: results Analyses showed a significant three-way interaction between Participants' Gender, Gender Correspondence (Finder–Participant), and Temporal Priority, F (1, 6) = 10.44, MSe = 4853.46, $p < 0.05$, $\eta^2_p = 0.63$. Post hoc LSD showed that for male participants there was no difference between matching and mismatching conditions both in case of gender correspondence ($M = 897$ and 941, respectively) and no gender correspondence ($M = 952$ and 932, respectively; $ps \geq 0.09$); nevertheless, males were faster in matching trials when the finder was a male (correspondence: $M = 897$ ms) than a female (no correspondence: $M = 952$ ms, $p < 0.05$, see Fig. 7). Conversely, females were faster in matching ($M = 1005$ ms) than in mismatching trials ($M = 1082$ ms), but only if the sentence referred to the ownership of a male ($p < 0.05$), and not to the ownership of a female ($M = 1011$ ms for both matching and mismatching conditions, $p = 0.99$, see Fig. 7).

c. Full co-presence: results Separate analyses on the full co-presence condition, in which the finder was always present, showed an interaction between Gender correspondence (Finder–Participant) and Temporal priority, F (1, 6) = 20.44, MSe = 2403.71, $p < 0.005$, $\eta^2_p = 0.77$. Post hoc LSD showed that, in matching conditions, participants were faster in case of gender correspondence ($M = 857$ ms) that when there was no such correspondence ($M = 897$ ms, $p < 0.01$, see Fig. 8). In mismatching trials, participants were slower when the gender of the first finder corresponded to their own ($M = 911$ ms) than when they did not correspond ($M = 881$ ms, $p < 0.05$). More importantly, however, when there was gender correspondence we found the matching effect: an advantage in RTs when the owner specified by the sentence matched the first finder as shown in the picture ($M = 857$ ms) compared to the no matching condition ($M = 911$ ms, $p < 0.005$, see Fig. 8).

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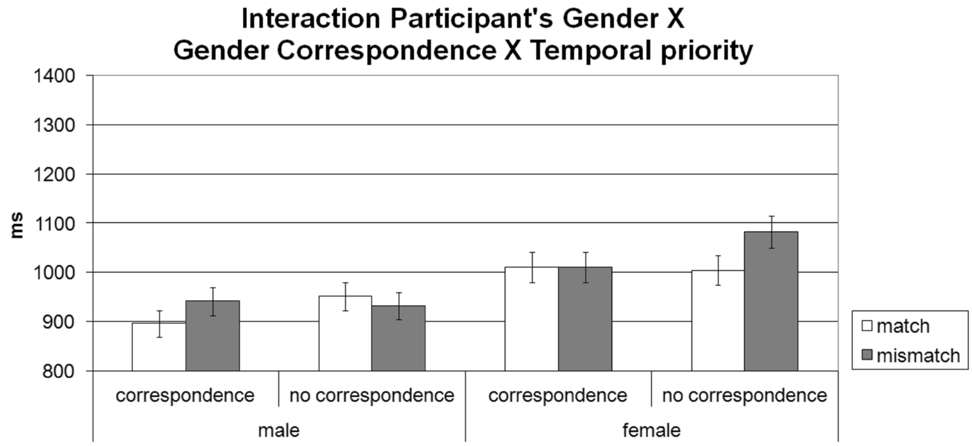

Fig. 7 In the PARTIAL CO-PRESENCE condition, males in matching trials were faster when the finder was a male instead of a female. Females were faster in matching than in mismatching trials but only when the finder was a male. *Error bars* represent the standard error

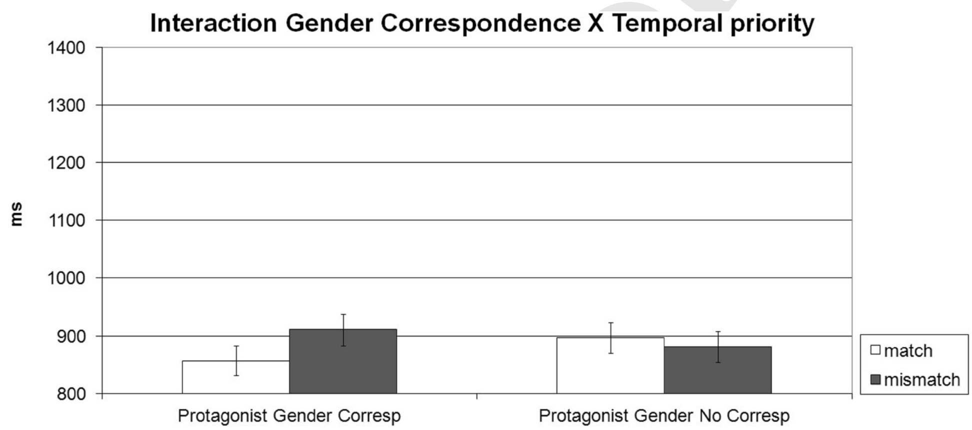

Fig. 8 In the FULL CO-PRESENCE condition, when there was gender correspondence between the finder and the participant, we found an advantage when the first finder in the picture matched the owner as expressed in the sentence. *Error bars* represent the standard error

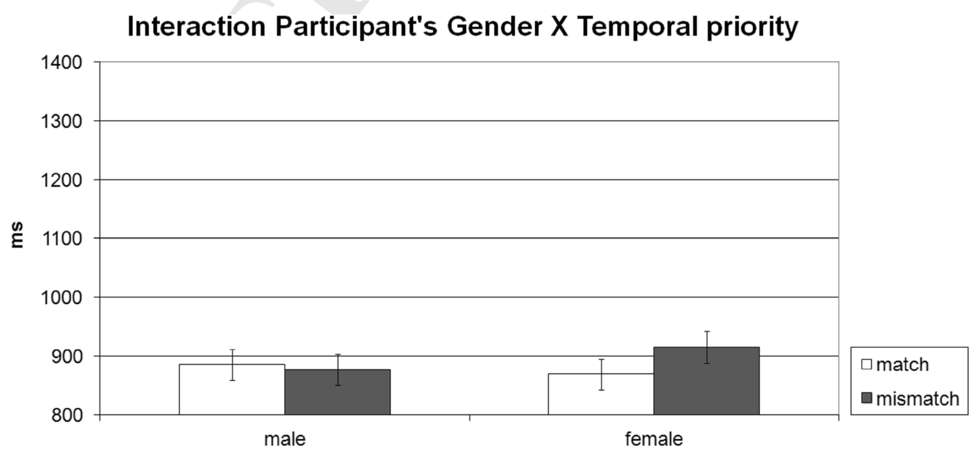

Fig. 9 In the FULL CO-PRESENCE condition with females we found an advantage when the owner as described by the sentence matched the first finder. *Error bars* represent the standard error

Finally we found an interaction between Participants' gender and Temporal priority, F (1, 6) = 9.44, MSe = 3230.24, $p < 0.05$, $\eta_p^2 = 0.61$. Post hoc LSD showed that in mismatching trials, males ($M = 877$ ms) were faster than females ($M = 915$ ms, $p < 0.05$, see Fig. 9). Interestingly, however, the matching effect was present with females: they were faster when the owner as described by the sentence matched the finder ($M = 869$ ms) than when they mismatched ($M = 915$ ms, $p < 0.01$, see Fig. 9).

Discussion

The absence of effects in the NO CO-PRESENCE condition suggests that temporary ownership becomes relevant only when at least two characters (who are potentially in conflict

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over an object) are present at the same time: the simultaneous presence of two characters likely renders the decision of who is going to establish possession more salient.

Among the co-presence conditions, the less ambiguous is the FULL CO-PRESENCE one, since the first finder is physically co-present with the second character until the end. Results indicate that participants are sensitive to the temporal priority cue, especially if they are females and if the gender of the finder corresponds to that of the participant.

In the PARTIAL CO-PRESENCE condition, gender cues work differently. Here, the matching effect is present only in females and only when the sentence ascribes ownership to a male. Hence, the association between ownership and male gender found in Experiment 1 holds here too, and it characterizes, though differently, both males' and females' responses.

Finally, we found no modulation of the social context on the matching effect with the temporal priority cue. This is probably due to both the bystander's far distance (characters' locations and perspectives were chosen to avoid ambiguity with other possible cues, see Experiments 3 and 4) and to participants' age (adults). Further studies are needed to account for possible different effects of social context on cues of possession.

Overall, we can conclude that being the first to see an object represents a cue of control, provided that two characters are present on the scene. The predictive value of this cue is modulated by the gender of the characters and of the participants themselves (especially when the first finder is not there at the end). Hence, the association between the male gender and ownership suggested by the results of Experiment 1 is here confirmed and extended to the temporal proximity cue.

Experiment 3: spatial proximity vs. temporal priority

To investigate the relative weight of the different cues in tracking object ownership, in Experiment 3 we contrasted the cues of spatial proximity and temporal priority: the paradigm was the same as Experiment 1, but the design and factors we manipulated differed. In addition, as in Experiment 2 we presented a sequence of five (PARTIAL CO-PRESENCE) or four (FULL CO-PRESENCE) sets of pictures instead of a single picture (see Table 1). In the first and last picture an object was shown on a side of the table. In the second picture one character appeared: he/she was the first to find the object. Then, in the following picture/s, the other character appeared; different from Experiment 2 he/she was closer to the object than the first finder. The presence of the first character was manipulated: in the PARTIAL CO-PRESENCE condition only the second character remained on the scene until the final picture; in the FULL CO-PRESENCE condition, instead, both characters were present until the final picture. Since in the Experiment 2 we found significant effects only for the PARTIAL CO-PRESENCE and FULL CO-PRESENCE conditions, in Experiments 3 and 4 we will not test the NO CO-PRESENCE condition.

Method

Participants

In the third experiment we tested sixteen adults (mean age 23.69, SD = 2.98; 8 female). All were right-handed, except three adults.

Stimuli

As in Experiment 2, participants viewed four or five sequences of pictures: the first and the last picture showed a room with a table, an object was located on a side of the table. As anticipated, in the present experiment we contrasted spatial proximity with temporal priority both in the PARTIAL CO-PRESENCE and FULL CO-PRESENCE conditions. Therefore, the picture sequence was as follows. In the second picture the first character appeared: he/she was conceived as the first finder, the first to see the object (see Fig. 10, image on the left). In the third picture another character appeared on the other side of the table, with the object in his/her reaching space (see Fig. 10, image in the center). Then we designed the two following conditions, which were manipulated between participants: (1) PARTIAL CO-PRESENCE—in the fourth picture the first finder disappeared and only the other character remained on the scene (see Fig. 10, image on the right); (2) FULL CO-PRESENCE—in the fourth picture both characters remained on the scene. As in previous experiments, the character could be either a female or a male (about 25 years old). Due to the complexity of the present paradigm, in this experiment the Protagonist was defined as the first finder: this character shares with the participant both the gender (as in Experiment 2) and the perspective (as in Experiment 1). Thus, two different versions of the experiment were used, in accordance with participants' gender. Constraining both criteria to converge in defining the same character as protagonist allowed to avoid possible conflicts between perspective-based vs. gender-based resonance mechanisms (see Fig. 10; Table 1 and analyses below). We defined the Other as the character who did not share participant's perspective and whose gender did not match the one of the participant. Consistent with the scene perspective, the Other was depicted as a little smaller than the Protagonist (see Fig. 10). Like in Experiment 2, we also manipulated the presence as well as the gender and the age of the

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Fig. 10 In the Spatial Proximity vs. Temporal Priority experiment, a character found the object first; the other character appeared later but he/she was closer to the object relative to the first finder. Figure shows the PARTIAL CO-PRESENCE condition, in which only the second character remained on the scene. In the FULL CO-PRESENCE condition both the characters remained on the scene. In some conditions an external observer (bystander) could be present. As in the previous experiments, participants had to judge the sensibility of the sentence displayed after the scene

bystander: when present, the Bystander could be a female or a male (about 25 years old: a peer) or an older female or male (about 60 years old: a senior).

We selected 120 sequences of pictures (each sequence was composed of 4 or 5 pictures presented in sequence, as a kind of 'short video') resulting from all possible combinations between the critical factors 'First Finder': female, male; 'Spatial Proximity': female, male; 'Co-presence': PARTIAL/FULL; 'Kind of object': a pouch, a CD case, a book, an alarm clock, a pair of glasses, a mobile; 'Bystander': absent, female peer, male peer, female senior, male senior; see Fig. 10). As in the previous experiments, we selected 24 catch trials. We used the previously selected 120 sensible sentences referring to the ownership of the object (60 active sentences and 60 passive sentences) and 72 non-sensible sentences, 30 referring to ownership and 42 referring to other topics.

Procedure

Participants viewed 120 sequences of target pictures (each sequence of pictures was presented twice, $120 \times 2 = 240$) followed by 240 target sentences. Participants were thus presented with 6 repetitions of the relevant variables combinations. Half of the sentences in the OWN-construction (120/2) were paired with the matching-First Finder condition, while the other half with the matching-Closer Character condition. Symmetrically, sentences in the BELONG-construction were balanced across the two levels of the "Relevant Cue" variable.

In addition to the 240 target sentences, participants were also shown 72 randomly selected non-sensible sentences, preceded by 72 sequences of pictures (each of them was randomly selected from the 120 sequences of pictures and presented only once), and 24 randomly selected sensible and non-sensible sentences preceded by 24 sequences of pictures with a red detail (catch trials). Thus, participants completed 336 trials in total.

The procedure was same as Experiments 1 and 2: for each trial, half of the participants were instructed to press the right key with the right hand if the sentence was sensible, and the left key with the left hand if the sentence was not sensible. The other half of participants performed the same task with the opposite hand mapping. If in the picture there was a red triangle, circle or square (catch trial) participants had to refrain from responding.

Analyses

We conducted the analyses with participants as a random factor. After eliminating all incorrect responses, we focused the analysis on response times (RTs) to sensible sentences. The crucial variable we manipulated was the Relevant Cue (see Table 1): the MATCH–MISMATCH between ownership ascription as expressed by the sentence and the character who was the first to find the object (who never corresponded to the one closer to the object). We thus contrasted the MATCH between the sentence and the first finder vs. the MATCH between the sentence and the character who was closer to the object.

RTs were submitted to a 2 (Co-presence: PARTIAL; FULL) × 2 (Participants' Gender: female, male) × 5 (Bystander: absent, female peer, male peer, female senior, male senior) × 2 (Gender and perspective correspondence between the first finder and participant: yes; no) × 2 (Relevant Cue: MATCHING sentence—First Finder; MATCHING sentence—Closer Character) ANOVA. The factors Bystander, Gender-perspective correspondence and Relevant Cue were manipulated within participants.

Results

Analyses showed a four-way interaction between Participants' Gender, Bystander, Gender-perspective correspondence and Relevant Cue, $F(4, 8) = 2.72$, MSe = 8645,20,

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$p < 0.05$, $\eta_p^2 = 0.20$. In case of gender-perspective correspondence (First finder–Participant) we found no significant effects for male participants. Conversely, when the third-party observer was a female peer or was absent, female participants (for female first finders condition) revealed to favor spatial proximity: they were faster when the character spatially closer to the object (and thus not the first finder) was the character to whom ownership was ascribed by the sentence (female peer bystander: $M = 1090$ vs. 1202; absent bystander: $M = 1040$ vs. 1149, LSD post hoc: $ps < 0.05$); in all the other conditions (Bystander: male peer, female and male seniors) spatial proximity and temporal priority did not significantly differ.

Discussion

Experiment 1 showed that participants used spatial proximity to track temporary ownership (matching effect, provided that no bystander was present) while in Experiment 2 a similar effect for temporal priority was present only when there was gender correspondence between the first finder and the participant.

When spatial proximity and temporal priority were contrasted, in line with our hypothesis, participants tended to preferentially track object ownership on the basis of spatial proximity rather than of temporal priority: spatial proximity is relatively more reliable than temporal priority to predict who is going to establish control. However, the advantage of spatial proximity over the temporal priority cue was present only in women and when the third-party bystander was either absent or a peer of the same gender. Taken together, these results suggest that the value of spatial proximity and temporal priority as cues to predict possession is sensitive to other contextual cues such as gender and the presence or absence of third-party observers.

Experiment 4: touch vs. temporal priority

Previous experiments have shown that the cues of spatial proximity and temporal priority influence ownership ascription, and that, when contrasted, spatial priority is more effective. Moreover, these cues are modulated and influenced by other contextual cues such as gender and the presence of third-party observers. In the last experiment, we focused on touching the object that, is the strongest cue of control. We contrasted touch and temporal priority to investigate the relative weight of each cue in tracking object ownership. The paradigm was the same as Experiment 1, but the design and the factors we manipulated differed. As in Experiments 2 and 3 we presented a sequence of four or five—depending on the condition—pictures instead of a single picture. In the first and last picture an object was shown on a side of the table. In the second picture one character appeared: he/she was the first to find the object. Thus, one character found the object first; the second character appeared later, in the third picture, but it touched the object. The presence of the first character was manipulated: in the PARTIAL CO-PRESENCE condition only the second character remained on the scene until the final picture. In the FULL CO-PRESENCE condition, instead, both characters were present until the final picture.

Method

Participants

In the last experiment we tested sixteen adults (mean age 24.02, SD = 2.40; 8 female). All were right-handed, except two adults.

Stimuli

As in Experiments 2 and 3, participants viewed four or five sequences of pictures: the first and the last image showed a room with a table; an object was located on a side of the table (see Fig. 11). We contrasted touch and temporal priority in the PARTIAL CO-PRESENCE and the FULL CO-PRESENCE conditions. The picture sequence was as follows. In the second picture the first character appeared: he/she was conceived as the first finder, the first to see the object (see Fig. 11, image on the left). In the third picture the other character appeared, on the same side of the table as the first one, and he/she touched the object (see Fig. 11, image in the center). Then we designed the two following conditions that were manipulated between participants: (1) PARTIAL CO-PRESENCE—in the fourth picture the first finder disappeared and only the other character remained on the scene (see Fig. 11, image on the right); (2) FULL CO-PRESENCE—in the fourth picture both characters remained on the scene. As in previous experiments, the character could be either a female or a male (about 25 years old).

In the present paradigm, the perspective of the finder and that of the touching character corresponded. Furthermore, the two characters, who differed in gender (male/female vs. female/male), were on the same side of the table and had the same physical distance from the object (see Fig. 11). As in Experiment 2, in this experiment the Protagonist was defined by gender correspondence between the character and the participant.

As in Experiments 2 and 3, the Bystander could be a female or a male (about 25 years old, a peer) or an older female or male (about 60 years old, a senior). We built 120 sequences of pictures (each sequence composed of 4 or 5 pictures, as a kind of 'short video'), resulting from all

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Fig. 11 In the Touch vs. Temporal priority experiment, a character found the object first; the other character appeared later and he/she touched the object. The figure shows the PARTIAL CO-PRESENCE condition, in which only the second character remained on the scene. In the FULL CO-PRESENCE condition both characters were present in the final picture. Depending on the condition, the bystander could be present or not. The task consisted in judging the sensibility of the sentence following the scene, only if previous pictures did not contain a red detail (catch trial)

possible combinations between the critical factors ('First Finder': female, male;'Co-presence': PARTIAL CO-PRESENCE, FULL CO-PRESENCE; 'Bystander': absent, female peer, male peer, female senior, male senior; the shown objects were the same as in Experiment 3: a pouch, a CD case, a book, an alarm clock, a pair of glasses, a mobile; see Fig. 11). As in the previous experiments, we selected 24 catch trials. As for the linguistic stimuli, we used the same 120 (×2) sensible sentences and 72 non-sensible sentences used for the third experiment.

Procedure

Participants viewed 120 sequences of target pictures (each sequence of pictures was presented twice, 120 × 2 = 240) followed by 240 target sentences. Participants were thus presented with 6 repetitions of the relevant combinations. Half of the sentences in the OWN-construction (120/2) were paired with the matching-First Finder condition, while the other half with the matching-Touching Character condition. Symmetrically, sentences in the BELONG-construction were balanced across the two levels of the Relevant Cue variable.

In addition to the 240 target sentences, participants were also shown 72 randomly selected non-sensible sentences, preceded by 72 sequences of pictures (each of them was randomly selected from the 120 sequences of pictures and presented only once), and 24 randomly selected sensible and non-sensible sentences preceded by 24 sequences of pictures with a red detail (catch trials). Thus, participants completed 336 trials in total.

We used the same procedure of previous experiments; as before, the task consisted in judging the sensibility of sentences by pressing the right key with the right hand if the sentence was sensible and the left key with the left hand if the sentence was not sensible. We balanced the hands of responses. In case of catch trials participants had to refrain from responding.

Analyses

We conducted the analyses with participants as a random factor. Due to the high percentage of errors (41%), one participant was eliminated from the analyses. After eliminating all incorrect responses, we focused the analysis on response times (RTs) to sensible sentences. The crucial variable we manipulated was the Relevant Cue: the match–mismatch between the first to find the object (vs. who is touching it) as shown in the picture and ownership ascription as expressed by the sentence. We thus contrasted the MATCH between the sentence and the first finder vs. the MATCH between the sentence and the character who touched the object, that is the character that did not find the object first.

RTs were submitted to a 2 (Co-presence: PARTIAL; FULL) × 2 (Participants' Gender: Female, Male) × 5 (Bystander: Absent, Female Peer, Male Peer, Female Senior, Male Senior) × 2 (Gender correspondence: First Finder–Participant: Yes; No) × 2 (Relevant cue: MATCHING sentence—First Finder; MATCHING sentence—Touching Character) ANOVA. The factors Bystander, Gender correspondence and Relevant Cue were manipulated within participants.

Results

Analyses showed a significant main effect of Participants' Gender, F (1, 8) = 5.38, MSe = 307932,80, $p < 0.05$, $\eta_p^2 = 0.40$: females ($M = 954$ ms) were faster than males ($M = 1148$ ms). We also found a three-way interaction between Gender, Gender correspondence, and Relevant cue, F (1, 8) = 6.87, MSe = 3777,42, $p < 0.05$, $\eta_p^2 = 0.46$. Male participants responded faster when the owner as described by the sentence matched the touching character ($M = 1123$ ms) than the first finder ($M = 1170$ ms; post hoc LSD $p < 0.05$) in case of no gender correspondence (i.e., the girl finds the object but the

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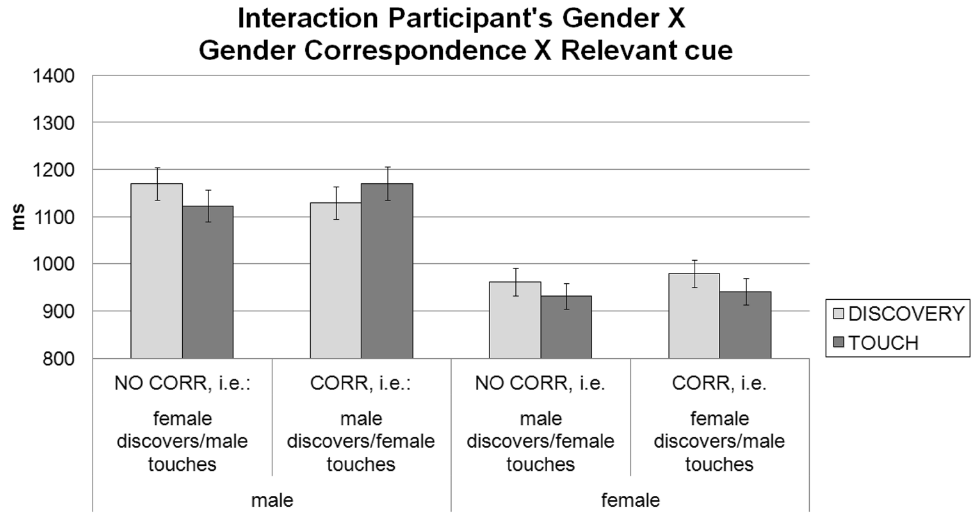

Fig. 12 The three-way interaction between gender, gender correspondence, and relevant cue. For males, when the female finds the object but the male touches it, touch is more important than the first finder; vice versa, when the male is the first to find the object and the female touches it, we find an advantage when the owner as described by the sentence matches the first finder. Conversely females are consistent in judging touch as more crucial than temporal priority. *Error bars* represent the standard error

male touches it); vice versa, in case of gender correspondence (i.e., the male finds and the female touches) responses were faster when the owner as described by the sentence matched the first finder ($M = 1130$ ms) rather than the character who touched the object ($M = 1171$ ms; post hoc LSD $p < 0.05$). Conversely, for female participants touch was more important than temporal priority independent of the gender of the character, i.e., both in case of gender correspondence (i.e., the female finds and the male touches: $M = 980$ vs. 941 ms, post hoc LSD $p < 0.05$) and of no gender correspondence (i.e., the male finds and the female touches: $M = 962$ vs. 932 ms, post hoc LSD, $p = 0.07$, see Fig. 12).

Finally analyses showed a three-way interaction between Co-presence, Gender correspondence, and Relevant cue, $F\ (1,\ 8) = 13.21$, $MSe = 3777.41$, $p < 0.01$, $\eta_p^2 = 0.62$. Post hoc LSD showed that the interaction was due to the fact that in the PARTIAL CO-PRESENCE condition, in case of no gender correspondence between the finder and the participant (i.e., gender correspondence between the participant and the touching character) there was an advantage of touch ($M = 1001$ ms) on temporal priority ($M = 1076$ ms, $p < 0.01$). In case of gender correspondence between the first finder and the participant (i.e., no gender correspondence between the touching character and the participant) there was no difference between the two cues ($p = 0.13$, see Fig. 13: consider that in this case, partial co-presence condition, the final scene showed the second character, alone, touching the object). In the FULL CO-PRESENCE condition, when the gender of the first finder differed from the participant's gender (i.e., gender correspondence between the touching character and the participant), we found no difference between the two relevant cues ($p = 0.84$). In case of gender correspondence between the first finder and the participant (i.e., no correspondence between touching character and the participant) touching the object was more relevant than temporal priority (M: 1048 ms vs. 1079 ms, $p = 0.05$, see Fig. 13).

Discussion

Results of Experiment 4 are still consistent with the temporary ownership hypothesis. Touch was indeed considered more important than temporal priority in tracking object ownership. However, this advantage was modulated by gender, since it was present only in females. The interaction between Gender, Gender correspondence, and Relevant cue reveals that male participants always ascribed ownership to the male character, independently of whether he was the first finder or instead touched the object. Thus, their judgment seemed to be driven by the gender cue alone. For male participants, gender cues shift the predictive value of touch and temporal priority when tracking object ownership: ownership is preferentially ascribed to male characters. This finding is consistent with the results of Experiments 2 on Temporal Priority, in which male participants were faster in matching trials only when the finder was a male. Actually across the experiments also female participants tended to ascribe ownership to male characters (in Experiment 1, they were faster when the protagonist was a boy rather than a girl or a robot; in Experiment 2, they were faster in matching trials only if sentences referred to the ownership of a male). The consistent findings obtained with male and female participants of a preferential ascription of ownership to male characters could be due to the fact that males can be expected to acquire physical control over the object more easily given their strength (but see the General Discussion for other possibilities).

Co-presence of the two characters, however, influences the process. The interaction between Co-presence, Gender correspondence, and Relevant cue highlights the higher

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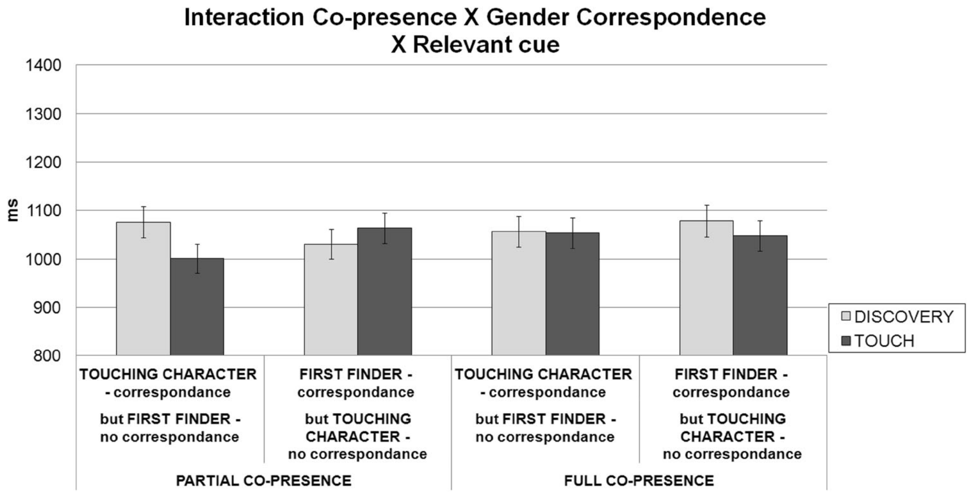

Fig. 13 The three-way interaction between the co-presence, gender correspondence, and relevant cue. It is worth noting that, due to the particular paradigm, when the participant's gender differs from the first finder's gender, it matches the gender of the touching character. In the PARTIAL CO-PRESENCE condition, in case of gender correspondence between the first finder and the participant, there is no difference between the two cues: consider that in this case the final scene shows the second character, alone, touching the object. In the FULL CO-PRESENCE condition, in case of gender correspondence between the first finder and the participant, touching the object is more relevant than finding it. *Error bars* represent the standard error

importance of touch compared to temporal priority as a cue to determine ownership: in the PARTIAL CO-PRESENCE condition, when participants' gender corresponded to the gender of the character who touched the object, ownership was determined primarily on the basis of touch. In other words, we found a gender resonance effect: males expect other males who are alone touching the object to be owners and, in the same condition, females expect other females to be owners. However, in the FULL CO-PRESENCE condition touch prevailed over temporal priority even when participants' gender did not correspond to the gender of the character who touched the object. That is, if both characters are present (a male and a female) then touch is more important when the gender of the first finder corresponds to that of the participant (male participants expect female character who is touching the object to be the owner and vice versa), thereby revealing the conventional nature of ownership ascription.

General discussion

Virtually any social encounter we have in our everyday life is around more or less valuable objects. Tracking their ownership status is thus crucial to avoid costly conflicts. Evolutionary models have shown that a minimal sense of object ownership grounded on respect of possession established by others is a very general trait that we might have in common with many other animals (Sherratt & Mesterton-Gibbons, 2015). A recent study by Pietraszewski & Shaw (2015) provides evidence that 6–8-year-old children follow the logic of these evolutionary explanations using cues of ownership to predict the likely winner in third-party contests. Consistently, in this work we have unpacked the psychology of ownership even further. In four different experiments, we have explored how different visual cues of physical control over objects (spatial proximity, temporal priority, touch) are used to track who is going to establish possession over an object and thereby become the (temporary) owner of the object.

To sum up our results and to relate them to our theoretical questions (see Table 1), we report Table 2, in which the main findings are related to our specific hypotheses.

A first important support to our hypothesis is the different weight played by the cues we have considered. Results indicate that both spatial proximity and touch are stronger cues compared to temporal priority in predicting how we track object ownership. Even if a direct comparison between spatial proximity and touch was not possible with our paradigm, the advantage of spatial proximity and touch over temporal priority reveals that cues that are more reliable to predict who is going to establish control over an object are more relevant to track its ownership status. Moreover, this may also suggest that even the conceptual representation of ownership is, at least partially, grounded in the sensorimotor mechanisms that are sufficient to track temporary ownership. Ownership judgments would imply forming a sensorimotor-based simulation of the interaction with an object in a context where social norms are operative.

Second, instead of directly measuring the ownership judgments of participants as commonly done in the

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literature (Beggan & Brown, 1994, Friedman, 2008, 2010; Palamar et al., 2012; Kanngiesser & Hood, 2014; DeScioli & Karpoff, 2015), we have demonstrated their influence with a sentence sensibility task. This is consistent with other studies assessing the role of sensorimotor processes in ownership understanding using implicit tasks. The extensive literature on the endowment effect indicates, for instance, that objects are valued significantly more if they are "owned" by the self (Kahneman, Knetsch & Thaler, 1990; Ericson & Andreas, 2014). Such implicit effects on object valuation are present even if one is merely touching an object (Wolf, Arkes & Muhanna, 2008; Peck & Shu, 2009) or only imagining doing it (Peck, Barger & Webb, 2013). Moreover, as discussed in the Introduction, verbally acquired knowledge that an object belongs to someone else can modulate the affordances of an object by, for instance, eliminating the automatic potentiation of action towards a graspable object (Constable et al., 2011), or can alter lifting movements in a way that reveals an implicit resistance to interact with objects owned by others. (Constable et al., 2011; Constable, Kritikos, Lipp, & Bayliss, 2014). Finally, knowledge of the ownership status of objects influences the linguistic choice of spatial demonstratives like "this" and "that" in subtle and unconscious ways (Coventry, Griffiths & Hamilton, 2014): participants tend to use "this" more often for objects owned by them than for objects owned by someone else. This reveals that knowledge of object ownership might also modulate the perception of how spatially close an object is. Taken together this evidence suggests that knowledge of object ownership directly influences basic sensory-motor processes. While also our work highlights the role of perceptual experiences for ownership grounding, to our knowledge it is the first that addresses the role played by different cues in a systematic fashion, comparing their importance and weight. Furthermore, compared to previous literature our results allowed us to identify possible constraints for each cue that might operate below our conscious control. The spatial proximity cue was indeed more effective when the agent was alone and no third-party bystander was present, while two participants should be present to allow the temporal priority cue to be effective.

Third, in this study we have found support for the temporary ownership hypothesis, which predicts that a minimal sense of object ownership can rely on processing of cues of physical control over objects by oneself or others (for a discussion on the basic sense of ownership and the evolved sense of fairness, see Tummolini, Scorolli & Borghi, 2013). Interestingly, this sense of control over objects or event, also known as sense of agency (Haggard & Eitam, 2015), has been found to play a key role also for body ownership, i.e., the perception that a body or a body part like a hand is one's own body or hand. Indeed, Ma and Hommel (2015) have provided evidence that even non-corporeal objects like a balloon or a square can be felt as part of one's own body provided that one has systematic control over their spatiotemporal dynamics, i.e., if changes to an object can be directly related to one's own actions. In this view, a bottom-up multisensory matching process—the intermodal match between the visual pattern created by controlling the object and the proprioceptive one created by moving one's real hand—is sufficient to induce the feeling that such an object is part of one's own body. Interestingly, Aglioti et al. (1996) have collected data about a patient with somatoparaphrenia who was impaired both in judgments about her left hand ownership and about self-owned objects related to the left hand (e.g., rings and wristwatch). Surprisingly, the subject was able to judge that these objects were self-owned and to access biographical memories about them if self-owned objects were shown both in her extrapersonal (out of reach) space or on her right hand. When the objects were again associated with the left hand, she denied to own them and judged that they belonged to the experimenter. The similarity between such a bottom-up approach to body ownership and the one we advocate here might suggest the existence of a feeling of object ownership. Such feeling, even if distinct from the feeling of body ownership—we do not typically mistake the fork we use when eating for our own body part, see Botvinik (2004)—might share some basic neural mechanisms with it.

Finally, compared to previous studies, the relevance of the cue of gender in ownership ascription strikes us as completely new. The influence of gender is twofold. Across the experiments, females seemed to be more sensitive to different cues of physical control (see Experiment 2 on temporal priority in full co-presence; see the relative advantage of spatial proximity and of touch on temporal priority, respectively, in Experiments 3 and 4), while males are more guided by the association between their own gender and ownership (only in Experiment 1 females seem to be sensitive to this association as well, but the result is ambiguous due to the absence of an interaction between Gender, Protagonist and Spatial Proximity). It is, therefore, possible that the two genders differ in the way in which they rely on visual cues of physical control to track temporary ownership.

In line with the temporary ownership hypothesis, it can be suggested that due to their greater physical strength males are probably more able to keep objects under their control. This experiential basis could be the source of the stronger association between male gender and ownership we found evidence of. However, to make sense of gender cues in our study, it is important to

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stress that evolutionary models predict that participants can, in principle, become attuned to any asymmetric cues to ascribe temporary ownership over an object. Though most models in the literature have indeed focused on the role of cues of possession, gender asymmetries can play a role too. Even without assuming any specific association between gender and strength, it has been suggested, for instance, that gender cues can be the focal points of coordination and become entrenched with more fundamental norms of possession. McAdams (2009) has shown that unequal ownership norms can also be stable: if males are expected to respect possession of other males (but not of females) and females are expected to defer to males while respecting possessions of other females, it is in the interest of all to comply with this pattern. Such a pattern, if it exists, is not necessarily the product of natural selection but can spread—and become ingrained in our implicit biases—also via cultural evolutionary processes that follow a similar logic (see Sugden, 2004 for a model of the cultural evolution of norms of possession).

In this study, we have provided evidence of the existence of a minimal sense of object ownership grounded on respect of possession established by others. This minimal sense is compatible with more complex and flexible processes supporting reasoning about permanent ownership. Still, our study has revealed that ownership intuitions are also the product of implicit cognitive processes. Our work has unexpectedly revealed the importance of gender in representing temporary ownership. Further research on the origin and influence of societal roles in ownership judgments could help to investigate and understand whether the effect of gender cues is grounded in cultural and social stereotypes, in embodied sensorimotor experience, or in both.

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Compliance with ethical standards

Conflict of interest No conflict exists. Author Claudia Scorolli declares that she has no conflict of interest; author Anna Borghi declares that she has no conflict of interest; author Luca Tummolini declares that he has no conflict of interest

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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