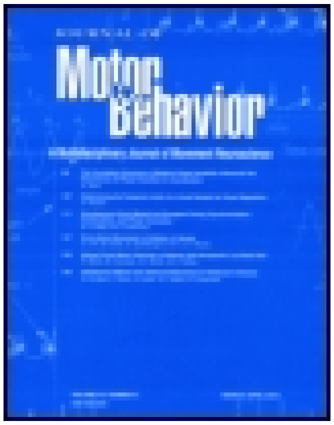

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RESEARCH ARTICLE

Reaching for Objects or Asking for them: Distance Estimation in 7- to 15-Year-Old Children

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ABSTRACT. This study aims to determine if, in children, subjective perception of space is modulated by the experience of reaching distal objects by means of tools and verbal labels. We presented 7–15-year-old participants with objects located in the near and far space, and in the threshold area between these spaces (border space). Before and after a training session, separate groups of participants estimated objects' location by providing a verbal estimation of their distance ($n = 12$) or by rolling a toy car to match their location (motor-based estimation; $n = 16$). The training session required interaction with the targets (i.e., actively experiencing the perceived distance) and included use of a rake or a linguistic label when far objects were involved. A control condition in which training implied use of a short, ineffective tool was also tested ($n = 6$). Results showed that verbal estimations were not affected by the training phase ($p > .05$). In contrast, training modulated motor-based estimations relative to border space. Specifically, maximal distance of toy car displacements was reduced following all kinds of training ($p < .01$). These results indicate that, similarly to adults, the boundary between near and far space is not fixed in children and that both active tool use and verbal labels can modulate this uncertain boundary.

Keywords: body representation, children, distance estimation, embodied cognition, reaching space, space perception, tool use

Learning whether external stimuli are near or far from a part of the body is crucial for adaptive behavior. A near object can prompt motor preparation (Serino, Annella, & Avenanti, 2009), aimed for example at avoiding it (if dangerous) or at approaching it (if interesting). In contrast, far objects can stimulate the need for the contribution of others, as when we ask someone to give us an interesting stimulus located out of reach.

Studies on tool use in adults have shown that the boundary between near and far space is not a stable one: several lines of evidence suggest that tool use can modify the way space is perceived and represented (Berlucchi & Aglioti, 1997; Berti & Frassinetti, 2000; Farnè, Iriki, & Ladavas, 2005; Maravita & Iriki, 2004; see also Arbib, Bonaiuto, Jacobs, & Frey, 2009). For example, studies on patients affected by spatial neglect or cross-modal extinction showed that distal space is recoded as proximal space when patients use tools (Farnè et al., 2011; Farnè & Ladavas, 2000; Farnè et al., 2005), provided that tools allow actually reaching far objects. Even if few studies reported no effect of tools after active use in healthy participants (e.g., de Grave, Brenner, & Smeets, 2011), most observations suggest that the perceived boundary between reachable and nonreachable spaces is largely influenced by previous interactions with them.

To date, the majority of these studies focused on adults. However, it is reasonable to expect that flexibility of the boundary between reachable and nonreachable space will be even more evident at a time of life when the concept of within arm's reach is constantly affected by the natural effects of growth: Do children and adolescents correctly estimate reachability of a target? Are they as sensitive to the effects of tools as adults are? To our knowledge, relatively few studies have explored distance estimation in young participants in both small (Caçola & Gabbard, 2012; Gabbard, Caçola, & Cordova, 2009; Gabbard, Cordova, & Ammar, 2007; Gabbard, Cordova, & Lee, 2009; Giovannini, Jacomuzzi, Bruno, Semenza, & Surian, 2009; Hund & Plumert, 2007; Rochat, 1995) and large-scale environments (Da Silva, Matsushima, Aznar-Casanova, & Ribeiro-Filho, 2006; Herman, Norton, & Roth, 1983). In particular, for small-scale space, judgments of reachability were reported to be accurately scaled to arm length (Rochat 1995), although in these experiments overt quantification was never required. In fact, when actions are concerned, it has been consistently demonstrated that children have a good behavioral, motor knowledge of the extension of their reaching space (Rochat, 1995; Rochat & Wraga, 1997). For example, it has been reported (McKenzie, Skouteris, Day, Hartman, & Yonas, 1993) that infants learn early that leaning forward (8 months of age) or using a tool (12 months of age) both allow for reaching a wider range of targets compared to simply extending the arm. At 3 years old, children "resemble adults in their ability to perceive what objects afford for actions" (Rochat, 1995, p. 317). Besides, by 6 years old they seem to be equally able to correctly estimate what they can reach with the help of a tool (Caçola & Gabbard, 2012). Indeed, visual pathways are relatively mature by 7 years old (Rival, Olivier, Ceyte, & Bard, 2004), and at 7–8 years old children are able to localize targets with respect to their body as well as to use object-centered information (Gentilucci, Benuzzi, Bertolani, & Gangitano, 2001). It is generally assumed that children acquire the ability to make correct estimations in different quantifiable

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domains by 9 years old (Harel, Koch, & Perona, 2007), confirming that the study of the perceived boundary between reachable and nonreachable space could be successfully addressed from a cognitive developmental perspective.

Interestingly, only few studies on space representation have taken into account the role of language as a possible instrument for reaching targets placed outside arm's length, even if pointing gestures and verbal requests are commonly used in declarative-referential contexts by children (Franco & Butterworth 1996; Grassman & Tomasello, 2010; Liebal, Bennne, Carpenter, & Tomasello, 2009) and adults (Gentilucci, Dalla Volta, & Gianelli, 2008). To our knowledge only two recent studies, both conducted on adults, focused on how demonstratives such as *this* and *that*, respectively, map on to reachable and nonreachable space (Bonfiglioli, Finocchiaro, Gesierich, Rositani, & Vescovi, 2009; Coventry, Valdés, Castillo, & Guijarro-Fuentes, 2008), but little is known as to whether subjective space representation is affected by forms of verbal interaction. Similarly, a number of authors have proposed that words can be considered as kinds of tools (e.g., Clark, 1998; Tylèn, Weed, Wallentin, Roepstorff, & Frith, 2010; Borghi & Cimatti, 2010), but to our knowledge no researchers so far have investigated whether words, similarly to tools, can affect subjective space representation.

The present study, which has an exploratory character, was devised to investigate three issues: first, whether subjective perception of nonreachable space can be modulated by the use of words, in a similar way as it is affected by the use of rakes, sticks and similar tools. To test this hypothesis, we investigated whether using verbal aids to drive a target closer to the self would affect subjective perception of object's location. Second, to better qualify the concept of far space, we explored two regions: border space (i.e., the portion of space located immediately beyond reaching distance) and far space (i.e., the region that can be reached only after large postural changes [e.g., by walking]). Finally, with few exceptions (Caçola & Gabbard 2012; Gabbard, Caçola, & Cordova, 2009; Gabbard et al., 2007; Gabbard, Cordova, & Lee, 2009) to our knowledge little information is available on space estimation in children and adolescents. Developmental studies mostly focus on landmarks retrieval and spatial memory (Bullens, Klugkist, & Postma, 2011; Bullens et al., 2010; Huttenlocher, 2008), and little is known as to whether subjective perception of spatial locations is affected by social and motor interactions in a population largely affected by the effects of growth. In absence of previous findings, as well as of specific hypotheses put forward by the current literature, we chose to select a broad sample spreading from one year after beginning of primary school to one year before completing compulsory education (in Italy, ranging from 7 to 15 years old).

In one session, we presented participants with objects located within arm reach (near space), clearly out of reach (far space), and at the boundary between these two regions (border space). Children produced estimations about object location before and after a training session during which they could actively grasp the objects either directly (near space) or by using a rake (rake group) or a verbal command (word group; border and far space). The rationale behind using the verbal command lies in hypothesizing that words, similarly to tools, allow reaching for far objects (although in this case no direct motor interaction by the participant is required). We outlined two possible scenarios. S1 (active interaction) assumes that motor interaction with the operational space is instrumental in building a map of reaching space. Hence, training sessions with the rake should affect estimations regarding both border and far space; in contrast, training session with verbal command, in which no direct interaction is implied, should be entirely ineffective. S2 (goal achievement) assumes that obtaining the target is critical, independently of how the goal is achieved. Clearly, the rake and the word both allow reaching for the object, though through different means: the individual use of the tool (rake) versus the involvement and collaboration of others (word). If goal achievement plays a critical role in subjective perception of distances, then training sessions with both rake and word should affect estimations regarding border and far space (as they both succeed in bringing the object nearer to the participant). In this respect, words could be considered as sort of social tools. Hence changes in distance estimations following rake (but not word) training would speak in favor of S1; conversely, changes emerging from both training types would rather point to S2. To rule out possible generalized effects, a control condition providing a tool that was effective only in the border space was also included. This short-tool condition is neutral with respect to the two scenarios but not to the two types of spaces. Namely, the short tool enables participants to reach the goal (S2), and this is achieved through active interaction (S1): hence, both scenarios predict an effect on distance estimation. However, being the short tool effective only for targets located in the border space, its effects should be detected only for judgments concerning that region of space, unless mere exposure to the stimuli or nonspecific factors were involved.

Method

Participants

We recruited 38 children (7–15 years old) from local schools. For technical reasons and participants' tiredness or dropout during the experiment, the final group included 34 children (M age $= 10.32$ years, $SD = 2.20$ years, age range 7–15 years; 18 girls, 16 boys). All were right-handed, native Italian speakers with normal or corrected-to-normal vision, and naive as to the purpose of the experiment. As athletes tend to have greater opportunity for cognitive calibration of perceptual experience (and often give more accurate estimates of egocentric distance along the ground compared to nonathletes; Durgin, Leonard-Solis, Masters, Schmelz, & Li, 2012), we decided to select only nonathletes (i.e., participants that had never performed professional or top-level sports or participated to competitive scholastic teams; Durgin, et al., 2012). Upon arrival, participants were randomly assigned to one of five possible conditions. Specifically, 28 participants were assigned to the four experimental conditions: verbal estimation (VE), two conditions (n = 12: rake = 5, M age = 9.8 years, SD = 1.30 years; word = 7, M age = 9.57 years, SD = 1.33 years) and motor-based estimation, two conditions (n = 16: rake = 9, M age = 10.11 years, SD = 2.37 years; word = 7, M age = 11, SD = 1.73 years; see subsequent sections for details). Six participants were assigned to the control condition short tool (M age = 11.16 years, SD = 3.71 years). The experiment was carried out following the principles of the Helsinki Declaration and was approved by the local ethics committee (Department of Psychology, University of Bologna).

Stimuli

Stimuli were a small wooden cube, a pink prism and a green cylinder (maximal depth for all objects: 4 cm). Their possible locations on the table were defined (for each participant) to match one of three possible distances— near, border, and far space (see Figure 1a)—the boundary between these positions being placed around arm's length (Longo & Lourenco, 2006, 2007; Lourenco, Longo, & Pathman, 2011). Specifically, each child sat in front of a table, and locations were determined as the distance between a starting point placed on the table edge (4 cm from the participant's frontal plane and in correspondence with his or her body midline) and the tip of the index finger:

1. When the participant hold the hand in pinch position, in a natural posture as when writing = near space;
2. When he or she stretched the arm, flexing the trunk forward, as when reaching for something away from the body = border space;
3. By adding 50% of item 2 to the border distance = far space. For children in the short-tool group, to compute far space, 15 cm were added to the border distance. This was done because they were on average taller than their peers and the method used for the remaining participants would have located the target outside the table limits.

Procedure

The experiment was run in one session, organized in three separate phases, which are detailed subsequently. We reasoned that the tasks at use should be interesting enough to catch attention for a sufficient number of trials, simple enough to perform—considering the children's perceptuomotor and cognitive abilities—and measurable in a way that prevented excessive variability among participants. Thus, before performing the final study, we conducted pilot

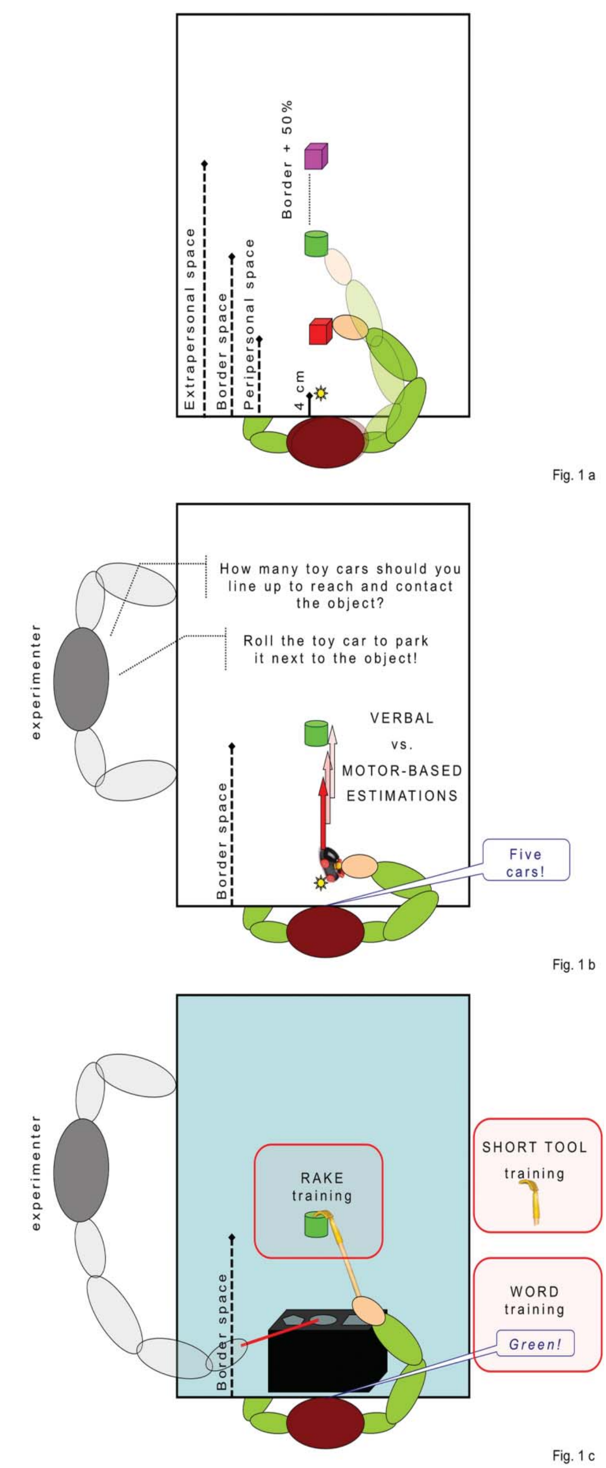

FIGURE 1. Schematic description of the setup. (a) Near, border, and far object positions. (b) In Phase 1 and 3, participants estimated the distance of the objects from the self either verbally (verbal estimation) or by rolling the car near to them (motor-based estimation). (c) In Phase 2 (training), they grasped the objects and put them in a box. Border and far objects could be reached using a rake, a short tool, or by asking for it.

experiments (eight participants: four ranging from 31 to 35 years old [two girls] and four ranging from 8 to 10 years old [two girls]) to define the number of experimental trials and the main parameters of the present tasks.

Briefly: in the first phase (1: pretraining phase), participants were shown objects in various locations and were asked to estimate the distance from the self at which each object was located (Figure 1b; for a similar procedure see also Balcetis & Dunning, 2009). In the second phase (2: training phase), they were asked to pick up the objects and place them in a box. According to the objects' distance, they were provided with instruments to reach for them. In the third phase (3: posttraining phase), participants were once more shown objects in various locations and asked to estimate their distance from the self (i.e., same procedure as in phase1).

For Phases 1 and 3, estimations could be verbal or motor based. For VEs, a red and a blue plastic toy car (length: 4 cm) were used as references. The toy car was chosen as a reference based on results from pilot experiments that showed excessive variability among participants when using the decimal system. On each trial, the experimenter showed the object to the child and placed the red toy car in the starting position. Then she asked the participant how many similar cars he/she would need to line up to reach the object, "How many toy cars should you line up to reach and contact the object?" (see Figure 1b). For motor-based estimations, the experimenter placed the blue toy car in the starting position and asked participants to roll it with sufficient force to make it stop next to the wooden object, on its right side: "Roll the toy car to park it next to the object" (see Figure 1b). To familiarize with the toy car movement, children rolled it near to an object (different from the target ones) until able to stop it at approximately 2.5 cm from it in at least three trials in a row. On average, all tested children managed the task after six familiarization trials. Due to mechanical constraints, the toy cars could be moved only along a rectilinear trajectory.

In both Phase 1 and 3, five estimations for each portion of space were collected (based on pilot studies showing that this number of estimations could be well managed by children).

For Phase 2 (training), in each trial, the three wooden objects were randomly located at one of the three distances (near, border, far space). Participants were asked to grasp one object and put it into a black box endowed with differently shaped holes. For each trial, the experimenter indicated one hole using a laser pointer (see Figure 1c). To grab the objects in near space, children could use their hands directly. In contrast, when the object was in the border and far space, according to group (see Participants section), children were advised to use a tool, or to ask for the object. In particular, children in the rake group were given a rake (positioned on a stool, on the right side of the participant) that allowed reaching both border and far objects; children in the short-tool group received a small rake (or a small shovel) that allowed reaching border but not far objects; children in the word group were asked to use the object's color (a linguistic label) to obtain the objects (see Figure 1c). Note that in the latter condition the object was not handed to the participant directly: an experimenter, hidden by a vertical panel, used a magnetic tool placed beneath the table to shift the correct object toward the participant.

For each object and location, the training session consisted of five repetitions (for a total of 45 trials).

Data Collection

Dependent variables were the participants' estimations of object distance in the pre- and posttraining phases for the two farther spaces (border and far space). For the VE group, the estimated number of toy cars necessary to cover the distance was manually recorded by one experimenter. For the motor-based estimation, the 3D optoelectronic SMART system (BTS Bioengineering, Milan, Italy) was used. This was done to collect more accurate measurements and, critically, to speed up procedures in view of the fact that collecting distances with a ruler or a tape measure would have been time consuming, resulting in a too-tedious situation for the children. The SMART system consists of four video cameras detecting infrared reflecting markers at a sampling rate of 120 Hz (spatial resolution: 0.3 mm). One marker was applied on the toy car roof to capture the corresponding kinematics, an indirect measure of the participants' impressed force. Recorded data were filtered using a linear smoothing rectangular filter.

We computed the maximal distance reached by the toy car (MD) as the maximal value of the x component of the car trajectory vector. The physical dimension of MD corresponds to the measure explicitly addressed by the VE.

Data Analyses

Raw data (Barnett & Lewis, 1994; Sprent, 1998) relative to VE and MD, for the two farther spaces (border, far) before and after the training session, were submitted to statistical analyses. Specifically, we conducted a 3 Training (rake, word, short tool) $\times$ 2 Space (border, far) $\times$ 2 Phase (pretraining, posttraining) analysis of covariance (ANCOVA): the variable training was manipulated between participants and the actual objects' distances (border and far positions) were treated as covariates. The real distances at which each object was located were entered as covariates into the analyses in order to take into account the fact that these values differed across participants, depending on height and arm length. Significance level was set at .05. Fisher's least significant difference test was used for post hoc comparisons when justified.

Control Analysis: Group Homogeneity

To ensure that participants assigned to the different groups were comparable in terms of ability to judge a visually presented distance we computed a measure of distance bias. From estimations provided before training, we calculated the difference between judged distance and real target location (near, border, and far spaces), scaled as a proportion of arm reachability.

Distance bias: Judged target distance—real target distance arm reachability. This allowed normalizing for the different absolute distances used for each participant. These values were submitted to a 2 Response Group (verbal, motor based) × 3 Training Group (rake, word, short tool) × 3 Space (near, border, far) analysis of variance (ANOVA). No main effect of type of response, training group, or space emerged (all ps $> .05$). In addition, there were no significant interactions (all ps $> .05$) indicating that participants in the randomly assigned groups were comparable in terms of their ability to estimate distances in this type of task.

In addition, to rule out possible confounds due to age and height, we performed separate t tests comparing ages and arm reachability (i.e., MD covered by each participant when stretching the arm and the trunk). The groups did not differ as far as age is concerned ($p = .70$). Participants in the short-tool group ($M = 77.50$ cm; $SD = 13.92$) were significantly taller than the ones from both the other groups ($p < .005$: rake condition: $M = 57.44$ cm; $SD = 6.29$; word condition: $M = 64.43$ cm; $SD = 7.47$): this could explain why their throws generated larger responses compared to the other children.

Results

Verbal Estimation

There were neither procedural errors nor missing cells in the analyses. Children in the VE group correctly claimed that a larger number of toy cars were required to reach objects in the far compared to the border space (see Table 1 for means and standard deviations for each condition; see upper panel of Figure 2 for the overall findings). In addition, their estimates were overall larger in the post- compared to the pretraining session, regardless of the kind of training performed. However, the 3 Kind of Training × 2 Space × 2 Phase ANCOVA showed only a significant main effect of space, $F(1, 15) = 87.803$, *Mean Squared Error, MSe* $= 6.514$, $\eta_p^2 = .85$, observed power $= 1$, $p < .0000001$ (far space: $M = 19.44$, $SD = 5.29$; border space: $M = 13.85$, $SD = 3.73$). No main effect of kind of training or phase emerged. There were no significant interactions.

Motor-Based Estimation: Maximal Distance

Procedural errors accounted for 4.54% of overall collected data. These trials were repeated at the end of the session hence there were no missing cells in the analyses. Similarly to children in the previous group, participants in the motor-based estimation group correctly rolled the toy car farther when dealing with objects located in the far compared to the border space (see Table 2 for means and standard deviations for each condition). With respect to kind of training, estimates were larger in the short-tool group (see Method section, Distance Bias). As for phase, estimates produced after all kinds of training were smaller compared to the pretraining ones, but only for the border space. In agreement with these descriptive data, the 3 × 2 × 2 ANCOVA on MD showed a significant main effect of space, $F(2, 19) = 17.754$, $MSe = 0.04$, $\eta_p^2 = .35$, observed power $= 0.76$, $p < .0005$ (border: $M = 67.39$ cm, $SD = 26.98$ cm; far: $M = 86.45$ cm, $SD = 21.30$ cm), and kind of training, $F(2, 17) = 8.425$, $MSe = 0.07$, $\eta_p^2 = .44$, observed power $= 0.80$, $p < .003$ (rake $M = 69.14$ cm, SD 21.93 cm; word: $M = 76.68$ cm, $SD = 22.73$ cm; short

TABLE 1. Distance Estimation for the Verbal Estimation Group ($n = 18$)

	Before training		After training		Real distance	
Border space	*M*	*SD*	*M*	*SD*	*M*	*SD*
Rake	62.40	14.03	64.80	8.67	54.20	6.06
Word	46.29	7.95	48.29	8.52	56.29	7.36
Short tool	56.00	22.77	60.00	17.53	77.50	13.92
Far space						
Rake	91.20	8.67	92.00	11.66	81.30	9.09
Word	67.14	17.20	70.00	23.75	84.43	11.05
Short tool	70.67	22.72	83.33	26.34	92.50	13.92

Note. For simplicity, estimates were converted in centimeters, although originally expressed as number of toy cars required to cover the distance between starting position and presented objects. Means and standard deviations refer to estimates expressed before and after the training phase (using rake, verbal label, or short tool) for the two farther spaces (border, far). Real distance corresponds to the mean value of the actual object location in the border and far space: as these values were selected based on participants' reachability characteristics, real distances vary across groups.

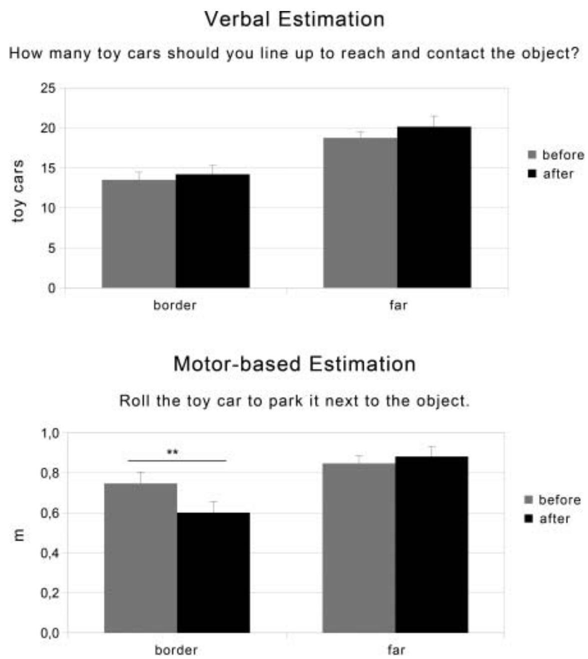

FIGURE 2. Mean responses for participants in the verbal estimation (upper panel) and motor-based estimation (lower panel) groups. Performance is reported before (light grey bars) and after (black bars) the intervening training session, for the border and far space. Whiskers indicate standard errors.

tool: $M = 88.87$ cm, $SD = 31.21$ cm). In addition, the interaction between space and phase was also significant, $F(1, 19) = 5.862$, $MSe = 0.03$, $\eta_p^2 = 0.51$, observed power = 0.91, $p < .03$. Post hoc analyses revealed that estimations relative to the border but not the far space changed significantly after the training sessions ($p < .01$; Figure 2 lower panel).

Discussion

In this study we proposed two scenarios that offered different hypotheses on the role played on distance perception by interaction with the operational space (S1) or goal achievement by means of a tool (S2). Our findings well match the predictions made in relation to the second scenario: In fact, distance estimation in the border space changed after participants had interacted with the objects not only actively (as would have been predicted by S1) but also indirectly by asking for the target, namely by means of a verbal label (i.e., a kind of social tool, as predicted by S2). Hence, successfully reaching for the target seems to be the critical event in modulating perceived distance. This modulation emerges only for motor-based estimations and it occurs only for border space, suggesting a great sensitiveness of this portion of space to previous effective use of both physical and social tools. The nonreachable, farther, space seems to be somehow unchangeable. This would be in line with previous studies showing that children rapidly acquire a sufficient understanding of what lays out of reach (Rochat, 1995). We discuss these findings with respect to present ideas on space representation and on the role of words and tools in modulating distance perception.

The first finding that emerges from the present study is the differential effect played by training on verbal and motor-based estimations. While the former appeared to be impermeable to the intervening training phase, the latter showed a modulation of responses for targets located in border space. This dissociation between implicit and explicit estimates would be in line with previous evidence (Ambrosini, Scorolli, Borghi, & Costantini, 2012), and could depend on the fact that two of three instruments used to bring the target within reach during training implied some form of motor interaction. Namely, in the two conditions involving the rake, participants had to plan and actually execute an action directed at the target's location. In

TABLE 2. Distance Estimation for the Motor-Based Estimation Group ($n = 22$)

	Before training		After training		Real distance	
Border space	*M*	*SD*	*M*	*SD*	*M*	*SD*
Rake	62.67	19.25	52.10	20.42	57.44	6.29
Word	79.36	24.33	63.20	25.55	64.43	7.46
Short tool	87.23	35.42	68.49	33.03	77.50	13.92
Far space						
Rake	78.34	15.16	83.46	19.68	86.22	9.31
Word	82.90	18.13	81.27	21.29	96.57	10.89
Short tool	96.50	20.89	103.27	29.69	92.50	13.92

Note. Estimates (in centimeters) correspond to the maximal distance reached by the toy cars along the *x*-axis. Means and standard deviations refer to estimates expressed before and after the training phase (using rake, verbal label or short tool) for the two farther spaces (border, far). Real distance corresponds to the mean value of the actual object location in the border and far space.

fact, the short tool, although inadequate to contact far objects, still allowed active interaction with the operational space. It is thus possible that feedback obtained from such interaction was used to correct and confirm a predictive model relative to target distance. This knowledge could be easily transferred to the motor-based response, which also implied active interaction with the target, but not to the VE response, which likely taps on more perceptual abilities. Alternatively, it could be speculated that changes in body schema during growth may emphasize uncertainty about whether a target can be considered "within arm's reach" (the border space). This uncertainty is more likely to affect the estimations requiring visuomotor transformation (the motor-based response) than those involving perceptual judgment, as the latter basically implies deciding how many times a given length must be repeated to match the requested distance.

The second finding relates to modulation of the boundary between near and far space (border space in the present study) produced by the training sessions. After training, MD was systematically shorter. Border space represents a peculiar region, being neither a purely visual space nor a stable visuomotor space: in fact, at this level a target can be considered within reach depending on the degrees of freedom allowed for the action (i.e., Will I simply stretch the arm? Will I additionally flex the trunk?). In adults, this area of space has been reported to undergo significant changes after tool use (Berlucchi, & Aglioti, 1997; Berti & Frassinetti, 2000; Farnè et al., 2011; Farnè et al., 2005; Farnè & Ladavas, 2000; Maravita & Iriki, 2004). Here we show that the same occurs in children and adolescents, suggesting that the effects of motor experience are powerful well before the body has completed its natural growth and adult body schema has been established. In line with observations in adults' studies, the reduction of MD in the posttraining session found here could be viewed as a change in the perceived extension of the operational space. Interestingly, in previous studies, no effect was reported if participants just held tools in their hands without using them, or if they performed a pointing rather than a reaching task tools (Farnè et al., 2011; Farnè et al., 2005; Farnè & Ladavas, 2000). Compared to these studies, here the modification in perceived distance did not differentiate between the instruments provided. This is intriguing if one considers that in addition to the rake, we tested the role of verbal command, which implies no motor action.

The absence of a differential effect of rake versus verbal command (i.e., a negative result) suggests caution. Moreover, due to the exploratory nature of our study, the present findings are drawn from relatively small samples and the overall age range was quite large. Nevertheless, we are confident that the findings are sufficiently informative and representative for at least two reasons. First, the low amount of variation found in the data (standard deviation) indicates that participants were very consistent in their responses. Second, a series of preliminary analyses were run to account for groups' homogeneity (as far as age, height, and ability to estimate distances were concerned; see Method section). These observations argue in favor of the reliability of the present findings, pointing to an interesting possible similarity between the effects of words and tools on space evaluation. Namely, they seem to suggest that under certain conditions, words can be viewed as kinds of tools. Previous studies used words associated to a specific portion of space, such as demonstratives (Bonfiglioli et al., 2009; Coventry et al., 2008). Here we used the objects' color, which bears no direct relation to space. This suggests that the effect may more generally relate to the communicative role of language; however, whether this is true for all kinds of words remains to be determined (for a discussion, Borghi, Scorolli, Caligiore, Baldassarre & Tummolini, 2013).

The notion that words could act as social tools implies a reconceptualization of current embodied views of language and is relevant for the debate on the future of embodied cognition (Scorolli, 2014). In the last 10–15 years embodied and grounded theories of language have benefited of a large body of evidence showing that perceptual, motor, and emotional systems are activated during language processing, when words refer to objects and their properties (nouns or adjectives, Gentilucci, Benuzzi, Bertolani, Daprati, & Gangitano, 2000; Scorolli, Borghi, & Glenberg, 2009), to objects' locations (spatial demonstratives: Bonfiglioli et al., 2009; Coventry et al., 2008), to actions (verbs: Scorolli & Borghi, 2007; Borghi & Scorolli, 2009; Borghi, Gianelli & Scorolli, 2010; Glenberg & Kaschak, 2002; Pulvermüller, Haërle, & Hummel, 2001; Pulvermüller, Hauk, Nikulin, & Ilmoniemi, 2005), to complex experiences (for reviews, see Barsalou, 2008; Fischer & Zwaan, 2008; Gallese, 2008; Glenberg & Gallese, 2012; Jirak, Menz, Buccino, Borghi, & Binkofski, 2010; Meteyard, Cuadrado, Bahrami, & Vigliocco, 2012; Pulvermüller et al., 2005; Toni, de Lange, Noordzij, & Hagoort, 2008). In this framework, the present exploratory study deals with the relationship between words and working space in children and adolescents. An emergent promising view is starting to emphasize how language plays an important scaffolding role for our thought processes (e.g., Borghi & Cangelosi, 2014; Dove, 2014). Words can be conceived of as cognitive tools that improve and augment our computational abilities (Clark, 1998). Our findings further suggest that words can not only affect our cognitive evaluations but also modify our way to operate in the world (see Borghi et al., 2013). Whether this is due to the social character of words should be determined by further research but these findings provide novel directions for a better understanding of the relations between words, space and action (see Clark, 1998).

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