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Kids observing other kids' hands: visuomotor priming in children

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Abstract

We investigated motor resonance in children using a priming paradigm.

Participants were asked to judge the weight of an object shortly primed by a hand in an action-related posture (grasp) or a non action-related one (fist). The hand prime could belong to a child or to an adult. We found faster response times when the object was preceded by a grasp hand posture (motor resonance effect). More crucially, participants were faster when the prime was a child's hand, suggesting that it could belong to their body schema, particularly when the child's hand was followed by a light object (motor simulation effect). A control experiment helped us to clarify the role of the hand prime. To our knowledge this is the first behavioural evidence of motor simulation and motor resonance in children. Implications of the results for the development of the sense of body ownership and for conceptual development are discussed.

Keywords: Motor resonance, Motor simulation, Visuomotor priming, Body schema, Body ownership, Embodied cognition.

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1. Introduction

The body mediates all the interactions we have with objects and other organisms in our world. Our own body determines our perception of objects, for example perception of slant and distance change if we are carrying a heavy backpack (Proffitt, Stefanucci, Banton, & Epstein, 2003). We also use our body to perceive and understand other people's actions, for example we process perceived actions that we can perform and ones that we can't perform differently (Calvo-Merino, Grezes, Glaser, Passingham, Haggard, 2006). Highly important for our sense of body is the capability to differentiate our own body from the body of others (Borghi & Cimatti, 2010). There is evidence that our brain "resonates" when we see others performing actions. This 'resonance' mechanism is modulated by the similarity between the actions we observe and the actions we are able to perform. The neural underpinnings of motor resonance are thought to reside in the Mirror Neuron System (MNS) and Canonical Neuron System, discovered originally in the monkey premotor cortex (Murata, et al., 1997; Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992). Mirror neurons fire both when a grasping action is perceived and performed; canonical neurons fire when a given action is performed and when the subject sees an object that the action can be performed upon. Neurophysiological and neuroimaging studies suggest that a similar system and resonant mechanisms are also present in humans (for a review see Rizzolatti & Craighero, 2004). These mechanisms are modulated by the similarity between the perceived actions and the actions we are able to execute. Brain imaging and behavioural studies have shown that, when participants observe others dancing, climbing, or playing basketball, resonant mechanisms are evoked, and that this motor resonance is stronger when expert athletes rather than novices observe other experts (e.g. Aglioti, Cesari, Romani, & Urgesi, 2008; Cross, Kraemer, Hamilton, Kelley, & Grafton, 2009; Pezzulo, Barca, Bocconi, & Borghi, 2010). Behavioural evidence has shown that, when the actions observed are part of the motor repertoire of the perceiver, actions are recognized more easily (Knoblich & Flach, 2001). These findings are in line with the ideomotor theories (Hommel, Muesseler, Aschersleben, & Prinz, 2001; Prinz, 1997), according to which perceptual features and motor plans rely on a common representational code: in other words, the more similar the action we see and the action we can perform are, the easier we simulate.

Bruzzo, Borghi & Ghirlanda (2008) investigated whether observing actions similar to the actions that are part of our motor repertoire influences processing perceived actions. They used

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a priming paradigm and found that participants were faster to decide whether an action made sense or not when they observed a hand interacting with an object (e.g., grasping an orange) in the actor (egocentric) perspective rather than in an allocentric perspective. This shows that it is easier to put ourselves in others' shoes and to resonate while perceiving an action when we share action-relevant characteristics with the actor, e.g. the view point (egocentric or allocentric).

We think it would be worth to distinguish between motor resonance and motor simulation, given that in the literature contrasting definitions have been provided (for a brief overview see Borghi & Cimatti, 2010; for different definitions see Gallese, 2009; Jeannerod, 2007).

In this paper we will use the term "motor simulation" to refer to the fact that observing objects and others interacting with them activates a simulated motor action. In other words, observation of graspable objects, such as notebooks and dictionaries, should activate a motor simulation, the underlying neural basis of which is probably the canonical neuron system. Motor simulation refers to the process of internally simulating an action when perceiving an object that can be acted upon (first person perspective). Motor resonance, the neural basis of which is the mirror neuron system, would also be activated during observation of others interacting with objects – for example, when we observe somebody lifting a dictionary with the hand. Our mirror neuron system seems to resonate with differing intensity depending on the similarity between the actions we observe and the actions that are part of our motor competence. For example, Calvo Merino *et al* (2006) have shown that dancers' mirror neuron system resonated more when observing dancers of their own gender. Motor resonance refers to the overlap of characteristics between the perceiver's actions and the perceived actions.

In spite of the large body of evidence obtained (Aglioti, et al., 2008; Buccino, et al., 2001; Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995; Urgesi, Moro, Candidi, & Aglioti, 2006), some mechanisms underlying motor resonance are still poorly understood. Results have shown that motor resonance increases when participants and the observed actor share the same culture (Molnar-Szakacs, Wu, Robles, & Iacoboni, 2007) and perspective (Bruzzo et al., 2008), and when they have a similar motor competence (Calvo-Merino et al., 2006). So far, however, few studies (Cattaneo *et al*., 2007; Lepage & Theoret, 2006; Martineau, Cochin, Magne and Barthelemy, 2008) investigated the extent to which this motor resonance process changes during the lifespan, in conjunction with our bodily modifications. The present study aims to fill this gap, investigating to what extent motor simulation and motor resonance processes occur in children.

We addressed this issue using a visuo-motor priming paradigm, in which a hand prime was followed by a target-object. Behavioural evidence with visuomotor priming paradigms has shown that observing an effector in potential interaction with an object re-activates our perceptual and action experience with it (Borghi, Bonfiglioli, Lugli, et al., 2007; Borghi, Bonfiglioli, Ricciardelli, et al., 2007; Vainio, Symes, Ellis, Tucker, & Ottoboni, 2008): for example, Borghi and colleagues (Borghi et al., 2007; Setti, Borghi, & Tessari, 2009) have demonstrated that an action-related prime (i.e. a static grasping hand) can activate information regarding how to manipulate (e.g. unimanual or bimanual grasp; precision or power grip) target objects or nouns referring to them. Along the same line, neuroimaging studies have shown that observing static pictures of the same objects being grasped or touched is sufficient to selectively activate the frontal mirror region (Johnson-Frey, et al., 2003); further TMS evidence confirms that a grasping hand in (implied) motion affects the primary motor area (Urgesi, et al., 2006). In a previous study, Kalenine, Bonthoux and Borghi (2009) have shown with children from the age of 7 (even if the developmental pattern is not linear) that action primes (hand in grasping posture) can prime basic level concepts, i.e. specific objects (e.g. 'saw'), more effectively than superordinate concepts (i.e. including multiple objects, e.g. 'tool').

In a previous study Setti, Liuzza, Burke, Borghi and Newell (in prep.) investigated to what extent motor resonance increases when participants share the same age). The authors used a priming paradigm. A hand prime was followed by heavy vs. light manipulable objects; participants were required to decide whether the target-object was heavy or light. They found that both young adults and older adults responded faster to hand primes of their same gender, but overall they did not respond faster when they observed hands of actors of their same age compared to a different age in terms of resonance to others' actions. A possible reason for the absence of the motor resonance effect with people of the same age could be due to the simple fact that humans are not sensitive to the age differences. An alternative reason is that age matters and impacts motor resonance, but only when the body schema changes substantially. Given that from youth to older adulthood only partial changes in body schema occur, the difference between the younger and older hand may have been too subtle for a difference in motor resonance to be found. In addition, the lifting actions alluded to in Setti *et al.* (in preparation) study may be too simple to be susceptible to a different motor simulation between younger and older (see also Poliakoff, Galpin, Dick, & Tipper, 2009), i.e. both older and younger adults can easily simulate lifting of the objects used as stimuli.

In the present study we used a similar paradigm to investigate the extent to which children were sensitive to the difference between children's and adults hands. Few studies have investigated if the MNS is at play since childhood. Among them Lepage and Theoret (2006), for example, have demonstrated that, in children aged between 4 and 11 years, action observation reduces the magnitude of the mu (8–13 Hz) rhythm which is considered to reflect the activation of the mirror fronto-parietal system. Martineau *et al.* (2008) compared EEG activity during the observation of videos showing actions or still scenes in autistic children and neurotypical children between 5 and 7 years of age (3 girls and 11 boys, aged 5 years 3 months–7 years 11 months). The authors found similar mu suppression during observation of human actions in the group of healthy children but not in autistic children. Similarly, it has been found (Cattaneo et al., 2007) that normally developing children between 5 and 9 years old, but not autistic spectrum disorder children of the same age, show an electro-myographic activity coherent with the observed action. This indicates that there is evidence of motor simulation activity in young neurotypical children.

Here, analogously to the study from Setti *et al.* (in preparation), we used a priming paradigm and a weight judgment task with children aged 7 to 10. The prime was a hand in grasping posture (either belonging to a child or an adult actor) or a hand in no-grasping posture (fist) and targets were heavy or light objects, the task required participants to decide if the target object was heavy or light. Based on the aforementioned evidence we hypothesised that a motor simulation would be activated while observing objects, and that a motor resonance process would be activated while observing others hands in potential interaction with objects.

We formulated the following predictions:

a. If observing objects activates a motor simulation (first person perspective, canonical mirror system), then heavy objects should be processed slower than light ones, given that in real life lifting heavy objects requires more time and effort than lifting light ones.

b.If observing actions with objects activates a motor resonance (mirror neuron system), then objects preceded by hands in a grasping posture should be processed faster than objects preceded by fist hand primes.

c.Because motor resonance should be modulated by the similarity between an observer and a model performing an action, we predicted that children would be more susceptible to motor resonance when the actor has the same body schema as the viewer. Therefore, we predict that, when the prime is an action that is portrayed by a child’s hand, reaction times should be faster.

d. If, as we hypothesize, a child mirror neuron system is more likely to resonate when the hand prime is similar to the subject's hand, the difference between the light and heavy objects should be more pronounced when preceded by a child hand prime than by an adult's hand prime.

e. Finally, if an interaction between action posture, age of the prime and weight of the target occurs, we aim to assess in what direction the presence of the prime modulates performance compared to a baseline without any prime. In other words, we hypothesize that, without any prime, we should observe the same pattern of results that we would observe in presence of a dissimilar prime or of a non-action prime. To this purpose, we ran a control experiment, in which no prime preceded the target stimuli.

2. Experiment 1

2.1 Participants

Sixty-one children (28 Female; mean age = 8.46 years old; range = 7-10; st. dev. =1.09) volunteered to take part in the study with their parents informed consent conforming to the Declaration of Helsinki. They had self-reported good vision and hearing and they all reported to be right handed. None of the participants suffered from neurological illness. This age group was chosen as the study by Kalenine et al. (2009) suggests that children at this age are already susceptible to visuo-motor resonance, however this particular study did not directly compare action primes with perceptually similar no-action primes (action primes were compared with scenes). In addition a study by Mounoud et al. (2007) suggests that actions are part of an automatically activated conceptual knowledge of certain kinds of objects (i.e. tools) from age five. However none of these studies directly address visuo-motor resonance.

2.2 Stimuli

We used 3 pictures of familiar light objects (empty box of matches; block notes; mobile phone) and 3 pictures of familiar heavy objects (dictionary; brick; gym weight) as targets (Figure 1 A). The pictures were black and white and were edited with Adobe Photoshop®. Their average size was 13 x 10.5º and pictures were presented to participants at a distance of 57cm from the screen. Pictures used as primes displayed a hand in grasping or no grasping position (fist) on a neutral background. The actor portraying the grasping or no grasping action could be female or male and the hand could belong to an adult or child (Figure 1 B). Both the female and male child actors were 4 year-old and the female and male adult actors were 25 and 28 respectively.

2.3 Design and Procedure

The gender of the prime was matched with the gender of participants. Every target stimulus was presented 16 times, and every hand prime 24 times, for a total of 96 trials.

Participants were seated at approximately 57cm from the computer screen (DELL laptop XPS M1530, monitor 19 inches) and they were presented with a fixation cross for 500 ms, followed by a visual image of a hand (prime) for 700ms, followed by the picture of an object that could be heavy (e.g. dictionary) or light (e.g. matches box). Their task was to respond by pressing the 'm' key with the index finger of their right hand if the object was heavy and the 'z' key with the index finger of their left hand if it was light (half of the participants responded heavy with the left hand and half with the right hand). The experiment lasted less than 10 minutes and it was programmed and delivered with E-Prime software.

2.4 Results

The Mean participant error rate was 12% (0.09 SD). We excluded 8 participants from the correct RT analysis because their accuracy in one of the experimental conditions was less than 50%. Participants' response times (RTs) over or above two SD from the subject's RT grand mean were removed from the analysis (5.3%).

We entered the percentage of errors in a 2x2x2 ANOVA with Age of the prime (child vs. adult), Kind of prime (grasp-vs. no grasp) and Weight of the target (heavy vs. light) as within participant variables. We found no significant main effect. Importantly, there was no effect of the target weight, nor interactions ($F(1, 60) < 1.81$, *p*s $> .18$, see Figure 2B). Table 1 also reports the sensitivity (d prime) and the response bias (beta). Furthermore, mean accuracy scores and mean RTs for each subject did not positively correlate ($r = -.17$, $p > .12$). Since we can conclude that there is no speed-accuracy trade off at play, we focused our analysis on RTs.

Correct RTs were entered in a 2 x 2 x 2 ANOVA with Age of the hand prime (child vs. adult), Kind of prime (grasp-vs. no grasp) and Weight of the target (heavy vs. light) as within participant variables. We found a significant main effect of the Kind of prime (grasp vs. no grasp, ($F_{(1, 52)} = 5.48$, $p < .05$), participants performing faster when primed by a hand in action posture (grasp) than when the hand prime posture did not portray the grasping action (fist) (739ms ± 98SD vs. 759ms ± 120 SD) respectively). We also found that the main effect of the Age of the hand approached significance ($F_{(1, 52)} = 2.98$, $p = .09$), due to the fact that participants tended to be faster when primed by a child's hand as opposed to an adult one (743ms ± 103 SD vs. 755ms ± 113 SD). The Kind of prime interacted significantly with the Weight of the target, ($F_{(1, 52)} = 10.1$, $p <.005$). Newman-Keuls post-hoc test revealed that, within the action prime condition (i.e. when a hand in a grasp posture preceded the target), participants were faster to process light objects than heavy ones (722ms ± 104 SD vs. 757ms ± 121 SD, $p < .02$). Furthermore, light objects were processed significantly faster ($p = .03$) when primed by an action hand posture than when primed by a fist (*ps* <.03).

Importantly, we found a significant three way interaction between Kind of prime, Age of the hand prime and Weight of the target, ($F_{(1, 52)} = 4.97$, $p = .03$, see Figure 2A). Newman-Keuls post-hoc test revealed that the interaction was due to the fact that the response to light targets primed by a child hand in an action posture was faster (699ms ± 164 SD) than all the other conditions, *ps* < .02).

3. Experiment 2

The most important result of Experiment 1 consisted in the facilitation found when kids observed a child hand prime. As to the target-objects, we did not find any difference in RTs between Light and Heavy Objects when they were preceded by an adult hand or by a hand prime that did not display an action (fist). Since we did not have a non-prime condition, we could not establish if the difference in RTs between Light and Heavy targets found in the Child grasp prime condition has a pattern which reflects or differs from a baseline without any prime. To clarify this point we ran a control experiment in which we presented only the target-objects without the hand prime. If observing objects activates a motor simulation (probably mediated by the canonical neurons system) even in absence of a hand prime, then we should find an advantage of light over heavy objects.

3.1 Participants

Twelve children (7 Females; mean age = 8.92 years old; range = 6-13; st. dev. =2.23) volunteered to take part in the study with their parents informed consent conforming to the Declaration of Helsinki. They had self-reported good vision and hearing and they all reported to be right handed. None of the participants suffered from neurological illness.

3.2 Stimuli

The target-stimuli were the same as those used in Experiment 1 but the hand primes were not presented.

3.3 *Design and Procedure*

The design was the same as that of Experiment 1, but without the prime. Every target stimulus was presented 16 times, so every condition (heavy target, light target) included 48 observations. The experiment lasted about 5 minutes.

3.4 Results

The Mean participant error rate was 13.11% (0.33 SD). We excluded one participant from the correct RT analysis because the accuracy in one of the experimental conditions was less than 50%. Participants' response times over or above two SD from the subject's RT grand mean were removed from the analysis (5.2%).

We compared Mean correct RTs of the Weight of the target (heavy vs. light) by a two tailed paired sample T test and we did not find any significant difference (mean light= 745ms ± 155 SD vs. mean heavy= 702ms±167 SD, $t(10)= 1.30$, $p= 0.22$, Cohen's *d*= 0.27, see Figure 3 A). This result confirms that, similarly to a baseline condition in which no prime precedes the target, the lack of a dissimilar prime (an adult hand) as well as of a similar prime which does not perform any action (a child fist) does not cause any difference in the speed of processing of heavy vs. light objects.

Even though the RTs for the heavy objects seem to be faster than in the Experiment 1, the Equal Variances Not Assumed T-Test showed no difference between the two experiments ($t(12.24)= 0.96$; $p > .3$).

In order to rule out the speed-accuracy trade off, we compared Mean accuracy (percentage of correct responses on the total number of trials per condition) of the Weight of the target (heavy vs. light) by a two tailed paired sample T test and we found that participants performed worse with light (80%) than with heavy (94%) objects ($t\ (11)= 2.90$, $p < .05$, see Figure 3 B). This result, even if significant, is convergent with the RTs result (as is evident by looking at figures 3 A and B) and rules out a trade off between speed and accuracy. The difference we found n accuracy seems to be due to a response bias toward “heavy”, as shown in Table 1.

In order to assess whether any specific item was at the grounds of this difference, we conducted an analysis of variance with the target object as a factor. This analysis showed an effect of the stimulus ($F(5, 55) = 5.48$, $p < .001$). Newman-Keuls post-hoc test revealed that this was due to one single target, the notebook, which has an accuracy rate (67%) which was significantly (*ps* < .05) worse than any other stimulus percentage rate (all above 83%). The same does not apply to the first experiment, where the significant analysis of variance ($F(5,300) = 2.50$, $p < .05$) of the single stimuli is not explained by the worst performance of a single item compared to others, but just by a worse performance with the brick compared to the gym weight (85.3% vs 90.6%, $p < .05$).

In Experiment 2 we performed a second T-test on the accuracy scores removing the notebook stimulus. In this case, no significant difference between heavy and light targets occurred ($t(12) = 1.89$, $p = .08$).

We followed the same procedure with RTs and the T-test confirmed that no difference between heavy and light targets was at play ($t(10) = .47$, $p = .64$).

3. Discussion

The present study investigated motor simulation and motor resonance in children from age 7 to 9. We hypothesized that motor resonance would be more pronounced when the actor was a child, because of the difference in body schema between children and adults.

4.1 Motor simulation and motor resonance in children

4.1.1 Motor simulation. Heavy and light stimuli did not differ in RTs; this suggests that no automatic motor simulation of object lifting, triggered by the simple object observation (and with the probable mediation of the canonical neurons system), was found. This difference is not observed, neither when the target objects were presented in isolation, as we showed in a control experiment (Experiment 2), nor when they were preceded by an adult hand prime or a child hand prime that did not imply an action (fist).

More importantly, Experiment 1 results showed that response times were faster when graspable objects were preceded by a visual hand prime in an action rather than in a no-action posture (fist). This indicates that observing a static hand displaying a grasping position followed by an object activates a motor simulation. Importantly, this simulation is not triggered by the generic observation of a hand, but by the observation of a hand displaying an implicit action. This confirms and extends to children results that have been previously found in adults (e.g., Borghi, 2005; Borghi *et al*., 2007).

4.1.2 Motor resonance and motor simulation. We found that children's responses were facilitated when the hand prime was a child hand. This effect interacted with the Kind of prime (action posture vs. no-action posture) and with the Weight of the target. Children were faster when a prime depicting an action portrayed by a child preceded a light object, possibly because the internal simulation of a grasping action is stronger when the actor is also a child. In addition the simulation is quicker/easier when the object is light than when it is heavy (the action of lifting a light object is less demanding than lifting a heavy object). Significantly, this difference between heavy and light target is not observed in any other condition, nor when the objects were presented without the prime (Experiment 2). This interaction allows us to determine that our results are not simply due to world knowledge; rather, they are due to motor resonance effects. Indeed, the faster RTs obtained with light objects with a child hand prime is due to the fact that participants tend put themselves in the shoes of other children. If they were due to knowledge, targets preceded by adult's hands should be processed faster than those preceded by child's hands, given that it is intuitive that, due to their bodily characteristics, adults lift objects more easily than children. Therefore our results allow us to reject a possible alternative explanation, according to which children responded by trying to assess whether the object on each trial would be light or heavy for the particular hand shown in that trial's prime. This strategy could explain the advantage of the grasping over the fist prime, but it would not explain why children responded faster when they saw a child's hand in the grasping posture than when they observed an adult's hand in the grasping posture. Therefore we can conclude that our results are due to a motor resonance effect.

We suggest that this motor resonance occurs because participants (i.e. children), shared their body schema with the child-actor portrayed in the prime. This interpretation is in line with the absence of motor resonance linked to age in Setti *et al*., (in prep.). The discrepancy between the present study, in which children are presented with children's and adults hands, and Setti et al., (in prep.) study, in which younger and older adults are presented with younger and older adults' hands, suggests that the changes in body schema later in life may be not as radical as from childhood to adulthood, therefore not producing an age effect in motor resonance. Alternatively the lack of a differential resonance effect between younger and older adults in our previous study may be due to the fact that both older and younger adults can easily simulate lifting the particular objects we used as stimuli. However the results of the present work favour the interpretation in terms of body schema similarities, as here a difference in motor resonance was found even if we assume that both children and adults can simulate the lifting actions.

4.2 Theoretical implications of the present study.

First, our study has implications for literature on conceptual development. Since the seminal work by Piaget (1952), a variety of studies with different paradigms (property verification; feature production) have shown that children's conceptual knowledge is grounded in perception and action (Borghi & Caramelli, 2003) and that interaction with objects has a direct impact on categorization (Smith, 2005). In addition, studies with priming paradigms show that from approximately 5 years of age children automatically activate action-related information when perceiving a tool (Mounoud, et al., 2007) and that a hand in a grasping posture can prime basic level concepts (e.g. 'saw'), more effectively than superordinate concepts (e.g. 'tool') from the age of 7 (even if the developmental pattern is not linear). Taken together this series of studies suggests that, when perceiving an object, children simulate the corresponding actions evoked by the object, and that when observing a hand a grasping action with a single object is simulated. The present study, however, is the first to provide behavioural evidence of motor simulation and motor resonance in children. Further work is needed to understand the development of the mechanisms underlying these two processes and to precisely disentangle their relationship with body schema changes during the lifespan.

Regarding the neural underpinnings of the visuo-motor simulation during development, the earliest indirect evidence available to date of an MNS in infants comes from a study by Shimada and Hiraki (2006). This study demonstrated by means of near infrared spectroscopy the presence of action execution and observation matching system in 6-month-old human infants. Lepage and Theoret (2007) recently proposed that the development of the MNS can be conceptualized as a process whereby the child learns to refrain from acting out the automatic matching mechanism that links action perception and execution. Such development could be viewed as a process leading from mandatory reenactment to a covert simulation of the observed motor acts, most likely through the maturation of prefrontal inhibiting mechanisms. In our study we found evidence of both motor simulation and motor resonance in children, from 7 years on. This suggests that in 7-year-olds an automatic matching mechanism is no longer present, given that the activation of the resonant processes is modulated by the similarity in body schema between the actor and the agent. Further studies are needed, to understand when this modulation process – which implies the recognition of the differences between our own body and others' body - starts.

Finally, our study gives us some hints on the development of the notion of self. Recent studies and theoretical proposals have explored the existing relationship between the sense of body ownership (e.g., de Vignemont, in press) and the sense of agency, i.e. the ability to control our own actions. Tsakiris, Longo, and Haggard (2010) have shown with an fMRI study that activation of midline cortical structures was linked to the sense of sensory-driven body ownership, whereas sense of agency activated the Pre-Supplementary Motor Area. Even if there is no evidence for overlap between the neural circuits involved in body ownership and agency, being able to perform a voluntary action intuitively seems to be the precondition for developing the sense of possessing a unitary body. When we respond to external stimuli the body is perceived simply as a collection of fragmented and not integrated body parts. Once we act on objects, instead, we begin to perceive our body as a functional whole, clearly distinct from others' bodies (Tsakiris, Prabhu, & Haggard, 2006). Developing a sense of body ownership implies recognizing that this body is unique, and that it moves in a coherent and unitary way (Tsakiris, et al., 2010). Crucially for the present study, an important part of the acquisition of the sense of our body concerns the ability to distinguish ourselves from others, and this ability is grounded in action. The fact that we found an effect of age-related motor resonance in children, whereas it was not present with younger and older adults (Setti et al., in prep.), opens some interesting scenarios. It suggests that children at this age have developed a clear social sensitivity and that this social sensitivity is truly grounded and embodied (Semin & Smith, 2008): children record and differently resonate to the differences between kinds of bodies, and in particular between their own body and the body of adults. The alternative explanation, that a child's hand could portray social identity features (Molnar-Szakacs et al., 2007) not shared by adults, i.e. that the children respond faster to members of their own in-group, is less clearly supported by the data. Namely, it would explain the advantage obtained with kids' hands compared to adults' hands, but it would not explain the pattern found in the interactions (in particular faster response times to light objects when the prime is a child hand implying action).

Further studies will allow us to better understand how the process of motor resonance develops in time and during our life. This is crucial, also in light of the fact that the motor resonance process informs us about complex relationships between the sense of our own body and our social awareness, between embodiment and sociality.

4.3 Conclusions

The present study shows by means of a visuomotor priming paradigm how motor simulation occurs in 7-10 year old children. In addition, it shows that motor resonance in children is strengthened when a light target object is preceded by a child’s hand in an action posture compared to an adult hand. These findings provide new insights relevant to the development of the Mirror Neuron System and the role of congruence between the observer and the actor’s body schema in facilitating motor resonance.

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Figure captions

Fig. 1. A. An example of hand primes used in the Experiment 1. B. Target stimuli used in the Experiment 1 and 2. Subjects were asked to judge them as heavy or light.

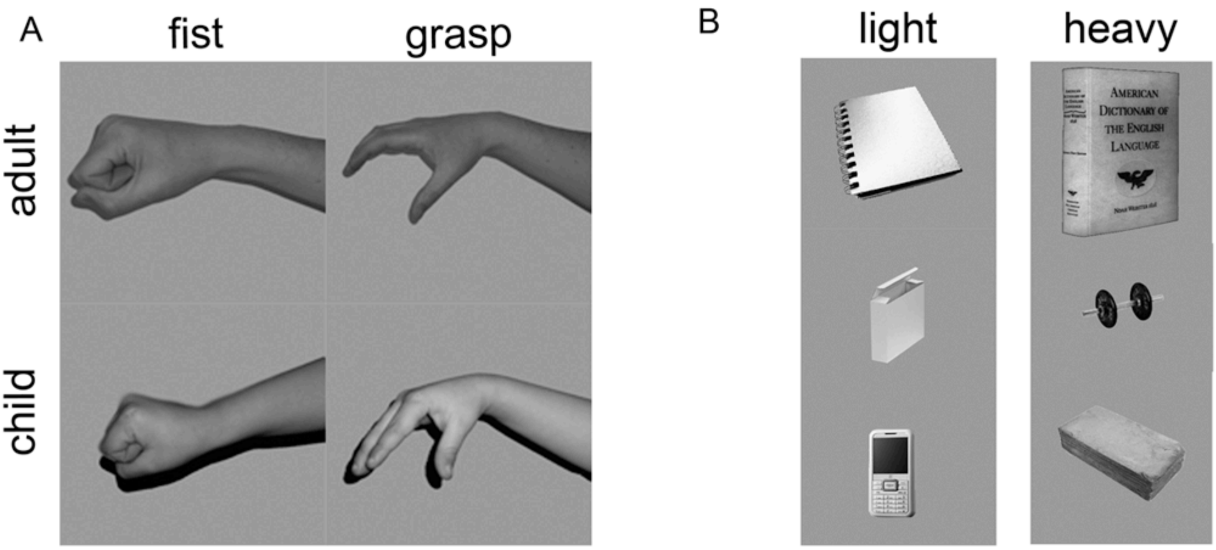
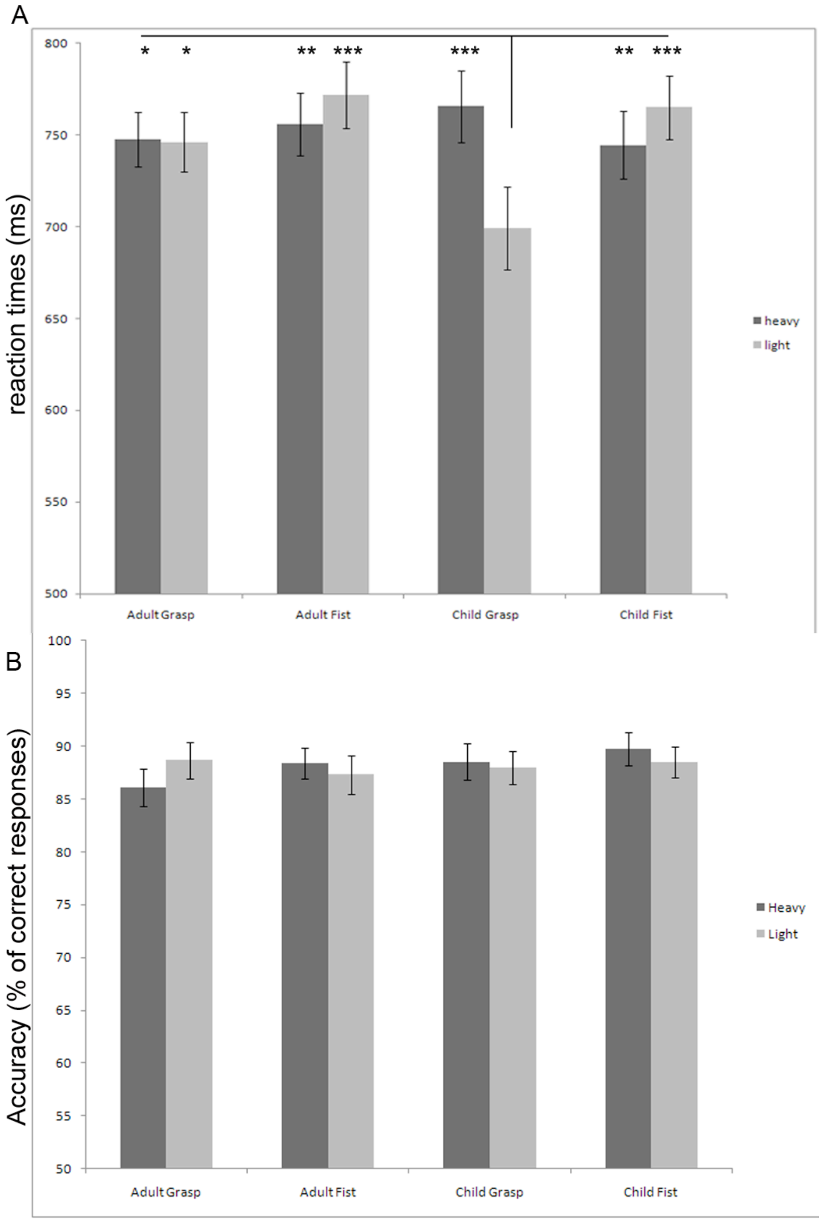


Fig. 2. A. Experiment 1: response times (in ms) for heavy and light objects when preceded by a Child or an Adult hand in Grasp or Fist posture. Asterisks mean that the p Newman-Keuls post-hoc is significant (*=p<.05; **=p<.01; ***=p<.005). Error bars represent the standard error of the mean. **B. Experiment 1:** Accuracy (percentage of correct responses) for heavy and light objects when preceded by a Child or an Adult hand in Grasp or Fist posture. Error bars represent the standard error of the mean.



A
reaction times (ms)
800
750
700
650
600
550
500
* *
** ***
***
** ***
Adult Grasp
Adult Fist
Child Grasp
Child Fist
heavy
light
B
Accuracy (% of correct responses)
100
95
90
85
80
75
70
65
60
55
50
Adult Grasp
Adult Fist
Child Grasp
Child Fist
Heavy
Light

32

Fig. 3. A. Mean Response times of the Experiment 2. **B.** Mean Accuracy in the Experiment 2. (*=p<.05).

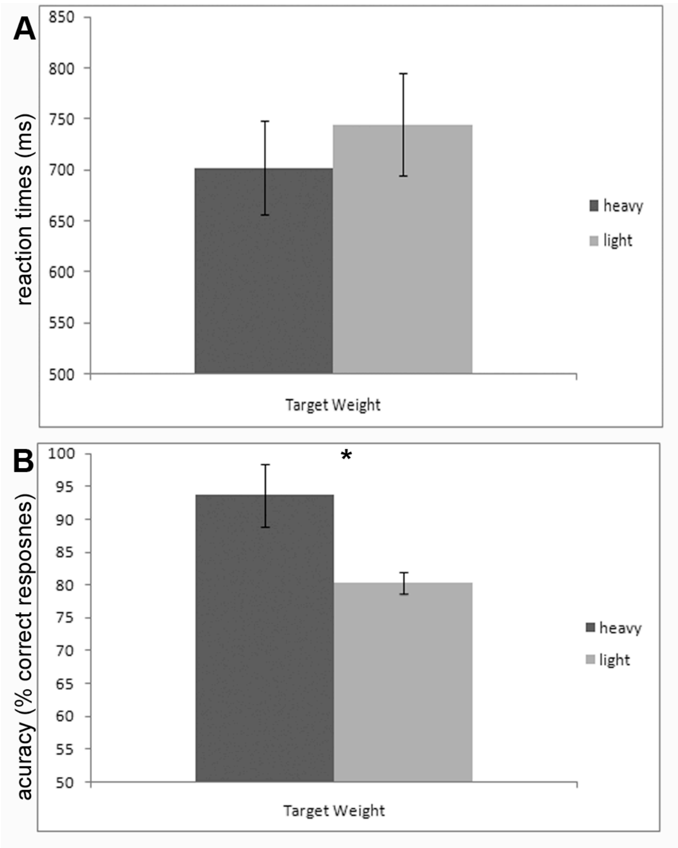


Table 1. Response bias in Experiments 1 (in each prime condition) and 2.

The table reports the proportions of responses in each condition, the sensitivity (D Prime) and the response bias (Beta) for each prime condition.

Experiment 1	Response "heavy"	Response "light"

Adult grasp		
target heavy	.86	.14
target light	.11	.89
D prime	2.29	
Beta	1.15	
Adult fist		
target heavy	0.88	0.12
target light	0.13	0.87
D prime	2.34	
Beta	0.94	
Child grasp		
target heavy	0.89	0.11
target light	0.12	0.88
D prime	2.38	
Beta	0.97	
Child fist		
target heavy	.90	0.10
target light	0.11	0.89
D prime	2.47	

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Beta	0.92	
Experiment 2	Response “heavy”	Response “light”
target heavy	.94	.06
target light	.19	.81
D prime	2.45	
Beta	0.44	