Human and robotics hands grasping danger

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Abstract — **Behavioural and neuroscience studies have shown that observing objects activates affordances, evoking motor responses. The aim of the present study is twofold. First, we intend to investigate whether children are sensitive to the distinction between neutral/graspable (affordances) and dangerous objects. Second, we aim to verify whether children's responses are modulated also by the agent who is interacting with the objects (human hand contrasted with robot hand, and male hand contrasted to female hand). We conducted an experiment on school-age children using a priming paradigm: a prime given by a hand or a control object was followed by graspable or dangerous objects. Children were required to categorize them into artefacts or natural objects by pressing two keys on a keyboard. Our results clearly showed that children are able to distinguish between neutral and dangerous objects: the latter produced an interference effect. In addition, we demonstrated that children are sensitive to the difference between actions performed by biological and non-biological agents: responses were faster when the prime was a grasping hand of a human compared to control stimuli. Results were interpreted in terms of gradient of vulnerability (female hand induced the most inhibition, while robot hand induced the least one) and of motor resonance (resonance is higher when the similarity between the hand prime and the participant's hand is higher).**

Affordance; dangerous objects; motor resonance; vulnerability (key words)

I. INTRODUCTION

In order to survive, humans must become able to respond adequately to the invites objects offer to them. For example, they have to learn to grasp useful objects, such as food and tools, etc., and to avoid grasping potentially dangerous objects, such as broken glasses and porcupines.

In 1979 Gibson [1], coined the term "affordances" to indicate properties the environment provides to organisms, which are relevant to the organisms' goals and that can be directly registered by their perceptual system. Affordances are variable and pertain the specific relationship existing between an organism and an object: a heavy box for instance can afford *lifting* to an adult human but not to an infant or to a ladybird. Since the very notion of affordances implies a tight relationship between perception and action, in the last twenty years, studies on affordances have flourished, especially within the framework of embodied and grounded perspectives of cognition. A variety of behavioural and neuroscientific studies have shown that observing stimuli activates a motor response [e.g., 2, 3, 4] and that even comprehending words activates the affordances of the objects they refer to [e.g., 5, 6, 7, 8]. Among the studies focusing on the role of affordance in the control of the action, Fajen [9, 10] proposed an innovative approach, the so called "affordance-based control", starting from the "information-based control" and the "model-based control" approaches. He argued that key aspects of the *information-based control* and the theory of affordances can be assimilated to form a new theoretical approach. Unlike *information-based control*, *affordance-based control* postulated that the primary function of perception is to allow individuals to see the world in terms of what they can and cannot do. Successful performance depends on the perception of possibilities for action (i.e., affordances) that are perceived directly from information in optic flow. This approach highlights the close relation between information in optic flow and movement that is characteristic of visually guided action. Moreover, it may also explain how individuals consider the dynamic properties of their body and the environment: the perception of affordances must be recalibrated following a change in action capabilities and a scaling of task-specific information.

A number of computational models have been proposed [11, 12, 13]. In the field of cognitive psychology and cognitive neuroscience, a major difference between the Gibsonian view and recent studies is that, in contrast with the externalist perspective promoted by Gibson, current research takes into account as well how affordances are represented in the brain. However, the majority of studies focus on affordances in adults, with a few notable exceptions [see the work of Linda Smith on categorization, action, and word extension: e.g., 14, 15, 16].

In contrast, the present study focuses on how affordances develop as it aims to investigate whether school-age children are sensitive to differences in object typology (i.e. between neutral vs. dangerous objects) and object category (i.e. between artefact and natural objects), and whether they resonate while observing a hand priming an object.

We perceive affordances from multiple perspectives [13]. Specifically, we perceive not only the affordances that the environment offers to us, but also the affordances that the environment offers to others. The second type of affordances (that is, the affordances from an observer perspective) appears when we observe the potential interaction of someone else (human, animal or even robot) with the environment. Costantini and colleagues [17] have shown that participants respond to objects affordances when objects are located in their own peripersonal but not extrapersonal space, unless they are located in the other's peripersonal space. This indicates that we are sensitive to objects' affordances and at the same time that we are able to see objects from the point of view of another person. Consistently with the idea that we perceive affordances from an observer perspective, behavioral studies with a priming paradigm have shown that when the target-object is preceded by a hand prime displaying a congruent grip, categorization responses are facilitated. Borghi and colleagues [18] found a compatibility effect between the prime-hand posture (precision vs. power) and the grip required to grasp the target-object (precision vs. power), provided that the experiment was preceded by a motor training phase. Vainio and colleagues [19] replicated the effect without a motor training. Overall, these studies suggest that when observing a hand priming an object a facilitation effect is found.

A. Studies on motor resonance

The reported evidence [e.g., 18, 19] has shown that observing graspable objects elicits grasping motor responses, particularly when an agent (hand) is seen in potential interaction with the objects.

Relevant to our aims, a variety of neuroscience studies showed a motor resonance effect activated by the observation of others' actions. Specifically, recent brain imaging researches on action observation have demonstrated a relation between the activation of the mirror neuron system and the motor familiarity with same kinds of actions; namely, the higher is the similarity between the observed motor program and the motor program participants are capable to perform, the more the mirror neuron system is activated. For example, Calvo-Merino and colleagues [20, 21] conducted a series of studies on action observation on expert dancers and they showed that premotor and parietal areas were more activated when dancers observed ballet moves from their own motor repertoire.

The studies we overviewed leave some questions open. First, we have now clear evidence that participants are facilitated when responding to graspable objects (affordances). But what happens when potentially graspable objects are potentially dangerous? Different transcranial magnetic stimulation (TMS) studies on empathy for pain have investigated passive responses to pain observation [22, 23], complemented by behavioral studies [24]. The results of such research showed that, after watching a needle inserted deep into a model hand, the significant motor evoked potential (MEP) amplitude decreases. This effect is specific for the observed body part; it does not occur with the foot nor with a natural object (tomato) or with a tactile stimulation (innocuous cotton bud control).

In our laboratory a further study was carried out with adults participants [25]. We used the same paradigm of the present work (for the methodology we refer to next paragraph) to explore whether adults are sensitive to: i) differences in object typology; ii) differences in object category; iii) fine-grained aspects of the biological stimuli. Results showed that adults' performance is modulated by these three variables, namely: i) response times were slower to dangerous than to neutral objects; ii) female participants responded faster to natural objects than to artefacts); iii) male participants respond faster to hands of their own gender, characterized by a specific posture, the grasping one).

The first aim of the present study is to investigate with a priming paradigm whether also children are aware of the distinction between graspable objects (affordances) and dangerous objects.

The second open issue concerns whether children are sensitive to both the affordances and the potential dangers offered by the objects in the environment to others. In writings of J.J. Gibson, support for the observer perspective can also be seen. While describing the nature of the optical information for perceiving affordances, Gibson [1] mentions that it is required for a child to perceive the affordances of things in the environment for others as well as itself: *"The child begins, no doubt, by perceiving the affordances of things for her, for her own personal behavior. But she must learn to perceive the affordances of things for other observers as well as herself" [1, p. 141)"*. The second aim of the present study is to investigate whether children's responses are modulated not only by objects' affordances (graspable vs. dangerous objects) but also by the agent who may interact with it. Specifically, we contrasted a human with a robotic hand, and hands of different gender.

We hypothesize that the ability to distinguish object typology (i.e. between dangerous and neutral objects) emerges quite early in development, as it is crucial from an adaptive point of view. Moreover, we predict that children are also sensitive to the distinction between actions performed by biological and non-biological agents, but they are not yet able to discriminate more fine-grained aspects, differently from adults. Thus, we argue that performance should not be different between adults and children, as far as object typology and biological stimuli were concerned, but differences should emerge as regards more fine-grained aspects.

II. EXPERIMENT

The aim of the experiment is to investigate whether school-age children are sensitive to differences in object dangerousness (i.e. neutral vs. dangerous objects). Moreover, we are interested to explore what happens during the observation of a prime (i.e. a hand or a control object) followed by an object and to verify whether priming the stimulus with a biological hand (i.e. a prime more similar to the participants hand) would facilitate the motor responses compared to a non-biological hand (i.e. a robotic and a control prime). Furthermore, the hands showed as primes belong to children of the same age of the participants. To these aims, we run an experiment in which participants were required to distinguish between artefacts and natural objects, so that the object dangerousness was not relevant to the task.

III. METHOD

A. Participants

Twenty-six participants (16 males and 10 females) with a mean age of 7.4 (range: 6-8) years took part in the experiment. All subjects were right-handed and had normal or corrected-to-normal vision. All were naive as to the purpose of the experiment and their parents gave informed consent.

B. Apparatus and stimuli

Participants sat in front of a 17-inch colour monitor (the eye-to-screen distance was approximately 50 cm). E-Prime 2.0 software was used for presenting stimuli and collecting responses.

The experimental stimuli (see Table I for the complete list and the pictures of the stimuli) consisted of sixteen colour pictures of living and non-living objects preceded by a prime, in order to enhance (grasping hand) or to reduce (static hand) aspects related to the action, so that a simulation effect was induced. All the objects would be normally grasped with a power grip. There were four categories (dangerous-natural objects, dangerous-artefact objects, neutral-natural objects, neutral-artefact objects), with four objects for each class. Each target-object was preceded by one of the six primes: a grasping hand of a male child, a grasping hand of a female child, a grasping hand of a robot, a static hand of a male child, a static hand of a female child, a control stimulus (brick).

The set of stimuli was the same used in another study [25] in which we asked an independent group of forty-three participants to rate on a five-point scale the dangerousness of the target objects. The analysis revealed that there was a significant difference between neutral and dangerous objects.

C. Procedure

Participants were required to decide as fast as possible whether the target-stimulus was an artefact or a natural object by pressing one of two designed keys. Half of the participants were required to make a right-hand key-response if the target was artefact and a left-hand key-response if it was natural, whereas the opposite hand-to-category arrangement was applied to the other half.

The experiment consisted of one practice block of 24 trials and one experimental block of 96 trials. Each trial began with a fixation point (+) displayed for 500 ms in the centre of the screen. Then, a prime was shown for 200 ms, followed by a white screen (SOA) for 50 ms. Then, a target object was shown and remained on the centre of the screen until a response had been made or 2000 ms had elapsed. Participants received feedback on reaction time (RT) after pressing the right or the wrong key (the reaction time value or "Error", respectively). The next trial began after the feedback disappeared.

The order of conditions was balanced across participants. Overall the experiment lasted about 10/15 minutes.

IV. RESULTS

Reaction times (RT) for incorrect responses and RTs more than two standard deviations from each participant's overall mean were excluded from the analysis. Error trials were excluded from further analyses. We decided to use ANOVA since it is widely used in RTs analyses in psychology and neuroscience. Indeed, compared to other statistics ANOVA is remarkably robust to deviations from normality – and slight deviations from normality typically characterize RTs distributions (see [26] and [27] for discussion on robustness of ANOVA). The correct RTs were entered into a mixed 2 x 2 x 2 x 6 analysis of variance (ANOVA), with *Participant Gender* (male and female) as between participants factor, and *Object Typology* (neutral and dangerous), *Category* (artefact and natural), and *Prime* (grasping hand of a male child, grasping hand of a female child, grasping hand of a robot, static hand of a male child, static hand of a female child, control stimulus) as within participants' factors. LSD post-hoc tests were also conducted on significant interactions.

The analysis revealed the main effect of *Object Typology* [F (1, 24) = 5.1, MSE = 20273, p = .03], showing that responses were faster when the object was neutral and slower when the stimuli were dangerous (694 vs. 721, respectively). Moreover, we obtained an effect of *Prime* [F (5, 120) = 2.3, MSE = 7561, p = .05]. The second main effect revealed that participants responded faster to the stimuli preceded by a human hand prime (i.e. a biological hand, 701 ms) and slower to the stimuli preceded by a robot hand and control stimulus (i.e. a non-biological hand, 722 ms). As revealed by the post-hoc test, response times were faster when the prime was the grasping hand of a female (M = 690) than the grasping hand of a robot (M = 725, $p < .01$) or the control stimulus (M = 714, p = .04). Moreover, response times were faster when the prime was the static hand of a female (M = 699) than the grasping hand of a robot (M = 725, p = .03), (see figure 1).

Furthermore, there was a significant interaction between *Object Category* and *Participant Gender* [F (1, 24) = 4.3, MSE = 24434, p < .05]. The post-hoc test showed that males responded faster to natural objects and slower to artefacts objects (M = 686 vs. 720 respectively, p < .05), while there was no difference between natural and artefact objects as far as females were concerned (722 vs. 702, respectively, p > .05), (see figure 2).

In order to better understand our result, we performed two separated analyses by levels of *Prime*, separating the grasping hands from the static primes. Thus, in the first analysis, we considered *Participant Gender* (male and female) as between participants factor, and *Object Typology* (neutral and dangerous), *Category* (artefact and natural), and *Prime* (grasping hand of a male child, grasping hand of a female child, grasping hand of a robot) as within participants' factors.

The main effect of *Prime* [F (2, 48) = 3.9, MSE = 9025, p = .03] showed that participants responded faster to the stimuli preceded by a grasping hand of a female (690 ms) and slower to the stimuli preceded by a grasping robot hand (728 ms, p < .01), (see figure 3).

In the second separated analysis, we considered *Participant Gender* (male and female) as between participants factor, and *Object Typology* (neutral and dangerous), *Category* (artefact and natural), and *Prime* (static hand of a male child, static hand of a female child, control stimulus) as within participants' factors.

The main effect of *Object Typology* [F (1, 24) = 4.5, MSE = 14269, p < .05] revealed that responses were faster when the object was neutral and slower when the stimuli were dangerous (690 vs. 720, respectively).

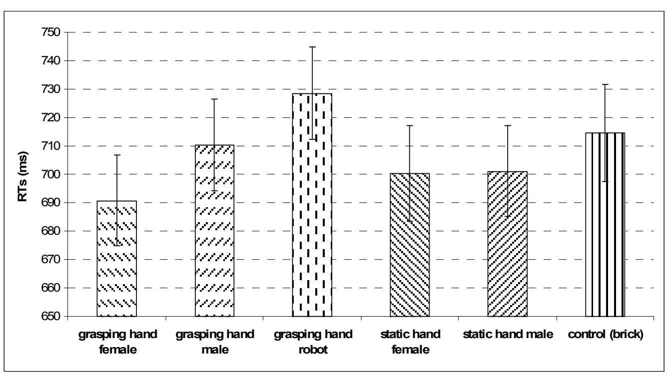

Figure 1. Significant *Prime* effect for RTs (analysis 1), values are in ms and bars are SEM.

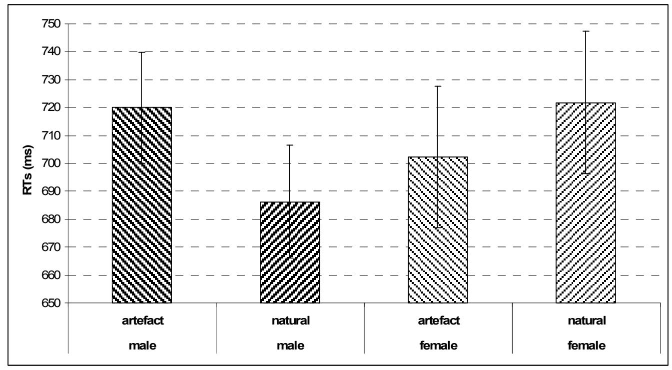

Figure 2. Significant *Object Category* and *Participant Gender* interaction for RTs (analysis 1), values are in ms and bars are SEM.

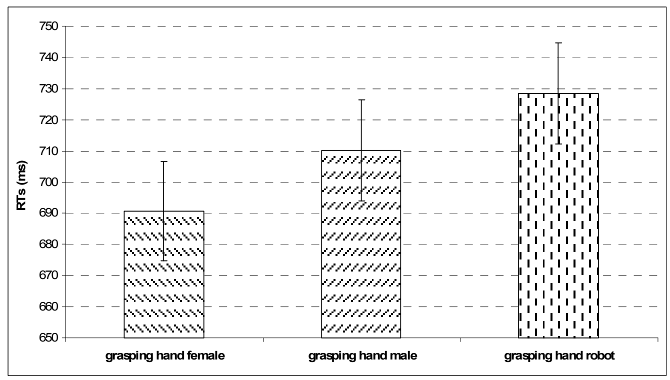

Figure 3. Significant *Prime* effect for RTs (analysis 2), values are in ms and bars are SEM.

V. DISCUSSION

Our results clearly demonstrate that school-age children are sensitive to the distinction between graspable and dangerous objects. As revealed by the response time patterns, dangerous objects yielded longer RTs, probably due to the fact that a response was prepared, followed by a blocking mechanism leading to interference. To our knowledge, this is the first behavioural study demonstrating the capability to distinguish between neutral and dangerous objects in children.

Interestingly, children seem to be aware also of the difference between object categories. Specifically, males responded faster to natural objects than to artefacts. This result is in line with the literature [18, 19, 28] and could be due to the activation of both manipulative and functional information with artefacts, while with natural objects only manipulative information is activated.

In addition, our results clearly show that children are sensitive to the difference between actions performed by biological and non-biological agents. Overall, we found that children responded faster when the prime was a grasping hand of a human compared to control stimuli (robotics hand, brick). The amount of inhibition that the observed [person's] hand induced on the reaction [to push the proper button] is related with the perceived vulnerability of the hand for dangerous objects. The results show that female hand induced the most inhibition, followed by male hand. Robot's hand induced the least inhibition since it was perceived as less vulnerable than the others.

This difference in vulnerability, as reflected in RTs, can be due simply to the disembodied knowledge that robotics hands are less vulnerable than human hands. In contrast with a non embodied explanation, we tend to interpret our result in terms of motor resonance: in line with common coding theories [e.g., 29], resonance would be higher when the similarity between the hand prime and the participant's hand is higher. To clarify, we tend to consider the two explanations (based on vulnerability and motor resonance) as compatible rather than as contrasting, and both in keeping with an embodied approach to cognition. Indeed, in previous studies, we provided evidence of resonant effects, in both children and adults, showing with a variety of paradigms that, the higher the similarity between the hand (or the movements of the observed organism) and our own hand (or our movement), the more facilitation occurs. For example, Ranzini and colleagues [30], have shown with a line bisection paradigm that adults are sensitive to the relationship between a hand they observe and an object (a line). They found a stronger lateralization effect with human than for robot hands, indicating that attention is directed where a potential action takes place, and that a more marked motor resonance effect occurs with biological than with non-biological effectors. In the same vein, Liuzza and colleagues [31] have demonstrated for the first time motor resonance in children. Indeed, they showed with a priming paradigm that children are faster in categorizing light vs. heavy objects when they are preceded by children's rather than by adults' hands. Results of the present study corroborate and widely extend previous ones, showing resonant mechanisms when interacting with dangerous objects.

A final result is worth noticing. The analyses separated by gender we performed allow us to conclude that children are sensitive to the difference between biological and non-biological stimuli, but only when a specific intention (i.e., grasping objects) is detected. Indeed, we found evidence for resonant mechanisms only when grasping hands were presented, while no difference was detected between static hands and the control stimulus. When static primes are presented, the attention is captured by the difference between dangerous vs. not dangerous objects. This suggests that two different underlying mechanisms are at play: the first, possibly based on the canonical neuron system, is triggered by objects affordances; the other one, probably based on the mirror neuron system, is activated while observing affordances from others' point of view, thus it probably underlies resonant mechanisms [32].

Overall, to our knowledge our study represents a first step in demonstrating that young children are well aware of the distinction between dangerous and neutral objects, and also of the effects that these different objects can have on other organisms, such as other humans, males and females, and robots. Further research is needed, in order to better understand the neural mechanisms underlying these behavioral effects and to be able to successfully model them.

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TABLE I. EXPERIMENTAL STIMULI (6 PRIMES AND 16 OBJECTS).

 Prime: Control Stimulus	 Prime: Grasping hand of a robot
 Prime: Grasping hand of a male child	 Prime: Grasping hand of a female child
Prime: Static hand of a male child 	Prime: Static hand of a female child 
Objects	
 Bulb	 Broken bulb
 Glass	 Broken glass
 Tomato	 Cactus

 Cat	 Scorpio
 Chick	 Husk
 Plant	 Porcupine
 Spoon	 Knife
 Lighted out match	 Lighted match