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Impaired vitality form recognition in autism

Magali J. Rochat [a], Vania Veroni [a], Nadia Bruschweiler-Stern [b], Cinzia Pieraccini [c], Frédérique Bonnet-Brilhault [d], Catherine Barthélémy [d], Joëlle Malvy [d], Corrado Sinigaglia [e], Daniel N. Stern [f,g], Giacomo Rizzolatti [a,h,*]

[a] University of Parma, Department of Neuroscience, via Volturno 39, I-43100 Parma, Italy
[b] Centre Brazelton Suisse, Clinique des Grangettes, 1224 Chêne-Bourg (GE), Switzerland
[c] Neuropsichiatria Infantile, Azienda Unità Sanitaria Locale di Empoli, Via Tosco-romagnola Est 112, 50053 Empoli, Italy
[d] UMR_S Inserm U 930, CNRS ERL 3106, Université François Rabelais de Tours, CHU Tours, IFR 135 Imagerie Fonctionnelle, 37000 Tours, France
[e] University of Milan, Department of Philosophy, via Festa del Perdono 7, I-20122 Milano, Italy
[f] University of Geneva, Section of Psychology, Bld du Pont d'Arve 40 Geneva, Switzerland
[g] Cornell University Medical School, Department of Psychiatry New-York Hospital, New York, NY, USA
[h] IIT (Italian Institute of Technology), Brain Center for Social and Motor Cognition, Parma, Italy

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ABSTRACT

Along with the understanding of the goal of an action ("what" is done) and the intention underlying it ("why" it is done), social interactions largely depend on the appraisal of the action from the dynamics of the movement: "how" it is performed (its "vitality form"). Do individuals with autism, especially children, possess this capacity? Here we show that, unlike typically developing individuals, individuals with autism reveal severe deficits in recognizing vitality forms, and their capacity to appraise them does not improve with age. Deficit in vitality form recognition appears, therefore, to be a newly recognized trait marker of autism.

1. Introduction

The capacity of individuals to attribute goals and intentions to others has been a focus of much research. Many studies were performed in the frame of the so-called theory of mind (Premak & Woodruff, 1978), that is a specific cognitive ability that enables individuals to interpret the behavior of others in terms of mental states such as beliefs and desires (e.g. Baldwin, 1991; Baron-Cohen, 1991; Wimmer & Perner, 1983; Gergely, Bekkering, & Király, 2002; Meltzoff & Brookes, 2001). A milestone in theory of mind research was the demonstration that typically developing (TD) children are able by 4 years to understand that other people hold beliefs that are recognized as false (Wimmer & Perner, 1983). This finding acquired a particular importance by the discovery that children with autism fail false belief tasks (Baron-Cohen, Leslie, & Frith, 1985). It was therefore proposed that the core deficit in autism is a deficit of theory of mind (Baron-Cohen, Tager-Flusberg, & Cohen, 1993; Frith, 2003; Leslie, 1987).

More recently, following the discovery of mirror neurons (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996) and the subsequent demonstration that a subpopulation of mirror neurons code agent's intention (Bonini et al., 2011; Fogassi et al., 2005), a series of physiologically-inspired studies, were carried out to assess the capacity of TD children, children with autism (Cattaneo et al., 2007), and, more recently, children with Williams syndrome, to understand actions done by others (Sparaci, Stefanini, Marotta, Vicari, & Rizzolatti, 2012).

The capacity to understand others' actions is a complex process that requires the capacity to analyse the various action components. A first clear distinction must be made between understanding *what* the agent is doing (i.e., the goal of the observed action) and understanding *why* the agent is doing it (i.e., the intention underlying it). For example, when an individual observes another person moving his/her hand towards a mug, he or she immediately understands *what* the agent is doing (e.g., grasping the mug), but also he might understand *why* he is doing it (e.g., grasping the mug for drinking or grasping for moving it away).

* Corresponding author at: University of Parma, Department of Neuroscience, via Volturno 39, I-43100 Parma, Italy. Tel.: +3905 21033 879; fax: +3905 2190 3900.
E-mail addresses: magalijane.rochat@unipr.it (M.J. Rochat), vania.veroni@unipr.it (V. Veroni), nadia.bruschweiler@grangettes.ch (N. Bruschweiler-Stern), c.pieraccini@usl11.tos.it (C. Pieraccini), f.bonnet-brilhault@chu-tours.fr (F. Bonnet-Brilhault), catherine.barthelemy@chu-tours.fr (C. Barthélémy), j.malvy@chu-tours.fr (J. Malvy), corrado.sinigaglia@unimi.it (C. Sinigaglia), daniel.stern88@yahoo.com (D.N. Stern), giacomo.rizzolatti@unipr.it (G. Rizzolatti).

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Although these two kinds of action understanding are often strictly intertwined, they appear to rely on different neural mechanisms (see Bonini et al., 2011; Fogassi et al., 2005).

Goal and intention understanding can be found dissociated one from another. Indeed, it has been shown that children with ASD do not differ from TD children when they are asked to recognize *what* an agent is doing, i.e., the action goal (Boria et al., 2009; Hamilton, Brindley & Frith, 2007). In contrast, they are impaired relative to TD children in understanding *why* an agent is performing a certain action, i.e., in understanding the intention of that action (Boria et al., 2009). More recently, it has been shown that children with Williams syndrome are impaired in understanding *what* the others are doing, compared to both mental-age and chronological-age TD controls, while they show mental-age appropriate performance in understanding why an individual is acting (Sparaci et al., 2012).

It is worth noting, however, that understanding an observed action does not consist only in recognizing what is the goal of an action and why that action has been performed. There is another fundamental component related to the dynamics of action that is critically involved in warranting social interactions with other people (Stern, 1985). Action dynamics enable the observer to understand the cognitive/emotional state of the agent of the performed action. For instance, a minute variation in the temporal contour, force, or direction of the actions may let the recipient of the action, as well as a neutral observer, to understand whether the agent is gentle or angry, whether he or she performs the action willingly or hesitating, and so on. The dynamics of action carrying this kind of information in a specific stretch of time has been called "vitality affects" (Stern, 1985) or "vitality forms" (Stern, 2010).

As stressed by Stern (2010) the concept of vitality refers to a *Gestalt*, a spontaneous integration of different dynamic events (movement, force, space, time, direction/intention) that are linked and perceived together in a coherent *whole.* It constitutes a phenomenal reality that is rooted in physical action but that would nevertheless lose its holistic meaning whenever fragmented into its physical composing elements. The perception of vitality forms is defined as "the felt experience of force in movement with a temporal contour and a sense of aliveness, of going somewhere""the felt experience of force in movement with a temporal contour and a sense of aliveness, of going somewhere" (Stern, 2010). Regardless of its content (thoughts, actions, emotions), the perceived Gestalt of vitality concerns the specific manner with which dynamic happenings unfold in space and time. It can thus be applied to every dynamic features emerging from the interpersonal relationships or time-based art expressions that "move us by the expression of vitality that resonate in us" (Stern, 2010, pp. 3–17).

There are no experiments that investigated whether individuals with ASD are impaired in *understanding* "vitality forms". Some studies showed that children with ASD have difficulties in *imitating* actions performed with different "styles" (Hobson & Hobson, 2008; Hobson & Lee, 1999). In particular, it was shown that, while children with ASD do not differ from TD children in imitating the goal-directed component of relatively complex actions, they have difficulties in replicating the style (e.g. gentle or forceful) with which the action was demonstrated, especially when imitation of the style was not essential for achieving the action goal. The authors explained the failure of ASD children in incorporating the style of the demonstrator into their own repertoire in light of their weak propensity to identify themselves with others (Hobson, 1989, 1993, 2002). In conclusion, while it is clear that individuals with ASD often do not use the style of the demonstrator in replicating an observed action, it is still far from clear what might be the cause of this behavior. Is it restricted to the imitation domain? Or does it depend on a more fundamental deficit in recognizing different vitality forms?

To answer these questions we investigated the capacity of individuals with ASD and TD controls to recognize similarities and differences of actions characterized by same or different vitality forms. We will refer to this task as the *How* Task. Participants were also required to decide whether an observed action was similar or different relative to its goal, regardless of the vitality form with which it was executed. We will refer to this task as the *What* Task. The results showed a clear dissociation between the two tasks. Individuals with ASD did not differ from controls in the *What* Task. In contrast, they showed a clear deficit in the *How* Task. The significance of these findings for a better understanding of social and communicative deficits observed in autism will be discussed.

2. Materials and methods

2.1. Participants

Twenty patients with confirmed diagnosis of autism spectrum disorder (ASD) and 20 healthy controls took part in the experiment. Three of the patients with ASD had intelligence quotient (I.Q.) values under the intellectual normative range (<71), and were discarded. Thus, the ASD group included 17 individuals: 6 were adolescents/adults (6 males aged from 14.0 to 19.2 years-old, mean $=16.1\pm2.2$) and 11 were children (9 males, 2 females aged from 6.10 to 12.8 years-old, mean $=9.9\pm2.2$). The group of healthy controls consisted of 6 adolescents/adults (6 males, aged from 13.3 to 18.6 years-old, mean $=16.2\pm2.2$) and 11 typically developing (TD) children (7 males, 4 females aged from 7.1 to 12.8 years-old, mean $=10.0\pm1.7$). None of them reported cognitive deficits.

Patients with ASD were recruited in 3 different clinical centers: in Italy, at the Center for Autism of Empoli (ASL 11), and at the Center for Communication and Socialization Disorders of Parma, and in France, at the Center for Functional Exploration and Neurophysiology in Pediatric Neuropsychiatry (CHU Bretonneau) in Tours. The diagnoses of autism were established independently by the team of clinical specialists pertaining to the different Centers for Autism, including qualified child and adolescent psychiatrists or pediatricians not associated with this research. Modules 2, 3 and 4 of the Autism Diagnostic Observation Schedule (ADOS) were used to confirm the diagnosis of ASD. In Module 2, scores from 8 to 12 indicate spectrum disorder, while autism is indicated by scores from 12 and above; in Modules 3 and 4 spectrum disorder is indicated by scores from 7 to 10, with the cut-off for autism fixed from 10 and above. Based on the results of this scale, 12 patients met the criteria for autism, while 5 patients met the criteria for spectrum disorder. All patients had an IQ >71 calculated with the Wechsler Intelligence Scale for Adults (WAIS), the Wechsler Intelligence Scale for Children 3rd ed. (WISC-III), and Preschool and Primary Scale of Intelligence (WPPSI) depending on the participants' age. Table 1 reports chronological age, IQ, verbal age, and ADOS values for all participants of the ASD group.

The control group was matched to the ASD group for chronological and verbal age, the latest being evaluated using the Peabody Picture Vocabulary test-Revised (PPVT-R). Results from the two samples *t*-test analyses showed no significant differences between the two groups, either for what concerned the mean chronological age (ASD group, mean $=12.06\pm$ SD $=3.72$; Control group, 12.18 ± 3.59, $t(32)=-0.98$, n.s.) or the mean verbal age (ASD group, 113.15 ± 25.93; Control group, 127.19 ± 22.92, $t(27)=1.55$, n.s.).

PPVT-R scores were not available for 4 ASD patients who, however, presented no deficiencies at the Wechsler subtests of language comprehension and verbal reasoning. Those patients have been thus matched to controls for chronological age.

Table 1
Demographics for ASD and TD subjects participating in the study.

	ASD participants ($N=17$) (Mean/SD)	TD participants ($N=17$) (Mean/SD)
Chronological age	12.06 ± 3.72	12.18 ± 3.58
IQ	83.0 ± 10.87	NA
Verbal age (PPVT-R, raw scores)	113.15 ± 25.92	127.19 ± 22.92
ADOS (mod. 2) total algorithm	12.33 ± 4.04	NA
ADOS (mod. 3) total algorithm	13.00 ± 5.21	NA
ADOS (mod. 4) total algorithm	12.00 ± 4.34	NA

The experiment was approved by the local ethical committee and was conducted according to the Helsinki declaration. The participants' parents or legal guardian signed an informed written consent.

2.2. Stimuli

Stimuli consisted of short video-clips showing different types of actions. The content of the video-clips was the following. In a sober environment, two actors (a male and a female) sat at a table facing each other with arms crossed. One actor (male or female) made an action towards the other and then came back to his/her resting position (Fig. 1). Video-clips with the actor or with the actress starting the action were balanced and randomized across trials. The eight presented actions were: to give a mug, to retrieve it, to give a high-five, to shake hands, to point somewhere, to raise one's own hand in front of the interlocutor in a stop sign, to caress the other's forearm, to take the other's hands. Each type of action was executed with two different vitality forms: vigorous or gentle. Thus, 32 different stimuli were obtained (8 types of actions $\times$ 2 actors $\times$ 2 vitality forms). The video-clips were presented centrally on a computer screen.

The following procedure was used to construct the video-clips. During the shootings, the actors were instructed to execute the various actions with strength and energy (*Vigorous* vitality form) and then to repeat them in a mild and soft manner (*Gentle* vitality form). They were also asked to avoid expressing any emotion with their face or body. The valence of the stimuli was then assessed in a behavioral study. Twenty healthy adults were asked to watch the videos and to define with an adjective the dynamic envelop of the observed behavior (e.g., precipitous, gentle, quiet, harsh, etc…). The same adults were subsequently asked to rate the intensity of the defined vitality forms according to a 5-point Likert scale (0 = very low to 5 = very high). By using this preliminary testing we were able to select the two most recurrent adjectives describing the vitality forms shown in the video-clips (*Vigorous* or *Gentle*) and to use them to ascribe all stimuli to two main categories. Finally, the intensity ratings allowed us to ensure the existence of intensity homogeneity among the used stimuli.

2.3. Procedure

Participants sat in a quiet room in front of a computer screen. They were presented with sequences of two video-clips. The second video-clip of the sequence could be identical to the first one or differ from it on type of action, on vitality form, or on both. Video-clips were coupled following 4 combinations: same action – same vitality form (SASV); same action – different vitality forms (SADV); different actions – same vitality form (DASV); different actions – different vitality forms (DADV). Each combination was repeated 8 times, using different stimuli. Only 4 combinations of SASV stimuli (the easiest combination) were presented in order to reduce the length of the experimental sessions. Thus, each subject received a block of a total of 28 stimulus combinations. This block was repeated twice.

In order to exclude that a poor understanding of the task could determine deficits in performance, subjects received, before the experimental sessions, a pre-training session followed by a short training one. In the pre-training session, participants were introduced to the two tasks, the *What* Task and the *How* Task. In the *What* Task, they were instructed to pay attention to the action of the first video-clip and to decide whether the action of the second video-clip was the same or not, irrespective of the manner with which the actions were executed.

The instructions the participants received in the pre-training "*What*" task were, literally, the following: "You will be presented with pairs of short videoclips in which a boy and a girl are interacting. Look carefully at what they are doing. After showing you two videoclips, I will ask you whether the actor's action was the same or different in the two videoclips. Here is an example: (*the first videoclip shows the actress vigorously waving at the actor*). What action was the girl performing? She was waving. Now look at the second videoclip (*the second videoclip shows the actress gently waving at the actor*). What action was the girl performing this time? She was waving again. So were her actions the same or different in the two videoclips?"

In the pre-training of the "*How* Task", participants were told to pay attention on how the action was executed in the first video and to decide whether the vitality form with which it was executed in the second video was the same or not, irrespective of the type of the presented actions. The literal instructions were the following: "You will be presented with pairs of short videoclips during which a boy and a girl are interacting. Look carefully at the way their actions are performed, that is: in a gentle or in a vigorous way. After you saw two videoclips, I will ask you to tell me whether you think the actor acted in the same or in a different way from one videoclip to another. Here is an example: (the first videoclip shows the actress vigorously waving at the actor). How did the girl perform her action, was it done in a gentle or in a vigorous way? She acted in a vigorous way. Now look at the second videoclip (the second videoclip shows the actress gently waving at the actor). How did the girl act this time? Did she act in a gentle or in a vigorous way? She acted in a gentle way. So did she perform her actions in the same or in a different way across the two videoclips?" No individuals reported difficulties in understanding the instructions, refused to perform the test, or stopped doing it during the experimental sessions. Note that all ASD individuals were high-functioning individuals without any cognitive deficits.

Following pre-training, a training phase was given for both *What* and *How* Tasks consisting of 8 trials, two for each kind of stimulus combination (SASV, SADV,

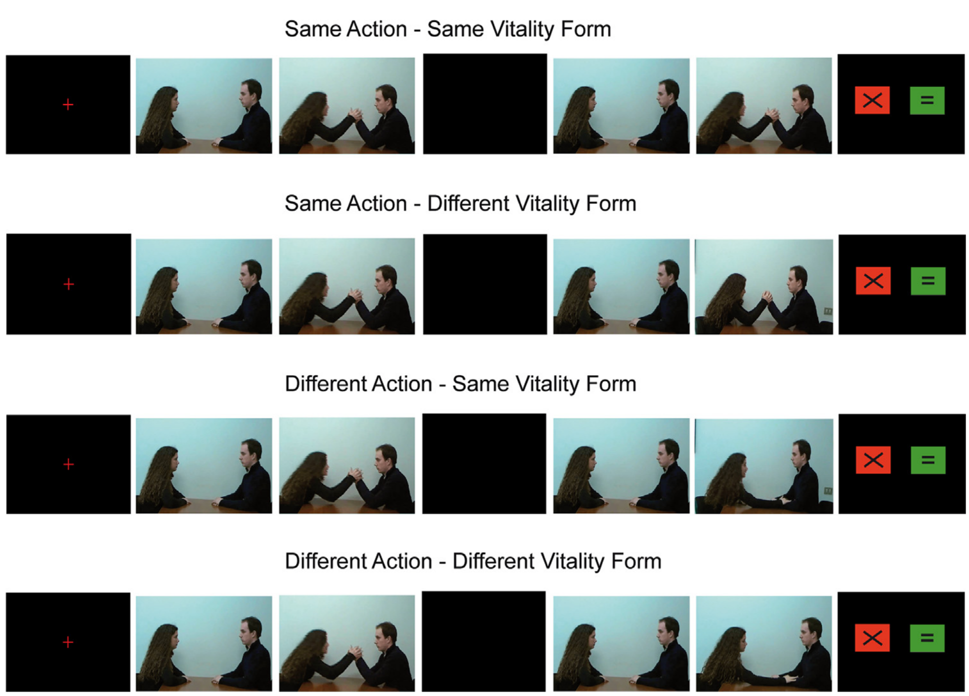

Fig. 1. Stimuli sequences and combinations: all stimuli sequences started with the presentation of a fixation cross, followed by the presentation of the first video-clip depicting an interaction between two actors. In the figure, the first and the last pictures of the video-clip are presented. After the end of the first video-clip, the screen turns black until the second video-clip starts. At the end of the second video-clip, a decision screen is displayed, depicting an *equal* and a *different* symbols on a black background. The decision screen disappears when the experimenter presses a key to record the participant's answer.
The two video-clips displayed in a stimuli sequence can be identical or different on the basis of the action type and/or the vitality form (VF), resulting in 4 possible combinations: the same action executed with the same VF; the same action with different VFs, different actions with the same VF; different actions executed with different VFs.

DASV or DADV). The actions the subjects observed in the training trials were different from those subsequently displayed in the experimental trials. Subjects were considered ready to start the experimental tasks when they answered correctly to at least 3/4 of the training trials. Paired sample *t*-test showed that the amount of correct responses was similar between TD and ASD individuals, both during the training trials of the What Task (ASD$=7.52\pm1.33$; TD$=7.82\pm0.53$; $t(32)=0.848$, n.s.) and during those of the How Task (ASD$=6.65\pm1.66$; TD$=7.41\pm1.06$; $t(32)=1.602$, n.s.). Only 2 out of 17 ASD participants did not pass the fixed criteria and needed to run a second set of training trials, then obtaining 100% of correct answers. These data suggest that all individuals understood correctly both tasks instructions.

The *What* and *How* Tasks were administered in two separate blocks. The order of presentation of the two tasks was balanced across participants. Each task consisted of 28 trials displayed on a computer screen using Matlab 7.6.0 (R2008) software. Moreover, in order to keep a good attention level through the tasks, different brief animated cartoons (lasting around 20 s. each) were inserted every 7 trials. The entire session lasted approximately 30 min (15 min. per task).

Each trial started with the presentation of a red fixation cross (1 s), followed by the first video-clip (Fig. 1). Following an inter-stimulus interval (black screen presented for 500 ms), a second video pertaining to the same or different stimulus combination (SASV, DASV, SADV or DADV) was displayed. At the end of the second video a "decisional screen" displayed "same" and "different" symbols on the two sides of the computer screen. Participants had to express verbally whether the two displayed videoclips were same or different according to the *What* or *How* Tasks. The experimenter pressed a specific key for "same" and "different" responses, respectively, to record the participants' responses. Absence of response or unreliable responses due to lack of attention to one or both videos was recorded by pressing a third key. These last trials were discarded from analysis. Successive analyses showed that the amount of discarded trials did not significantly differ between TD (0.71 ± 0.77) and ASD (1.65 ± 2.47) groups ($t(32)=-1.395$, n.s.). These data suggest that the amount of attention to the videoclips (as expressed by the reliable trials) was identical in the two groups. No eye-tracking or other looking-time measurements were done in this experiment. In both tasks the measured variable was the performance accuracy calculated as the number of errors divided by the number of accepted trials.

2.4. Statistics

Descriptive statistics evidenced a non-normal distribution of our data (*skewness*$=1.148$; *kurtosis*$=0.113$), a finding confirmed by the Shapiro-Wilks *W* test of normality ($W=0.806$, $p<0.000$). As the normality assumption was violated, error ratios were normalized through the Arcsine transformation: (ARCSIN(SQRT (x)))180/ 3.141592. Analyses were then conducted using Statistica 7.0 software. We used the following parametrical statistical tests: one-way analysis of variance (ANOVA), repeated-measures ANOVAs, analysis of covariance (ANCOVA), paired sample *t*-tests, a Pearson correlation and simple linear regressions in order to construct developmental trajectories (see Supplementary Results). All analyses were done using two-tailed probabilities ($\alpha=0.05$). In order to better balance Type I and II errors, the modified Holm-Bonferroni step-down procedure was used as post-hoc test (see Holm, 1979; Jaccard & Guilamo-Ramos, 2002). Finally, Wilcoxon matched-pairs tests were used to investigate the error tendency within the ASD group.

3. Results

Fig. 2 shows the mean normalized error rates of TD and ASD participants in the *What* and the *How* Tasks. A repeated-measures ANOVA was conducted on normalized error ratio considering Task as a within factor (2 levels: What, How), and Group (2 levels: ASD, TD) and Order of Presentation (2 levels: What first, How first) as between factors. The results showed a significant effect of Group ($F_{(1,30)}=8.920$, $p<0.005$) and Task ($F_{(1,30)}=15.191$, $p<0.001$). Order of Presentation was not significant. The interaction Task x Group was significant ($F_{(1,30)}=5.428$, $p<0.05$).

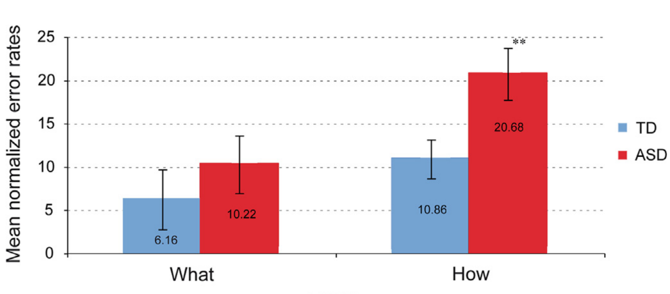

Fig. 2. Mean normalized error rates ± s.e.m. during judgment of similarity or differences between pairs of stimuli presented in the *What* and *How* Tasks conditions. ** Indicates significant difference ($p<.001$).

The modified Holm–Bonferroni step-down procedure showed that, in TD individuals, the difference in error rates between the *How* (10.86 ± 5.95) and *What* (6.16 ± 9.15) Tasks was not significantly different from chance, while in participants with ASD the error ratio was significantly higher in the *How* Task (20.68 ± 7.90) relative to the *What* Task (10.22 ± 8.83, $p<0.001$). When comparing the normalized error ratio between groups, while the ASD group performance was similar to the controls in the *What* Task, this group had a significantly worst performance in the *How* Task ($p<0.005$). Furthermore, Wilcoxon matched-pairs tests showed that all patients with ASD had a worse performance in the *How* Task (W(17), Z$=2.816$, $p<0.005$), and that their difficulty to detect a change between vitality forms was not influenced by the order of presentation, i.e., by the fact that a gentle action preceded the presentation of a vigorous one or vice versa (W(12), Z$=1.820$, *n.s*).

In order to further rule out the possible effect of the order of presentation of the tasks on the subjects performance, two separate ANOVAs have been conducted for each group, considering Task (2 levels: What, How), and Order of Presentation (2 levels: What first, How first) as a within factors. Results confirmed that the main effects of Task and Order of presentation and their interaction were not significant for the TD group (all *p*s >0.05), while for the ASD group, only the Task main effect was significant ($F_{(1,15)}=14.546$, $p<0.005$) but not the interaction between Task and Order ($p=0.965$). As already mentioned in Methods, the possibility that the difficulties of individuals with ASD in recognizing the action's vitality form could be due to compromised verbal abilities was ruled out by the results of PPVT-R verbal test that showed a similar performance in both TD and ASD groups. Finally, the lack of correlation between ASD participants' error ratio in the How task and their performance at the PPVT-R test ($r=0.046$, n.s.) further excluded this possibility. A similar pattern of performance emerged from further analyses (ANCOVAs and simple linear regressions) reported in Supplementary results.

The absolute number of errors in the *How* Task was 21 for TD group and 56 for the ASD group. In order to assess how the errors were distributed in the four stimulus combinations (SASV, DADV, SADV and DASV) in the two groups, their distribution was analysed. The results are illustrated in Fig. 3. In both groups, errors were largely concentrated in DADV stimulus combination, which could be considered as the most cognitively demanding combination. However, in the ASD group only, a second peak of errors was recorded in DASV stimulus combinations, highlighting their difficulties in detecting a similar vitality form across different

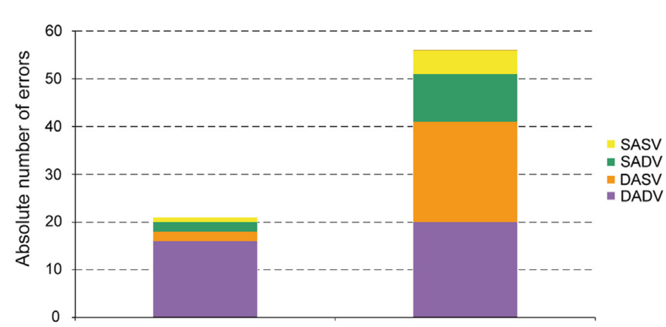

Fig. 3. Distribution of errors in the *How* Task among the four stimuli combinations for ASD and controls. SASV=same action executed with the same vitality form (VF); DASV=different actions with the same VF; SADV=same action with different VFs; DADV=different actions executed with different VFs.

instances of action. A repeated measure ANOVA, carried out with Group (two levels: TD, ASD) and Stimulus Combinations (four levels: SASV, SADV, DASV, DADV) as between factors revealed a main effect of Group ($F_{(1,32)}=8.441$, $p<0.05$) and of Stimulus combination ($F_{(3,96)}=132.86$, $p<0.001$). These results were further analysed in a two sample Student's *t*-test which revealed that unlike controls (0.12 ± 0.33), participants with ASD made a large number of errors in both DASV and DADV stimulus combinations (1.24 ± 1.48), $t(17)=3.04$, $p<0.001$. Finally, in order to investigate the effect of age on the performance of patients with ASD, we conducted a one-way ANOVA with age as main factor. Results showed no effect of age on performance ($F_{(1,15)}=2.131$, n. s.).

4. Discussion

Social interactions require, besides the understanding of goals of the observed actions and the intentions underlying them, also the understanding of information carried out by others' actions dynamics. A caress can be warm or detached; a grasp can be gentle or vigorous. Stern called the information provided by action dynamics "vitality affects" or "vitality forms" (1985; 2010). Time profile (start, duration and the end of an action), force, space and direction are the elements of movement dynamics that enable individuals to understand vitality forms (Stern, 2010).

In the present study we explored whether individuals with ASD are able to recognize actions and vitality forms as expressed in a two-person interaction. Their performance was compared to a group of matched TD individuals. The results showed that, while the performance of individuals with ASD in recognizing others' action is similar to that of TD individuals, ASD individuals are clearly impaired in recognizing action vitality forms.

Our findings on preserved ability of individuals with ASD in recognizing others' actions are consistent with previous studies showing that children with ASD do not differ from TD children in understanding what others are doing (Boria et al., 2009; Hamilton et al., 2007). They also show that this capacity is not limited to object-related actions, but includes actions with social meaning.

The finding that individuals with ASD make frequently errors in vitality form recognition are in line with data by Hobson and Hobson (2008), see also Hobson, 1989, 1993, 2002; Hobson & Lee, 1999). These authors found that children with ASD are impaired in imitation of movements performed with specific "styles". In particular, individuals with and without ASD do not differ one from another in their ability to imitate even complex goal-directed actions, but those with ASD are significantly impaired in imitating the style of the experimenter's action when this is *not necessary* for goal achievement.

Hobson and Hobson (2008) interpreted their findings arguing that the deficit in style imitation observed in ASD children was due a failure to incorporate the observed style into their repertoire, "as would be anticipated if they were not identifying with the person demonstrating the actions" (Hobson & Hobson, 2008). In other words, style recognition is not a primary deficit, but rather a deficit secondary to the lack of the capacity of identifying themselves with others. Our results indicate that the difficulties that individuals with ASD present in imitating actions performed with a specific vitality form or style is not is not limited to an imitation contest. Rather, they suggest that the impairment in vitality form recognition is a *primary* deficit due to difficulty to make sense of others' behavior on the basis of action dynamics.

Several authors have underlined the existence of an atypical processing of perceptual information in autism (Dakin & Frith, 2005; Frith & Happé, 2005; Happé, 1999; Mottron & Burack, 2001; Mottron, Dawson, Soulières, Hubert & Burack 2006). Annaz et al. (2010) showed that, in autistic children, the perception of biological motion is specifically affected in comparison with other visual perceptual abilities, such as the ability to identify a series of dots moving in the same direction or to detect a moving figure standing out from surrounding background noise elements. Furthermore, contrary to TD children, individuals with ASD have difficulties to extract relevant social information from simple motion cues (Annaz, Campbell, Coleman, Milne, & Swettenham, 2012; Rutherford, Pennington, & Rogers, 2006). These findings are of particular relevance for our study because they clearly indicate that the deficits in recognizing forms of vitality are not due to basic deficits in motion perception but to a deficit in transforming the physical aspects of movements into psychological categories.

Autistic individuals are also impaired in correctly processing social information conveyed by faces or body movements (Reed et al., 2007). They are even more impaired when asked to report the emotions depicted in the observed actions (Atkinson, 2009; Congiu, Schlottmann, & Ray, 2010; Hubert et al., 2007; Moore, Hobson & Lee, 1997) or expressed on a face (Ashwin, Wheelwright & Baron-Cohen, 2006; Teunisse & De Gelder, 2001). It is important to stress, however, as also stated by Stern (2010), that vitality forms express psychological states distinct from emotions. Vitality forms convey, as emotions do, information on the internal state of the acting individuals, but they lack that strong contagious effect that determines vegetative and often overt motor responses in the observer during emotion observation.

Dissociation between neural substrates active during basic emotions and those active during vitality forms recognition has been recently demonstrated by a brain imaging study. In an fMRI study, Di Cesare et al. (2013) assessed the neural correlates of vitality form recognition presenting participants with videos showing two actors performing different actions with same or different vitality forms. Similarly to the present experiments participants were asked to focus their attention on either the goal or the vitality form of the presented action. The results showed that both action goal and vitality form recognition recruited the parieto-frontal network typically involved in encoding hand and arm actions (see Caspers, Zilles, Laird & Eickhoff, 2010; Rizzolatti & Craighero, 2004, Rizzolatti & Sinigaglia, 2010). Most importantly, the contrast-vitality effect vs. action recognition-revealed activation of the dorso-central insular cortex. This region is considered an extension of the parietal lobe and is connected with areas in the medial temporal region (see Mesulam & Mufson, 1982). This region is *not* connected with the anterior insula, that is with the insular sector involved in emotions expression and recognition (Kurth, Zilles, Fox, Laird, & Eickhoff, 2010; Caruana et al., 2011). This indicates that the circuitry mediating emotions and vitality forms are anatomically different.

Finally, it is worth noting that our data indicate that the impairment shown by individuals with ASD in vitality form recognition is present not only in children with ASD, but persists through maturation. This finding is of great interest especially considering that other kinds of action understanding deficiencies, including those indexed by Theories of Mind (ToM) tests, tend to vanish with age (Frith, 2003; Happé, 1995). This suggests that individuals with ASD may overcome cognitive action understanding deficits, but not the basic sensory-motor deficits affecting vitality form recognition. This is even more interesting in light of a number of studies arguing that vitality form recognition is a primordial way of relating to and understanding others, thus representing a core element of social interactions (Rochat, 2009; Stern, 1984, 1985, 2004, 2010; Trevarthen & Aitken, 2001; Trevarthen, 1998). Impairment in vitality form recognition could therefore be at the basis of the social impairment characterizing people with ASD, with cascading effects on the ability to be socially tuned, including the mentalization deficits identified in other studies (Baron-Cohen et al., 1985; Frith, 2003; Happé, 1995). These preliminary findings open a wide range of questions for future research, such as the extents to which ASD differ from TD individuals in the vitality dynamics of their own goal-directed actions and in their appreciation of time-based arts aesthetic expression.

Summing up, our findings indicate that individuals with ASD are significantly impaired in vitality form recognition. This impairment concerns a component of action, that is, action dynamics, which is as much as crucial as the action goal in making sense of another's behavior. Because of its persistence in development, the impairment in vitality form recognition might shed new light on the core social deficits in autism, providing a new conceptual platform for clinical interventions with young as well as older individuals diagnosed with autism.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.neuropsychologia.2013.06.002.

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