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ORIGINAL ARTICLE

Recognition of Action Vitality Forms is Linked to Social Communication Traits in Autism

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Abstract

Vitality Forms (VFs) capture the essence of human movement, revealing how we engage in actions. Perceiving and expressing VFs are crucial for social communication, allowing us to understand the behavior of others. Despite their pervasiveness in our life, research on VFs in autism is limited. The present study aims to investigate the perception of different VFs in children presenting an Autism Spectrum Condition (ASC) in comparison to neurotypical children (NT). Both groups observed pre-recorded actions with different VFs previously performed by the same ASC and NT children. After the observation of each action, children judged their VFs using a four-point Likert scale. Our results highlight three key findings: (1) ASC children recognized VFs, but with significantly lower accuracy (57.2%) than NT children (70%); (2) ASC children took longer to recognize VFs (1751ms) compared to NT children (1323ms); (3) these differences correlated with the ADOS Social Affect score in ASC children. The slower and less accurate VFs recognition in ASC suggests a potential delay in understanding VFs, possibly due to a different processing of visual cues like speed or acceleration. Overall, this study contributes to shed light on how VFs impact social communication in autistic children, informing future interventions and support.

Keywords Social cognition · Action perception · Affective communication · Action forms

Introduction

The American psychiatrist and psychoanalyst Daniel Stern firstly proposed the concept of Vitality Forms (VFs) (Stern, 2010). Vitality, in his view, is a "manifestation of life" which constantly permeates human daily experiences. It manifests in various dynamics, primarily conveyed through movement. Vitality dynamics refer, according to Stern, to shifts in forces that occur during motion. VFs dynamics convey the affective tone of our behavior, ranging from positive to negative, and thus define our modalities of interaction. They are expressed through patterns of movement, space, velocity, and force, defining the ways in which an action can be performed. For instance, a door can be opened gently or forcefully. These different manners (the "how" of the action) of performing the same action (the "what" of the action) involve distinct kinematic parameters and express different affective tones. Importantly, VFs differ from basic emotions (joy, anger, sadness, fear, love, disliking, and liking) in various respects such as triggering events, duration, voluntary nature, and brain activity (for a detailed discussion

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see Di Cesare et al., 2020). Basic emotions are short-lasting events triggered by internal or external events, typically ending soon after the stimuli terminate. These emotions are not voluntary and are not always related to actions; they can be elicited passively (e.g., feeling happy without action) and often induce visceromotor responses. In contrast, VFs are voluntary events that modulate behaviors providing information about the affective states of the agents involved. Indeed, when interacting with another individual, the execution of a rude or gentle action enables one to communicate their mood. Conversely, the observation of these VFs allows an observer to understand the mood or attitude of an agent.

In recent years, Di Cesare and colleagues have experimentally investigated VFs to identify the kinematic patterns characterizing them (Niewiadomski et al., 2021) and to define their neural underpinnings (Di Cesare et al., 2021). These authors discovered that we are endowed with a mirror mechanism (Rizzolatti & Craighero, 2004; Iacoboni & Dapretto, 2006; Rizzolatti & Fabbri-Destro, 2008; Keysers & Fadiga, 2008) situated in the middle and posterior insula short gyri and the middle cingulate cortex which allows us to both express and understand VFs (Di Cesare et al., 2015; Cesare et al., 2021). Notably this insular sector is different from the anterior one, typically involved in the emotional processes of states such as anger and fear (e.g., Wicker et al., 2003; Gallese et al., 2004; Singer et al., 2004; Grosbras & Paus, 2005; de Gelder, 2006; Jabbi et al., 2008; Pichon et al., 2009), was not found, confirming the differentiation between VFs and emotions. Interestingly, it has been empirically shown that VFs are also conveyed through linguistic communication (Di Cesare et al., 2017a; Cesare et al., 2017b, 2021). Auditory vitality forms are shaped by the physical properties of sound and convey how a message is delivered, independent of its content. For example, we can greet a friend warmly or coldly by adjusting the tone of our voice to express enthusiasm or neutrality. Recently, vitality forms (VFs) have been studied in relation to socio-cognitive traits in individuals on the autism spectrum. People with autism spectrum condition (ASC) often face challenges in social interactions due to difficulties in understanding the nuances of social behaviors. Empirical findings suggest that some ASC children struggle to recognize VFs, while they do not differ from neurotypical (NT) children in identifying the goal of an action (Rochat et al., 2013; Di Cesare et al., 2017a; Cesare et al., 2017b). In a study by Di Cesare and colleagueCesare et al. (2017a, b), ASC and NT children watched video clips of a person performing an action and were asked to verbally judge whether the person's behavior was gentle or rude. Similarly, Rochat et al. (2013) had ASC children watch short pairs of video clips and judge whether the actions in the first and second videos conveyed the same vitality. Both studies suggest that ASC children perceive VFs atypically and may struggle to recognize the styles in which actions are performed. It seems that ASC individuals are more likely to identify extreme forms of vitality, while subtle patterns are harder for them to interpret. Although these studies point to a deficit in VFs perception in ASC children, they do not provide details about the accuracy and reaction times (RTs) during task performance, which could be crucial for a deeper understanding of VFs processing difficulties in this population. In relation to the expression of VFs in autism, we recently conducted a study (Di Cesare et al., 2024) to explore the spatiotemporal characteristics of gentle and rude VFs performed by both autistic and NT children in social and non-social contexts. This study was the first to explore how the presence of a recipient might influence the production of VFs. The primary goals were to determine whether ASC children use different kinematics to express VFs compared to NT children, and whether a social context impacts the expression of VFs. Our findings suggest that autistic children express both gentle and rude VFs, appropriately adjusting the motor profile of their actions. However, and interestingly, they do so using distinct kinematic parameters compared to NT children, suggesting that autistic individuals employ different motor strategies.

Building on previous research, this study investigates the perception of VFs in autistic children compared to NT children, addressing two key gaps in the literature. First, we designed our stimuli to explore VFs recognition, in relation to the distinct kinematic patterns expressed by autistic and neurotypical peers. To this end, we created short video clips depicting actions performed by both autistic and neurotypical children, asking participants to categorize the VFs expressed through the kinematic patterns of these two populations. Second, our task measured not only participants' accuracy but also, importantly, their reaction times (RTs), providing insight into the time required to process the information conveyed through these VFs. We hypothesized that autistic children are faster and more accurate in recognizing VFs in actions performed by their autistic peers compared to those performed by NT children. This hypothesis is grounded in previous findings suggesting a mirror mechanism underlying the production and recognition of VFs (Di Cesare et al., 2015, 2021). Specifically, observing actions performed by autistic peers, rather than by NT children, is expected to elicit a stronger motor resonance in the autistic group.

Methods

Participants

In this study, a group of children with autism spectrum condition (ASC) ($n=20$) and a group of neurotypical (NT) children ($n=23$) were recruited. Both the ASC and NT groups consisted of right-handed males with an IQ greater than 70. There were no significant differences between the two groups in terms of age and IQ ($p > 0.05$). Exclusion criteria for ASC children included the presence of neurometabolic or genetic syndromes, epileptic encephalopathies and/or epilepsy, structural malformations of the central nervous system, and movement disorders. For NT children, exclusion criteria included a family history of autism, a personal history of language delay, intellectual disability, or any neurodivergent conditions such as autism, ADHD, motor dyspraxia, dyslexia, or anxiety. One autistic child was excluded from the study due to extreme outlier reaction time values above the mean (more than 3 SD from the mean). The study was approved by the local ethics committee of Palermo (protocol number 09-2021) and an informed consent was obtained from all children's families prior to the experiment.

Neuropsychological Assessment

The neuropsychological assessment was conducted at the clinical facilities by a multidisciplinary team consisting of two developmental psychologists, a child neuropsychiatrist and a speech and language pathologist. In the ASC group, the diagnosis of autism spectrum condition (ASC) was based on DSM-5 criteria (American Psychiatric Association, 2013) and confirmed using the Autism Diagnostic Observation Schedule, 2nd Edition (ADOS-2) (Lord et al., 1989; Gotham et al., 2009). Additionally, intellectual ability was assessed using the Italian translation (Orsini et al., 2012 of the Wechsler Intelligence Scale for Children, 4th Edition (WISC-IV) (Wechsler, 1949). For NT children, Raven's Standard Progressive Matrices (RPM) (Raven, 2003) were used to evaluate non-verbal intelligence and logical reasoning. To evaluate emotional comprehension skills in both groups, participants completed the Test of Emotion Comprehension (TEC) (Pons & Harris, 2005), which assesses this ability across nine distinct domains.

The demographic and clinical characteristics of both groups are outlined in Table 1.

Stimuli

The stimuli consisted of 80 video-clips showing a passing action performed with two different VFs: gentle (40 videos) and rude (40 videos). Each video presented either a gentle or rude passing action from an egocentric perspective, featuring both ASC and NT children. Specifically, there were 20 videos of gentle actions and 20 videos of rude actions for both ASC and NT groups. These video-clips were recorded in a previous study from the same sample of ASC and NT children. To prevent the children from recognizing their own hand and arm features, which could influence the experiment, all video clips were converted into cartoon animations (for details, see Fig. 1 and supplementary materials). Each action in the videos included two distinct phases (Fig. 1A): the reaching phase, which showed the movement from the starting position to grasp the object, and the moving phase, which depicted the transition from grasping the object to placing it.

Table 1 Clinical characteristics of the sample

	ASC children ($n=19$) (Mean ± SD)	NT children ($n=23$) (Mean ± SD)
Age (year)	10.8 ± 2.2	10.6 ± 2.1
IQ total score	98.8 ± 14.8	91.2 ± 8.5
ADOS-2 SA	9.7 ± 3.9	n.a.
ADOS-2 RRB	3 ± 2.2	n.a.
ADOS-2 total score	12.6 ± 4.1	n.a.
TEC total score	6 ± 1.7	8.2 ± 0.8

IQ Intellectual Quotient, *SA* Social Affect, *RRB* Restricted Repetitive Behaviors, *TEC* Test of Emotion Comprehension, *n.a* not applicable

Experimental Paradigm

During the experimental session, the child sat at a desk with a tablet positioned 12 cm away from the initial starting position (pinch). The child was instructed to observe the actions presented on the tablet (12" x 10") and classify them as gentle, neutral, or rude. These labels were represented by three different emoticons: happy for gentle, neutral for neutral, and angry for rude. The inclusion of the neutral label ensured that the actions conveyed the intended gentle and rude vitality forms. Additionally, a fourth label, "do not know," was provided to allow children to express uncertainty in recognizing the stimuli, represented by a gray emoticon with no expression (see Fig. 1B).

After observing each action, the child selected one of four possible labels displayed on the tablet (Fig. 1B). A total of 80 actions were presented: 20 rude actions by ASC children, 20 rude actions by NT children, 20 gentle actions by ASC children, and 20 gentle actions by NT children. Prior to the experiment, children were reintroduced to the concept of VFs (gentle, neutral, and rude) using the same procedure as in our previous study. A semi-structured survey was administered to each child. The experimenter first asked the child to define 'gentle,' 'neutral,' and 'rude' ('What does the word gentle/neutral/rude mean?'), and then to provide examples ('Can you give an example of being gentle/neutral/rude?'). Following the survey, each child viewed 12 brief video clips depicting actions with different VFs. After each clip, they were asked to verbally classify the action as gentle, neutral, or rude. Results showed that all children accurately identified the VFs, with over 75% correct responses.

Actions' Categorization

After the experimental session, we evaluated how the presented actions were perceived by both NT and ASC children by analyzing their categorizations based on perceived

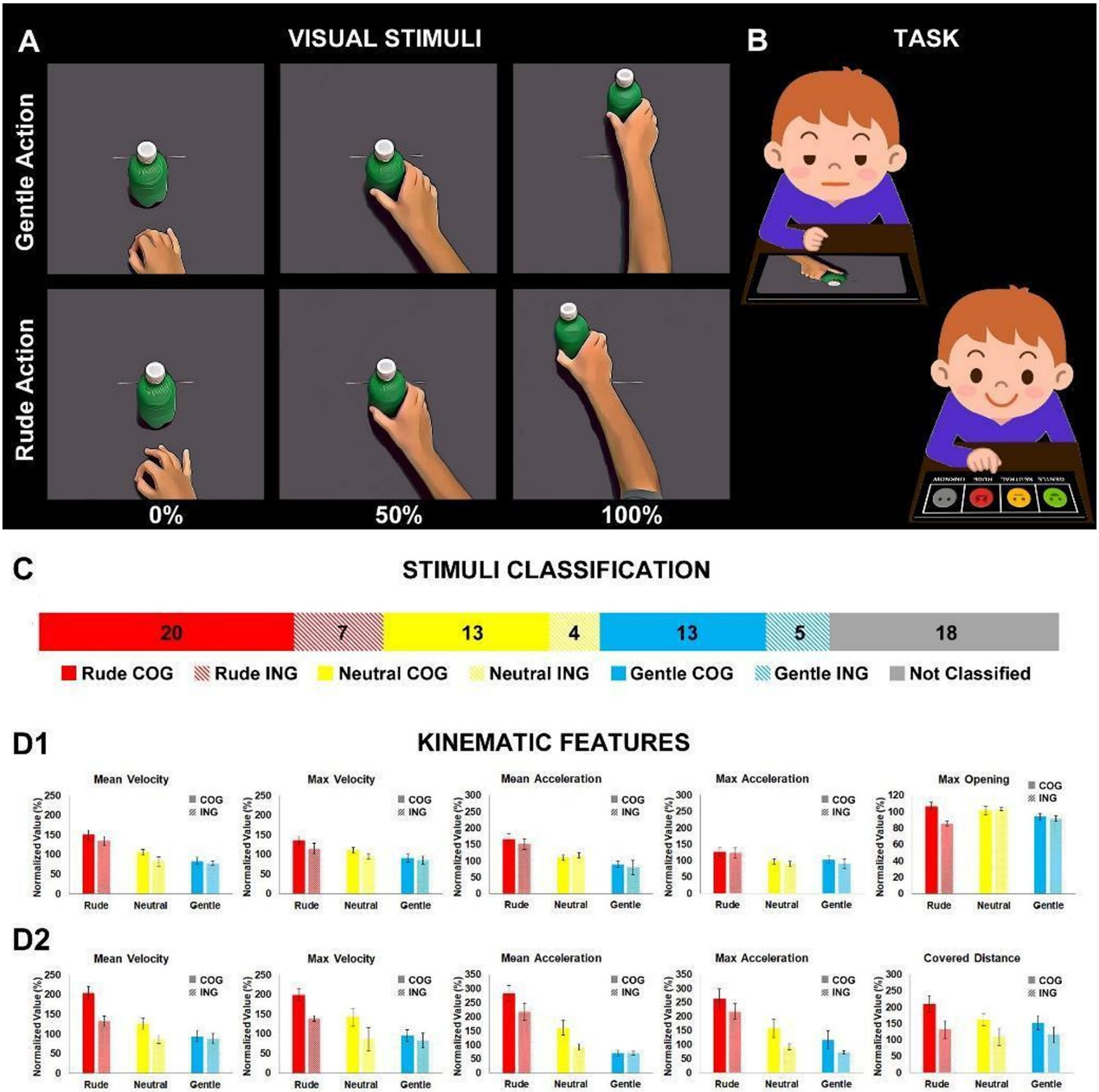

Fig. 1 Experimental Task and Stimuli. Video frames of the task showing gentle and rude passing actions transformed into cartoons, at different time intervals: starting phase (0%), middle phase (50%), and ending phase (100%). These stimuli were observed by both the ASC and NT groups during the experiment (A). Example of the task (B). Categorization of the actions observed by both ASC and NT children (C). Kinematic features of the observed actions relative to the grasping phase (D1) and moving phase (D2)

VFs. The NT group was used as the normative standard, and their responses were treated as the 'expected response'. The results indicated that a set of actions was significantly categorized as rude (ASC: 20; NT: 27), gentle (ASC: 24; NT: 18), or neutral (ASC: 20; NT: 17), with no actions significantly categorized as 'I don't know.' Additionally, 16 actions were not significantly categorized by the ASC group, and 18 by the NT group. The term 'significantly categorized' refers to the statistical reliability with which a given action was assigned to one of the four response categories (rude, gentle, neutral, or "I don't know") after viewing each stimulus. Thus, non-significantly categorized actions are those for which the response distribution did not show a clear consensus and failed to reach statistical significance. Given that the NT group was considered the normative standard, the 18 non-significantly categorized actions were excluded from

Table 2 Results of the categorization analysis, displaying the number of actions perceived as gentle, neutral, and rude by the ASC group, the NT group, both groups (congruent actions), or only by the NT group (incongruent actions)

Perceived VFs	ASC	NT	Congruent	Incongruent
Rude	20	27	20	7
Gentle	24	18	13	5
Neutral	20	17	13	4
Don't Know	0	0	0	0
Not categorized	16	18	–	–
Total Observed Actions	80	80	46	16

further analysis to ensure that only stimuli with a consistent interpretation by the NT group (i.e., significantly categorized) were included. The final analysis was conducted on the remaining 62 actions. This analysis revealed an interesting pattern: some of these 62 actions were categorized similarly by both groups, labeled as 'congruent actions' ($n=46$), while others were categorized differently, labeled as 'incongruent actions' ($n=16$) (Table 2). Consequently, we identified six categories of observed actions: congruent rude actions, incongruent rude actions, congruent gentle actions, incongruent gentle actions, congruent neutral actions, and incongruent neutral actions.

Data Analysis and Results

To examine differences between the ASC and NT groups in terms of VF recognition accuracy and reaction times, we performed a General Linear Model (GLM) analysis. The analysis included three factors: GROUP (ASC or NT), VITALITY (rude, gentle, neutral), and ACTION JUDGEMENT (congruent, incongruent). Before conducting the statistical analysis, data sphericity was tested using Mauchly's test ($p>0.05$). If sphericity was not met ($p<0.05$), the Greenhouse–Geisser correction was applied.

VFs Accuracy Analysis

The results revealed a main effect of ACTION JUDGEMENT ($F=61.45$, $P<0.001$), indicating higher accuracy in recognizing congruent actions compared to incongruent ones (Fig. 2A-1). Additionally, a significant GROUP effect was observed ($F=15.67$, $P<0.001$), with the NT group demonstrating significantly higher accuracy than the ASC group (Fig. < link rid="fig2”>2</link>A-2). No main effect was found for VITALITY($F=1.97$ $P=0.14$) nor was a significant interaction observed between Group (ASC vs. NT) and Vitality ($F=0.65$, $P=0.52$), indicating that both groups responded similarly across the different vitality forms. However, there was a significant interaction effect between GROUP and ACTION JUDGEMENT ($F=13.81$, $P<0.001$). Post hoc analysis, using Bonferroni correction, revealed a significant difference between the ASC and NT groups specifically in the incongruent condition with ASC children demonstrating significantly lower accuracy ($P<0.001$, Figs. 2A and 3).

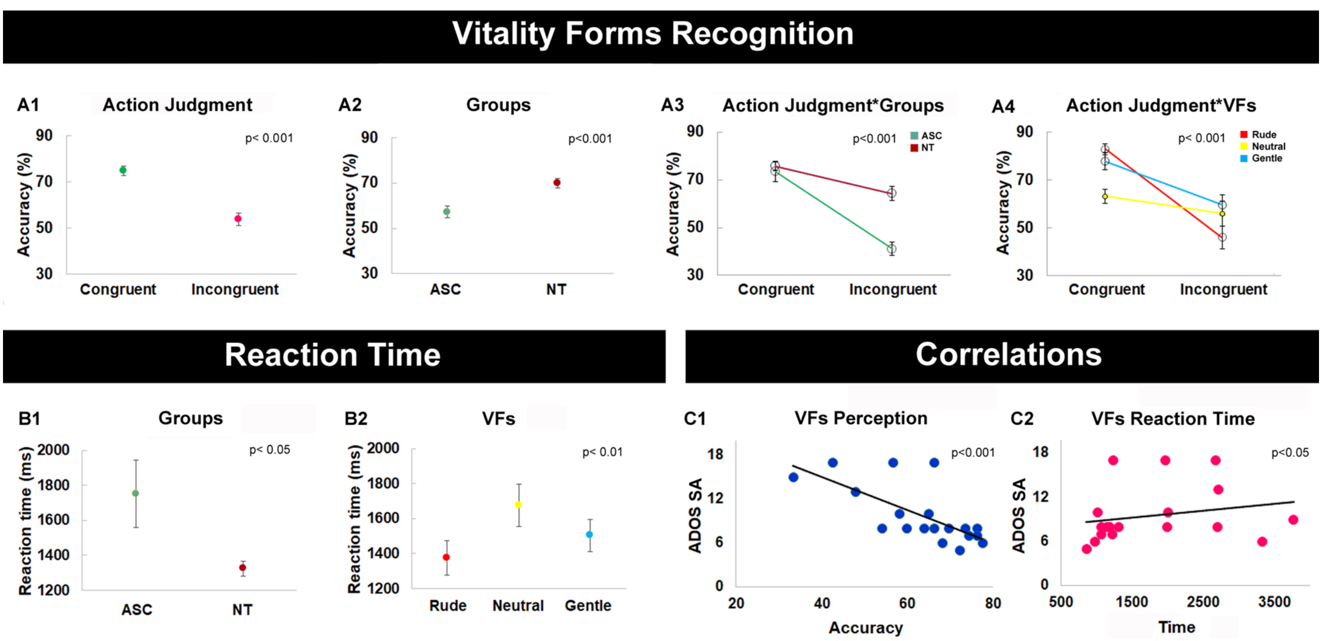

Fig. 2 Overview of the main results. Significant differences between ASC and NT groups regarding observation of VFs (A) and reaction times (B) (vertical bars represent the standard errors). Correlation analysis between the *VFs perception* (C1), *reaction time* and the scores at ADOS-2 Social Affect (SA) domain in ASC children (C2)

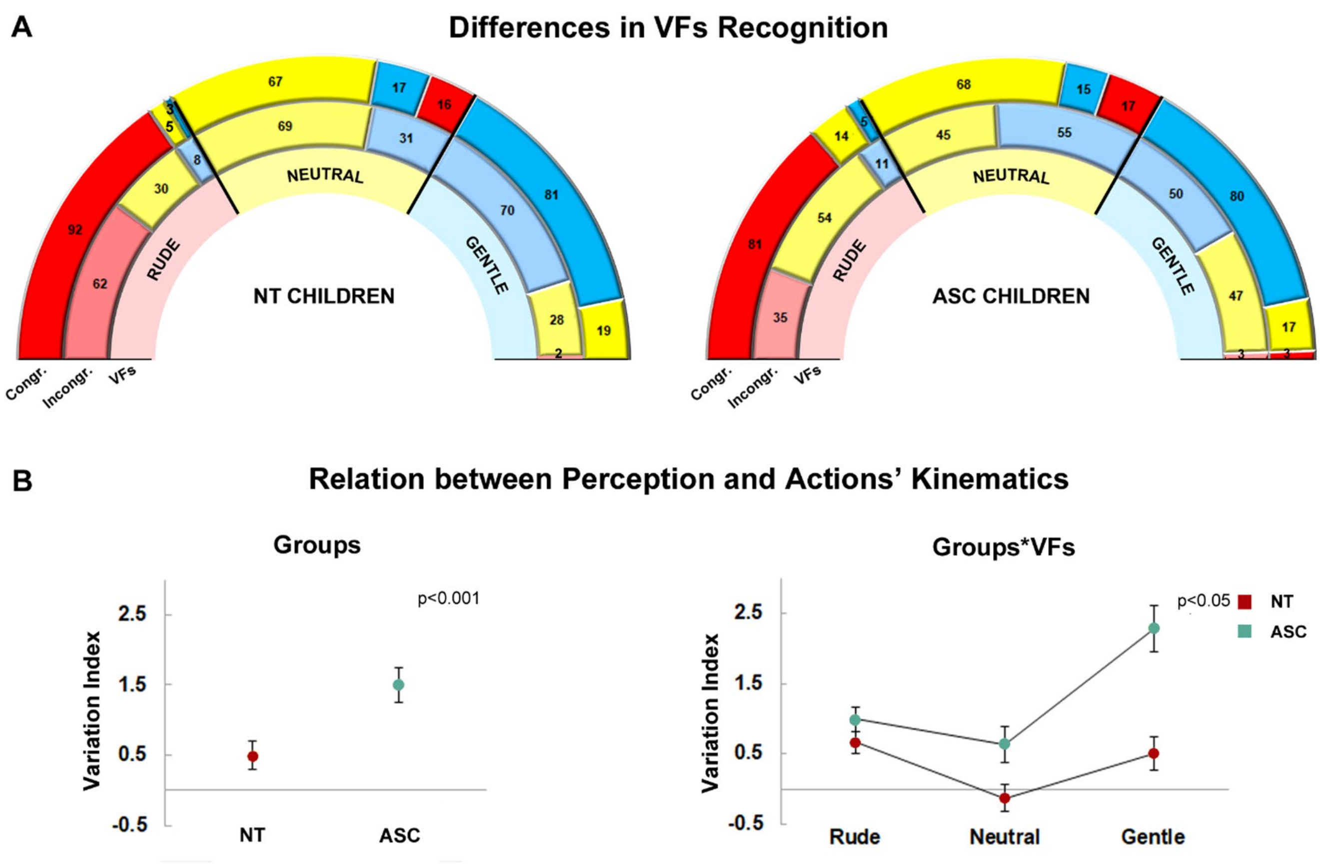

Fig. 3 Response categories obtained for ASC and NT groups during the observation of gentle, neutral, rude actions judged congruently (Congr.) and incongruently (Incongr.) (**A**). Note the change in category that occurred in ASC group passing from congruent to incongruent actions such as for rude or neutral VFs. Relation between perception and kinematics of the observed actions (**B**). High values of variation index denote greater variation of perception due to a kinematic change between congruent and incongruent actions

Moreover, a second interaction effect was found between ACTION JUDGEMENT and VITALITY ($P<0.001$; Fig. 2A-4). Post hoc analysis highlighted significant differences between congruent and incongruent judgments relative to different vitality forms: rude congruent vs. rude incongruent ($P<0.001$), gentle congruent vs. gentle incongruent ($P=0.01$), rude congruent vs. neutral congruent ($P=0.008$), rude congruent vs. neutral incongruent ($P<0.001$), rude congruent vs. gentle incongruent ($P<0.001$), rude incongruent vs. gentle congruent ($P<0.001$), rude incongruent vs. neutral congruent ($P=0.03$), and gentle congruent vs. neutral incongruent ($P=0.001$). This finding replicates previous results (Di Cesare et al., 2017a; Cesare et al., 2017b), which also reported no group × VF interaction. Notably, accuracy differences were primarily driven by the type of stimulus rather than by group-specific profiles in processing vitality forms.

Finally, it was hypothesized that ASC children might better recognize VFs conveyed by actions performed by individuals from the same group (ASC) compared to those performed by the NT group. To test this hypothesis, we compared accuracy between actions performed by the ASC group and those by the NT group. The results showed no significant differences ($P=0.92$).

Reaction Times Analysis

The results indicated a main effect of GROUP ($F=5.64$, $P=0.02$), with the ASC group displaying significantly longer reaction times compared to the NT group (Fig. 2B-1). An effect of VITALITY was also observed ($P=0.002$), showing that participants responded more slowly to neutral actions than to rude ones (Bonferroni correction, $P=0.03$, Fig. < link rid="fig2”>2</link>B-2). Additionally, we compared reaction times for observing actions performed by the ASC group versus those performed by the NT group; these analyses did not yield significant results ($P>0.07$).

Correlation Analysis

To explore the relationship between VFs recognition accuracy and reaction time in ASC children and their social communication traits, we correlated VFs accuracy with the Social Affect (SA) scores and the total score from the ADOS-2. The results showed a significant negative correlation between VFs accuracy and both the ADOS-2 SA (= −0.73, $P<0.001$) and the ADOS-2 total score (= −0.72, $P<0.001$), indicating that lower accuracy in VFs recognition was associated with higher levels of autistic traits in the social communication domain, as well as with overall ADOS-2 scores (Fig. 2C-1). Regarding reaction times, we found a significant positive correlation between reaction time and the ADOS-SA scale (= 0.46, $P=0.04$), suggesting that longer response times were linked to higher scores in the social affect domain (Fig. < link rid="fig2”>2</link>C-2). In contrast, no significant correlations were found between either VFs accuracy or reaction time and the TEC (VFs Accuracy: = 0.11, $P=0.62$; Reaction Time: = −0.22, $P=0.35$).

Kinematic Features of the Observed Actions

To investigate possible kinematic differences in the actions observed during the experiment (gentle, neutral, and rude), we referred to a kinematic analysis conducted in our previous study (Di Cesare et al., 2017a, b). Specifically, we compared various spatiotemporal features, including mean velocity (Vm), maximum velocity (Vmax), mean acceleration (Am), maximum acceleration (Amax), maximum hand opening (Omax), and maximum covered distance (Dmax), characterizing actions judged as congruent or incongruent. This analysis highlighted two main findings: first, these kinematic features varied across VFs (gentle, neutral, and rude) during both the reaching and moving phases (Fig. < link rid="fig1”>1</link>D-Figs. 1 and D and 2); second, actions judged congruently differed from those judged incongruently, particularly during the moving phase (Figs. 1D and 2). These kinematic differences may explain the distinct perceptions of VFs (gentle, neutral, and rude) observed between ASC and NT groups.

Actions Congruently Judged vs. Actions Incongruently Judged

To examine differences between actions judged congruently and incongruently for each vitality form (VF)—gentle, neutral, and rude—we conducted an a priori contrast analysis, followed by a Post Hoc analysis using the Bonferroni method. Results indicated that for congruently judged actions, both groups significantly selected the expected category based on previous categorization. Specifically, congruently judged rude actions were categorized as rude (ASC: 81.4%, $P<0.001$; NT: 91.9%, $P<0.001$), neutral actions as neutral (ASC: 67.7%, $P<0.001$; NT: 67%, $P<0.001$), and gentle actions as gentle (ASC: 80.1%, $P<0.001$; NT: 80.5%, $P<0.001$).

In contrast, for incongruently judged actions, the NT group consistently selected the expected category (rude: 62%, $P<0.001$; neutral: 68.5%, $P<0.001$; gentle: 69.9%, $P<0.001$). However, the ASC group showed different categorization patterns. Specifically, rude incongruent actions were often categorized as neutral (54.3%; neutral vs. gentle, $P<0.001$; neutral vs. rude, $P=0.002$), neutral incongruent actions were categorized as both neutral and gentle (neutral: 44.5%, gentle: 55.5%; neutral vs. gentle, $P=0.21$), and gentle incongruent actions were categorized similarly as neutral and gentle (gentle: 49.9%, neutral: 46.7%; gentle vs. neutral, $P=1.00$) (Fig. 3A). Notably, the same results was observed on a group of healthy adults (for details see supplementary Material, Figure S1).

These findings highlight a specific challenge for ASC children in recognizing incongruent action VFs. For additional details, see the Supplementary Materials.

Relation Between Perception and Actions' Kinematics

To assess how the perception of VFs varied with the kinematic characteristics of the observed stimuli, we calculated the Variation Index (VI). This index was computed using the following formula:

$$VI = \frac{p_{cog} - p_{ing}}{k_{cog} - k_{ing}}$$

where the difference between p_{cog} and p_{ing} represents the variation of perception obtained between congruently judged actions (p_{cog}) and incongruently judged actions (p_{ing}). Moreover, the difference between K_{cog} and k_{ing} denotes the kinematic variation between congruent and incongruent actions (including Vm, Vmax, Am, Amax, Omax and Dmax).

The Variation Index (VI) was calculated for both the ASC and NT groups. A VI value close to zero indicated a more similar perception of congruently and incongruently judged actions, regardless of their kinematic differences. In this context, positive and negative VI values respectively indicate a decrease or an increase in perception sensitivity to the kinematic variation of the observed stimuli.

To assess potential differences in VI between the ASC and NT groups during the observation of gentle, neutral, and rude actions, we conducted a new General Linear Model (GLM) analysis with GROUP (ASC or NT) and VITALITY (rude, gentle, and neutral) as factors. The results revealed a main effect of GROUP ($F=19.62$, $P<0.001$), showing a significantly lower VI for the NT group compared to the

ASC group. An effect of VITALITY was also observed ($P<0.001$). Notably, the interaction between VITALITY and GROUP was significant ($P=0.03$).

Post Hoc analysis, using the Bonferroni correction, indicated a significant difference between ASC and NT groups specifically for gentle actions ($P<0.001$), but not for rude ($P=1.00$) or neutral actions ($P=0.56$) (Fig. 3B). For further details, see the supplementary materials.

Discussion

In the current study, we investigated the perception of VFs in NT and ASC children. We explored both accuracy and reaction times (RTs) in recognizing VFs. Our findings provide new insights into how ASC children perceive and recognize VFs. Specifically, analysis of VFs recognition accuracy revealed a main effect of GROUP, with NT children showing significantly higher accuracy than the ASC group. There was also a main effect of ACTION JUDGEMENT, indicating that congruent actions were recognized more accurately than incongruent ones, while no significant effect was found for VITALITY, nor was a significant interaction observed between Group and Vitality, indicating that both groups responded similarly across the different vitality forms. These findings replicate previous results (Di Cesare et al., 2017a, b), which also reported no group by VF interaction, and support the idea that while congruent kinematic cues may be relatively preserved in autism, incongruent or ambiguous actions—those with more attenuated kinematic properties—were more difficult to categorize, particularly in the ASC group. This may reflect increased reliance on inferential, rather than automatic, processing mechanisms when interpreting subtler social signals.

Reaction time (RT) analysis showed a main effect of GROUP, with ASC children exhibiting significantly longer RTs than NT controls. An effect of VITALITY was also noted, with slower responses to neutral actions compared to rude ones. Correlation analysis demonstrated a significant negative correlation between VFs recognition and the ADOS-2 Social Affect (SA) scale, suggesting that reduced VFs recognition in ASC children correlates with higher autistic traits in social communication. In addition, a positive correlation between RTs and the ADOS2 SA scale indicated that higher autistic traits in social communication are associated with longer RTs, with no significant correlations found for other measures. To assess how VFs perception was affected by kinematic variations in the stimuli, a Variation Index (VI) was calculated. A lower VI in the NT group compared to the ASC group suggested that small kinematic differences had a greater impact on VFs recognition in ASC children. The analysis found main effects for GROUP and VITALITY, and a significant GROUP*VITALITY interaction. Post hoc analysis revealed significant differences between ASC and NT groups specifically for gentle actions, but not for rude or neutral ones. These results suggest that VFs recognition in ASC children is more sensitive to kinematic changes, indicating a less flexible perceptual system compared to NT children.

These results, taken together, suggest that while ASC children can identify VFs in actions performed by both their peers and neurotypical individuals, the underlying cognitive and perceptual mechanisms may be distinct. We hypothesize that VFs recognition in ASC may be mediated by a controlled, top-down process, rather than the automatic motor resonance typically seen in NT individuals. This is supported by longer RTs in the ASC group, suggesting a slower, more cognitively demanding process. Furthermore, the findings from the Variation Index (VI) analysis suggest that ASC children do not rely on motor knowledge reactivation for VFs recognition, leading to greater variability in categorization with even slight kinematic changes.

These alterations could contribute to social communication difficulties in ASC. Di Cesare et al. (2015, 2021) identified the mirror mechanism for VFs production and recognition in the middle and posterior insula in neurotypical individuals. Given that this brain region appears dysfunctional in ASC, the impaired mirror mechanism could explain difficulties in automatic VFs recognition in this population. This is in line with existing literature on the alterations of gray matter volume in the insular cortex in ASC individuals (Kosaka et al., 2010; Cauda et al., 2011; Ecker et al., 2012). Indeed, Ebisch et al. (2011) have demonstrated reduced connectivity between the anterior and posterior insular cortex and brain regions involved in emotional and sensory processing.

Limitations

This study has different limitations that should be acknowledged. First, the sample size was relatively small, which may limit the generalizability of the findings. Future studies should aim to include larger, more diverse samples to strengthen the robustness of the results. Additionally, our study primarily relied on behavioral data without concurrent neuroimaging measures, leaving the neural mechanisms underlying VF perception in ASC speculative. Incorporating functional imaging data would provide more direct insights into the specific brain regions and networks involved. Finally, while we explored kinematic variations in VFs recognition, the range of actions observed was limited. Future research could include a broader spectrum of action to better understand the impact of kinematic changes on VF perception in ASC.

Conclusion

Overall, our results indicate that ASC children can recognize VFs in actions performed by both ASC peers and NT individuals, but the mechanisms underlying their perception differ. VFs recognition in ASC appears to rely more on a top-down, inferential and more cognitively demanding process rather than an automatic, bottom-up motor resonance and mirror mechanism. This cognitive approach appears more susceptible to kinematic variations in the observed stimuli, as demonstrated by the increased categorization variability in the ASC group. These insights not only improve our understanding of the perceptual and cognitive mechanisms in ASC but also underscore the importance of exploring alternative strategies for supporting VFs recognition in this population. Future investigations should further examine the role of the insular cortex and its connectivity in VFs recognition, potentially leading to more targeted interventions to enhance social communication skills in children with ASC.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10803-025-06953-2.

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Declarations

Competing Interests None.

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