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**Personal space regulation in childhood autism: effects of social interaction and person's perspective**

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## Lay abstract

In the current study, personal space, i.e., the protective area surrounding the body in which others' intrusion may cause discomfort, was investigated in children with Typical Development (TD) and with Autism Spectrum Disorder (ASD). The distance we maintain from other people depends on both situational and individual factors. To measure this space, two features can be considered, one is permeability (i.e., space extension) and the second is flexibility, that is how easily this space changes following interaction with other people. This space can be measured by asking participants to move toward another person (confederate), and to stop at their comfortable distance. Studies using this paradigm revealed that ASD children prefer larger personal space, and are less susceptible to reduce interpersonal distance after a brief cooperative interaction with others, compared to TD children.

Here, we explored how the quality of social interaction influences personal space. The comfort interpersonal distance was measured before and after a play-time interval during which the confederate cooperated or not with the child. Moreover, to verify whether participants chose for themselves or for other people the same comfort distance, the task was performed both in first- and third-person perspective. Finally, the severity of social impairment in everyday activities was considered as a relevant factor influencing personal space regulation.

Our results revealed that the degree of impairment in everyday social interactions reported in ASD children impacts on their ability to adapt the comfort distance after a cooperative interaction, differently in first- and in third-person perspective.

**Scientific Abstract**

Studies in children with Typical Development (TD) and with Autism Spectrum Disorder (ASD) revealed that autism affects the personal space regulation, influencing both its size (permeability) and its changes depending on social interaction (flexibility).

Here, we investigate how the nature of social interaction (Cooperative vs. Uncooperative) and the person perspective influence permeability and flexibility of interpersonal distance. Moreover, we tested whether the deficit observed in ASD children, reflects the social impairment in daily interactions.

The stop-distance paradigm was used to measure the preferred distance between the participant and an unfamiliar adult (first-person perspective, Experiment 1), and between two other people (third-person perspective, Experiment 2). Interpersonal distance was measured before and after the interaction with a confederate. The Wing Subgroups Questionnaire was used to evaluate social impairment (SI) in everyday activities, and each ASD participant was accordingly assigned either to the lower (low-SI ASD), or to the higher social impairment group (high-SI ASD).

We observed larger interpersonal distance (*permeability*) in both ASD groups compared to TD children. Moreover, depending on the nature of social interaction, a modulation of interpersonal distance (*flexibility*) was observed in TD children, both from the first- and third-person perspective. Similar findings were found in low-SI but not in high-SI ASD children, in Experiment 1. Conversely, in Experiment 2, no change was observed in both ASD groups. These findings reveal that social impairment severity and a person's perspective may account for the deficit observed in autism when flexibility, but not permeability, of personal space is considered.

**Keywords**: interpersonal distance; autism; social interaction; perspective taking.

**Introduction**

When we are engaged in a social interaction, we automatically and reliably regulate the distance maintained between ourselves and other persons. Interpersonal distance has been traditionally used as a measure of the extent of personal space, defined as the space around an individual in which intrusion by others may cause discomfort (Hall, 1966; Hayduk, 1983). In order to define personal space, two main features have to be considered: one is *permeability*, which refers to how individuals tolerate intrusion by others, and can be operationalized in terms of space extension; the other distinctive feature of personal space is *flexibility*, which refers to how easily this space may change, depending on emotional context (Tajadura-Jiménez et al., 2011), the degree of intimacy and familiarity with the interlocutor, his/her gender or age (Remland et al., 1995).

Several studies have shown that interpersonal space might be impaired in neuropsychiatric disorders, such as personality disorder (Vieira et al., 2014; Schienle et al., 2015), schizophrenia (Park et al., 2009; Delevoye-Turrell et al., 2011), and autism (Parsons et al., 2004; Gessaroli et al., 2013; Kennedy et al., 2014).

A study by Gessaroli et al., (2013) revealed that children with Autism Spectrum Disorder (ASD) prefer larger personal space compared to children with Typical Development (TD), thereby indicating a deficit of personal space *permeability*. The presence of an abnormal interpersonal distance was expected in ASD individuals since they primarily suffer from social and communicative deficits (Frith and Frith, 2006; Senju, 2012; Happé and Frith, 2014). However, the findings concerning how personal space is altered in ASD remain controversial. Indeed, previous studies have revealed that ASD participants may show inappropriate behaviours along two opposite edges. While some research reported that ASD individuals stay too far from other people and avoid any contact (Freitag, 1970; Gessaroli et al., 2013), other studies concluded that ASD are likely to stay closer to others than the norm (Pedersen et al.,1989, 1997; Parsons et al., 2004; Kennedy et al., 2014).

For instance, Kennedy and coworkers (2014) reported abnormalities in social distance regulation using both parent-report data and behavioural measures in individuals with ASD. Furthermore, adopting virtual reality, Parsons and colleagues (2004) investigated social appropriateness in ASD adolescents. The study showed how some ASD participants do not respect the space of virtual characters, including walking directly in-between two characters engaged in a conversation. By contrast, other ASD adolescents seemed to have a general understanding of interpersonal distance rules.

In addition, in autism, not only permeability but also flexibility of personal space seems to be altered. In this respect, Gessaroli and colleagues (2013) investigated whether personal space may shrink following a brief cooperative interaction with an unfamiliar adult in TD and ASD children. After the interaction, a reduction of interpersonal distance was observed in TD but not in ASD children, suggesting a lack of personal space *flexibility*. However, this study did not rule out whether the lack of modulation of personal space in ASD children was due to social interaction *per se* or to the cooperative nature of social interaction. Indeed, the authors compared the effects on interpersonal distance of a positive interaction between the confederate and the child with a condition in which no interaction occurred. However, the cooperative vs. uncooperative nature of the interaction may be relevant, such that a cooperative social interaction may engage TD but not ASD children, resulting in a reduction of personal space in the former but not in the latter population. By contrast, a social interaction that is not characterized by positive feelings may yield similar effects on personal space, both in TD and ASD children.

Given this empirical background, we hypothesized that the nature of social interaction may play a key role in explaining the abnormal regulation of interpersonal distance modulation previously reported in ASD children (Parsons et al., 2004; Gessaroli et al., 2013; Kennedy et al., 2014).

To this aim, in a first experiment (Experiment 1) a stop-distance paradigm was used to measure personal space in ASD and TD children, both before and after a brief social interaction with an unfamiliar adult (woman confederate). In a between-subject design, the confederate adopted two different relational attitudes with participants, thus resulting in either a Cooperative or an Uncooperative interaction.

We expected larger personal space in ASD compared to TD children (i.e. a deficit in permeability), and a reduction of personal space size following a Cooperative interaction in TD but not in ASD children (i.e. a deficit in flexibility). Conversely, no such effect was expected following an Uncooperative interaction in both groups.

In addition, we conducted a second experiment (Experiment 2) in which participants judged the comfortable interpersonal distance between two unfamiliar individuals (one child and one adult), before and after having observed them engaged in a social interaction. Here, the critical question is whether the deficit reported in ASD children when they regulate interpersonal distance between themselves and others also manifests itself when they estimate others interpersonal distance. Indeed, research on social cognition has pointed out that when ASD individuals observe a social interaction they reveal difficulties in adopting anothers perspective (Frith, 1996).

Finally, we investigated whether the impairment in interpersonal distance regulation in ASD children may be related to the social impairment reported in everyday life. To this aim, a critical question of the Wing Subgroups Questionnaire (Castelloe et al., 1993; WSQ, for details referred to Clinical Assessment section), assessing the child's social impairment severity reported when he approaches an unfamiliar adult in everyday life, was adopted as an index of appropriate space regulation. We hypothesized that the greater the severity of social impairment in social daily interactions, the higher the impairment observed in interpersonal distance regulation.

## Methods

## Participants

Twenty-four male children with high-functioning Autism Spectrum Disorder (ASD; mean age±sd: 10.3±1.15 years; mean education±sd: 4.3±1.10 years) participated in the study. Participants with Autism were recruited through two regional centres for children with ASD. All children with Autism had attended the centre for a minimum of four years during which they received individual and group-based intervention based on cognitive behavioural therapy. The diagnostic classification of ASD was given by an experienced clinician according to established *Diagnostic and Statistical Manual of Mental Disorders, 4$^{th}$ Edition*, criteria (DSM-IV, American Psychiatric Association, 2000). Specifically, restricted, repetitive and stereotyped patterns of behavior, interests and activities and a qualitative impairment in social interaction and communication were considered as diagnostic criteria.

Fourteen male children with Typical Development were recruited in local schools as age-matched control group (mean age±sd: 9.7±1.08 years; mean education±sd: 3.7±1.08 years).

All participants completed the Raven Matrices to obtain an index of logical reasoning.

For each child, we received parental written informed consent to participate in the study. The study was approved by the Hospital Ethics Committees (Reggio Emilia and Rimini, Italy) and was conducted in agreement with the Helsinki Declaration, 2008.

*Clinical Assessment*

In order to confirm the diagnosis, all ASD children were assessed with the Autism Diagnostic Observation Schedule – Generic scale (ADOS-G; Lord et al., 2000). A Full Scale IQ score of 70 or above, as assessed by the Italian adaptation of the Wechsler Intelligence Scale for Children (WISC-III, Wechsler, 1991), was taken to be an index of high-functioning Autism (see Table 1 for details).

*Insert Table 1 about here*

**Table 1:**

Demographical and clinical data on TD and ASD children are reported according to the Type of Interaction groups.

| | Uncooperative Interaction | | | | | Cooperative Interaction | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Group** | N | AGE | CPM | IQ total | ADOS | N | AGE | CPM | IQ total | ADOS |
| TD | 7 | 10 | 79 | ---- | ---- | 7 | 10 | 78 | ---- | ---- |
| low-SI ASD | 5 | 10 | 68 | 91 | 11 | 7 | 9 | 81 | 103 | 10 |
| high-SI ASD | 7 | 11 | 73 | 81 | 14 | 5 | 11 | 78 | 97 | 13 |

Age (years); CPM (Coloured Progressive Matrices) corrected for age and reported as percentile; IQ scores corrected for age; ADOS (Autism Diagnostic Observation Schedule) = total score are reported.

To investigate whether interpersonal distance regulation reflects the level of social impairment reported in everyday activities, we adopted the Wing Subgroups Questionnaire. In order to determine the severity of social impairment in ASD children, the rating on one item from the Wing Subgroup Questionnaire (Castelloe et al., 1993) was taken as an index of appropriate personal space regulation during daily social interaction. The item, which states "*When the child is with unfamiliar adults or children, he readily approaches others to interact. His manner of interacting is generally appropriate (not awkward or unusual)*", was translated into Italian and administered to the therapist who was in charge of the child's treatment. The therapist evaluated how well the statement describes the child's behavior in everyday activities on a 7-point Likert scale, ranging from 0 (never) to 6 (always). Note that the lower the value, the greater are the difficulties in space regulation. Based on these scores (overall mean=2.2; range=0-5), ASD children were categorized as ASD with low social impairment (n=12; low-SI ASD; mean score=3.5±1.01; mean age±sd: 10.1±1.23 years; mean duration of therapy±sd: 4.6±2.29 years) and ASD with high social impairment (n=12; high-SI ASD; mean score=0.8±0.78; mean age±sd: 10.6±1.07 years; mean duration of therapy±sd: 5.1±1.24 years), by using a median split (median value=3).

During the experimental procedure, to allow successful blinding of participants, both the therapist and the adult confederate involved in the experimental procedure were not aware to which group (low- or high-SI ASD) each child with Autism was assigned. Accordingly, ASD children were randomly assigned either to the Cooperative (low-SI ASD n=7; high-SI ASD n=5) or to the Uncooperative Interaction (low-SI ASD n=5; high-SI ASD n=7).

**Procedure**

In order to obtain a measure of personal space, the stop-distance paradigm (Kennedy et al., 2009; Gessaroli et al., 2013) was used in two separate experiments. In social psychology substantial evidence has been marshaled demonstrating the reliability of the stop-distance paradigm as a measure to derive estimates of interpersonal distance (Greenberg et al., 1980). Experiments were conducted in a room 7 x 8 meters, where four people were always present: two female adults (one experimenter and one confederate), and two male children (one participant and one confederate). Before starting the experiment, all participants received an explanation of the task: then, the adult- and the child-confederate were introduced.

In the Experiment 1 (First-person perspective of interpersonal distance**)**, the participant and the adult-confederate were standing at two predefined locations facing each other, five meters away. The child-confederate, who was naïve as to the purpose of the study, was seated on a chair in front of them (two meters away), halfway between the participant and the adult-confederate (see Figure 1a).

*Insert Figure 1 about here*

In half of the trials, the adult-confederate approached at a natural gait toward the participant (adult approaching). Participants were instructed to tell the adult-confederate to stop at their preferred distance (i.e., the distance between themselves and the confederate at which they felt most comfortable). In the other half of the trials, the participant approached the adult-confederate (child approaching), and stopping at his preferred distance. During the approach, the adult-confederate made no eye contact, maintained a neutral facial expression and never touched the participant.

The interpersonal distance was measured with a digital laser measurer (Agatec, DM100, error ±.003 m), as the distance between the adult-confederate's and the participant's chest.

Since we were interested in observing changes of personal space extension after interacting with an unfamiliar individual, the whole procedure was repeated twice, before and after a 10-minute interval of play-time.

During the interval, the experimenter invited the participant to sit at the table next to the adult-confederate and to play together with LEGO. The child-confederate quietly observed the interaction two meters away from the participant and the adult-confederate (see Figure 1c). To explore whether and how the nature of social interaction specifically modulates interpersonal distance, participants were submitted either to a Cooperative or Uncooperative interaction. To address this issue, during the interaction, the participant was confronted either with a reciprocal and cooperative adult-confederate (Cooperative interaction; see Figure 1c), or with a silent and uncooperative adult-confederate (Uncooperative interaction; see Figure 1d).

In Experiment 2 (Third-person perspective of interpersonal distance), the adult- and child-confederate were standing at two predefined locations facing each other, five meters away, and the participant was seated on the chair in front of them. In order to ensure an adequate observation of each experimental trial without having to rotate the head, the participant stood in the halfway point between the adult- and the child-confederate (two meters away, see Figure 1b). In half of the trials, the adult-confederate moved toward the child, whereas in the other half of the trials, the child-confederate approached the adult. Each participant was instructed to stop either the adult- or the child-confederate, depending on the trial, at the distance he judged most comfortable for them (i.e., the distance between the child- and the adult-confederate at which they felt most comfortable). As for Experiment 1, the whole procedure was repeated twice, before and after a 10-minute interval of play-time.

During the interval, the experimenter invited the child-confederate to sit at the table next to the adult-confederate and to play together with LEGO. In this phase, the participant observed the interaction two meters away from the adult- and the child-confederate (see Figure 1c).

Again, during the interaction, the participant was confronted or with a Cooperative or with a Uncooperative interaction.

All participants performed both Experiment 1 and 2, and were randomly assigned either to the Cooperative or to Uncooperative interaction condition. The order of the experiments was counterbalanced across participants, so that half of the participants performed Experiment 1 first, and the remaining half performed Experiment 2 first.

For each experiment, a total of 20 completely randomized trials were performed, 10 before and 10 after the interaction, half for each approach condition depending on whether the adult or the child began the movement. All the above described procedure was video recorded.

## Results

*Statistical analysis*

For each participant, interpersonal distance scores above 1.5 standard deviation of the overall mean were excluded from the data set (8% out of all cases). Since our data were not normally distributed, as the Kolmogorov-Smirnov test showed, we applied a natural log transformation. Statistical analysis was conducted on transformed data, however, for the sake of clarity, interpersonal distance reported here are expressed in mm.

Since we were interested in simultaneously comparing three different groups (TD, low-SI ASD, and high-SI ASD), on two different conditions (Uncooperative and Cooperative Interaction), in order to avoid that potential and relevant group differences may be left uncovered, we used the Duncan's new multiple range test (MRT) for post-hoc comparisons as it affords an adequate level of power. The magnitude of the effect size was expressed by partial eta squared ($\eta^2_p$). Data manipulation and statistical analyses were performed using STATISTICA 10 software.

In order to exclude possible difference across the three groups on age and educational level, two Analyses of Variance (ANOVA) tests were conducted. These analyses confirmed that the three groups did not statistically differ on age [$F(2,35)=1.78$; $p=.18$], or educational level [$F(2,35)=1.51$; $p=.24$].

In addition, to rule out possible differences across groups due to different level of mental age, the Kruskal-Wallis test was used to compare the three groups on percentile score obtained from completion of the Raven Matrices. No significant differences were found [$H(2)=2.53$; $p=.28$].

As for children with Autism, a t-test for independent samples confirmed that two groups (low- and high-SI ASD) did not differ on therapy duration ($t_{22}=-0.68$; $p=.50$).

*Analysis of interpersonal distance before the interaction*

First of all, to exclude possible differences across the groups assigned to the Cooperative or to the Uncooperative group before the interaction, we conducted separate ANOVAs for Experiment 1 and 2 on the preferred interpersonal distance adopted with Group (TD, high-SI ASD, low-SI ASD) and Type of Interaction (Cooperative and Uncooperative) as between-subject variables, and Person Moving (adult and child approaching) as within-subject variable.

Experiment 1

The variable Group was significant [$F(2,32)=6.34$; $p<.005$; $\eta^2_p=.28$]: TD children preferred shorter distance (1094 mm) compared to both ASD groups (low-SI ASD=1621 mm; $p<.05$; high-SI ASD=1912 mm; $p<.003$). Conversely, the two ASD groups were not significantly different from each other ($p=.18$, see Figure 2a).

*Insert Figure 2 about here*

The variable Person Moving was significant [$F(1,32)=7.22$; $p<.01$; $\eta^2_p=.18$]: participants chose shorter distance when they move toward the confederate (1417 mm), compared to when the confederate approached to them (1621 mm; see Figure 3a).

*Insert Figure 3 about here*

The variable Type of Interaction [$F(2,32)=0.54$, $p=.47$], as well as its interaction with Group were not significant [$F(2,32)=1.61$, $p=.21$; observed power=.32]. Thus, no differences were observed between groups assigned to Cooperative and Uncooperative interaction, both for TD and ASD children.

Experiment 2

A significant effect was found for the variable Group [$F(2,32)=2.73$; $p<.005$; $\eta^2_p=.28$]: TD children preferred shorter distance (903 mm) compared to both ASD groups (low-SI ASD=1509 mm; $p<.01$; high-SI ASD=1781 mm; $p<.005$). By contrast, no difference was found comparing the two ASD groups ($p=.58$, see Figure 2b).

The variable Person Moving was significant [$F(1,32)=8.72$; $p<.005$; $\eta^2_p=.21$]: participants chose shorter distance when the child moved toward the confederate (1309 mm) compared to when the confederate approached the child (1434 mm; see Figure 3b). As in Experiment 1, the variable Type of Interaction [$F(2,32)=0.28$, $p=.60$], as well as its interaction with Group, failed to reach significance [$F(2,32)=1.25$, $p=.30$; observed power=.25].

*Analysis of interpersonal distance before and after social interaction*

In order to test the effect of the quality interaction (Uncooperative vs. Cooperative), an ANOVA was conducted on differences between interpersonal distances measured before and after social interaction (post- minus pre-interaction interpersonal distance). Separate ANOVAs were conducted for Experiment 1 and 2, including Group (TD, low-SI ASD and high-SI ASD), and Type of Interaction (Uncooperative and Cooperative) as between-subject variables. Note that, negative values indicated a reduction in personal space after social interaction, whereas positive values indicated an enlargement of personal space after social interaction.

Experiment 1

The variable Type of Interaction [$F(1,32)=10.91$; $p<.002$; $\eta^2_p=.25$], as well as its interaction with Group [$F(2,32)=3.52$; $p<.04$; $\eta^2_p=.18$], was significant.

As far as the *TD children*, shorter interpersonal distance was observed in the Cooperative interaction (-267 mm), compared to the Uncooperative (69 mm; p<.006). A similar pattern was found in the low-SI ASD group who preferred shorter interpersonal distance following a Cooperative (-254 mm), compared to an Uncooperative (100 mm; p<.02) interaction.

On the other hand, no such as effect was observed in the high-SI ASD group, in which interpersonal distance did not differ between Cooperative (-68 mm) and Uncooperative (-52 mm; p=.80) interaction. This suggested that interpersonal distance was susceptible to changes depending on the Type of Interaction both in TD and low-SI ASD children, but not in high-SI ASD children. Furthermore, concerning the Cooperative interaction, TD children preferred shorter interpersonal distance compared to high-SI ASD children (p<.02). A trend toward significance was observed when low-SI and high-SI ASD children were compared (p=.09). No difference was found comparing TD and low-SI ASD children (p=.44).

By contrast, no significant effects were observed comparing the three groups following the Uncooperative interaction (all p*s*>.28; see Figure 4a).

*Insert Figure 4 about here*

Experiment 2

The variable Type of Interaction [$F(1,32)=13.06$; $p<.001$; $\eta^2_p=.29$], as well as its interaction with Group [$F(2,32)=3.72$; $p<.04$; $\eta^2_p=.19$], were significant.

Concerning the *TD children*, shorter interpersonal distance was observed in the Cooperative (-215 mm) compared to the Uncooperative (174 mm; p<.0001) interaction. Conversely, no difference were found in low-SI ASD (Cooperative=-10 mm; Uncooperative=124 mm; p=.19), and in high-SI ASD groups (Cooperative=45 mm; Uncooperative=168 mm; p=.56), in which no change was observed in interpersonal distance depending on the Type of Interaction.

Following the Cooperative interaction, TD children chose shorter interpersonal distance compared to low-SI and high-SI ASD children (all p*s*<.05). By contrast, the ASD groups did not differ from each other (p=.30).

No significant effects were observed comparing the three groups following the Uncooperative interaction (all p*s*>.47, see Figure 4b).

To sum up, in Experiment 1 when participants judged interpersonal distance following a Cooperative interaction, comparable changes in the preferred interpersonal distance were reported in TD children and in ASD with low level of social impairment, but not in ASD with high level of social impairment. By contrast, when participants judged others' interpersonal distance (Experiment 2) following a Cooperative interaction, a lack of change was found in both ASD groups compared to TD children.

On the other hand, no differences were found across the three groups following an Uncooperative interaction, both when participants judged interpersonal distance adopting a first- (Experiment 1), as well as a third-person (Experiment 2) perspective.

Since half of the participants performed Experiment 1 first, and the remaining half performed Experiment 2 first, to verify possible spurious effect due to the order of the experiments, additional ANOVAs were performed on differences between interpersonal distances before and after social interaction that included Order of experiments as a factor. Separate ANOVAs were conducted for Experiment 1 and 2, with Group (TD, low-SI ASD and high-SI ASD), Type of Interaction (Uncooperative and Cooperative) and Order of Experiments (Experiment 1 first and Experiment 2 first) as between-subject factors. Both analyses did not reveal any significant effect, neither for the factor Order of Experiments, nor for its interaction with the other factors (Type of Interaction and Group; all $ps>.18$), thus allowing us to rule out that results were dependent on the order of experiments.

A further analysis was conducted to exclude that differences observed across low-SI and high-SI ASD groups may be simply ascribed to differences in the strength of interaction (see Supplementary results section).

**Discussion**

The aim of the present study was to investigate interpersonal distance and how it is modulated by a brief social interaction with an unfamiliar adult female, either from a first-person perspective (Experiment 1), or a third-person perspective (Experiment 2). To this purpose, a group of children with Typical Development (TD) and Autism (ASD) performed the stop-distance task, a well-established and reliable paradigm to obtain a measure of interpersonal distance (Kennedy et al., 2009; Gessaroli et al., 2013).

In line with previous studies (Freitag, 1970; Gessaroli et al., 2013), our results indicated that before social interaction, ASD participants prefer larger interpersonal distance with an unfamiliar adult (i.e., a decreased permeability), as compared to TD children (Experiment 1). A possible explanation is that ASD individuals, due to their social deficit, tend to avoid physical proximity with others, resulting in larger preferred interpersonal distance compared to controls. Intrusion of one's own personal space may elicit threat and anxiety that individuals tend to reduce by keeping other people farther away (Perry et al., 2013, 2015). Accordingly, larger interpersonal distance was found both in low-SI and high-SI ASD groups compared to TD children, revealing less tolerance to others' approach that is independent from the social impairment severity.

Despite the described differences in interpersonal space permeability, an interesting commonality in judging the interpersonal distance was found across TD and ASD groups. Indeed, all participants preferred shorter interpersonal distance when they approached the confederate compared to when the confederate approached them. This effect suggests that, since we cannot predict people approaching us, we resolve this unpredictability by maintaining others at larger distance. This phenomenon might be particularly relevant to assess potentially threatening social situations, such as people that are too close to us (Lloyd and Morrison, 2008). The presence of this effect also in ASD children, regardless of their social impairment degree, suggests that assessing potentially unsafe social cues is a spared mechanism in individuals with high-functioning autism.

Of interest for this study was to explore the effect of the *nature* of social interaction on personal space flexibility. Consistent with our hypothesis, different changes in interpersonal distance were revealed as a function of the type of social interaction in TD children. Specifically, results showed that TD children reduced their personal space following a Cooperative, but not an Uncooperative, interaction with an unfamiliar adult. The differential effect of the type of social interaction highlights the dynamic properties of personal space in TD children, and confirms the critical role of external and situational factors that affect the regulation of interpersonal distance (Hayduk, 1983; Teneggi et al., 2013).

As to ASD children, different patterns were observed depending on the social impairment level. In line with our hypothesis, a change was reported in personal space in low-SI ASD children, in which inappropriate social responses were less commonly observed, but not in high-SI ASD children, in which inappropriate social responses were more frequently reported. Thus, low-SI ASD children reduced their interpersonal distance following a Cooperative but not an Uncooperative interaction, while no such effect was observed in the high-SI ASD group (Experiment 1).

Furthermore, we provide an interesting relationship between observations reported by clinical therapists and interpersonal distance regulation, here measured by using the stop-distance task. Thus, our findings reveal that, when the social deficit observed in daily life is taken into account, critical differences in interpersonal distance regulation emerge across individuals with ASD. Specifically, we provide evidence for the impact of social impairment severity on interpersonal distance flexibility. Indeed, a lack of interpersonal distance flexibility seems to be associated with poor social functioning, as revealed by the absence of modulation in high-SI ASD children. Hence, we may suggest that due to their better social functioning, low-SI ASD children are more frequently exposed to effective social interactions, which in turn increase their opportunities to learn about social rules and thus improve their ability to adequately regulate interpersonal distance.

As to the second aim of the present study, we investigated a novel aspect of interpersonal distance regulation, namely how children estimate the personal space requirements of other people (third-person perspective of interpersonal distance), and whether they adjust this distance after observing individuals interacting with each other (Experiment 2).

In TD children, we found critical differences in interpersonal distance judged between two individuals depending on the type of their social interaction. This finding has two main implications: first, the interpersonal distance between an observed dyad, such as an adult and another child, is flexible and adjustable to changes as well as is the interpersonal distance between us and others; second, TD children are able to easily extract the meaning of an observed social interaction and use this information to update personal space requirements of others. Indeed, completely different changes were observed following a Cooperative and an Uncooperative social interaction, suggesting that TD children appropriately adjust the space between two persons according to nature of their previous interaction.

Regarding the ASD population, a different pattern of results emerged in first- and third-person perspective when we consider permeability and flexibility. Indeed, ASD children preferred larger interpersonal distance compared to TD children, in both experiments, suggesting that interpersonal distance *permeability* is equally affected when they were asked to adopt a first- or a third-person perspective. This result is consistent with neuropsychological evidence by Kennedy and coworkers (2009), who reported that an individual with bilateral amygdala lesion, S.M., considerably underestimated interpersonal distance both from the first- and third-person point of view.

By contrast, interpersonal distance *flexibility* is not equally impaired when ASD individuals were asked to adopt a first- or a third-person perspective. This is demonstrated by the completely different performance observed in Experiment 1 and 2 when ASD children were considered. Thus, following a social interaction, low-SI ASD children regulate interpersonal distance between themselves and the adult (Experiment 1), whereas no such change was found when they were asked to regulate interpersonal distance between others (Experiment 2). Together, these results suggest that the ability to dynamically adapt and appropriately regulate interpersonal distance between themselves and others is not a sufficient requisite to appropriately estimate interpersonal distance between other people. Therefore, our data support a marked inflexibility in ASD children that impairs their judgment of interpersonal distance between other people, regardless of the severity of their social impairment.

A possible explanation is that, in Experiment 2, ASD children failed to appropriately adopt anothers perspective, thereby resulting in a deficit in interpersonal distance regulation. Indeed, taking someone else's spatial perspective, requires that observers shift from their current egocentric frame of reference to others' point of view. However, a detailed analysis of our data does not seem to support this hypothesis. In Experiment 1, participants chose larger distance when the adult-confederate approached them, compared to when they moved toward the adult-confederate. Likewise, in Experiment 2, participants chose larger distance when the adult-confederate approached the child compared to when the child moved toward the adult-confederate. This was true both for TD and ASD children suggesting that, even if we did not explicitly ask participants to adopt the child or the adult perspective, in Experiment 2 they did take the other child's perspective. Consistently, recent studies conducted on high functioning ASD people (Zwickel et al., 2011; Schwarzkopf et al., 2014), have consistently shown that the ability to spontaneously adopt anothers' visual perspective is spared in high functioning autism.

The literature on perspective taking provides us with a possible explanation of why, even if ASD children "are able to put themselves in other's shoes", they fail in modulating others' interpersonal distance. In this respect, a distinction has been proposed between a perceptual form of perspective taking, which is mainly referred to how other people see the world, and the capacity to infer mental states of other people, which is mainly referred to as mentalizing (Frith and Frith, 2006). Both the above mentioned processes play a crucial role in social cognition (Teufel et al., 2010; Yang et al., 2015), and require the ability to decenter one's own perspective to match the one of the target person: one to imagine what the other is seeing, and the second one to recognize other's thoughts, feelings and desires.

In agreement with previous studies (Zwickel et al., 2011; Schwarzkopf et al., 2014; Pearson et al., 2015), we submit that the ability to visuospatially decenter one's own perspective and then match that of the observed child is spared in children with Autism. Conversely, the ability to infer mental states, such as how pleasant the child experienced the social interaction, and consequently how close he would stand to the adult confederate seems to be impaired in ASD individuals (Baron-Cohen et al., 2001)

Finally, it is worth noting that differences in flexibility among the three groups (TD, low-SI and high-SI ASD children) emerged only after a Cooperative interaction whereas no difference was found in interpersonal distance across the three groups in both Experiments after an Uncooperative interaction. This result suggests that the Uncooperative interaction is perceived as a not comfortable and potentially unsafe situation. Indeed, during the Uncooperative interaction, participants were presented with an unfamiliar adult who shows a still face and adopts a distancing posture that are perceived more distressing and arousing than a neutral expression, because of the emotion it conveys. Furthermore, this is especially true when participants adopt a third-, as compared to a first-person, perspective, because they are asked *to observe* a distressful interaction. Thus, since the social observation may be considered as an efficient way to learn about potential harmful situations in the environment, it is plausible to hypothesize that this is preserved in children with Autism.

Summing up, the present findings provide critical evidence to further our understanding of the mechanisms of personal space regulation in typical and atypical development. First, they reveal three possible factors that may have a role in influencing the personal space *flexibility* in ASD children: the nature of social interaction, the severity of social impairment and the person's perspective. However, these factors do not influence personal space *permeability*, thereby suggesting that permeability and flexibility of interpersonal distance may be subtended by partly separate mechanisms. Second, our findings put in evidence a close link between interpersonal distance regulation and social behaviors observed in everyday life. This suggests that the differences observed in interpersonal distance regulation in ASD children may in part reflect the heterogeneity of cognitive underpinnings characterizing ASD. Hence, our findings may be a starting point to encourage diagnosis and rehabilitative interventions, which take into account the altered aspects of social interaction.

## Abbreviations

ASD = Autism Spectrum Disorder

TD = Typical Development

WSQ = Wing Subgroup Questionnaire

low-SI ASD = children with low social impairment

high-SI ASD = children with high social impairment

## Competing interests

The authors declare that they have no competing interests.

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