Visual Exploration and Observation of Real-Life Interactions Between Children with ASD and Service Dogs

Nicolas Dollion1,2,3,4 © · Manon Toutain1 · Nathe François4 · Noël Champagne4 · Pierrich Plusquellec2,3 · Marine Grandgeorge1

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Abstract

Two original studies explored relationships between visual attention of children with ASD (candidates for receiving a service dog) and their behaviors during their first interaction with a service dog. The first study consisted in video behavioural analyses of 16 children with ASD interacting with a service dog. During the interaction with a service dog, the time children with ASD spent looking towards social items vs objects was associated with how they interacted with the service dog. The second study was exploratory (i.e. 6 children), using the same behavioural approach but coupled with eye-tracking data. The more children with ASD looked at both their parent and the evaluator, as opposed to inanimate items, the more they interacted with the service dog.

Keywords Autism spectrum disorder · Visual attention · Eye-tracking · Human–animal interaction · Service dog

Introduction

Autism spectrum disorder (ASD) figures among neurodevelopmental disorders, and its symptoms appear mainly during early childhood. It is characterized by a triad of alterations persisting over time and development (DSM-5; APA, 2013): (1) impairment of communication skills, including language deficits, deficit in joint attention and avoidance of reciprocal gaze; (2) difficulties in social interactions, with limited interest and issues to connect with others as well as (3) restricted and/or repetitive behaviours and interests, including verbal and motor stereotypies (APA, 2013; Wing & Gould, 1979).

Difficulties concerning social interactions are among the central issues related to ASD. Different behavioural specificities characterize the social interactions of people with ASD such as a particular inter-individual distance adjustment (Asada et al., 2016; Gessaroli et al., 2013), avoidance or aversion of human gaze (Grandin, 1995), emotional synchrony problems (i.e. infrequency or absence of social smiles), echolalia (e.g. repetition of the same word or phrase) (APA, 2013). These issues relative to people with ASD’s social interactions also extend to the extraction of information in social context and from social stimuli. When exploring a visual scene including social agents, people with ASD rarely gaze at the social stimuli (i.e. faces; Osterling & Dawson, 1994; Papagiannopoulou et al., 2014; Riby & Hancock, 2008), and they respond poorly to them in social contexts (i.e. to the pronunciation of their first name, Dawson et al., 1998). In addition, other visual attention abnormalities are associated with ASD, such as abnormal eye contact (i.e. weaker, Dawson et al., 2000) and difficulties in facial recognition (Klin et al., 1999).

Social interactions difficulties could be partly overcome through different types of treatment or interventions. Indeed,
in parallel to drug management, more and more non-pharmacological alternatives have been developed to improve the daily lives of people with ASD, and in particular intervention methods involving animals (O’Haire, 2017; Philippe-Peyroutet & Grandgeorge, 2018; Redefer & Goodman, 1989). It would appear that interactions with animals (i.e., either as a therapy animals in animal assisted intervention, or as pets or service dogs at home) have positive effects on various facets of children with ASD’s development: physical (e.g. motor development facilitator; Byström & Persson, 2015), social (e.g. increased social motivation to communicate and prosocial behaviours; Carlisle, 2012; Redefer & Goodman, 1989) and emotional aspects (e.g. comforting, regulating feelings and stress; Byström & Persson, 2015; Viau et al., 2010). Similarly, a decrease of problematic behaviours has been observed (e.g. running away, crises; Carlisle, 2012; Redefer & Goodman, 1989). Integrating an animal into the home of children with ASD (i.e., either a pet or a service dog) has been demonstrated to improve their prosocial skills related to empathy (e.g., with pets, offering sharing and comfort, Grandgeorge et al., 2012b). Moreover, in the presence of a therapy dog, children with ASD laugh more often, are in a happier mood, and engage more in conversation with the therapist about the therapy dog (Martin & Farnum, 2002). An animal, whatever its status (i.e. pet, therapy or service animal), may also facilitate a positive reinforcement of children with ASD’s social behaviours, and this in turn facilitates communication with others and the development of their social skills (Carlisle, 2012). However, it is important to note that these benefits may vary according to various factors such as the severity of children with ASD’s sensory impairment or their parents’ attitude (Carlisle, 2014a). Among the various forms of interventions including animals, an increasing use and demand of service dogs for children with ASD emerges (Walther et al., 2017). Service dogs for children with ASD received a specialized training in order to follow and support these children in all aspects of their life, with the aim to increase their daily functioning and well-being (Davis et al., 2004; O’Haire et al., 2015). In fact, the latest INESSS report (2019), summarizing the benefits of dogs for children with ASD, highlights that service dogs bring more benefits (e.g. social skills) than do pet dogs.

The benefits of owning a pet seem to be greater if the child bonds with the animal (Melson, 1991). Therefore, the benefits for children with ASD stem from the initial attraction to the animal (Carlisle, 2012; Maurer et al., 2011). Numerous children with ASD are attracted to animals (Doblin et al., submitted; Grandgeorge et al., 2012a; Grandin, 1995; Prothmann, et al, 2009, Maurer et al., 2011) and various hypotheses have been proposed to explain this attraction (Leslie, 1994; Prothmann, et al., 2009; Redefer & Goodman, 1989). Among them, authors propose that this attraction may rely on the specificities of the interaction with the animal for children with ASD. Animals’ behaviours would be more predictable and less complex to decode than those of human beings, and the interaction with the animal relies on modalities more suited to people with ASD (i.e. favouring tactile versus verbal modality) (Redefer & Goodman, 1989). Leslie (1994) even suggests the distinction between animals, as agents of actions (i.e. communicating their intentions non-verbally via body language) and humans, as agents of attitudes (i.e. using meta-representations). In line with these specificities of interactions with animals and their benefits for children with ASD, some authors suggest that a phenomenon of behaviour generalisation could be at the core of these benefits. Animals act as the first "transitional objects" for children with ASD, and they then extend this initial connection and the behavioural strategies developed during interactions with animals to other human beings (Martin & Farnum, 2002; Winnicott, 1986). Similarly, animals would be a very attractive multisensory stimulus for these children (Martin & Farnum, 2002; Redefer & Goodman, 1989). More recently, studies tend to show that nature of the interactions observed between children with ASD and animals, and particularly visual behaviours, could be one way to explore among the explanatory mechanisms (Grandgeorge et al., 2016, 2017; Vallyamattam et al., 2020).

Knowing the issues of people with ASD regarding interactions with human agents, notably concerning attraction to social agents and stimuli and their visual exploration, it seems legitimate to hypothesize that these difficulties may also extend to interspecific interactions. Nevertheless, studies tend to show that these difficulties would be less marked with animals (Carlisle, 2014b; Maurer et al., 2011). Indeed, as stated above, numerous children with ASD are attracted to animals and are not only able to interact with them, but also to establish privileged relationships with them (Grandgeorge et al., 2012b; Maurer et al., 2011). Several studies confirm that animals are attractive visual stimuli to children with ASD, both in 2D (i.e. picture of animals) and in real life (i.e. animal present in the room) (Celani, 2002; Prothmann et al., 2009). Experiments conducted using image presentation (human, animal versus object) show that children with ASD gaze more at animals than at humans and objects (Celani, 2002). Moreover, when given a choice, children with ASD interact preferentially (in terms of duration and occurrence) with an unfamiliar animal (e.g. stroking, initiation of play; Prothmann et al., 2009) than with an unfamiliar toy or an unfamiliar human. This interest in animals translates into various types of interaction and different interaction profiles. In their study in “close to life” conditions, Grandgeorge et al. (2012a, 2014) observe that during the first encounter with an unfamiliar guinea pig, children with ASD could interact according to three interaction profiles: (1) “turned towards humans” profile (the most frequent, with the child...
directing many glances towards the observer and its parent, with verbal interactions about the animal with its parent), (2) "self-centered" profile (the child manifests motor and verbal stereotypies, showing little or no interest in the animal) and finally (3) "confident" profile (common to neurotypical children in the same situation where the child goes straight to the animal, smiles and touches/kisses the animal) (Grandgeorge et al., 2012a). More recently, here again, three behavioural profiles of children with ASD interacting with an unknown service dog were distinguished: “proximal and contact with the service dog” (i.e., children who spend more time in contact with the service dog and initiated contact with it), “distant and command to the service dog” (i.e., children who notably gave commands to the service dog and interacted with it through distal behaviours such as vocalisations, gestures and gazes), as well as “disinterest for the service dog” (i.e., children who displayed more rejection gestures and vocalisation towards the service dog, and less attraction and neutral behaviors (e.g. vocalisations, gestures) towards it) (Dollion et al., submitted). It would thus seem that the animal represents a source of motivation to interact (visually, vocally), at least for many children with ASD. However, not all children with ASD are attracted by the animal and/or are able to establish a bond with it (Grandgeorge et al., 2012b). For example, Grandgeorge et al. (2012a) report that a third of the observed children did not exhibit any prosocial behaviours, either towards humans or animals, and some maintained a distance and remained indifferent to the presence of the unknown animal (i.e. guinea pig). Similarly, some children with ASD in the presence of an unknown service dog remained at distance and rejected it (Dollion et al., submitted). In addition, some children with ASD are attracted to more animals than to others. Some parents describe their children with ASD as being afraid of dogs, but that other pets are more tolerated, such as cats or rabbits (Carlisle, 2012, 2014a; Hart et al., 2018).

Visual exploration of conspecifics, especially human faces is a key element in social interactions used by neurotypical people (Racca et al., 2012). As previously highlighted, visual exploration of social stimuli also entangles specificities in ASD. Alterations in sensory and perceptual processes can lead to alterations in the establishment of representations and in interactions with their environment. Indeed, malfunction in the first perceptual processes may lead to alterations in the extraction of information, and this may result in a general misrepresentation of the object. Such alterations are often observed in people with ASD, including hypo-/hyper-sensitivity and perceptual disorder, such as defective sorting of information flow (e.g. auditory, visual, tactile). This could contribute to their difficulties in interpreting social situations and may explain the presence of context-inappropriate behavioural responses (e.g. Gepner & Féron, 2009). In relation to these alterations, the presence of an atypical visual exploration pattern in people with ASD (Klin et al., 2002; Riby & Hancock, 2008) could lead to poor information extraction, and therefore poor decision making, and explain certain behaviours specific to ASD (Mottron & Burack, 2012). For example, avoidance of human faces and of eye-contact during social interactions deprives perception of the orientation of other people’s attention and thus disrupts joint attention. This type of issue (i.e. establishing and maintaining joint attention) lead people with ASD to have difficulties sharing experiences (Bogdashina & Casanova, 2016), or poor synchronisation of emotions with others (i.e. understanding the emotional state of the other and therefore adapting/regulating their behaviour accordingly through the emotional contagion process (Prochazkova & Kret, 2017)). Therefore, atypical information extraction from social stimuli and agents could be an explanatory track to people with ASD’s interaction difficulties (Grandgeorge et al., 2016, 2017; Papagiannopoulou et al., 2014). Given these elements, it seems interesting to look at the visual strategies of the children with ASD with the animal, in order to know if alterations observed with human also extend to animals.

Among the visual cues that can be extracted during an interaction and that may significantly contribute to it, gaze is a non-verbal vector by which an individual communicates to his or her partner his or her state of attention and level of readiness to interact (Burgoon et al., 2016). Children with ASD do not exhibit a “triangular” (eyes and mouth) exploration pattern when gazing at human faces (Amestoy, 2013; Valiyamattam et al., 2020). They pay less attention to the eye area, and pay more attention to the lower hemi-facial area (Jones et al., 2008; Klin et al., 2002; Spezio et al., 2007). Yet, paying attention to the eye area allows an individual to capture a great deal of information and contributes to the establishment of interactions with others (Klin et al., 2002). Moreover, some authors suggest that staring at the eyes of a face may cause an increased emotional response for people with ASD (e.g. « his mind went blank and his thoughts stopped; it was like a twilight state» Grandin, 1995). Yet, although they explore significantly less of an animal’s eye area than do neurotypical children, it seems that the so-called “triangular” exploration is preserved in children with ASD when exploring animal faces (cats, dogs, horses) (Amestoy, 2013; Grandgeorge et al., 2016). Furthermore, a recent study confirmed the positive attentional bias towards animal images and showed that children with ASD pay significantly more visual attention to the face and eye area of frontal animal images compared to averted animal images (Valiyamattam et al., 2020). In addition, people with ASD’s recognition of human facial emotions is better when combined with an animal filter (e.g. human face with the contours of a gorilla or lion; Cross et al., 2019). Thus,
it appears that while alterations of the extraction of visual information from human social agents by children with ASD are observed, the same do not apply with animals.

While the benefits from the interaction with animals for people with ASD are well documented, the source of these benefits and their underlying mechanisms are still a matter of debate. All together, studies highlight that among the possible explanatory leads, one would be that the pattern of visual exploration used by children with ASD with animals differs from the one they use with human agents (Grandgeorge et al., 2016; Valiyamattam et al., 2020). Could this difference in information gathering be at the basis of the difference in interest and interaction profiles that can be observed in children with ASD when interacting with an animal (Grandgeorge et al., 2012a, 2014; Dollion et al., submitted)? Indeed, one could argue that the way children with ASD decode information about animals and interact with them is a direct reflection of their current representation of animals and therefore of their interest in them. In this context, the aim of our study was to explore the links between the visual attention of children with ASD towards animals, here dogs by the end of their training to become service dogs, 1 and the kind of interactions they developed with them. Based on the current literature (Grandgeorge et al., 2011, 2012a; Martin & Farnum, 2002; Prothmann et al., 2009; Dollion et al., submitted), we may hypothesize that the dog would be an attractive visual target for children with ASD, resulting in an increased attention towards it. Since not all children with ASD present the same level of interest, we expect that observations of their behaviour would reveal different profiles of interaction with the dog, as previously observed (Dollion et al., submitted). Our research was based on an ethological approach involving direct observations and, on an exploratory basis, eye-tracking in a real context of interactions. In the first study, behaviours displayed by children with ASD while interacting for the first time with a future service dog in a standardized situation were evaluated. In the second study, conducted with an exploratory approach, the same design was applied with the addition of a wearable eye-tracking system (i.e. eye-tracking glasses), in order to provide a finer measure of the children with ASD’s visual attention while interacting with the future service dog.

Study 1

Materials and Methods

Subjects

Videos were collected from Summer 2011 to Summer 2014.

Children with ASD  Recordings were extracted from the Mira Foundation’s database, which include videos of the standard evaluation performed by the foundation to establish the admissibility of children in their service dog program. The inclusion criteria for the present study were established as followed: child must have a diagnosis of ASD delivered by a clinician (i.e., pediatrician, pedo-psychiatrist, neuropsychologist), have a full recording of his/her first evaluation at the Mira Foundation and must not have previously been the recipient of a service dog, parents must have provided a written to use their child with ASD’s recording for the present study. For ethical reasons, all children included in the present study had been judged as being eligible for the Mira Foundation’s service dog program. Sixteen children with ASD were included in the first study (mean age ± SE: 8.5 ± 0.7 years old; 3.9–13.1 years old; 14 boys and 2 girls). Most of them (87.5%) had co-morbidities (e.g. Attention Deficit Hyperactivity Disorder or ADHD, intellectual deficiency, Tourette syndrome). Each child included in the project had been evaluated using the Childhood Autism Rating Scale (C.A.R.S; Schopler et al., 1980) by a professional (i.e. psychologist, psychoeducator, educational psychologist) to establish the severity level of their ASD. All were rated with a mild to moderate severity of ASD (C.A.R.S; mean score of 27.7 ± 1.0). All children with ASD were fully verbal, except for one who was partially verbal.

Dogs participants  Fifteen trained dogs were used. All originated from the Mira Foundation’s husbandry. They were 10 females and 5 males, including 5 Labradors, 3 Labernois and 5 Saint-Pierre (mean age: 22.0 ± 0.7 months at the time of the observations). All received the same training protocol and were at the end of their training to become service dog for children with ASD (i.e. about 2.5 months at least). As previously mentioned in footnote, dogs used in the present study were not service dogs per se, but were dogs by the end of their training to become service dogs. They will however be referred as service dogs in the rest of the manuscript for the sake of clarity. Each child with ASD met a different service dog, except two children with ASD who were observed within the same week and thus same service dog was present during observations.

1 It is important to specify that dogs used in the present study were not service dog per se, since they were not dogs matched and living with a child (Solomon et al., 2010; https://petpartners.org/learn/terminology/; https://www.ada.gov/service_animals_2010.htm), but were dogs by the end of their training and on the edge of becoming service dogs. However, for the sake of clarity, we will label them as service dogs in the rest of the manuscript.
Experimental Design

Material All observations were performed at the Mira Foundation (Quebec) in a room dedicated to observation and assessment of children with ASD (table, board games and toys, water point, carpet, window). This room was equipped with a wide-angle camera and an adjacent airlock with a one-way mirror, allowing non-participant observation.

Procedure The observations resorted to the usual procedure applied by the Mira Foundation and was conducted by a professional (i.e. psychologist, psychoeducator, educational psychologist) from the Mira foundation. In order to assess the eligibility of families to receive a service dog, a standard evaluation procedure was used in the presence of one or two parents. Brothers and sisters could be present as well (i.e., one sibling: N = 7; two siblings: N = 1). Evaluations were always performed as followed:

- **Phase 1: Habituation to the new environment** The evaluator leaves the room where the child with ASD and his/her family member(s) are left for 20 min to interact freely (e.g. involving games).
- **Phase 2: Presentation of service dog** The evaluator enters the room with a service dog on a leash and presents the service dog (name, age, breed).
- **Phase 3: Free interaction with the service dog** The evaluator leaves the room. The family is left for 10 min and can interact freely with the service dog.
- **Phase 4: Presentation of objects and commands** The evaluator enters the room with different objects (i.e. water bowl, kibble box, brush). She/He presents the objects and commands to which the service dog is trained to respond (i.e. sit, lie down, stay, come).
- **Phase 5: Free interaction with the service dog** The evaluator leaves the room and leaves the family to interact freely with the service dog for another 10 min.

Phases 2 and 3 were considered as finished when the evaluator knocked on the door. Parents were free to interact with their child with ASD during the evaluation. Siblings were free to interact with the child with ASD, as well as with the service dog and their parent(s). Then, following the completion of the evaluation (i.e. the five phases), based on observations during this assessment, the child’s file (i.e. including information concerning the child and professional report) and parent’s answers to a semi-directive interview conducted after the evaluation, the evaluator completed the C.A.R.S (Fig. 1).

The recording of videos of children with ASD during their evaluation was usually preformed and already implemented within the Mira foundation. The videos analysed in the present study were retrieved from Mira’s database.

Data Collection and Analyses

Data Analyses Phases 3 and 5 (approximately 10 min respectively) were extracted from video-recordings and analysed using The Observer XT software (version 11.0, Noldus, Netherlands). All child with ASD's behaviours towards the service dog and his/her parent's vocalisations concerning him/her and the service dog were considered (Table 1).

Ethological methods of behavioural coding were applied to analyse the videos (Altmann, 1974): (1) scan sampling (i.e. collecting behavioural data from an individual's current activity at preselected moments in times, thus allowing an estimation of the child’s time budget spent on the different activities) with an inter-scan interval of 5 s (i.e. 241 scans per child); (2) focal sampling (i.e. recording continuously an individual's behaviours of interest for a predefined sampling period, thus allowing an estimation of occurrences and durations of behavioural states).

Scan sampling was used to sample spatial distances between the child with ASD and the service dog, spatial distances between the child with ASD and his/her closest...
| Behavioural category | Definition | Subtypes and behaviours |
|----------------------|------------|------------------------|
| Child with ASD’s contact with service dog | Any area of a child’s and service dog’s body that come into physical contact | Contact initiator: child with ASD, service dog, parent  
Type of contact: active, passive (i.e. presence or absence of movement from the area of the child in contact with the service dog; adapted from Katcher et al., 1979; in Katcher, 1981)  
Nature of contact: direct (contact without an object) or indirect (contact through an object)  

| Vocalisation of child with ASD | Any child’s vocalisation concerning the service dog or related to it | Directed to: the service dog, the parent(s)  
Nature of vocalisations: service dog’s name, command, vocalisation expressing attraction to* or rejection of the service dog**, and neutral vocalisations about the dog**  
*Attraction vocalisations = all vocalisations emitted by the child with ASD reflecting an interest or a willing to get in contact with the service dog, a positive affect in the contact with it, a positive comment towards it or paraverbal vocalisations expressing positive affects toward the service dog (e.g., laugh, positive exclamation or excitement, giggles).  
**Rejection vocalisation = all vocalisations emitted by the child with ASD reflecting an absence of interest or an unwillingness to get in contact with the service dog, a negative affect in the contact with it, a negative comment towards it or paraverbal vocalisations expressing negative affects toward the service dog or the contact with it (e.g., scream, disgust vocalisation “eww”).  
***Neutral vocalisation = all vocalisations emitted by the child with ASD reflecting neither an attraction nor a rejection, such as describing the service dog, describing an ongoing action with the service dog, verbally presenting an object to the service dog and so on. |
| Vocalisation of parent | Any vocalisation emitted by the parent(s) regarding the interaction between the child and the service dog | Nature of vocalisations: (1) encourage interaction with the service dog, (2) moderate or curb the activity initiated between the child and the service dog, (3) rectify the activity initiated by the child |
| Child with ASD’s gesture towards service dog | Any gesture made by the child towards the service dog | Nature of gestures: command, gesture expressing attraction to or rejection of the service dog, inappropriate, other types of gestures, attempt to contact the service dog (i.e. approaches the dog with part of his/her body but withdraws just before making contact) |
| Distance between child with ASD and service dog | Distance between the closest part of the child’s body part and the service dog | Direct contact or indirect contact, ½ arm (length), 1 arm, 1½ arm, further away |
| Distance between child with ASD and parent | Distance between the closest part of the child’s body part and the parent (closest parent if more than one) | Direct contact or indirect contact, ½ arm (length), 1 arm, 1½ arm, further away |
| Gaze orientation of child with ASD | Global orientation of head and gaze | Directed towards: parent, service dog, board games, service dog’s accessories (i.e. brush, water bowl, kibble box), other directions (i.e., when the child’s gaze is not oriented towards any of the identified targets) |
| Care behaviour by child with ASD | All care behaviours expressed by the child concerning the service dog | Brushes the service dog, gives it water, gives it a kibble, holds its leash, other types of care (diverted use of the object), or unsuitable care (e.g. violent) |
Interactions of Children with ASD with a Service Dog

Approximately a quarter of the time, children with ASD were in physical contact with the service dog, and this contact was mostly initiated by the children (compared to the service dog, $z = 3.31, p < 0.001$; and the parents, $z = 3.52, p < 0.001$; Table 2). They were also initiated more frequently by the dog than by the parents ($z = 2.17, p < 0.05$). Most physical contacts consisted in active stroking (i.e., contact with movement) rather than in passive stroking (i.e., contact without movement) ($z = 2.84, p < 0.01$).

This physical appeal for a service dog was measured also through inter-individual distances. Indeed, children with ASD were in physical contact with the service dog more frequently than with their parents ($z = 3.05, p < 0.01$; Table 2). Conversely, they were more often further away (i.e., distance more than 1.5 arm) from their parents than from the service dog during interactions ($z = 2.95, p < 0.01$). No significant differences between the other child-to-parent versus child-to-dog distances could be evidenced ($0.88 \leq z \leq 1.22, p > 0.05$). Children with ASD were more frequently at a distance from the parents (contact to 0.5 arm versus 1 arm and more: $z = 3.05, p < 0.01$), while no preferred distance from the service dog was detected (contact to 0.5 arm versus 1 arm and more: $z = 0.21, p > 0.05$).

Children with ASD spoke (e.g., “come here”, “good dog”, “[dog’s name] sit”) and vocalized (e.g., laughs, giggles, exclamations) more to the service dog compared to their parent(s) ($z = 3.36, p < 0.001$) and to the “other” item ($z = 3.52, p < 0.001$). Children with ASD also vocalised more towards their parents than towards the “other” item ($z = 3.52, p < 0.001$). The type of vocalisations mostly used were commands (compared to other vocalisations $2.38 \leq z \geq 3.52$, all $p < 0.001$, except neutral $z = 0.41, p > 0.05$). The vocalisations directed to the service dog were mainly neutral (compared to attraction, $z = 2.59, p < 0.01$; and rejection, $z = 3.52, p < 0.001$), while rejection vocalisations were the least expressed ($3.21 \leq z \geq 3.52$, all $p < 0.001$). Gestures
Table 2 Behaviours displayed by children with ASD during interaction with the service dog. (A) Behaviours recorded by focal sampling (mean numbers of occurrences, except type of contact (i.e., passive/active stroke)) that was estimated in seconds (mean total duration); and (B) frequencies of behaviours recorded by scan sampling (percent of scans). Level of significance: *p* < 0.05 (Friedman tests)

| (A) Behaviors collected in focal sampling | Mean | SE  | Friedman test |
|-----------------------------------------|------|-----|---------------|
| Child with ASD’s contact with service dog | Initiated by the service dog | 8.1 | 1.5 | *F* = 22.6 |
| Initiated by the child with ASD | 32.3 | 3.5 | *p* < 0.001 |
| Initiated by the parents | 3.3 | 0.8 |
| Passive stroke | 58.0 | 12.1 | *F* = 9.0 |
| Active stroke | 226.3 | 57.1 | *p* = 0.003 |
| Child with ASD’s vocalisation | Attraction | 22.5 | 4.1 | *F* = 37.8 |
| Rejection | 3.6 | 1.3 | *p* < 0.001 |
| Service dog’s name | 27.0 | 6.4 |
| Neutral | 34.4 | 4.0 |
| Command | 46.8 | 11.0 |
| Directed to the service dog | 102.9 | 20.2 | *F* = 28.5 |
| Directed to the parents | 31.3 | 3.2 | *p* < 0.001 |
| Directed to other | 0.1 |
| Parent’s vocalisation | Encourage | 23.4 | 3.3 | *F* = 24.0 |
| Curb | 4.7 | 1.3 | *p* < 0.001 |
| Rectify | 12.4 |
| Child with ASD’s gesture towards service dog | Attraction | 4.4 | 1.4 | *F* = 57.7 |
| Rejection | 4.0 | 1.1 | *p* < 0.001 |
| Command | 37.2 | 10.4 |
| Others | 0.7 | 0.3 |
| Attempt | 0.5 | 0.2 |
| Inappropriate | 0.1 |

| (B) Behaviors collected in scan sampling | Mean | SE  | Friedman test |
|-----------------------------------------|------|-----|---------------|
| Child with ASD’s distance with service dog | Contact | 22.4 | 4.2 | *F* = 25.6 |
| 0.5 | 29.2 | 2.5 | *p* < 0.001 |
| 1 | 12.5 | 1.3 |
| 1.5 | 9.6 | 1.1 |
| More | 26.3 | 3.2 |
towards the service dog were mostly command gestures (3.36 ≤ z ≥ 3.52, p < 0.001), while there were as many gestures of rejection as gestures of attraction (z = 0.31, p > 0.05). Rejection, inadequate and attempt gestures were displayed the least (2.44 ≤ z ≥ 3.52, all p < 0.05).

Parents’ vocalisations aimed mainly at encouraging their child with ASD’s activity with the service dog (compared to rectifying, z = 3.10, p < 0.01, and moderating, z = 3.52, p < 0.001; Table 2). Moreover, parents rectified more than they moderated their child’s activity (z = 3.01, p < 0.01).

The service dog was the preferred target of children with ASD’s gaze during the interactions (2.90 ≤ z ≥ 3.52, p < 0.01). They gazed significantly less at service dog’s accessories than at “other” item (z = 3.47, p < 0.001) or their parents (z = 2.53, p = 0.01).

The children with ASD spent a fifth of the observation time displaying caring behaviours with the service dog. No significant differences were detected between the care behaviours considered, except that they gave water less frequently than they gave a kibble, brushed the service dog or held its leash (1.93 ≤ z ≥ 2.43, all p ≤ 0.05). No inappropriate care or gestures towards the service dog were observed, except for one child who pressed his foot intentionally on the service dog’s leg.

Profiles of Children with ASD’s Interactions with Service Dogs and Their Visual Attention

Even though overall behavioural trends were consistent, three factors of the PCA explained 51.2% of the variance in our dataset (Table 3). After extracting PCA scores from the behavioural variables on the three factors, it was possible to differentiate three interaction strategies.

The first factor (F1) explained 19.7% of the variance. It was positively loaded by contact with the service dog (i.e. initiated by the child with ASD, brushing, occurrences of contact with the service dog), gaze towards the parent and the service dog, neutral vocalisations about and addressed to the service dog and vocalisations directed to the parent; while it was negatively loaded by greater distance (i.e. distance of more than 1.5 arm length) from the service dog, gaze orientation towards board games and “other”. Thus, the higher the score on this factor, the more children with ASD were notably in physical contact with the service dog and initiated contact with it, the more they talked to the service dog and their parent, and gazed at them, and the less they were far from the service dog. Given these elements, this factor was thus labelled “proximal interaction and visual attention” (PIVA).

The second factor (F2) was representative of “distal interaction” with the service dog. It carried the main vocalisations (i.e. commands, service dog’s name) and gestures (i.e. command, attraction, other) directed towards
the service dog by the child with ASD, as well as offering a kibble and greater distance from the parent. Thus, the higher the score on this factor, the more children with ASD talked and addressed gestures to the service dog. Given these elements, this factor was labelled “distal interaction” (DI) with the service dog.

The third factor (F3) was characterized by vocal supervision of the child with ASD-service dog interactions by

| Behavioural categories                          | F1 Proximal interaction and visual attention (PIVA) | F2 Distal interaction (DI) | F3 Parental guidance (PG) |
|-------------------------------------------------|----------------------------------------------------|---------------------------|--------------------------|
| Child with ASD’s contact with service dog        |                                                     |                           |                          |
| Initiated by the service dog                     | −0.296                                             | 0.101                     | <0.100                   |
| Initiated by the child with ASD                  | 0.84                                               | 0.161                     | −0.198                   |
| Initiated by the parents                         | 0.23                                               | −0.115                    | 0.648                    |
| Passive stroking                                 | <0.100                                             | −0.114                    | −0.38                    |
| Active stroking                                  | 0.789                                              | −0.385                    | −0.126                   |
| Vocalisation of child with ASD                   |                                                     |                           |                          |
| Attraction                                       | 0.472                                              | 0.475                     | −0.397                   |
| Rejection                                        | −0.345                                             | <0.100                    | 0.166                    |
| Service dog’s name                               | <0.100                                             | 0.802                     | 0.16                     |
| Neutral                                          | 0.592                                              | 0.187                     | −0.42                    |
| Command                                          | 0.14                                               | 0.921                     | <0.100                   |
| Directed to the service dog                      | 0.14                                               | 0.945                     | <0.100                   |
| Directed to the parents                          | 0.732                                              | −0.377                    | −0.2                    |
| Vocalisation of parent                           |                                                     |                           |                          |
| Encourage                                        | <0.100                                             | −0.281                    | 0.777                    |
| Curb                                             | <0.100                                             | <0.100                    | 0.759                    |
| Rectify                                          | −0.257                                             | 0.211                     | 0.587                    |
| Child with ASD’s gesture towards service dog     |                                                     |                           |                          |
| Attraction                                       | −0.229                                             | 0.661                     | −0.113                   |
| Rejection                                        | −0.259                                             | 0.203                     | 0.443                    |
| Command                                          | 0.223                                              | 0.839                     | 0.172                    |
| Others                                           | −0.196                                             | 0.827                     | −0.206                   |
| Attempt                                          | 0.362                                              | −0.252                    | <0.100                   |
| Distance between child with ASD and dog          |                                                     |                           |                          |
| Contact                                          | 0.859                                              | −0.341                    | −0.129                   |
| 0.5                                              | <0.100                                             | 0.238                     | 0.601                    |
| 1                                                | −0.32                                              | 0.477                     | 0.187                    |
| 1.5                                              | −0.387                                             | <0.100                    | <0.100                   |
| More                                             | −0.813                                             | <0.100                    | −0.384                   |
| Distance between child with ASD and parent       |                                                     |                           |                          |
| Contact                                          | <0.100                                             | −0.17                     | 0.723                    |
| 0.5                                              | 0.234                                              | −0.497                    | 0.376                    |
| 1                                                | <0.100                                             | −0.409                    | <0.100                   |
| 1.5                                              | 0.158                                              | <0.100                    | −0.404                   |
| More                                             | −0.252                                             | 0.648                     | −0.46                    |
| Gaze orientation of child with ASD               |                                                     |                           |                          |
| Service dog                                      | 0.843                                              | 0.332                     | 0.209                    |
| Parents                                          | 0.575                                              | −0.13                     | −0.436                   |
| Board games                                      | −0.813                                             | −0.274                    | <0.100                   |
| Service dog’s accessories                        | −0.233                                             | <0.100                    | <0.100                   |
| Other                                            | −0.638                                             | −0.153                    | −0.252                   |
| Care behaviour by child with ASD                 |                                                     |                           |                          |
| Gives the service dog a kibble                   | 0.309                                              | 0.658                     | 0.228                    |
| Brushes the service dog                          | 0.571                                              | −0.484                    | −0.266                   |
| Keeps it on a leash                              | 0.207                                              | −0.181                    | 0.341                    |
| Gives it water                                   | 0.307                                              | 0.121                     | 0.15                     |
| Eigenvalue                                       | 7.679                                              | 7.265                     | 5.028                    |
| Percentage of cumulated variance                 | 19.7%                                              | 38.3%                     | 51.2%                    |
the parent (i.e. encourages, temper, rectify) as well as by the child with ASD’s contact with the service dog initiated by the parent, the child with ASD-parent contacts and being close to the service dog (within 0.5 arm length). Higher scores on this factor were thus associated with more parental vocal supervision of the interaction between the child with ASD and the service dog, and more initiation of contact between the child and the service dog by the parent. Given these elements, this factor was labelled “parental guidance” (PG).

Age of the children with ASD was correlated positively with the PIVA factor ($r = 0.65$, $p < 0.01$). However, their age was not correlated with the other two factors (DI factor ($F_2$): $r = 0.15$, $p > 0.05$; PG factor ($F_3$): $r = 0.06$, $p > 0.05$).

No significant correlations were observed with the severity of ASD assessed by the CARS ($r$ between $[-0.11; 0.36]$, all $p > 0.05$). Thus, children with ASD’s age was included as a confounding factor when testing correlations between gaze and interaction profiles. The more children with ASD looked at their parent, the more they interacted proximally (i.e. PIVA factor) with the service dog ($r = 0.53$, $p < 0.05$). However, they gazed less at their parent when they were more subjected to parental vocal guidance while interacting with the service dog (i.e., PG factor; $r = -0.62$, $p < 0.05$). Furthermore, the more the children with ASD interacted proximally (i.e. PIVA factor) with the service dog, the less they gazed at board games ($r = -0.65$, $p < 0.01$). The other correlations between factors (i.e., DI and PG factors) and gaze orientations were not significant (all tests, $r$ between $[0.02; 0.47]$, $p > 0.075$). It thus appears that gazing at their parents during the interaction with the service dog was associated with children with ASD interacting more proximally with the service dog (i.e., more time in contact with the service dog and more initiation of contacts) and receiving less parental supervision during interaction (i.e., less rectification, encouragement and temperance); while gazing less at board games was associated with more proximal interaction with the service dog.

Interaction Profiles

For clarity, only statistically significant effects are reported below. As some behaviours appeared to be related, we aimed at establishing a more global view of these profiles of children with ASD. Three behavioural profiles emerged from the cluster analysis and are described below (Fig. 2; Kruskall–Wallis Test—$F_1$: $d = 2$, $N = 16$, $X^2 = 9.30$, $p < 0.01$; $F_2$: $X^2 = 9.58$, $p < 0.01$; $F_3$: $X^2 = 6.02$, $p < 0.05$).

Thus, on the PIVA factor ($F_1$), Group 1 ($N = 4$) differed from Group 2 ($N = 9$) ($p < 0.01$) (Fig. 2). Group 1 was characterized by more proximal interactions than Group 2. Group 1 corresponds to a child’s profile that can be labelled “tactile and visual contact with service dog”.

The DI factor ($F_2$) separated the “tactile and visual contact with service dog” children from the Group 3 children ($p < 0.01$). Group 3 children ($N = 3$) mostly interacted distally with the service dog. So, Group 3 corresponds to a child’s profile that can be labelled “vocal contact with the service dog”.

The “tactile and visual contact with service dog” children and Group 2 also differed on the PG factor ($F_3$) ($p < 0.05$). The “tactile and visual contact with service dog” children were less subjected to parental guidance during interactions than Group 2. Thus, the profile corresponding to Group 2 was labelled “subjected to parental supervision”.

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Fig. 2 Group distribution on the factors extracted from the PCA: average scores for each group on the factors ($\pm SE$). The more the score was positive, the more the behaviours positively related to that factor were expressed. Data that do not share a common letter differed significantly at $p > 0.05$ (Kruskall–Wallis tests followed by Dunn tests). White bars: “Tactile and visual contact with service dog” children’s profile (Group 1); black bars: “Subjected to parental supervision” children’s profile (Group 2); grey bars: “Vocal contact with the service dog” children’s profile (Group 3)
Gaze orientation differed between profiles by time children with ASD spent looking at their parents (Kruskall–Wallis test: $d_{df} = 2$, $N = 16$ for all tests, Cluster—Parent: $p < 0.05$; other variable $p > 0.05$, Fig. 3). Indeed, children with the “tactile and visual contact with service dog” profile gazed significantly more frequently at their parents than did children with ASD “subjected to parental supervision” ($p < 0.05$). Although no significant differences were found between profiles for the “board games” variable ($p > 0.05$), two-by-two comparisons showed significant differences between profiles as children with ASD “subjected to parental supervision” looked more at board games than did children with ASD of the “tactile and visual contact with service dog” group ($p < 0.05$).

Study 2

Materials and Methods

Subjects

Videos were collected from January to March, 2020.

Children with ASD Inclusion criteria were the same as for Study 1 with in addition three criteria linked to eye tracking usage: children had to be between 6 and 15 years old, not have any epileptic disorder and not wear glasses with a strong correction (i.e., glasses that the child may not be retrieved without discomfort feeling or clear vision difficulties [blurry vision, issues with details within a few meters, and so on]). Nine children corresponding to these inclusion criteria and evaluated at the Mira Foundation were invited to participate. Two children with ASD declined the offer, and one removed the eye-tracking glasses during the experiment. In all, 6 children with ASD participated in the present study (mean ± SE: 9.3 ± 1.1 years old; range: 6.4 and 14.0 years old; 3 boys and 3 girls). All were diagnosed with ASD and were evaluated by a professional from the Mira Foundation (i.e. evaluator). All were evaluated with mild to moderate severity of ASD (C.A.R.S. mean score of 31.2 ± 1.8). Only one child had co-morbidities (i.e. ADHD and Anxiety disorder not otherwise specified [AnxNos]). All children with ASD were fully verbal.

Dogs participants Four trained dogs were recruited. They originated from the Mira Foundation’s husbandry. All were females, including 2 Labradors, 1 Labernois and 1 Saint-Pierre (mean age: 25.3 ± 1.0 months old at the time of the observations. They had the same training characteristics as in Study 1.

Experimental Design

Material This study was conducted at the Mira Foundation, in the same room as for Study 1 (see Sect. 2.1). In this study, the observation room was equipped with two wide-angle cameras (Nest Cam, 1920×1080p, 30 images/sec) placed in opposite corners of room to cover the entire room. The conditions and the layout of the room were standardized: same games and placement of objects, shutters systematically closed with the lights on. Eye movements were collected using eye-tracking glasses (Tobii Pro Glasses 2) with a sampling at 60 Hz. Data acquisition and recording were performed with the dedicated software: Tobii Pro Glasses Controller (version 1.114.20033).

Procedure The procedure was identical to the evaluation procedure described in Study 1, except for phases 2 and 4, during which the children with ASD had to wear the eye-tracking glasses (Fig. 1). All children with ASD had the opportunity to test the glasses before the start of the 5
phases evaluation, to ensure their acceptance to participate (i.e. no discomfort, size of glasses was adjusted as needed).

- **Phase 2: Presentation of service dog** The evaluator enters the room, invites the child with ASD to sit on a chair, installs the eye-tracking glasses and performs a one-point calibration. The evaluator brings the service dog into the room and presents the service dog (i.e. name, sex, age, breed, long or short coat, colour, temperament). Then, the evaluator asks the child with ASD two questions concerning the service dog: "How do you like it? Have you ever seen such a big dog?" (mean duration \( \pm SE = 45.5 \pm 4.9 \) s). Finally, she/he approaches the child with ASD with the service dog and invites the child with ASD to pet it (average duration \( \pm SE = 13.8 \pm 2.6 \) s of approach and potential contact). Following this, the glasses are removed.

- **Phase 4: Presentation of objects and commands** The evaluator enters the room, places the child with ASD on the chair, installs the glasses and performs the calibration. The evaluator brings accessories for the service dog (i.e. a bowl of water, kibbles and a brush, all presented on a stool placed on a predefined mark on the floor), presents the different accessories and the commands to which the service dog is trained to respond (i.e. lie down, sit, stay, come; average duration \( \pm SE = 98.7 \pm 14.5 \) s). Then, the evaluator invites the child with ASD to approach the service dog and give it a kibble (mean duration \( \pm SE = 13.3 \pm 1.3 \) s of approach and potential contact).

One or two parents could be present during phases 1 (i.e. habituation phase), 3 (i.e. first free interaction phase) and 5 (i.e. second free interaction phase), as well as brothers and sisters (i.e., one sibling: \( N = 2 \)).

During phases 2 and 4, with the eye-tracking glasses, siblings were asked to wait outside the room and only one of the parents had to stay.

The procedure was standardized to optimize the acquisition of valid oculometric data (phases 2 and 4). The evaluator’s speech was predefined using a script and the position of all individuals within the room was set. The evaluator was placed behind a defined mark on the floor (2.15 m from the child with ASD), the service dog was laying down next to him/her, the parent was asked to sit on a chair specifically placed (i.e. away from the child with ASD, 3 m to their side) and the child with ASD had to sit on a dedicated chair. In addition, a predefined ideal time for each phase had to be respected as much as possible by the evaluators (i.e. 1 min 30 for phase 2 and 2 min 30 for phase 4). The child with ASD was asked not to remove the glasses during the experiment. Furthermore, while the child with ASD was wearing the eye-tracking glasses (i.e. phase 2 and 4) the parent was instructed to remain still and silent. The parent could however answer if the child with ASD questioned him/her directly. Parents were free to interact with their child with ASD during the rest of the evaluation (phases 1, 3 and 5). On the same periods (phase1, 3 and 5) siblings were free to interact with the child with ASD, as well as with the service dog and their parent.

### Data Collection and Analyses

All sessions of evaluation were video recorded for subsequent analysis.

### Data analyses

Behavioural measures were the same as in Study 1.

For Eye-Tracking measurements: six Areas Of Interest (AOI) were defined for Phase 2 (presentation of service dog): the whole service dog, the service dog’s head, the evaluator’s head, the parent’s head, the board games, and the rest of the visual scene, named “other” (i.e. any fixations or saccades recorded elsewhere outside the AOIs defined above).

The same six AOIs were used for Phase 4 (presentation of objects and commands) with, in addition, a seventh AOI: “service dog’s accessories” (including brush, water bowl and kibble box). Each AOI was defined to encompass the entire element of interest (e.g. for the service dog AOI, it included the whole service dog from tip of tail to muzzle, and from top of head to tip of legs).

Considering the inter- and intra-individual variability of the actors in the visual scene, the differences in distance between child and service dog as well as the service dog’s and the child’s head movements during the observation, an additional space has been tolerated and applied around the target item of each AOI. A tolerance of half a service dog’s leg for the service dog’s body and service dog’s head AOIs was applied, and half a hand for the evaluator’s head, the parent’s head and the objects AOIs.

Eye-tracking data were analysed using "Tobii Pro Lab" software Version 1.102.15986 (x 64). Extraction of oculometric data was performed using an "I-VT attention filter" (i.e. I-VT: Velocity-Threshold Identification) with a velocity threshold set at 100 degrees/second. For both phases, the starting point of eye-tracking extraction was set when the evaluator began his/her first introductory word (i.e. "I present you..."). The approach phase began when he/she put his/her foot on the other side of the mark on the ground, and ended when the evaluator began her/his first word to announce the end of the experiment ("we are going to take off the glasses"). For each AOI, the number...
of fixations and the total duration of fixation within the AOI were extracted.

**Statistical analyses** Since data were not normally distributed, we used non-parametric statistics (Siegel & Castellan, 1988). In order to homogenize the extracted data accurately: (1) codable times and occurrences were reproportioned over 20 min for all individuals (minimum/maximum codable duration for phase 3 were 8.7 and 11 min and for phase 5 between were 9.6 and 13.2 min); (2) durations of phases 2 and 4 were reproportioned to their respective ideal times as defined in the initial evaluators’ script (i.e. 1 min 30 for phase 2 and 2 min 30 for phase 4). The eye-tracking data collected (target, occurrence and duration of gaze) were then related to the behavioural traits adopted by the children with ASD with the service dog. Spearman correlations were performed: (1) between the different AOI variables, and (2) between AOI variables and behavioural variables. Mann–Whitney tests were conducted between the AOI variables. All possible comparisons have been made between the AOIs, except for the comparison between the service dog AOI and the service dog head AOI, since these AOI were in fact non-exclusive (i.e. the service dog AOI included the service dog head AOI).

**Results**

**Characterisation of the Visual Exploratory Pattern Based on Oculometric Analysis**

For clarity, only statistically significant effects are reported below. Children with ASD spent more time gazing at the service dog (mean percentage fixation duration: 44.4 ± 3.2%), the service dog’s head (31.4 ± 2.5%) and the rest of the scene AOIs (31.3 ± 4.5%) than at the board games (0.1 ± 0.05%; all z ≥ 2.20, all p < 0.05), the service dog’s accessories (7.4 ± 1.5%; all z ≥ 2.20, all p < 0.05) and the evaluator’s head (16.0 ± 3.5%; all z ≥ 2.20, all p < 0.05, except for the rest of the visual scene: z = 1.78, p = 0.07) (Fig. 4a). The evaluator’s head and the service dog’s accessories were gazed at significantly more than the parent’s head and the board games (mean number of fixations: respectively
51.5 ± 7.6 and 43.9 ± 8.2 versus 21.1 ± 1.0 and 0.66 ± 0.4) (for all comparisons: z ≥ 2.02, p < 0.05). Furthermore, children with ASD spent more time gazing at the service dog’s head than at the rest of its body (mean percentage fixation duration: 31.4 ± 2.5% of the time, z = 2.20, p < 0.05).

Children with ASD also performed fixations on the service dog more frequently than on all the other AOIs considered (mean number of fixations: 282.9 ± 29.7 vs X between 0.66 ± 0.43 and 118.6 ± 22.2 for all other AOIs) (for all comparisons: z ≥ 2.02, p < 0.05). Similarly, fixations on the service dog’s head and on the rest of visual scene were significantly more frequent than on the other AOIs (respectively, 110.6 ± 16.2 and 118.6 ± 22.3 versus X between 0.66 ± 0.43 and 51.5 ± 7.6 for all other AOIs) (all comparisons: z ≥ 1.99, p < 0.05). The parent’s head and the board games were the least explored (respectively, 0.66 ± 0.44 and 2.09 ± 1.03, all z ≥ 2.20, p < 0.05). Finally, the number of fixations on the dog’s body was higher than on its head (z = 1.99, p < 0.05).

**Visual Exploration Patterns and Behavioural Variables Adopted by Children with ASD During Interactions with the Service Dog**

Correlation analyses were performed between the AOI variables to investigate associations of visual exploration of the different targets. No significant correlations were found either for total fixation time or for number of fixations (total fixation time: r between [-0.068; -0.83], p > 0.05; number of fixations: r between [-0.1; 0.83], p > 0.058).

Correlation analyses were performed between all AOI variables (i.e. total durations of fixation and number of fixations) with all behavioural variables collected for the six children with ASD (cf. Table 1). The selection of behavioural variables included in this analysis was based on results of study 1 (i.e. behavioural variables significantly supporting PCA factors and all gaze orientations).

Analyses on animate/social targets (i.e. parent’s head; evaluator’s head, service dog and service dog’s head) showed that the longer the children with ASD gazed at the service dog’s head during the presentation phases (phase 2 and 4), the more they paid attention to the service dog’s accessories during the free interaction phases (phase 3 and 5) (r = 0.89, p < 0.05); the longer they gazed at the parent’s head during the presentation phases (phase 2 and 4) the less the parent initiated contact with the service dog during the free interaction phases (phase 3 and 5) (r = 0.84, p < 0.05). Numbers of fixations on the parent’s head were positively correlated to vocalisations directed towards the service dog (r = 0.88, p < 0.05) and command gestures towards the service dog (r = 0.88, p < 0.021). Similarly, the more the children with ASD gazed at their parent’s head during the presentation phases (phase 2 and 4), the more they gazed at their parent during the interaction phase with the service dog (phase 3 and 5) (r = 0.88, p < 0.05). The longer they gazed at the evaluator’s head, the less they rejected vocally the service dog (r = −0.88, p < 0.05), and the less they paid attention to board games afterwards (phase 3 and 5) (r = −0.94, p < 0.05). The more they gazed at the evaluator’s head, the fewer they displayed rejection gestures towards the service dog (r = −0.890, p < 0.05).

Our data concerning inanimate/non-social targets (i.e. board games, service dog’s accessories, the rest of the scene) showed that the longer the children with ASD gazed at board games during the presentation phases (phase 2 and 4), the more time they spent near (i.e. one arm distance) their parent and stroked the service dog passively during the free interaction phases (phase 3 and 5) (all four tests, r = 0.850, p < 0.05). The more the children with ASD gazed at the service dog’s accessories during the presentation phases (phase 2 and 4), the more time they spent in contact with the parent (r = 0.81, p = 0.05), and the less they initiated contact with the service dog (r = −0.94, p < 0.017) as well as they spent less time actively stroking the service dog (r = −1.00, p < 0.01). Similarly, the more they gazed at the service dog’s accessories during the presentation (phase 2 and 4), the less they directed vocalisations towards their parent (r = −0.94, p < 0.05) and expressed neutral vocalisations about the service dog (r = −0.94, p < 0.05) and the more they displayed rejection vocalisations towards the service dog (r = 0.88, p < 0.05). The higher the number of fixations on the service dog’s accessories during the presentation phases (phase 2 and 4), the more children with ASD paid attention to board games (r = −0.94, p > 0.05), the less they were in contact with the service dog (r = −1.00, p > 0.01), and the more they were further from it during the free interaction phases (phase 3 and 5) (r = −0.94, p < 0.05). The more time the children with ASD spent gazing at the AOI covering the rest of the scene during the presentation phases (phase 2 and 4), the less they were subjected to their parent’s vocalisations moderating and correcting their interactions with the service dog (r = −0.81, p = 0.05; r = −1.000, p < 0.01; respectively).

**Discussion**

Our aim was to explore the links between the visual attention of children with ASD to animals, here future service dogs, and the interactions they had with them. In our study 1, children with ASD displayed different interaction strategies with the service dog, which were associated with different types of profiles of interactions with the service dog, and some of those strategies correlated with children with ASD's visual behaviours (i.e. exploration of social items versus objects) during interactions. In our study 2, children with ASD spent
most of the time exploring the service dog visually, particularly its head. We evidenced correlations between some behaviour and the visual exploration variables, notably those reflecting attention to animate/inanimate stimuli.

**Behavioural Strategies and Profiles of Children with ASD Interacting with a Service Dog**

Except for one child, all children with mild to moderate ASD interacted adequately with the service dog, as previously described with pet dogs by parents (Carlisle, 2012). In our two studies, children with ASD spent most of their time during the free interaction phases in physical contact with the service dog. This contact was mostly active (i.e. petting the service dog while moving) and initiated by the children. Furthermore, the most frequently displayed “care” behaviour included physical contact with the service dog: brushing and giving it a kibble. A previous experiment by Prothmann et al. (2009) showed that children with ASD prefer to interact with a therapy dog, notably by stroking it or by initiating interactive games rather than with other social partners (i.e. adult humans).

Of all the vocalisations and gestures we considered, the children with ASD used preferentially command vocalisations and gestures towards the service dog during interactions with it. This could be induced by two non-exclusive elements: the fact that the evaluator had previously shown them these behaviours could suggest a form of imitation (skill that is present even if impaired in ASD; Rogers & Pennington, 1991); children with ASD were encouraged by their parent to practice these commands with the service dog. The valence of the other vocalisations was generally neutral, while more rejection gestures than rejection vocalisations were observed. This could be explained by the fact that non-verbal behaviours are subtler and not systematically associated with vocalisations. For example, avoidance gestures which often resulted from unwanted contact with the service dog or a specific service dog’s body part (e.g. contact with the service dog’s mouth or teeth, service dog licking the child’s face), probably caused by sensory disturbances often associated with ASDs (Ben-Sasson et al., 2009; Carlisle, 2012). We confirmed that interactions between children with ASD and service dogs – and larger with animals—are by essence multimodal (i.e. vocal, tactile, visual), as previously observed during encounters with other animals (e.g. guinea pigs, Talarovičová et al., 2010, Grandgeorge, 2012a, 2014, therapy and pet dogs, Prothmann et al., 2005, Grandgeorge et al., 2020; pet cats, Grandgeorge et al., 2020, Hart et al., 2018). Amongst these modalities of interactions, both children with ASD (therapy and pet dogs, Prothmann et al., 2005, Carlisle, 2012; guinea pigs, Talarovičová et al., 2010) and children with typical development (Maurer et al., 2011; pet dogs, Filiatre et al., 1986) seem to prefer nonverbal interactions with animals.

As previously observed, all children with ASD do not interact in the same way with animals (Grandgeorge et al., 2014; guinea pig, Grandgeorge et al., 2012a; service dog, Dollion et al., submitted). They may deploy different strategies during an interaction and different profiles of interaction between children with ASD and animals can be identified. Here, with the service dog, children with ASD could be classified either in the first profile, “tactile and visual contact with service dog” (tended to interact proximally with the service dog), or in the second profile, “subjected to parental supervision” (interacting less proximally with the service dog), or in the third profile, interacting more through “vocal contact with the service dog”. These three profiles were similar to others previously identified (i.e. “proximal and contact with the service dog”, “distal and command to the service dog”, as well as “disinterest for the service dog”; Dollion et al., submitted) except that here, parental influence appeared more clearly. This could be easily explained by the addition of some parents’ behavioural items (e.g. parent vocalisations). Thus, all children with ASD do not exhibit the same interest in a service dog. Visual attention appeared to be a key element as the children with ASD with the “tactile and visual contact with service dog” profile looked more at their parent, while those with the “subjected to parental supervision” profile looked less at their parent. Looking at one’s parent in a new situation may reflect an active search for his/her interpretation, in order to use this evaluation to adapt his/her behaviour appropriately in an ambiguous situation (i.e. social referencing) (Planche, 2010). Social referencing is known to be poorly expressed by children with ASD and when they express it, they ignore the evaluative message or take it into account only after a certain delay (Planche, 2010). However, the interspecific context of interactions seems to facilitate the expression of social referencing for children with ASD. Indeed, some children with ASD display many adult-oriented gazes during the first encounter with an unfamiliar animal (guinea pig, Grandgeorge et al., 2012a). Children with ASD are also sensitive to the direction of social attention as, in a situation of “social rivalry” (i.e. educator pays attention to the child-dog dyad and then focuses his/her attention exclusively on the future service dog), they adapt their visual attention (i.e. increased glances, glances and joint attention) aiming at recovering the educator’s and dog’s attention that they had lost (Grandgeorge et al., 2017). In line with social referencing (Deleau, 1999) we hypothesized that since they spent more time looking at their parent(s), children with ASD with the “tactile and visual contact with dog” profile may have gathered information from their parent(s) relative to their interpretation of the situation, which may have lifted the ambiguity of the situation and promoted proximal interaction with the service.
On the contrary, since they paid less attention to their parent and spent more time looking at board games, children with ASD with the “subjected to parental intervention” profile may not have benefited from parental cues to lessen the ambiguity of the situation, and this could explain why they spend less time interacting proximally with the service dog. However, in line with social referencing, we cannot rule out that the opposite theory could be true: spending more time in contact with the service dog may also cause more uncertainty for the child (i.e. unpredictable and new interaction partner), which may have promoted the expression of social referencing behaviour towards parent(s). Furthermore, an alternative hypothesis concerning children with ASD with the “subjected to parental supervision” profile would be that since their parent was already very supportive vocally, these children may have experienced less need to seek parental cues. However, this last hypothesis does not fit entirely with the rational based on social referencing, since it predicts that children with ASD with the “subjected to parental supervision” profile would have interacted proximally with the service dog more as they received more parental cues and guidance.

**Visual Exploration and Interaction Strategies with the Service Dog**

Animals are clearly an attractive visual target for children with ASD (Grandgeorge et al., 2020; New et al., 2010; Prothmann et al., 2009). Here, children with ASD looked more frequently at the service dog, especially at the dog’s head. Previous studies using eye-tracking technology showed that children with ASD paid greater visual attention to images of animal faces than to images of human faces (dogs, Muszkat et al., 2015; dogs, cats, horses, Grandgeorge et al., 2016; dogs, cats, horses, cows, Valiyamattam et al., 2020). Similarly, Prothmann et al. (2009) reported that children with ASD clearly preferred interacting with a therapy dog to inanimate objects and humans. In view of our results showing a high percentage of time children with ASD spent exploring the service dog visually and in particular its head, one might have expected that this time would have varied between our subjects and would have been associated with behaviours displayed during interactions with the service dog. However, it appeared that all children with ASD looked at the service dog in a homogenous way during the presentation phases (i.e. the service dog remained an attractive visual target to children with ASD regardless of the behaviours displayed during the interaction). Indeed, the time spent looking at the service dog was not associated with any subsequent behavioural tendency, except that looking at the service dog’s head was synonymous of more attention to the service dog’s accessories during the free interaction phases with it. No similar fact has been described previously. Further investigation of this topic would be of interest in order to disentangle the meaning of attention towards the service dog’s accessories.

Looking at inanimate objects (i.e. board games and dog accessories) was associated with less active stroking of the dog, but more passive stroking (i.e. no movement on the dog), and more time spent close to their parent. Focusing on inanimate elements during the service dog’s presentation would mean that the child with ASD engaged less with the service dog during the interaction. This phenomenon has been observed previously in some children with ASD during therapy sessions with therapy dogs when interactions were characterized by little tactile contact and long periods of distancing him/herself from the therapy dog with brief but glancing frequently at it (Prothmann et al., 2005). The authors explained this by the fact that the dog remained unpredictable for the children with ASD. From these observations, we may hypothesize that if children with ASD look less at a service dog, they extract little information about it and thus, the service dog remains unpredictable and less attractive to them. Differences in the meaning of gazes towards the service dog’s accessories during the free interaction and the presentation phases could explain the results presented above. Indeed, the children with ASD may produce “care” behaviours while interacting with a service dog, such as give it a kibble or water, which would require them to focus their attention on the service dog’s accessories. However, during the general introduction to the service dog (including presentation of the dog, objects and commands), paying more attention to the service dog’s accessories may have another—non-exclusive—explanation. For example, this may reflect a lack of general attention focus or a reduced interest in social stimuli or the novelty of accessories may be more attractive than the service dog itself. Focusing on objects could also make it easier for children with ASD to concentrate on the words of the evaluator, or reflect avoidance of animate stimuli because of their unpredictable nature, which may generate anxiety (Grandin, 1995). Indeed, children with ASD have attentional orientation difficulties (O’Connor & Kirk, 2008), as well as concerning the perception of human biological movements (Blake et al., 2003).

Looking at the social agents (i.e. evaluator’s and parent’s head) was linked to interest and interaction behaviours towards the service dog. Visual attention toward social agents has been described in New et al.’s (2010) experiment in which both adults and children with ASD exhibit a bias (attentional or preferential) towards animated stimuli (i.e. human and animal). However, our study suggests a possible dichotomy around the initial attention towards animate/inanimate items in relation to the behaviours expressed by the children with ASD during subsequent interactions with a
service dog (i.e. the more they looked at a social agent during the presentation phase, the more they interacted with the service dog; the more they looked at inanimate items during the presentation phrase, the more they expressed withdrawal and rejection behaviours). Although our results are only exploratory, they could reflect that more than having a clear dissociation between humans and animals, the initial general social skills that the children with ASD had might influence the strategies they might be able to use during interactions with an animal. Indeed, our results seem to show that the children with ASD’s ability to gather information concerning social elements were linked to interactions with the service dog. Based on those exploratory observations, a hypothesis would that some general social skills applied to all social agents and altered by ASD might also be involved when children with ASD interact with animals; even so animals may have a specific status for people with ASD (Carlisle, 2014b). It would be of interest to investigate further this topic by investigating whether social deficits affect interest in and interactions with animals, and if so, to characterize which social deficits may be involved. Therefore, it appears that children with ASD’s abilities to gather information concerning social elements are involved in interactions with a service dog, resulting in the same difficulties to engage in interactions. Indeed, social communication difficulties intrinsic to ASD (i.e., absence/presence of verbal communication) have been demonstrated to affect children with ASD’s interaction with animals (guinea pig, Grandgeorge et al., 2014).

Parental Influence in Service Dog-Children with ASD Interactions

During interaction with a service dog, children with ASD were more likely to be at some distance from their parent(s). This observation may reflect a certain ease allowing them to interact physically “alone” with the service dog or to initiate an activity without being close to their parent(s). We cannot however rule out that this distancing from the parent may be caused by atypical regulation of inter-individual comfort distances related to ASDs (Gessaroli et al., 2013).

When parents spoke to their children with ASD, they mostly encouraged them to interact with the service dog rather than moderated their activity with the service dog. Interestingly, few reports focus on the parental role in child with ASD and dog interactions. With a larger point of view throughout studies about animal assisted interventions, as do therapists supporting children with ASD’s interactions with therapy animals, parents may have to promote and maintain their child’s engagement in activities with the service dog and help them to adjust their behavioural repertoire (Redefer & Goodman, 1989). Previous reports showed that parents could influence the relationships between the children with ASD and the animals indirectly (guinea pig, Grandgeorge et al, 2014; pet dog, Carlisle, 2014b). Thus, exploring the influence of parenting style on children with ASD’s interactions with animals could be of great interest for future studies. This could be all the more important because different parenting styles of parents of ASD children exist and they differ from those of parents of neurotypical children (e.g. Boonen et al., 2015). We also observed that parental guidance varied according to the children with ASD’s behaviours during interactions with a service dog. Indeed, children with the “subjected to parental supervision” profile (i.e. who received more parental guidance) were the ones who also interacted less proximally with the service dog, gazed less at their parent(s) and gazed more at board games. This result might reflect that parents adjust the guidance provided to their children with ASD according to their behaviour, and more specifically, according to their behaviour towards an animal and their visual attention.

Impact of Age and ASD Severity on the Children's Interaction with a Service Dog

The older the children with ASD were, the more they interacted proximally with the service dog, and the more they looked at it or at their parent (versus at board games or other items) during the interaction. Similarly, the older the children with ASD were, the more time they spent looking at the evaluator’s head during the presentation phase. A similar increase in the time spent looking at peoples’ head with age in individuals with ASD has been described in previous studies (e.g., Kaliukhovich et al., 2020). Thus, our study confirms that a child’s age seems to be a critical factor that must be considered when studying interactions between children with ASD and an animal. For example, Grandgeorge et al. (2012a) reported that the children with ASD who went directly to the unknown animal (i.e., guinea pig) were the oldest. At the same time, a child’s age is also important for neurotypical children in interaction with animals. Indeed, the older they are, the more they use verbal interactions with animals, as adults do (e.g. pet dogs: Eckerlin et al., 1989; pet cats: Mertens & Turner, 1988). It is important to note that, when controlling our data for children with ASD’s age, our results still highlight a significant link between visual attention and behavioural strategies during the interaction with a service dog. Exploring the ontogeny of interactions between children with ASD and animals, especially service dogs, could provide a great deal of elements of interests, notably for organisms providing service for children with ASD.

Previous studies reported that the severity of symptoms may affect interactions with animals (service dog, Dollion et al., 2019, submitted; guinea pig, Grandgeorge et al., 2014). However, in the present study, this variable did not seem to impact either the behavioural strategies adopted with the service dog or the orientation of gazes of
the children with ASD towards the service dog. This may be due to the fact that all the children included in our study had been diagnosed with mild to moderate ASD, resulting in less variability in the spectrum, which might have therefore lessened the effect of ASD severity.

**Limits, Conclusion and Perspectives**

Although our research demonstrated a link between visual attention of children with ASD and their behaviour, our sample was relatively restricted. Therefore, these observations, especially our second study, need to be replicated with a larger sample size, in order to improve the reliability of the data and to confirm our results. Testing a larger sample would also allow gender comparisons, which would be interesting as gender differences in neurotypical children–pets interactions are commonly observed (dogs, cats, birds, fishes; Rost & Hartmann, 1994; dogs, cats, Kidd & Kidd, 1987). An additional limitation would be that, for ethical reasons, all children with ASD included in the present research had been preselected for service dog placement. This preselection was partly based on their initial attraction to dogs. This recruitment constraint may have reduced inter-individual differences concerning attraction to service dogs. Further studies should include deeper attention to the whole body of social partners of the children with ASD. Indeed, because of the often-observed avoidance of eyes, some children with ASD may have fixated the evaluator's body (i.e. bust) rather than his/her face. Thus, delimiting our AOs solely on the head of social agents may have had a limiting effect on the data collected concerning attention paid to them.

To conclude, our research shows that a service dog is visually attractive and an attractive interaction partner for children with ASD. Furthermore, all children with ASD did not show the same interest in a service dog, and they had different types of strategies and interaction behaviors with it. This study demonstrated a link between children with ASD’s visual attention and their behaviour during interaction. The results obtained by eye-tracking not only confirmed the existence of this link but also seemed to indicate that the level of attention towards other humans (i.e. their parent(s) and the evaluator) is associated with how children with ASD interact with an animal. We notably observed that looking at their parent (as well as the evaluator [study 2]) was associated with children making more physical contact with the service dog and that parents seem to adapt the support they provide to their child (i.e., here their vocalisations) according to the way their child with ASD interacts with the service dog. Parents could thus be an important source of support and guidance for children with ASD’s interaction with an animal. Furthermore, these results seem to indicate that considering the child attention towards social partners (i.e., his/her parent and/or the evaluator) could be an additional element that service dog agencies may consider (on top of the child’s interaction with the dog) in their evaluation process for placement of a service dog. It would be interesting to further these results by studying in finer detail how children with ASD explore animal faces and bodies while interacting with them in "close to life" conditions.

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Declarations

Conflict of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

Ethical Approval Both these studies were observational, non-invasive, and did not involve pharmacological interventions for either the children with ASD or the service dogs. Both were performed in line with the principles of the Declaration of Helsinki and both study protocols received approval by the University of Montreal’s Research Ethics committee in Education and Psychology (Study 1: CERAS-2018–19-11-D; Study 2: CEREP-19–130-P).

Informed Consent Informed consent was obtained from all individual participants included in the study. All parents provided written consent to allow their child with ASD to participate in this study. All children with ASD also provided their verbal and written approval for their participation.

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