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Autistic and Nonautistic People Evaluate Eye Contact Cues in Context to Identify Communicative Opportunities

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Effective gaze-based joint attention requires distinguishing between communicative gaze and private gaze. Eye contact and repeated averted gaze shifts to the same location are key cues for gaze-based communication, but the temporal and perceptual dynamics of these cues in signaling communicative intent remain unclear. This study examines three perceptual properties of dynamic eye gaze displays and their influence on the perception of communicative intent. Autistic and nonautistic participants completed a semi-interactive task with an onscreen agent displaying dynamic eye movements searching for an object. Participants decided whether the agent was privately inspecting the objects or requesting the participant to "give" them one (i.e., attempting to communicate). We manipulated whether the agent displayed eye contact, made repeated gaze shifts at the same object, and the duration of gaze displays. We measured the frequency of "give" responses (indexing perceived communicative intent) and reaction times (indexing response certainty/bias). Participants were most likely to perceive communicative intent following displays comprising eye contact and repeated gaze. Gaze duration was a less potent signal, but increased perceptions of communicative intent in the absence of eye contact and repeated gaze. Autistic and nonautistic participants exhibited similar patterns, challenging the view that autistic people have broad "deficits" in understanding social gaze cues.

Public Significance Statement

This study reveals that eye contact and repeated gaze shifts are strong cues of communicative intent. Autistic and nonautistic people can effectively interpret these gaze cues to determine communicative intent, challenging the traditional view that autistic people have a reduced ability to understand social gaze. These findings enhance our understanding of social communication and could inform the design of artificial agents (e.g., social robots) so that they display the social behaviors that humans can intuitively understand and respond to.

Keywords: eye gaze, communicative intent, human–computer interaction, joint attention, autism

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Joint attention is the social act of two people aligning their attention so that they are focused on the same object or event (Bruner, 1974). This social skill plays a critical role in facilitating collaborative interactions (Gregory & Kessler, 2022) and supports the development of language and social cognition throughout the lifespan (Charman, 2003; Dawson et al., 2004; Mundy & Newell, 2007; Murray et al., 2008). Joint attention can be achieved through gestures or spoken language, with gaze cues being particularly important because they provide constant and rapid information about the visual perspectives and intentions of others (e.g., Gobel et al., 2015; Kleinke, 1986; Mundy & Newell, 2007). However, the ubiquity and dynamic nature of eye gaze also means that they can be an ambiguous cue in signaling joint attention opportunities (Yu & Smith, 2013, 2017). For example, eye movements may either signal an intentional communicative bid for joint attention or they may reflect a private visual search. As such, when responding to a joint attention bid, one must rapidly discern whether the social partner's gaze was intentionally communicating to signal joint attention. It remains unclear, though, what signals people rely on when making such evaluations.

Understanding how communicative intent is perceived is particularly important in the context of neurodevelopmental conditions like autism (e.g., Mundy, 2016). Indeed, delays or difficulty in following gaze and achieving joint attention have become key behavioral markers in the diagnosis of autistic children (Iwauchi et al., 2023; Lord et al., 2012; Zwaigenbaum et al., 2005). Autistic adults have also expressed difficulty in understanding the social meaning of communicative gaze (Caruana et al., 2018) or have described eye contact experiences with others as overwhelming and psychologically distressing (Trevisan et al., 2017; see Stuart et al., 2023 for a review). The mindreading system introduced by Baron-Cohen (1995) postulates that apparent differences in gaze processing between autistic and nonautistic people lead to differences in mentalizing abilities. The model comprises four cognitive modules that explain the ability to achieve joint attention and understand the minds of others. This includes an "intentionality detector," which refers to the cognitive ability to evaluate behaviors (e.g., eye movements) as intentional. This module works alongside the "Eye Direction Detector," which is argued to be specialized for recognizing eyes and interpreting the direction of gaze. Together, these two cognitive processes are proposed to support our capacity for joint attention. These processes are argued to underpin more complex mentalizing abilities. Consistent with this model, joint attention and mentalizing difficulties in autism are argued to stem from more fundamental cognitive divergences in the development of these gaze and intention processing systems. Indeed, this has inspired decades of research attempting to operationalize whether autistic people exhibit a reduced sensitivity to the spatial information conveyed by eye gaze. However, studies have failed to reliably evidence such divergences (e.g., Nation & Penny, 2008).

Despite the extensive experimental investigation of gaze-based joint attention in autistic people (see Chita-Tegmark, 2016; Frazier et al., 2017 for a review), studies have not consistently identified or explained "impairments" in autism using objective measures of behavior or attention (e.g., Caruana et al., 2024; Falck-Ytter & von Hofsten, 2011; Fletcher-Watson et al., 2008; Kuhn et al., 2010; Swettenham et al., 2003; Vida et al., 2013). As such, it remains unclear why gaze-based communication can be difficult for autistic people. While several eye-tracking studies suggest autistic people are less likely to look at faces (Nakano et al., 2010; Pelphrey et al., 2002) or spend less time fixating on the eyes than nonautistic people (e.g., Chita-Tegmark, 2016; Klin et al., 2002; Papagiannopoulou et al., 2014; Setien-Ramos et al., 2023), other studies did not replicate these findings (Chita-Tegmark, 2016; Falck-Ytter & von Hofsten, 2011; Frazier et al., 2017). Likewise, experimental designs that used eye gaze as a cue to direct participants' attention to a specific location in their visual field, using Posner-style cueing tasks, have not reliably replicated findings of reduced sensitivity to gaze information in autistic compared to nonautistic people (see Gillespie-Lynch et al., 2013; Nation & Penny, 2008 for related reviews).

One possible reason for inconsistent findings on gaze-based joint attention in autistic people may be a limited understanding of how perceptual factors influence the evaluation of communicative intent in typical development. Much of the gaze processing literature has focused on how people automatically respond to averted gaze cues in isolation. However, we know that daily social interactions demand the ability to respond to dynamic sequences of eye movements that include both averted gaze (i.e., gaze at a specific location) and direct gaze (i.e., eye contact; Caruana et al., 2015; Redcay et al., 2012; Tylén et al., 2012). This dynamic context of eye movements provides important clues about the relevance of upcoming eye movements, which can signal opportunities for joint attention (Alhasan & Caruana, 2023; Caruana et al., 2020). The process of evaluating and responding to such dynamic gaze displays requires not only the evaluation of spatial cues but also for these cues to be evaluated in context, which depends more on volitional attention processes than those indexed by cueing paradigms (Caruana et al., 2017).

An important contextual factor in dynamic eye movements is the display of averted gaze shifts. Repeated averted gaze shifts to the same location may emphasize the relevance of contextual information for joint attention. For example, Alhasan and Caruana (2023) showed that the relative context of direct and averted gaze together enhances predictiveness by providing information on where joint attention might be directed next. The study also showed that eye contact is essential for effective gaze-based joint attention, helping to distinguish between communicative and noncommunicative gaze shifts during visual searches. However, Alhasan and Caruana (2023) did not explicitly compare how repeated averted gaze displays to the same location are evaluated in the presence and absence of eye contact. Thus, the study could not directly address the role of eye contact in dynamic sequences or how eye contact interacts with repeated averted gaze displays to shape the evaluation of communicative intent.

In addition to averted gaze shifts, studies that are based on nondynamic contexts have established the importance of eye contact signals during social communication and suggest that eye contact is an important cue for preparing people for social interaction (Cañigueral & Hamilton, 2019). Eye contact displays offer an opportunity for joint attention and, therefore, increase the likelihood of initiating conversation (Cary, 1978). Eye contact has also been found to rapidly activate regions in the brain that are associated with representing the mental states and intentions of others (Caruana et al., 2015; Hooker et al., 2003; Kampe et al., 2003; Wicker et al., 2003), supporting models that claim eye contact rapidly primes neurocognitive mechanisms of understanding the intentions and perspectives of others (Senju & Johnson, 2009). However, studies on gaze perception and eye contact have not been able to effectively examine the perceptual features that support the interpretation of eye contact as communicative when embedded in more realistically dynamic interactions.

Caruana et al. (2025) began to explore the role of eye contact in more dynamic gaze displays. Participants were instructed to support a virtual agent in constructing an off-screen block model that was not visible to the participants using one of three blocks displayed on the screen (see Figure 1). In some trials, the required block would be accessible to the agent, while, in others, the agent would need the participants' assistance to obtain the required block. During each trial, participants had to observe the agent search through the blocks and decide whether to "give" one of the blocks to the agent (indicating their perception of communicative intent) or to "not give." The task comprised six gaze conditions that manipulated whether and when eye contact was displayed by the agent in a dynamic sequence of three gaze shifts. Sometimes eye contact was displayed early in the sequence, later in the sequence, at the beginning and end, or not at all.

Using the above paradigm, Caruana et al. found significant differences between all conditions such that sequences without eye contact (i.e., averted gaze to three different locations; see Figure 1B, I) were perceived as least communicative. This was characterized by fewer "give" responses and reaction times (RTs) in which participants were faster to "not give" than "give," suggesting greater subjective certainty of the absence of communicative intent or a bias to "not give." "Give" frequencies increased, and RTs became more variable in conditions where eye contact was displayed at later temporal positions in the sequence. However, the most communicative condition involved repeated averted gaze shifts to the same location (hereafter referred to as "repeated gaze") before and after an eye contact display (see Figure 1B, IV). This was characterized by the highest "give" frequencies and RTs. Here, participants were also significantly faster to "give" than "not give," indicating greater certainty of the agent's communicative intent or a bias to "give." Repeated gaze shifts before and after an eye contact display were perceived to be more communicative than the three conditions:

1. when eye contact occurred only at the end (not shown in Figure 1B),
2. when eye contact occurred twice (not shown in Figure 1B), and
3. when eye contact occurred in the same temporal position (i.e., second) without a repeated gaze to the same object (see Figure 1B, II).

These comparisons suggest that it is the temporal context, and not the frequency or recency of the display, that critically shapes its perceived communicativeness. However, since this previous study did not include a condition with repeated gaze without eye contact (see Figure 1B, II), we were unable to verify whether repeated gaze influences perceptions of communicative intent independently of eye contact, or to what extent these perceptual factors interact. Such knowledge is critical for informing which perceptual gaze signals are most important for signaling communication in both human and artificial interlocutors.

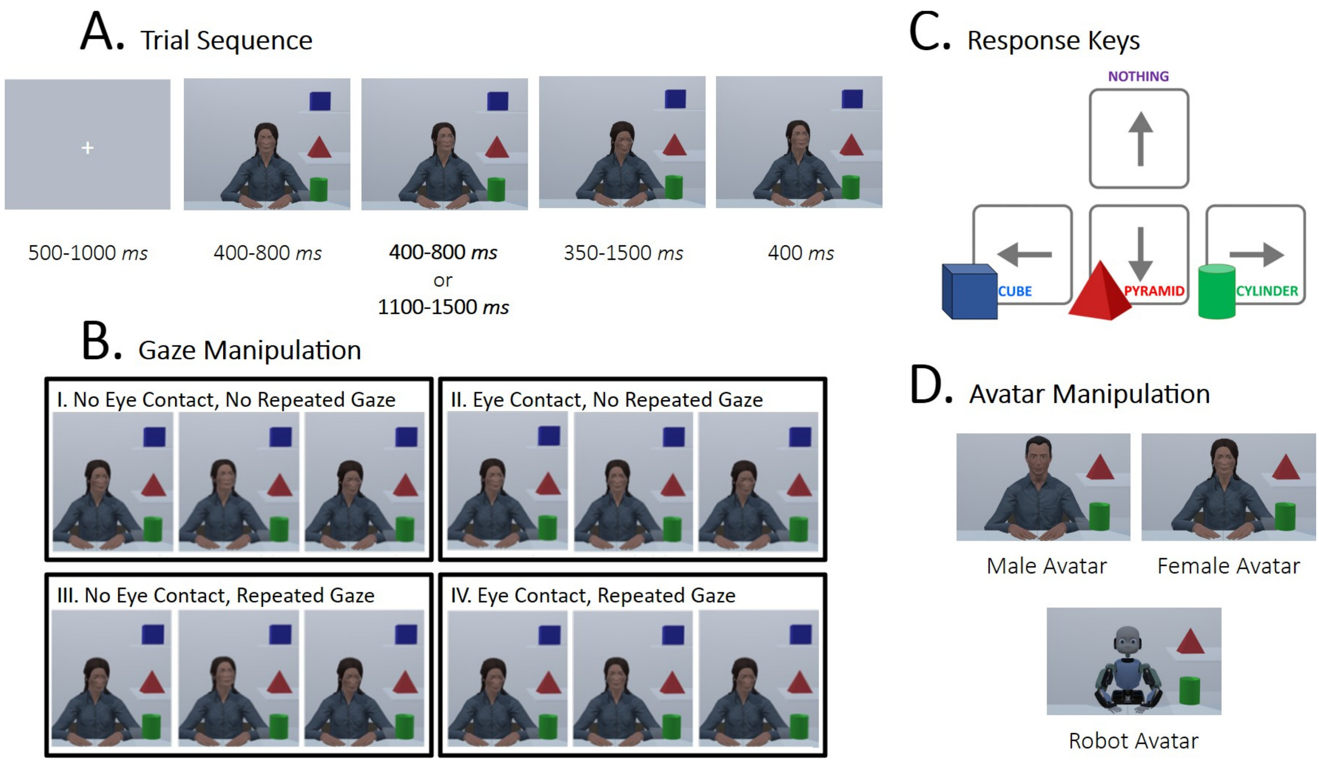
"Relevance theory" as proposed by Sperber and Wilson (1986) suggests that communication is driven by the principle of relevance, meaning that a signaler seeks to maximize relevance, while the receiver identifies the most relevant meaning in order to minimize the cognitive effort required to process the message. Within this theory, the idea of ostensive–inferential communication plays a key role, where the signaler uses ostensive cues (e.g., eye contact) to signal the relevance of subsequent communicative behaviors. The recipient then infers the signaler's intention based on the context and their own knowledge. If we consider the social context presented in Caruana et al. (2025), eye contact may serve as a clear signal of an interlocutor's intention to engage. Repeated gaze, on the other hand, may offer contextual information that informs the relevance or importance of the focus of one's attention. When presented together, these gaze cues can be useful in signaling an intentional bid for joint attention. However, the presentation of these gaze signals in isolation (e.g., repeated gaze without eye contact) is likely to be ambiguous as to whether they signal joint attention opportunities. For autistic people, the mindreading system proposed by Baron-Cohen (1995) would predict a reduced sensitivity to the communicative and contextual cues that eye contact and repeated gaze shifts provide. This would be reflected by: (a) lower rates of "give" responses (i.e., interpreting the gaze as communicative), and (b), where cues must be integrated across time and context, slower or more variable RTs, indicating greater uncertainty in processing gaze as a communicative act. These effects are likely to be exacerbated in the more ambiguous conditions, where, for instance, there are mixed signals (e.g., ostensive eye contact to signal communicative intent but no gaze repetition to signal contextual relevance).

The current study offers an opportunity to interrogate this model of joint attention in autism, by implementing a refined version of the paradigm developed by Caruana et al. (2025), examining whether autistic participants integrate ostensive cues of communicative intent (i.e., eye contact) and contextual cues for relevance (i.e., repeated gaze), which requires rapid eye movement detection and parsing to evaluate when dynamic eye movements present intentional bids for communication (i.e., joint attention).

We explored whether autistic and nonautistic people differ in their perception of communicative intent (Aim 1). We did not expect to see any evidence for "deficits" in the perception of communicative intent in autistic participants. This prediction was based on recent work challenging the traditional view of autism as a condition in which people have a reduced tendency to understand the social meaning of gaze cues, particularly in tasks that examine responses to more ecologically valid and dynamic social stimuli (e.g., Caruana et al., 2024; Pell et al., 2016; Stuart et al., 2023).

Aim 2 was to examine whether gaze effects generalize across different agents by manipulating the human likeness of the agent within participants. While previous work found no differences in the perception of communicative intent between human-looking and robot agents (Caruana et al., 2025), we included this manipulation in the current study again to confirm whether this is also the case for autistic people. Autistic people may evaluate gaze information differently from agents that either look human-like (human condition) or nonhuman (robot condition). This could be because autistic people have been found to show increased anthropomorphism tendencies (Caruana, White, & Remington, 2021; Clutterbuck et al., 2022; White & Remington, 2019). Alternatively, autistic people may find gaze information displayed by artificial agents less confronting or difficult to look at than human gaze. Valiyamattam et al. (2020), for instance, found that autistic people looked more at the eye region of pictures with nonhuman (i.e., animal) faces than human faces. Likewise, Wiese et al. (2014) showed that autistic

Figure 1
Trial Sequence and Task Design



Note. Trial sequence examples, including details of the gaze duration manipulation of the current study (A), which was applied to the second gaze shift. The second gaze shift displayed either direct gaze (B, II and IV) or averted gaze (B, I and III). In each trial, participants decided whether to "give" the agent one of the three blocks, or nothing at all, using the arrow keys on a standard keyboard (C). In one block, participants interacted with a male or female human-looking agent and, in the other, with a robot agent (D). The blocks appeared in counterbalanced order across trials, and avatar gender was counterbalanced across participants. See the online article for the color version of this figure.

people are more likely to follow the gaze of robots than humans. To further explore potential differences between autistic and nonautistic people when comparing the human and robot conditions, we collected additional subjective ratings of the agents.

In sum, the primary goals of the present study were to (a) assess whether autistic people exhibit distinct sensitivities to eye contact and repeated gaze cues in evaluating communicative intent, and (b) determine whether autistic individuals differ in their evaluation of the agent's communicative behaviors, depending on the agent form (human vs. robot).

Method

Participants

We recruited 321 participants using the online data collection platform Prolific. We ran separate batches to identify autistic ($n = 161$; 81 identified as female) and nonautistic samples ($n = 160$; 80 identified as female), based on their self-reported information in the Prolific recruitment database. The sample size was based on Caruana et al. (2025) who used a similar within-subjects design. The authors conducted an a priori sample size estimation using G*Power (V3.1; Faul et al., 2007) based on a small-to-medium within-subjects effect size of theoretical interest, namely, a Cohen's $d = 0.3$. This was based on the range of effect sizes identified in prior empirical work. We calculated Cohen's d retrospectively, using means and standard deviations. In Caruana, Inkley, et al. (2021), effect size of gaze congruency on saccadic RTs was small-to-medium ($d = 0.36$) in a task with similar stimuli. Likewise, studies manipulating gaze direction in the context of eye contact showed small-to-medium ($d = 0.42$; Caruana et al., 2020) and very small-to-medium effect sizes ($d = 0.09$–0.43; Alhasan & Caruana, 2023). The sample size estimation was performed using a paired-samples t test with the following parameters: two-tailed test, $\alpha = .05$, and desired power $(1-\beta) = 0.90$. This yielded a required minimum sample size of $n = 119$ ($df = 118$; noncentrality parameter $\delta = 3.27$; critical $t = 1.98$; see their preregistration in the additional online materials at https://osf.io/w68ut/registrations). Although this analysis was based on a simplified pairwise comparison, it was intended to provide a conservative benchmark for a minimum sample size. Caruana et al. (2025) oversampled to $n = 156$ to accommodate trial exclusions and to enable balanced sampling across participant subgroups.

In the present study, we followed this rationale in our preregistration (https://osf.io/6uyhr/) and aimed for the same target sample size per group (i.e., self-identified autistic and nonautistic participants). To further assess whether our final sample size provided adequate power for detecting main effects and interactions, we conducted a retrospective simulation-based power analysis using the Superpower (Lakens & Caldwell, 2021) and simr (Green & MacLeod, 2016) packages in R. We simulated three plausible scenarios, each assuming at least a medium effect size (Cohen's $d = 0.3$) as the minimum difference between two conditions. Simulation scripts and outputs are available in the additional online materials (folder 07_RetroPowerSimulation). Results suggested that our sample size yielded a moderate-to-high power (72% with Superpower, 100% with simr) for detecting a main effect of group, and high power (100%) to detect two-way and three-way interactions.

Autistic participants scored significantly higher on a measure of autistic traits (see the Measures section) than nonautistic participants, $t(4.3143 \times 104) = 153.67$, $p < .001$ (see Table 1 for descriptive statistics), indicating that our groups accurately represented their target populations. Participants had to be at least 18 years old, be fluent in English, reside in Western English-speaking countries (United Kingdom, United States, Ireland, Australia, New Zealand, and Canada), report no language-related disorders, and have a minimum Prolific approval rating of 95%. Participants were compensated with £9.50 per hour for an approximate duration of 30 min. Following the procedures approved by the Flinders University Human Research Ethics Committee (6804), participants provided written informed consent prior to completing the study.

Task and Procedure

We framed the task as described above within a "collaborative" context, instructing participants to "help" the agent complete the construction of an off-screen block model. In each trial, participants decided whether to "give" one of the blocks via a keyboard response or to "not give" (see Figure 1C). Full task instructions and experimental task code can be found in the Task Instructions folder in the file "Dyson 1a Instructions_12-01-2024_FR.pptx" in the additional online materials at https://osf.io/6uyhr/.

Before commencing the experimental task, participants had the opportunity to practice the response–key mapping across eight trials (two per response key). In these practice trials, participants were only shown a text prompt instructing the response (e.g., "give nothing" or "give cylinder"). Participants received feedback on each of these trials. Once the experiment began, participants viewed a series of images showing the agent looking toward one of the three objects (see Figure 1). The images were displayed in rapid succession to create the illusion of motion (see Figure 1A). At the end of each trial, participants were presented with a visual prompt reminding them of the response–key mapping as depicted in Figure 1C.

Table 1
Exposure Groups

Gender	Number of participants		Age		CATI total score	
	n	%	*M*	*SD*	*M*	*SD*
Autistic						
Female	65	26.64	34	10	158.97	29.99
Male	59	24.18	35	13	144.71	33.50
NA	2	0.82	NA	NA	155.50	34.65
Nonautistic						
Female	56	22.95	34	10	113.39	25.99
Male	62	25.41	35	11	106.98	25.84

Note. For two participants, no gender was recorded (NA). CATI = Comprehensive Autistic Traits Inventory; NA = not available.

Participants completed the experimental task in two blocks, one with a human agent and one with a robot agent. Blocks were counterbalanced across participants. Each block was divided into three mini blocks, allowing participants to take two self-paced breaks. Each of these blocks was identical in trial composition, with trials internally counterbalanced with respect to the variation and sequence of averted gaze directions across trials within each condition. In total, participants completed 96 trials for each agent (three mini blocks × 32 trials = 96), and 288 trials in total (96 trials × 2 agents = 192). We also counterbalanced whether the human avatar was male or female across participants (see example images of all agents used in the study depicted in Figure 1D).

Once participants finished a block, they completed the Godspeed rating scales, which is a standardized measure used in human–robot interaction research to examine people's perceptions of agents (Bartneck et al., 2009; see the Measures section). This allowed for subjective perceptions of the two agents to be compared within subjects, along with objective behavioral data. At the very end of the experiment, participants completed a self-report measure of autistic traits (English et al., 2021; see the Measures section).

Measures

Behavioral Measures

Following Caruana et al. (2025), we calculated, for each condition, the proportion of trials with a "give" response to index the likelihood of perceiving communicative intent and the RTs for "give" and "no-give" responses separately. The latter was operationalized as the latency between the end of the trial and the participant's button response. RTs provided an index of the participants' subjective certainty in the perception of communicative intent, with shorter RTs indicating participants were more certain in the decision.

Agent Perception

Participants completed the Godspeed Questionnaire subscales (Bartneck et al., 2009) at the end of each experimental block to assess participants' perception of each agent with respect to anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety. This standardized measure was included to provide a subjective measure of agent perception and to explore whether there were any differences between autistic and nonautistic participants in their evaluation of the artificial agents.

Autistic Traits

We measured participants' self-declared autism with the Comprehensive Autistic Traits Inventory (CATI; English et al., 2021) and to characterize our sample. This 42-item inventory evaluates "subthreshold" autistic traits that may be present in individuals who do not meet the diagnostic criteria for autism. The questionnaire is a reliable and cost-effective tool that measures the trait dimensions "social interactions, communication difficulty, social camouflage, repetitive behaviors, cognitive rigidity, and sensory sensitivity." Participants responded on a 5-point Likert scale, with higher scores indicating a greater endorsement of autistic traits.

Preprocessing Data

We followed the preprocessing procedure specified in our preregistration (https://osf.io/6uyhr/). Although there were no objectively "correct" or "incorrect" responses in our experimental task, we checked for illogical responses, indicative of a random response style. This included a "give" response for a block that the agent never gazed toward. Note that this was not possible in the no eye contact condition since the agent looked at all three blocks in these trials.

Analyses were conducted only on "logical" answers. Hence, we first removed 2,696 trials (4.37%) with excessively short (i.e., <150 ms) or long RTs (i.e., >3,000 ms), as these were likely to be preemptive or "guess" responses. Next, we removed 38 participants with more than 35% of illogical answers. Of the remaining 283 participants, we excluded 15 participants from analyses with a rate of illogical answers that were more than 2.5 *SD* away from the sample mean. We also removed one participant because they consistently provided "no-give" responses, which indicated that they may not have been following task instructions or fully engaging in the task. For the remaining sample, we further checked for evidence of acquiescent response styles by examining the distribution of their "give" responses across the three block options. Since the task was designed to counterbalance the block locations that the agent gazed toward last, we expected "give" responses to be equally distributed across the three "give" response keys, with an *SD* of response frequency close to zero. We excluded 12 participants (9.75% of the trials) with *SD*s that were 2.5 *SD*s greater than the average *SD* observed across these three response options. This deviation indicated a divergent preference to "give" a particular block significantly more (or less) than the others. We then removed all "illogical" response trials from the remaining participants (2.65% of trials) and, afterwards, excluded seven participants for whom we were required to remove an excessive number of trials (number of retained trials < 2.5 *SD*s of the sample mean). Finally, we removed four participants who were too slow or too fast from the remaining participants (RTs< or >2.5 *SD*s than the sample mean). The final data set contained 244 participants. The demographics of the final data set can be found in Table 1.

Design and Analysis

Behavioral Measures

The current study implemented a mixed design with a 2 (eye contact: eye contact/no eye contact) × 2 (repeated gaze: repeated gaze/no repeated gaze) × 2 (gaze duration: long/short) × 2 (group: autistic/nonautistic) × 2 (agent: human/robot) design. All factors were manipulated within subjects, except Group. We followed our analysis plan preregistered in the additional online materials at https://osf.io/6uyhr/. All analyses were conducted using custom R scripts with R Statistical Software (V4.5.0), which can be found, alongside all data, in the Analysis folder in the additional online materials at https://osf.io/6uyhr/. We first tested the two factors repeated gaze and eye contact across four conditions (see Figure 1B): (a) eye contact + repeated gaze: eye contact between two averted shifts to the same block (see Figure 1B, IV); (b) eye contact + no repeated gaze: eye contact between two averted shifts to different blocks (see Figure 1B, II); (c) no eye contact + repeated gaze: three averted gaze shifts, with the first and last to the same block (see Figure 1B, III); and (d) no eye contact + no repeated gaze: three averted gaze shifts to different blocks (see Figure 1B, I). We expected participants to be more likely to perceive communicative intent (i.e., "give" a block) and be more certain in their response (i.e., be faster to "give" than "not give") when the agent displayed eye contact than when it did not (i.e., main effect of eye contact). We also anticipated participants to be more likely and faster to "give" when the agent showed repeated gaze than unique gaze shifts (main effect of repeated gaze). Additionally, we predicted an Eye Contact × Repeated Gaze interaction, such that the effect of eye contact (i.e., stronger perceptions of communicative intent when eye contact was displayed) would be greatest in the absence of repeated gaze. We also anticipated that this interaction would reflect a pattern in which gaze sequences that involved repeated gaze without eye contact would be perceived as ambiguous in signaling communicative intent. This ambiguity would be reflected in lower "give" frequencies and a smaller difference in RT between "give" and "no-give" responses compared to sequences that involved repeated gaze and eye contact.

Secondly, we tested the role of gaze duration by manipulating the duration of the second (i.e., middle) gaze shift (see Figure 1A). Gaze duration can impact social evaluations, such as perception of assertiveness, decisiveness, dominance, aggression, and likeability (e.g., Brooks et al., 1986; Cañigueral & Hamilton, 2019; Kuzmanovic et al., 2009), as well as arousal and social (dis)comfort (Helminen et al., 2011; Jarick & Bencic, 2019). For this study, we selected two ranges of gaze durations from the range used in previous studies of gaze-based joint attention involving dynamic and interactive gaze displays (Alhasan & Caruana, 2023; Caruana, Seymour, et al., 2019; Caruana et al., 2020). In the short gaze duration condition, the range was from 400 to 800 ms, and in the long gaze duration condition, from 1,100 to 1,500 ms. We expected that participants would be more likely to perceive longer gaze displays as more communicative than shorter gaze displays (i.e., main effect of gaze duration). We also anticipated a Gaze Duration × Eye Contact interaction, such that participants would be most likely to perceive communicative intent when eye contact was displayed at longer durations.

For both behavioral measures (i.e., "give" frequencies and RTs), we adopted the same analysis approach as in Caruana et al. (2025), to examine main effects and interactions related to eye contact, repeated gaze, gaze duration, group, and agent. For RT analyses, as in our past work, we additionally included response type (give, no-give) as a fixed effect to account for asymmetries in response mapping: the "no-give" option was always tied to a single key, while "give" decisions were distributed across three different keys. Therefore, rather than interpreting raw RTs as indicators of confidence, we focused on within-condition comparisons between response types. This allowed us to examine whether specific gaze cues selectively speeded up one response over the other, which can suggest increased certainty or response bias in favor of that option. Here, we assessed relative RT differences between "give" and "no-give" responses as a more robust indicator of how gaze cues modulate the decision-making process of "giving" versus "not-giving" than comparing RTs between conditions, averaging across response type. This approach, using linear mixed effects (LME; see below), was also robust for missing responses in some conditions and response types. Given the typically skewed RT distribution, we transformed RTs using the box-cox powerTransform function from the car R package (V3.1.3; Fox et al., 2011) to avoid bias in the estimation of model parameters (Balota et al., 2013).

Subsequently, we fitted LME and generalized LME (GLME) models on unaggregated data, employing the maximum likelihood estimation method within the lme4 R package (V1.1.37; Bates et al., 2015). We used this approach since we anticipated that some participants might not have consistently provided a "give" or "no-give" response within each condition. Aggregating data in such instances could have led to bias because aggregated RTs in one condition would be based on more observations than RTs in others. To achieve a maximal random factor structure, we adhered to the analysis pipeline recommended by Scandola and Tidoni (2024), involving the use of model optimization and implementation of complex random intercept (CRI) models. This pipeline involves the definition of complex random effects structures, with intercepts defined using multiple interacting intercepts, when maximal models with random slopes for all random effects cannot be robustly estimated. More details on the full and reduced models can be found in the Analysis/04_MMsChecks folder in the additional online materials at https://osf.io/6uyhr/.

All *p*-values of the (G)LME models were estimated using the afex R package (V1.5.0; Singmann et al., 2024), with a significance criterion of $\alpha < .05$. For post hoc comparisons, we used the emmeans R package (V2.0.0; Lenth, 2024) to conduct pairwise comparisons of individual conditions averaged across all other conditions. For instance, for the Eye Contact × Repeated Gaze interaction, we compared the eye contact and no eye contact conditions for both no repeated gaze and repeated gaze, averaging across all other conditions. We used the same approach to all significant interactions. Moreover, we applied a Holm correction where appropriate to adjust contrasts for multiple comparisons.

Since results were similar across groups, we also repeated the analyses for each group separately to confirm whether or not the individual groups showed the same pattern of results. We found, in most cases, the same pattern of results for both the autistic and nonautistic groups. For the sake of brevity, we will only highlight differences between groups from these analyses. However, comprehensive results for the individual group models can be found in the Analysis/05_AnovaPH folder in the additional online materials at https://osf.io/6uyhr/.

Agent Perception

To further investigate whether agent perception differed between groups, we compared godspeed subscale scores across groups with cumulative link models using the ordinal R package (V2023.12.4.1; Christensen, 2023).

Transparency and Openness

This study adheres to the transparency and openness promotion guidelines to ensure the reproducibility and transparency of our research. The data collection for this study was conducted in 2024. All materials, data, and analysis scripts are available as the additional online materials on the Open Science Framework repository (https://osf.io/6uyhr/). We have preregistered our study design and analysis plan, which can be accessed at the same link.

We acknowledge that our findings are based on a sample of participants recruited from Western English-speaking countries, which may limit the generalizability of the results to other cultural or linguistic contexts. Additionally, the semi-interactive nature of the task with an onscreen agent may not fully capture the complexities of real-world social interactions. Future research should consider these constraints and aim to replicate our findings in more diverse and ecologically valid settings.

Results

Behavioral Measures

"Give" Frequencies

We investigated whether there were differences in the tendency to "give" (i.e., perceive communicative intent) across the gaze conditions (eye contact, repeated gaze, and gaze duration) and whether there were any differences in the influence of these gaze features between autistic and nonautistic people (i.e., group) or agent. Descriptive statistics for both behavioral measures are summarized by condition in Table 2.

The random effect parameters defined in each model[1] accounted for a substantial portion of variance as evidenced by the marginal R^2 (variance explained by fixed effects only) and conditional R^2 values (variance explained by both fixed and random effects) summarized in Table 3.

Do Eye Contact and Repeated Gaze Affect the Tendency to "Give"? We found significant main effects of eye contact ($\beta = -2.14$, $SE = 0.14$, $p < .001$) and repeated gaze ($\beta = -1.48$, $SE = 0.11$, $p < .001$). As predicted, participants were more likely to "give" both when the agent displayed eye contact than when it did not, and when gaze was repeated than when it was unique.

Critically, we found evidence for a significant interaction between eye contact and repeated gaze ($\beta = 0.49$, $SE = 0.09$, $p < .001$). This interaction was characterized by a higher likelihood to "give" when the agent displayed eye contact together with a repeated gaze and a smaller difference between "give" and "no-give" responses when averted gaze displays were unique (see Figure 2; for the interested reader, a similar figure using estimated marginal means can be found in the 03_plots_EMM folder in the additional online materials at https://osf.io/6uyhr/). Pairwise comparisons revealed significant differences in "give" frequencies between all four gaze conditions. People were significantly more likely to "give" when the agent displayed eye contact and repeated gaze (eye contact + repeated gaze) than when averted gaze displays were unique (eye contact + no repeated gaze; estimate $= -3.94$, $SE = 0.32$, 95% confidence interval [CI] [−4.71, −3.18], $z = -12.35$, $p < .001$); when the agent displayed eye contact and did not repeat the gaze than when it made no eye contact and repeated gaze (no eye contact + repeated gaze; estimate $= 1.31$, $SE = 0.35$, 95% CI [0.4, 2.22], $z = -12.35$, $p < .001$); and when the agent displayed no eye contact and repeated gaze than no eye contact with unique gaze displays (no eye contact + no repeated gaze; estimate $= -1.98$, $SE = 0.27$, 95% CI [−2.67, −1.29], $z = -7.41$, $p < .001$). All other comparisons between conditions were also significant (all $ps < .001$; see Analysis/05_AnovaPH folder in the

[1] The random effects structure as selected by the CRI approach differed slightly between models. See additional online materials at https://osf.io/6uyhr/ for the exact model structures.

Table 2
Descriptive Statistics

Gaze condition	Gaze duration	Agent	Group	Give frequency (%)	Give RT (ms)	No-give RT (ms)
Eye contact, no repeated gaze	Long	Human	Autistic	69.47 (37.03)	770.97 (499.71)	856.46 (542.97)
			Nonautistic	66.09 (41.14)	751.77 (508.54)	696.49 (423.21)
		Robot	Autistic	71.45 (37.74)	743.88 (458.79)	754.92 (467.76)
			Nonautistic	64.19 (41.08)	755.42 (519)	760.49 (499.79)
	Short	Human	Autistic	67.2 (36.83)	801.3 (516.42)	892.87 (517.98)
			Nonautistic	62.34 (40.48)	805.23 (526.65)	789.92 (503.22)
		Robot	Autistic	69.3 (36.97)	831.09 (525.22)	849.6 (514.24)
			Nonautistic	62.24 (41.57)	794.86 (510.14)	773.63 (491.95)
Eye contact, repeated gaze	Long	Human	Autistic	93.65 (16.49)	606.64 (358.11)	806.44 (571.69)
			Nonautistic	95.66 (12.6)	579.3 (351.39)	886.67 (674.24)
		Robot	Autistic	96.8 (12.05)	592.88 (323.07)	838.02 (541.88)
			Nonautistic	97.38 (10.04)	579.94 (350.05)	827.11 (564.54)
	Short	Human	Autistic	94.14 (15.66)	617.83 (344.44)	935.6 (554.86)
			Nonautistic	95.74 (9.81)	596.12 (333.05)	956.14 (503)
		Robot	Autistic	96.23 (12.43)	620.38 (354.41)	979.8 (721.34)
			Nonautistic	97.3 (6.83)	596.62 (349.49)	1,030.6 (617.74)
No eye contact, no repeated gaze	Long	Human	Autistic	39.42 (38.3)	736.14 (484.24)	696.43 (409.64)
			Nonautistic	31.58 (36.81)	821.33 (537.79)	649.99 (399.15)
		Robot	Autistic	37.45 (40.54)	800.43 (509.93)	705.86 (427.19)
			Nonautistic	30.13 (35.61)	809.85 (532.75)	679.39 (407.41)
	Short	Human	Autistic	33.11 (37.27)	795.16 (492.31)	709.43 (429.41)
			Nonautistic	24.43 (35.12)	837.23 (541.8)	670.55 (422.65)
		Robot	Autistic	31.77 (38.78)	852.68 (532.88)	716.07 (415.38)
			Nonautistic	22.8 (34.08)	814.19 (528.53)	688.35 (410.47)
No eye contact, repeated gaze	Long	Human	Autistic	59.07 (40.27)	721.82 (447.27)	696.13 (463.92)
			Nonautistic	52.9 (40.85)	773.21 (483.68)	661.63 (462.75)
		Robot	Autistic	58.19 (40.29)	736.97 (448.75)	708.97 (454.76)
			Nonautistic	55.22 (40.37)	786.67 (512.82)	678.17 (483.27)
	Short	Human	Autistic	57.31 (39.38)	776.49 (486.15)	727.84 (458.59)
			Nonautistic	50.24 (40.44)	774.48 (442.37)	695.18 (454.9)
		Robot	Autistic	57.18 (40.47)	795.42 (467.29)	703.61 (442.02)
			Nonautistic	50.82 (39.38)	797.91 (481.87)	695.84 (488.53)

Note. "Give" frequencies are summarized as the percentage of trials that participants responded by giving a block to the agent. Reaction times are summarized by response. Means and Standard deviations are reported in the format "*M* (*SD*)." RT = reaction time.

additional online materials at https://osf.io/6uyhr/ for a detailed report).

Does Gaze Duration Affect the Tendency to "Give"? We examined whether gaze duration also influenced the perception of communicative intent. We found that, as expected, gaze duration had a significant effect on "give" frequencies (β = −0.2, SE = 0.03, $p < .001$), with higher "give" frequencies for long gaze durations than short gaze durations.

Table 3
R^2 Values for Each (G)LME Analysis

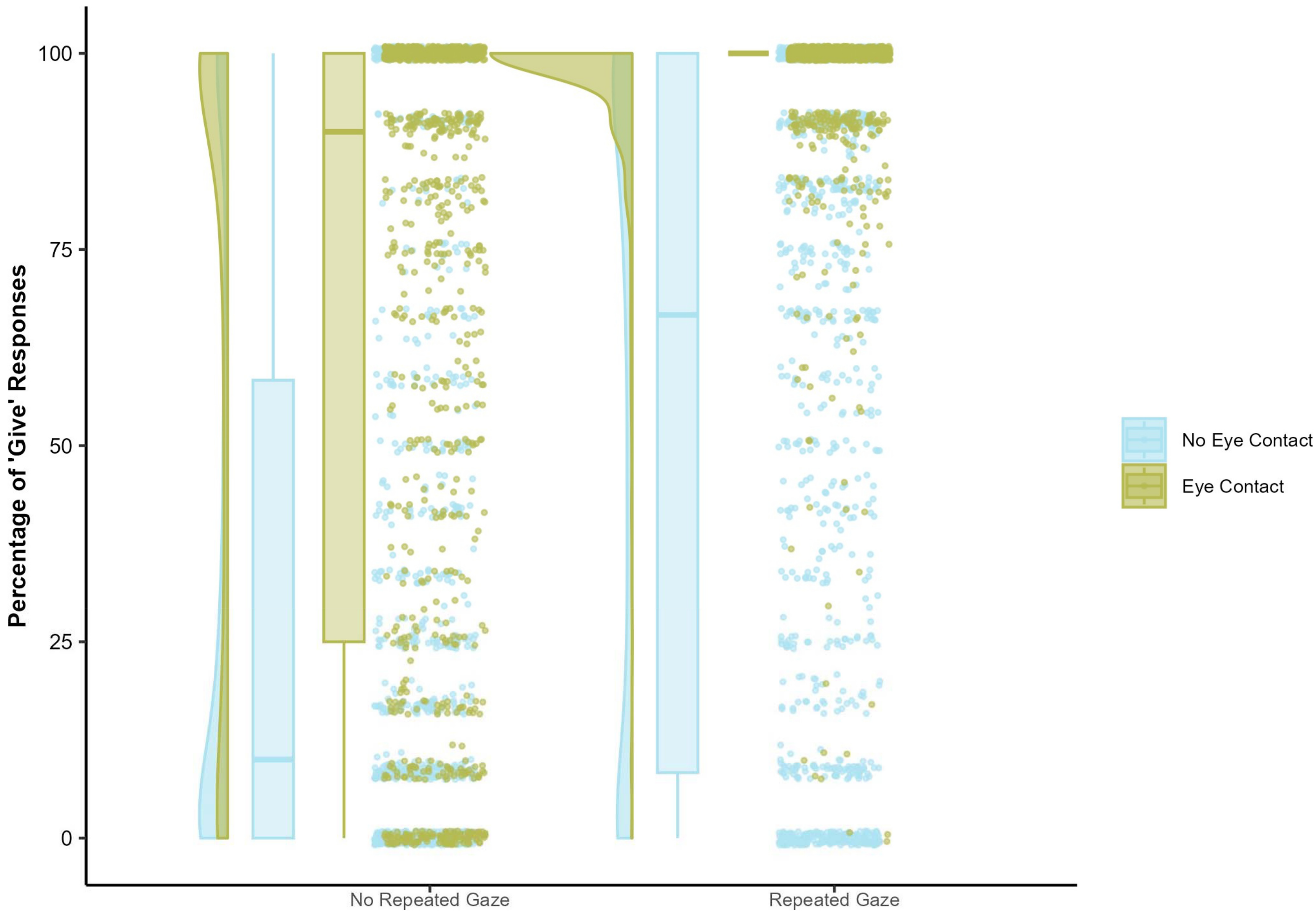
Subset	R^2 Marginal	R^2 Conditional
Give frequency data		
Nonautistic	.34	.86
Autistic	.28	.85
Full data set	.31	.86
Reaction time data		
Nonautistic	.05	.50
Autistic	.05	.44
Full data set	.05	.47

Note. Marginal R^2 values represent the variance explained by the fixed effects only, and conditional R^2 values represent the variance explained by both fixed and random effects. (G)LME = (generalised) llinear mixed-effects.

We also found evidence for a significant interaction between eye contact and gaze duration (β = −0.06, SE = 0.03, p = .021; see Figure 3). Follow-up pairwise comparisons of the individual eye contact and gaze duration conditions showed significantly higher "give" frequencies when the agent displayed eye contact with a long gaze duration (eye contact + long gaze duration) than a short gaze duration (eye contact + short gaze duration; estimate = −0.28, SE = 0.09, 95% CI [−0.51, −0.05], z = −3.21, $p < .001$); when the agent displayed eye contact with a short gaze duration than when it made no eye contact with a long gaze duration (no eye contact + long gaze duration; estimate = −3.87, SE = 0.29, 95% CI [−4.6, −3.14], z = −13.18, $p < .001$); and when the agent made no eye contact with a long gaze duration than with a short gaze duration (no eye contact + short gaze duration; estimate = −0.52, SE = 0.06, 95% CI [−0.69, −0.36], z = −8.15, $p < .001$). All other comparisons were also significant (all ps < .001; see Analysis/05_AnovaPH folder in the additional online materials at https://osf.io/6uyhr/ for a detailed report).

Furthermore, we found evidence for a significant interaction between repeated gaze and gaze duration (β = −0.08, SE = 0.02, $p < .001$; see Figure 4). Once more, participants were more likely to "give" when the agent repeated gaze with a long gaze duration (repeated gaze + long gaze duration) than short durations (repeated gaze + short gaze duration); and when the agent did not repeat the gaze display with a long gaze duration (no repeated gaze + long

Figure 2
"Give" Frequencies per Gaze Condition



Note. See the online article for the color version of this figure.

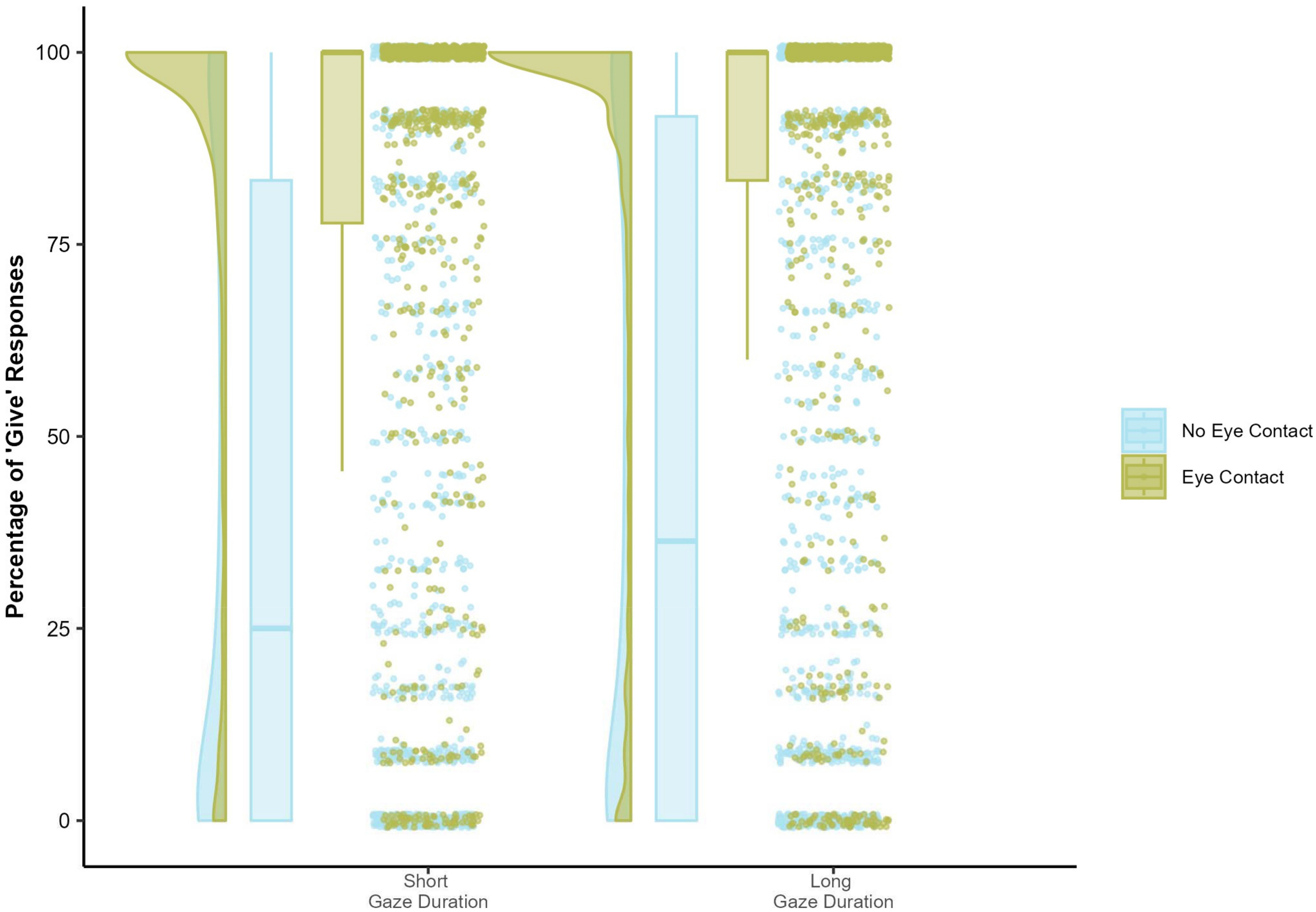
gaze duration) than a short duration (no repeated gaze + short gaze duration). All pairwise comparisons between individual repeated gaze and gaze duration conditions showed significant differences in "give" frequencies (all $ps < .001$; see the additional online materials at https://osf.io/6uyhr/ for a detailed report).

Do Autistic and Nonautistic Participants Differ in Their Tendency to "Give"? The primary focus of this study was to examine potential differences in the perception of communicative intent between autistic and nonautistic participants. As expected, we found no evidence for a main effect of group on "give" frequencies ($p = .246$) nor for an interaction between group and any of the gaze conditions (all $ps \geq .082$; see Figure 5).

Does the Human Likeness of the Gazing Avatar Affect the Tendency to "Give"? A secondary focus was to examine whether autistic people differed in their experience of gaze effects when evaluating the gaze displays made by human and robot agents. As expected, we found no evidence for a significant main effect of agent ($p = .109$). However, we found evidence for a significant interaction between agent and eye contact ($\beta = 0.11$, $SE = 0.04$, $p = .011$). The Agent × Eye Contact interaction was characterized by significantly lower "give" frequencies when eye contact was displayed by an agent that looked human (eye contact + human) than when it depicted a robot (eye contact + robot; estimate = −0.38, $SE = 0.14$, 95% CI [−0.76, −0.01], $z = -2.64$, $p = .016$). "Give" frequencies on trials where the agent did not make eye contact were not found to significantly differ between the human and robot agent conditions ($p = .699$).

We further explored whether the absence of a significant pairwise comparison between agent conditions for no eye contact was because of averaging across a diverse sample of autistic and nonautistic people, which has increased the variance in the data set. We examined whether there was any evidence for a different pattern of results when examining the nonautistic and autistic groups separately. We found that the Agent × Eye Contact interaction was significant in the autistic group ($\beta = 0.16$, $SE = 0.06$, $p = .008$) but not the nonautistic group ($p = .349$; see Figure 6). Pairwise comparisons between agent conditions across the levels of eye contact in the data set from the autistic sample confirmed the pattern observed in the full data set, with higher "give" frequencies when eye contact was displayed by a robot (eye contact + robot) than a human (eye contact + human; estimate = −0.52, $SE = 0.22$, 95% CI [−1.08, 0.03], $z = -2.42$, $p = .031$). Again, we found no evidence of differences in responses between agents when there was no eye contact ($p = .527$).

Figure 3
"Give" Frequencies per Gaze Duration Condition per Eye Contact Condition



Note. See the online article for the color version of this figure.

We also found evidence for a significant interaction between agent and repeated gaze ($\beta = 0.11$, $SE = 0.03$, $p < .001$). "Give" frequencies were significantly higher when the agent repeated an averted gaze display than when eye movements were unique. Importantly, participants gave more to the robot than the human when gaze was repeated (robot: 76.17%, $SD = 35.93$; human: 74.88%, $SD = 36.09$), but there was little difference when gaze was unique (robot: 48.79%, $SD = 42.57$; human: 49.31%, $SD = 41.65\%$). All pairwise comparisons between agent conditions across the levels of repeated gaze were significant (all *p*s < .001; see Analysis/05_AnovaPH folder; https://osf.io/6uyhr/), except for the comparison between agents for trials with unique gaze displays ($p = .594$). To examine this further, we again referred to the separate models for the autistic and nonautistic groups and found that both nonautistic participants ($\beta = 0.12$, $SE = 0.05$, $p = .020$) and autistic participants ($\beta = 0.13$, $SE = 0.04$, $p = .004$) showed evidence for a significant Agent × Repeated Gaze interaction (see Figure 7). For the nonautistic group, all pairwise comparisons between agent conditions across the levels of repeated gaze were significant (all *p*s < .001). For the autistic group, the pattern was the same as the findings reported in the full data set, with a nonsignificant comparison between human and robot conditions when the agent displayed a unique gaze sequence.

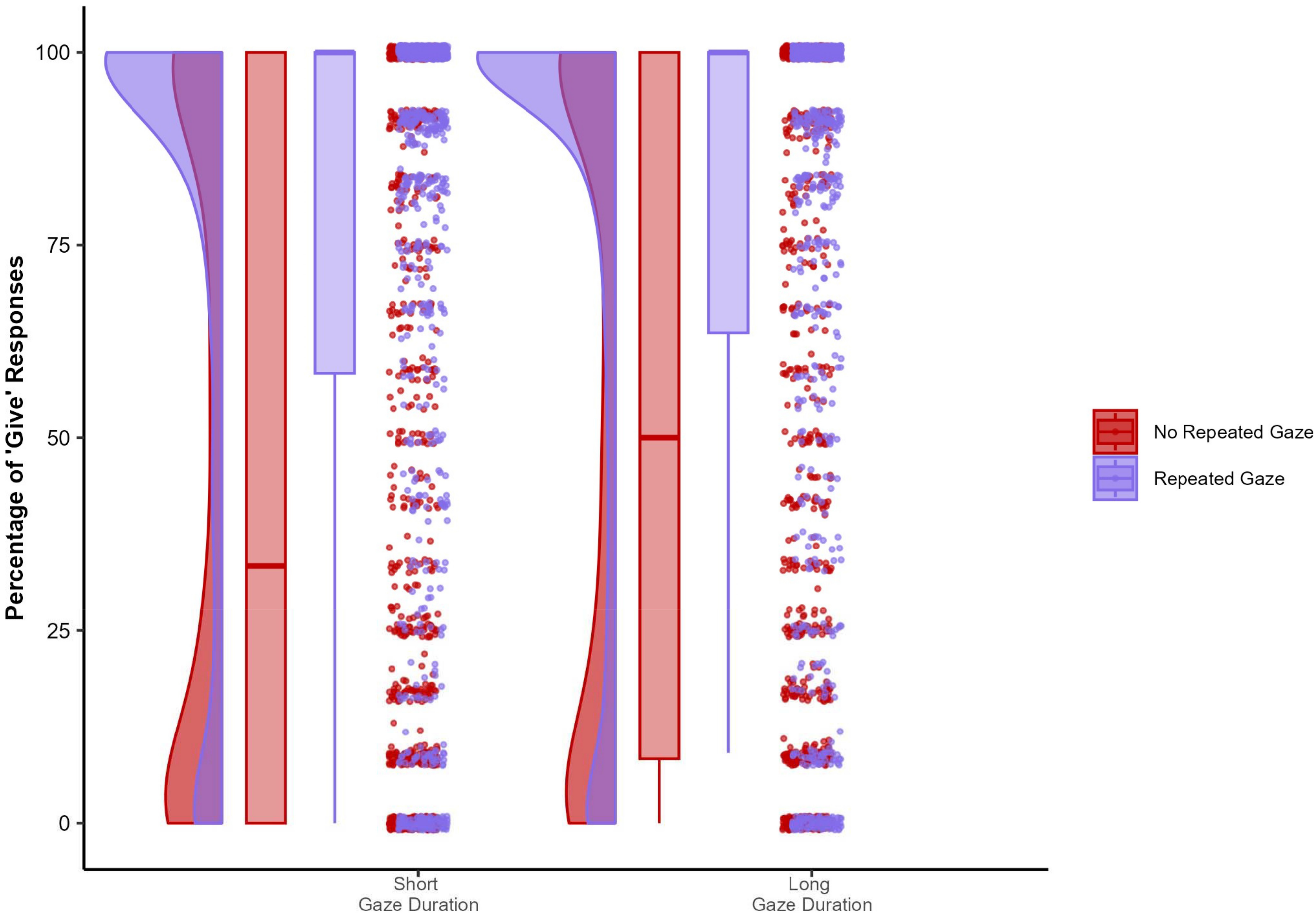
RTs

The frequency analysis reported above evaluated the influence on the likelihood of perceiving communicative intent. Our RT analysis provided an index of the degree of certainty or ambiguity experienced across conditions when deciding whether an agent's gaze was signaling communicative intent. Specifically, we preregistered that a significant difference in RTs to "give" versus "not give" a block within a particular condition would index response certainty, whereas the lack of such a difference would index ambiguity. Accordingly, our analyses focused only on interactions involving response (i.e., "give" vs. "no-give") as it would not have been informative to examine absolute RTs that average across response options. Descriptive statistics are summarized by condition in Table 2. As shown in Table 3, random effect parameters defined in these models[2] accounted for a substantial portion of variance as evidenced by the marginal and conditional R^2 values.

[2] The random effects structure as selected by the CRI approach differed slightly between models. See the Analysis/04_MMsChecks folder on the additional online materials at https://osf.io/6uyhr/ for the exact model structures.

Figure 4

"Give" Frequencies per Gaze Duration Condition per Repeated Gaze Condition

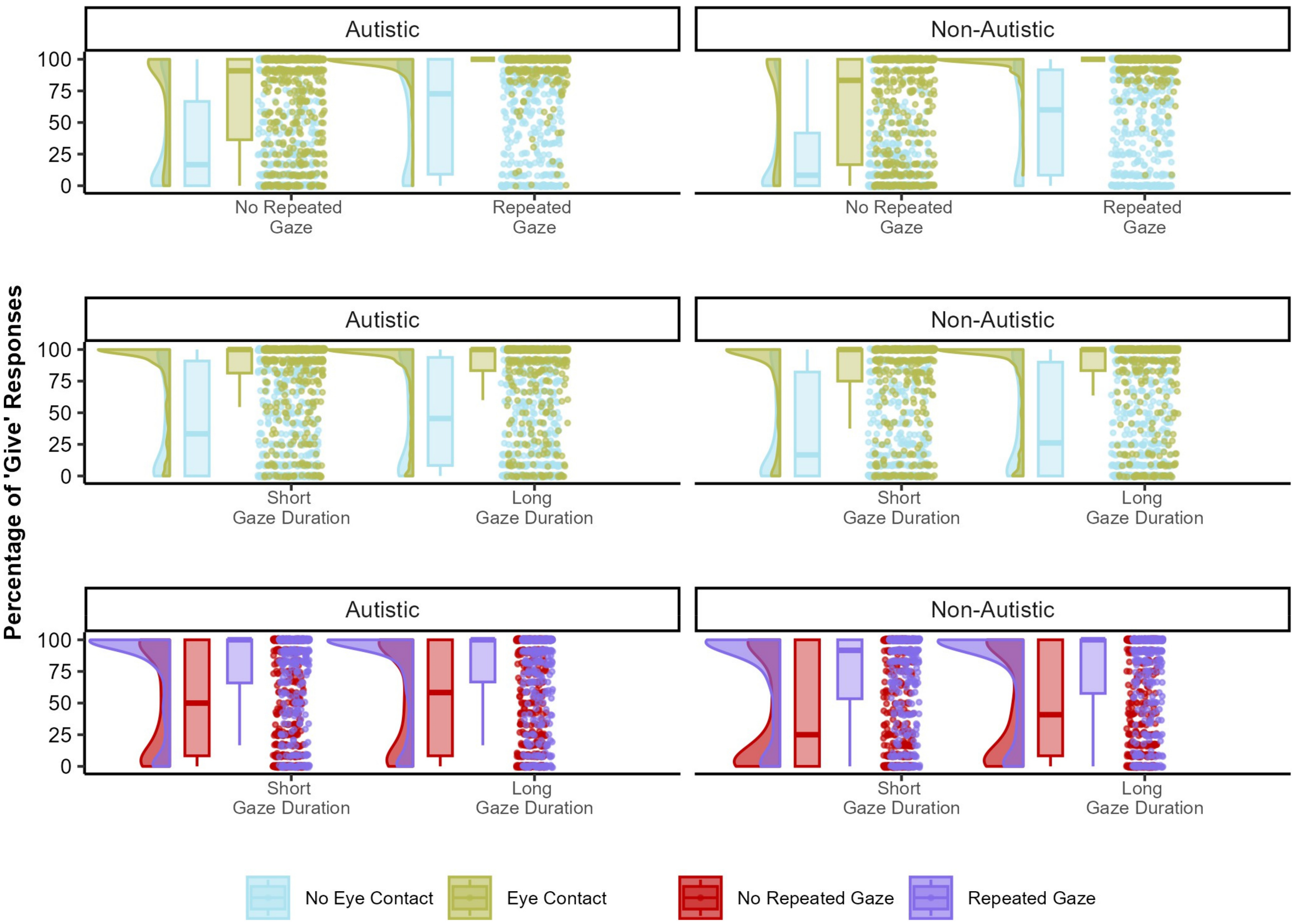


Note. See the online article for the color version of this figure.

Do Eye Contact and Repeated Gaze Affect the Decision Speed to "Give"? Again, we examined the interacting role of eye contact and repeated gaze. We found evidence for a Response × Eye Contact interaction ($\beta = -0.093$, $SE = 0.01$, $p < .001$, $\eta_p = .294$, 95% CI [0.238, 1.000]), and a Response × Repeated Gaze interaction ($\beta = -0.064$, $SE = 0.01$, $p < .001$, $\eta_p = .116$, 95% CI [0.083, 1.000]). We also found evidence for a Response × Eye Contact × Repeated Gaze interaction ($\beta = 0.023$, $SE = 0.01$, $p < .001$, $\eta_p = .021$, 95% CI [0.008, 1.000]; see Figure 8). This three-way interaction revealed that in the most communicative condition, based on our frequency data (i.e., eye contact + repeated gaze), participants were significantly faster to "give" than "not give" (estimate = 0.42, $SE = 0.04$, 95% CI [0.35, 0.5], $t = 10.83$, $p < .001$); in the least communicative condition (i.e., no eye contact + no repeated gaze), participants were significantly faster to "not give" than "give" (estimate = −0.21, $SE = 0.03$, 95% CI [−0.27, −0.14], $t = -7.62$, $p < .001$). For the more ambiguous conditions, differences in RTs between "give" and "no-give" responses were smaller. When the agent made no eye contact but repeated the averted gaze display, RTs were not found to differ (no eye contact + repeated gaze: $p = .348$). However, when the agent displayed eye contact but did not repeat the gaze, pairwise comparisons between "give" and "no-give" responses revealed significantly shorter "give" (give response + eye contact + no repeated gaze) than "no-give" response RTs (no give response + eye contact + no repeated gaze; estimate = 0.08, $SE = 0.03$, 95% CI [0, 0.15], $t = 2.74$, $p = .044$).

The significant pairwise comparison between "give" and "no-give" responses in the eye contact + no repeated gaze condition was not in line with previous findings (Caruana et al., 2025). Therefore, we further investigated the Response × Eye Contact × Repeated Gaze interaction by inspecting the separate analyses for each group, which showed that this new finding was being driven by the autistic participants in the full sample. Specifically, in the autistic group, we found no evidence for a significant interaction between response, eye contact, and repeated gaze ($p = .111$). Nevertheless, when the agent displayed eye contact but did not repeat the gaze, pairwise comparison in the autistic group between "give" (give + eye contact + no repeated gaze) and "no-give" responses were, as for the full data set, significant (no give + eye contact + no repeated gaze; estimate = 0.38, $SE = 0.05$, 95% CI [0.02, 0.22], $t = 7.12$, $p < .001$). This shows that only autistic participants were faster to "give" than "not give" in the eye contact + no repeated gaze condition. When inspecting the nonautistic group separately, our findings matched the pattern previously observed in the

Figure 5
"Give" Frequencies per Gaze Condition per Diagnostic Group



Note. See the online article for the color version of this figure.

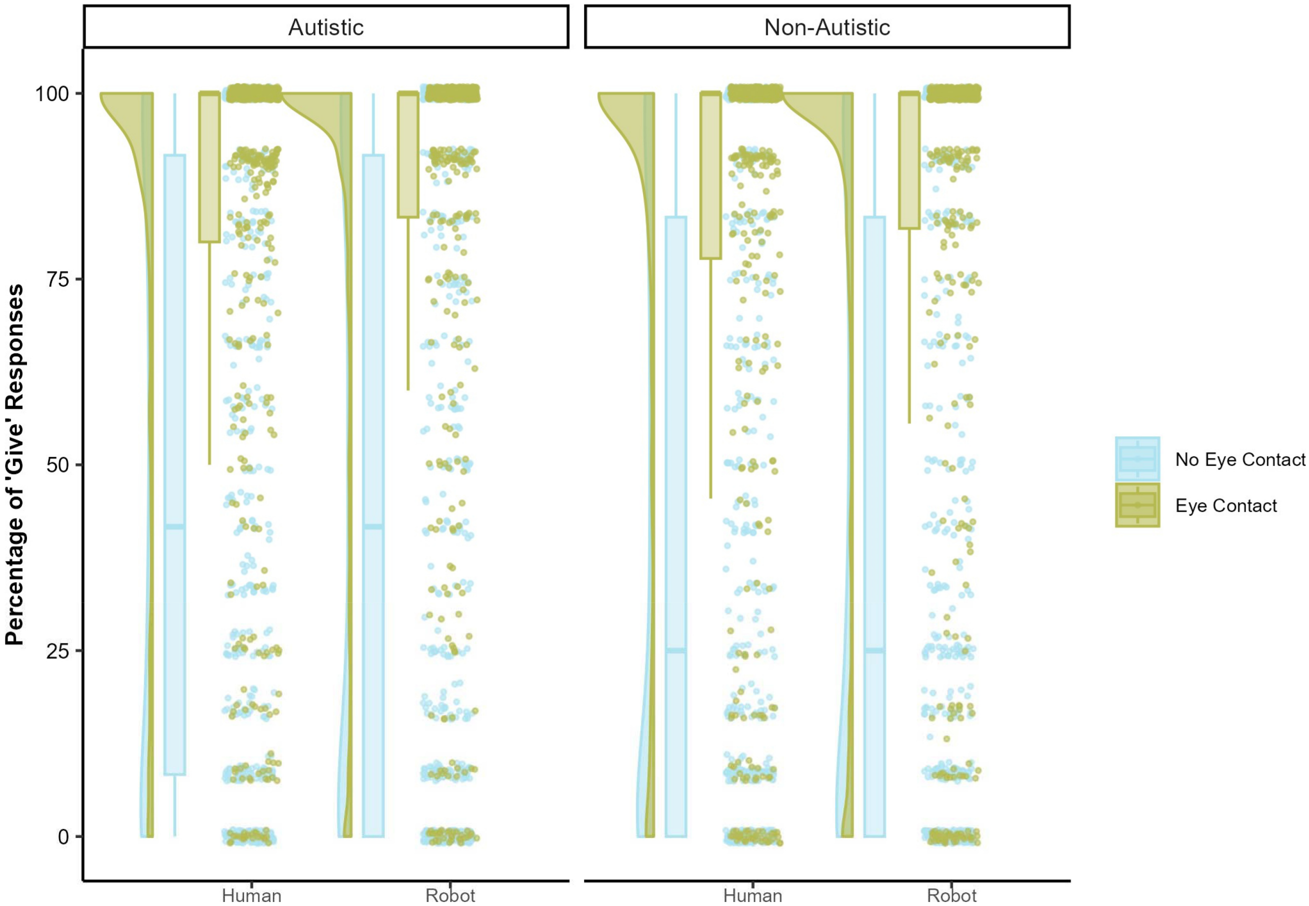
study by Caruana et al. (2025) with neurotypical participants. Specifically, we found a significant interaction between response, eye contact, and repeated gaze ($\beta = 0.034$, $SE = 0.01$, $p < .001$, $\eta_p = .044$, 95% CI [0.016, 1.000]). Pairwise comparisons between response conditions for each level of eye contact + repeated gaze condition in the nonautistic group confirmed that, when the agent made no eye contact and did not repeat the gaze, RTs were significantly shorter for "no-give" (no give response + no eye contact + no repeated gaze) than "give" responses (give response + no eye contact + no repeated gaze; estimate = −0.24, $SE = 0.04$, 95% CI [−0.35, −0.14], $t = -6.02$, $p < .001$). Further, when the agent displayed eye contact and repeated the averted gaze display, RTs were significantly shorter for "give" (give response + eye contact + repeated gaze) than "no-give" responses (no give response + eye contact + repeated gaze; estimate = 0.47, $SE = 0.06$, 95% CI [0.36, 0.58], $t = 8.18$, $p < .001$). We found no evidence for a significant difference in RTs between "give" and "no-give" responses in the ambiguous no eye contact + repeated gaze condition ($p = .105$), and no evidence for a significant difference in RTs between "give" and "no-give" responses in the eye contact + no repeated gaze condition ($p = .413$).

Does Gaze Duration Affect the Decision Speed to "Give"?

We also examined the influence of gaze duration on the perception of communicative intent. We found evidence for a significant interaction between response and gaze duration ($\beta = -0.009$, $SE = 0.004$, $p = .026$, $\eta_p = .002$, 95% CI [0.000, 1.000]). For long gaze durations, participants were significantly faster to "give" (give + long gaze duration) than "not give" (no give + long gaze duration; estimate = 0.08, $SE = 0.02$, 95% CI [0.03, 0.14], $t = 3.49$, $p < .001$). With a short gaze duration, RTs were not found to differ between "give" and "no-give" responses ($p = .053$).

To better understand the Response × Gaze Duration interaction, we again inspected the separate models for each group (see Figure 9). We found that only the nonautistic group showed evidence for a significant interaction ($\beta = -0.015$, $SE = 0.01$, $p = .018$, $\eta_p = .003$, 95% CI [0.000, 1.000]; autistic group: $p = .496$). When observing long gaze durations, nonautistic participants were faster to "give" (give + long gaze duration) than "not give" (no give + long gaze duration; estimate = 0.08, $SE = 0.03$, 95% CI [0.03, 0.14], $t = 2.23$, $p = .055$). We found no evidence for significant differences in RTs between response types in trials with short gaze durations ($p = .617$). This shows that response certainty was only influenced by gaze duration for nonautistic people.

Figure 6
"Give" Frequencies per Avatar per Eye Contact Condition per Diagnostic Group



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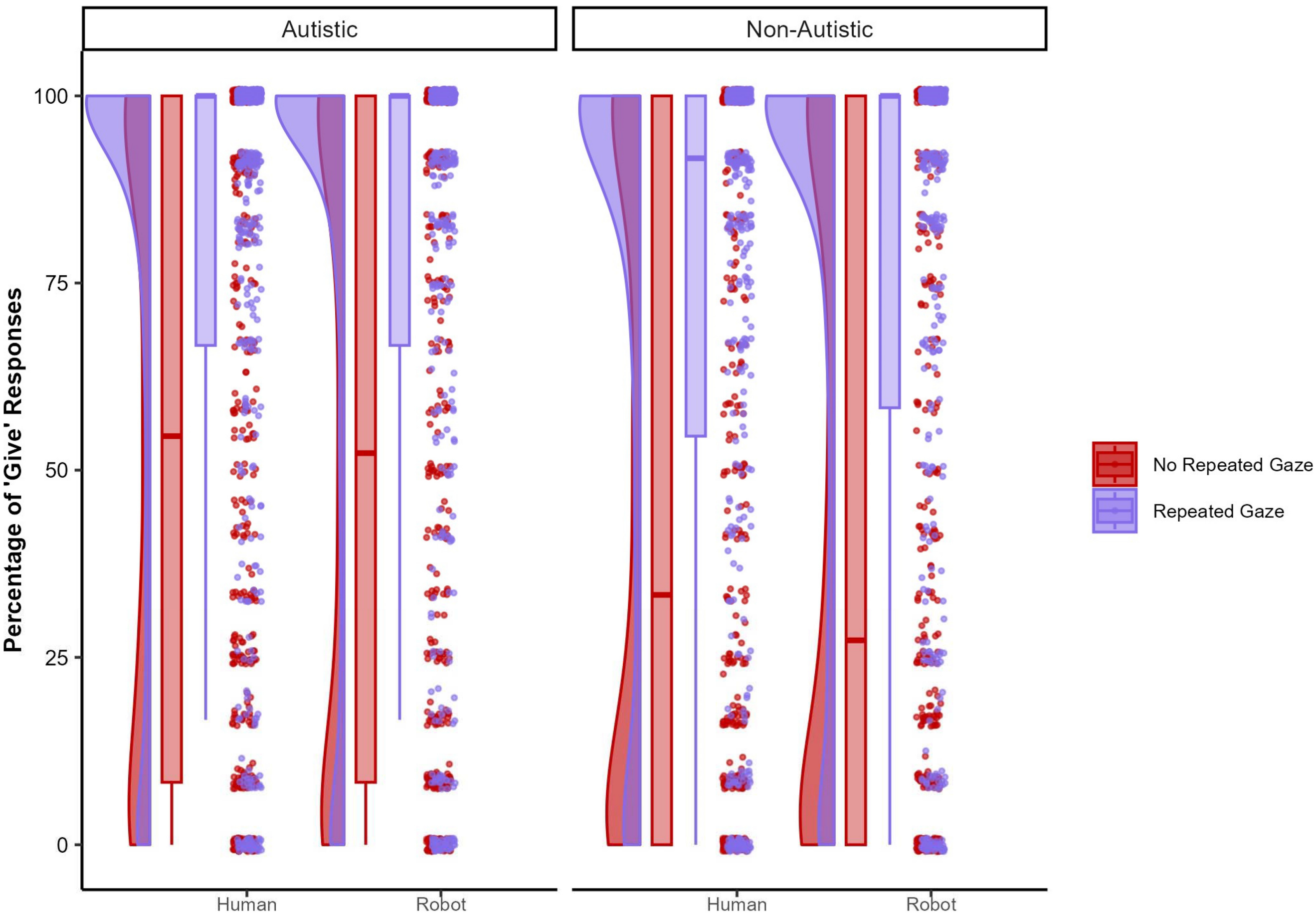
Do Autistic and Nonautistic Participants Differ in Their Decision Speed to "Give"? The main focus of this study was to examine potential differences between autistic and nonautistic participants. We found no evidence for a significant main effect of Group on RTs ($p = .719$). However, we found evidence for a significant interaction between group, response, eye contact, and repeated gaze ($\beta = -0.011$, $SE = 0.01$, $p = .039$, $\eta_p = .005$, 95% CI [0.000, 1.000]; see Figure 10). This revealed that autistic participants demonstrated greater certainty in their evaluation of communicative intent (i.e., were faster to "give") than nonautistic participants when evaluating the more ambiguous gaze conditions (i.e., eye contact + no repeated gaze). Specifically, in the least communicative condition (no eye contact + no repeated gaze), nonautistic participants were faster to "not give" than "give" (estimate = −0.24, $SE = 0.04$, 95% CI [−0.34, −0.15], $t = -6.21$, $p < .001$), and, in the most communicative condition (eye contact + repeated gaze), were faster to "give" than "not give" (estimate = 0.47, $SE = 0.06$, 95% CI [0.36, 0.58], $t = 8.32$, $p < .001$). We found no evidence for significant differences in "give" and "no-give" responses in the more ambiguous conditions (i.e., no eye contact + repeated gaze and eye contact + no repeated gaze; both $ps \geq .705$). Autistic participants, however, were significantly faster to "give" (give + eye contact + no repeated gaze than "not give" (no give + eye contact + no repeated gaze; estimate = 0.12, $SE = 0.04$, 95% CI [0, 0.24], $t = 3.07$, $p < .001$), when the agent made eye contact with a unique gaze display.

Finally, we found evidence for a significant interaction between group, response, eye contact, and gaze duration ($\beta = -0.012$, $SE = 0.004$, $p = .002$, $\eta_p = .003$, 95% CI [0.001, 1.000]; see Figure 11). Pairwise comparisons between response conditions in both groups across each level of eye contact and gaze duration showed that participants were significantly faster to "give" than "not give" when the agent displayed eye contact; and faster to "not give" than "give" when it did not (all $ps < .01$; see Analysis/05_AnovaPH folder; https://osf.io/6uyhr/). An exception for autistic participants was when the agent made no eye contact but showed a long gaze duration. In this condition, the difference in RTs between "give" and "not give" was not found to be significant (autistic group + no eye contact + long gaze duration: $p = .248$).

To investigate why the difference in RTs between "give" and "not give" was not significant in the no eye contact + long gaze duration condition for the autistic group, we again inspected the models for each group separately. We found that only the autistic group showed evidence for a significant interaction between response, eye contact, and gaze duration ($\beta = -0.02$, $SE = 0.01$, $p < .001$, $\eta_p = .018$, 95%

Figure 7

"Give" Frequencies per Avatar per Repeated Gaze Condition per Diagnostic Group



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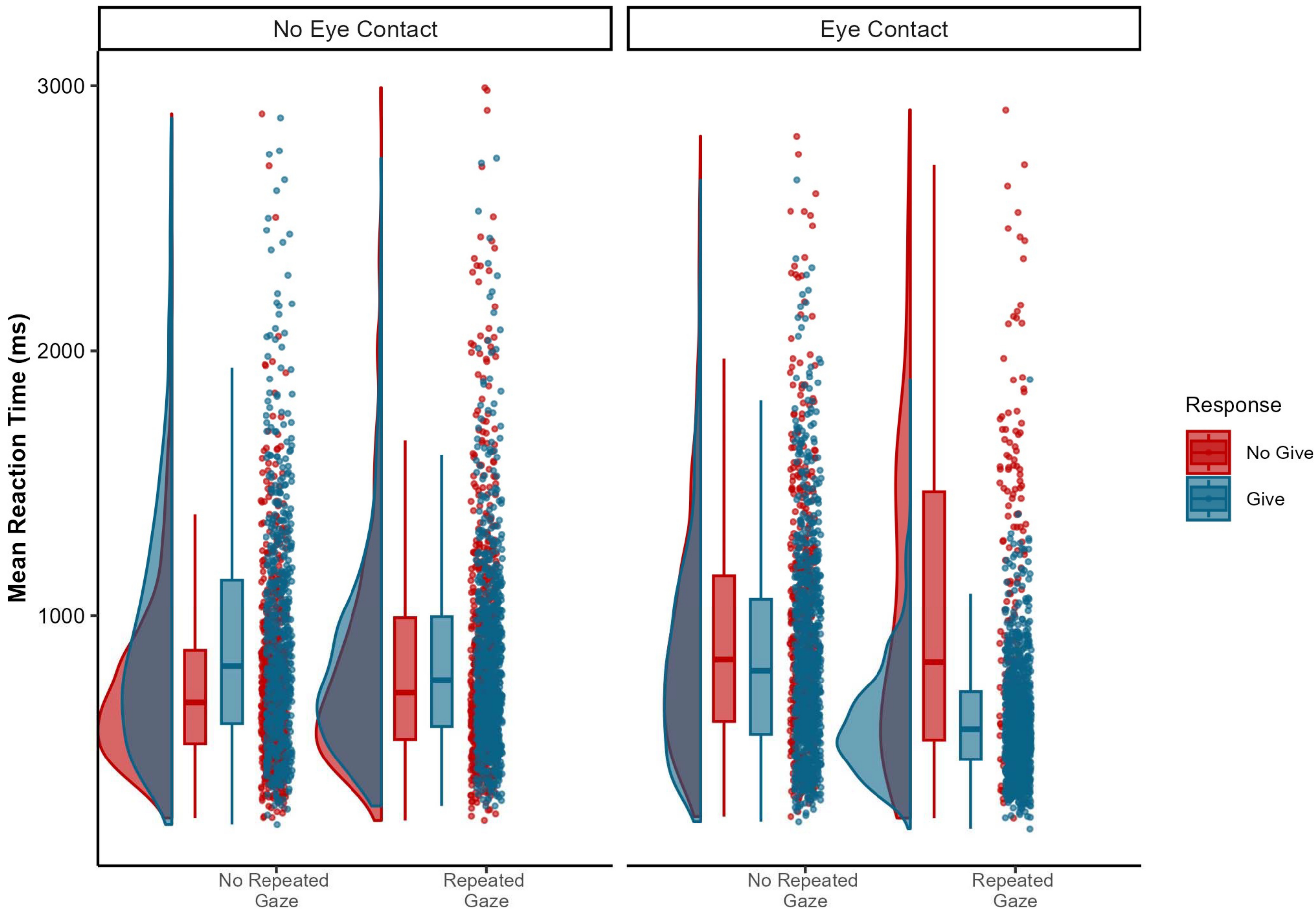
CI [0.006, 1.000]; nonautistic group: $p = .439$). Pairwise comparisons between response conditions across each level of eye contact and gaze duration in the autistic group showed, when the agent made no eye contact and gaze duration was short, autistic participants were faster to "not give" (no give + no eye contact + short gaze duration) than "give" (give + no eye contact + short gaze duration; estimate = −0.13, $SE = 0.03$, 95% CI [−0.23, −0.04], $t = -3.93$, $p < .001$). Likewise, when the agent displayed eye contact with a short gaze duration, autistic participants were faster to "give" (give + eye contact + short gaze duration) than "not give" (no give + eye contact + short gaze duration; estimate = 0.28, $SE = 0.04$, 95% CI [0.19, 0.37], $t = 6.78$, $p < .001$), and when the agent displayed eye contact with a long gaze duration, faster to "give" (give + eye contact + long gaze duration) than "not give" (no give + eye contact + long gaze duration; estimate = 0.22, $SE = 0.04$, 95% CI [0.1, 0.33], $t = 5.07$, $p < .001$). This shows that the Response × Eye Contact × Gaze Duration interaction was driven by variation in the autistic group.

Agent Perception

We also explored whether autistic and nonautistic people formed different perceptions of the human and robot stimuli using the subscales of the Godspeed Questionnaire (Bartneck et al., 2009). The results of a cumulative link model analysis revealed that autistic participants rated the human significantly lower than nonautistic participants on subscales of perceived anthropomorphism ($\beta = 0.1$, $SE = 0.02$, $z = 5.93$, $p < .001$); animacy ($\beta = 0.07$, $SE = 0.02$, $z = 4.33$, $p < .001$); perceived intelligence ($\beta = 0.06$, $SE = 0.02$, $z = 3.74$, $p < .001$); and perceived safety ($\beta = 0.23$, $SE = 0.02$, $z = 12.58$, $p < .001$). An exception was the likeability subscale, where autistic participants rated the Human significantly higher than nonautistic participants ($\beta = -0.25$, $SE = 0.02$, $z = -14.85$, $p < .001$). For the robot, autistic participants showed a reversed pattern in that they made significantly higher ratings on the anthropomorphism ($\beta = -0.15$, $SE = 0.02$, $z = -9.08$, $p < .001$); animacy ($\beta = -0.2$, $SE = 0.02$, $z = -11.99$, $p < .001$); likeability ($\beta = -0.32$, $SE = 0.02$, $z = -19.08$, $p < .001$); perceived intelligence ($\beta = -0.06$, $SE = 0.02$, $z = -3.84$, $p < .001$); and perceived safety subscales ($\beta = 0.31$, $SE = 0.02$, $z = 17.35$, $p < .001$) than nonautistic participants.

Given previous findings of increased anthropomorphizing tendencies in autistic compared to nonautistic people (White & Remington, 2019) and for those with stronger autistic traits (Caruana, White, & Remington, 2021), we further compared the difference scores

Figure 8
Reaction Times per Gaze Condition



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(human minus robot) for the godspeed anthropomorphism scale between groups using a Wilcoxon rank-sum test with continuity correction. Nonautistic participants judged the two avatars as significantly more different on the anthropomorphism scale ($M_{\text{nonautistic}} = 0.53$) than autistic participants ($M_{\text{autistic}} = 0.38$, $p = .012$, $r = -.16$).

Discussion

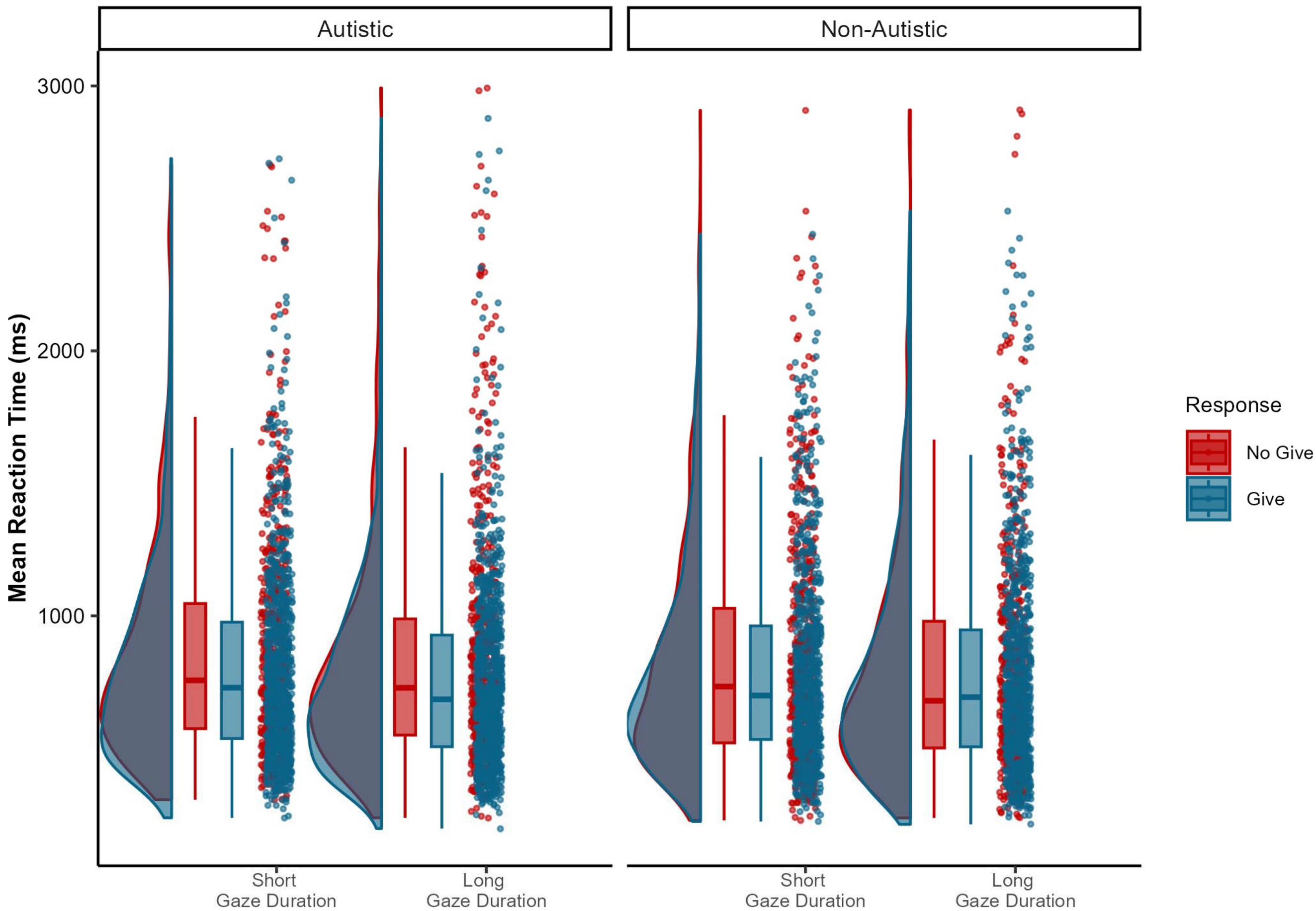
The current study explored whether autistic participants are differentially sensitive to eye contact and repeated gaze when evaluating communicative intent, and whether this differed depending on the observed agent form (human vs. robot). In line with our predictions, and consistent with recent work, we found no evidence of broad differences between groups. Autistic and nonautistic participants exhibited similar patterns across conditions. Both groups reliably used eye contact and repeated gaze to infer communicative intent, challenging longstanding accounts of a generalized "deficit" in autistic people's sensitivity to social gaze.

Secondary analyses further revealed how specific perceptual features shaped these judgements. Eye contact emerged as the most potent cue, while repeated gaze enhanced communicativeness when paired with eye contact. Longer gaze durations modestly increased perceptions of communicative intent, especially when eye contact and repeated gaze were absent. These effects were consistent across human and robot agents, suggesting that the underlying perceptual mechanisms generalize across different social partners. For a more in-depth discussion of the above response and RT findings for all gaze manipulations, see AdditionalDiscussion.pdf in the Analysis folder in the additional online materials.

No "Impairments" in Evaluating Communicative Intent in Autistic People but Different Agent Perceptions

The primary focus of this study was to explore whether autistic people perceived communicative intent similarly to nonautistic people. As expected, the autistic group did not differ in their perception of communicative intent. This finding challenges claims that autistic people are impaired in understanding the intentions of others (Baron-Cohen, 1995; Frith & Happé, 1999; Williams & Happe, 2010). Both autistic and nonautistic participants showed similar patterns of interpreting communicative intent from gaze sequences. This finding suggests that theory-of-mind processes may be intact or compensated for in contexts that include both averted gaze at a specific location and eye contact. Such contexts more closely

Figure 9
Reaction Times per Gaze Condition



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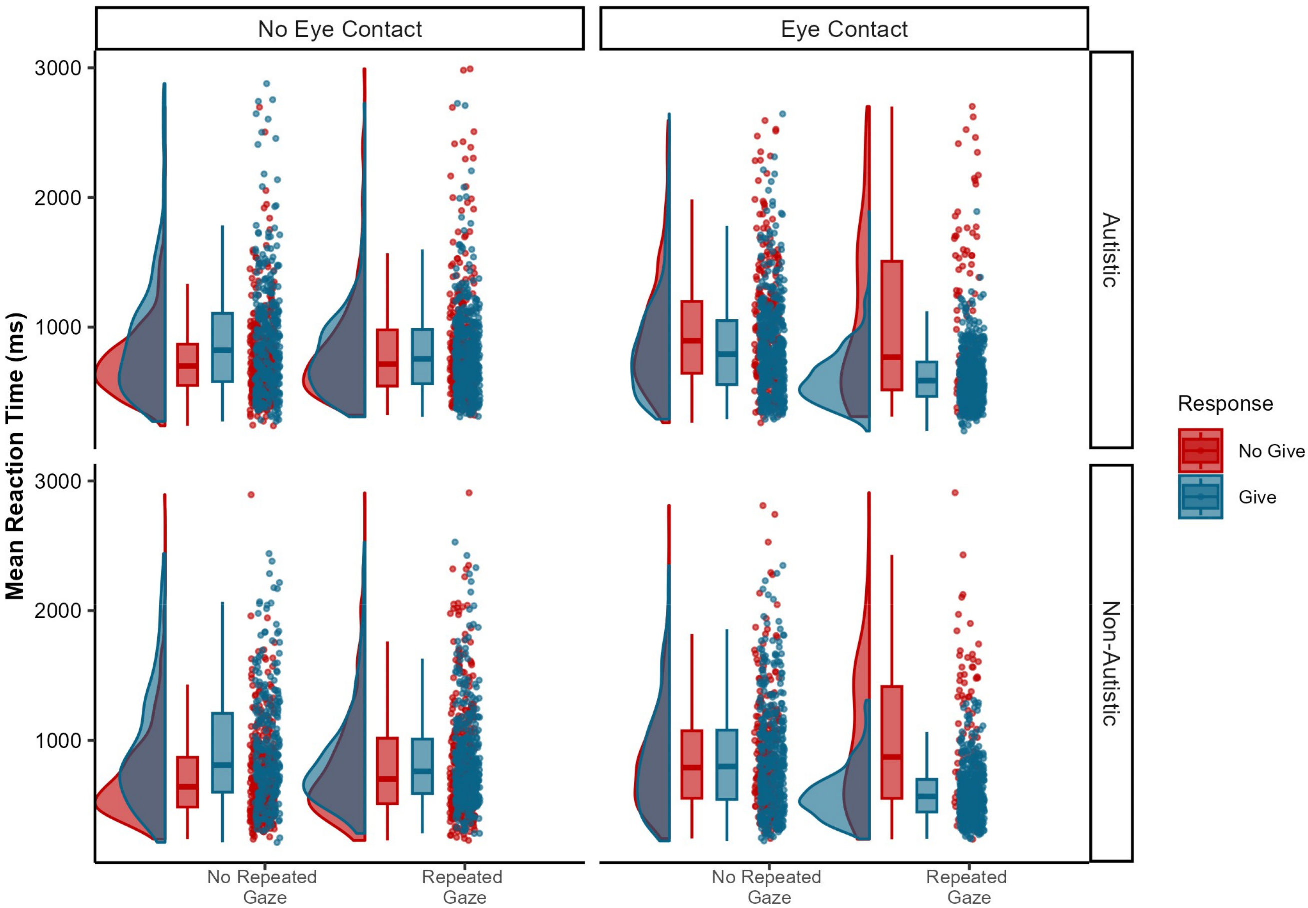
resemble daily social interactions, where people evaluate and respond to sequences of eye movements (Caruana et al., 2015; Redcay et al., 2012; Tylén et al., 2012), which depends more on volitional attention processes than evaluating isolated spatial cues in traditional cueing paradigms (Caruana et al., 2017). The context of current eye movements provides important information about the relevance of upcoming eye movements (Alhasan & Caruana, 2023; Caruana et al., 2020). Indeed, our results align with current research, indicating that autistic people do not exhibit gaze-based communication difficulties when evaluated in dynamic and interactive tasks (e.g., Caruana et al., 2024; Pell et al., 2016; Stuart et al., 2023).

However, we found evidence that the individual effects of eye contact and repeated gaze on RTs interacted differently for autistic and nonautistic people. Both groups were significantly faster to "not give" than "give" in the least communicative condition (no eye contact + no repeated gaze) and significantly faster to "give" than "not give" in the most communicative condition (eye contact + repeated gaze). In the ambiguous conditions (no eye contact + repeated gaze and eye contact + no repeated gaze), nonautistic participants showed no significant differences between "give" and "no-give," indicating greater uncertainty in the responses. In other words, nonautistic participants selectively used eye contact when it was paired with repeated gaze. This pattern replicates the pattern found in Caruana et al. (2025) in a neurotypical sample using the same general task. Autistic participants showed a somewhat different pattern in the ambiguous condition, eye contact + no repeated gaze, with significantly faster "give" than "no-give" responses. Thus, autistic participants appeared to rely on the eye contact signal more than nonautistic people, integrating it less with repeated gaze. Again, this pattern challenges accounts of mindreading deficits (Baron-Cohen, 1995; Frith & Happé, 1999; Williams & Happe, 2010), which would not anticipate greater certainty among autistic people in some ambiguous conditions, as was observed in the study (e.g., faster "give" responses with eye contact but no repeated gaze). Rather, these accounts would predict autistic people to show more variable RTs because of a reduced sensitivity to the communicative and contextual cues that eye contact and repeated gaze shifts provide.

Moreover, autistic participants—unlike nonautistic participants—were slower to "give" when the gaze sequence comprised longer gaze duration without eye contact. This pattern indicates greater ambiguity and uncertainty in autistic people when deciding whether the agent's behavior was communicative—likely because a long

Figure 10
Reaction Times per Gaze Condition



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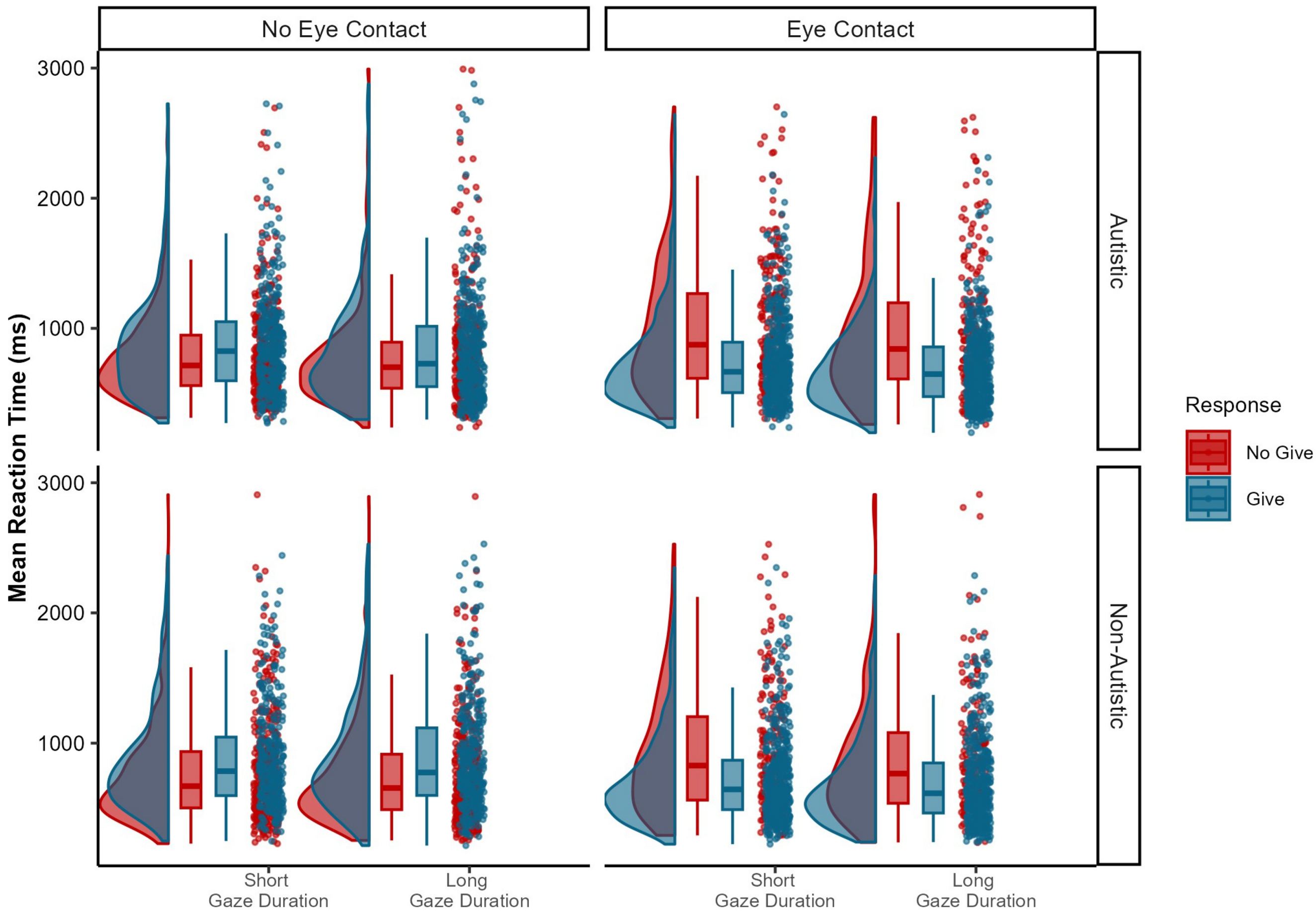
gaze duration was perceived as a signal of communicativeness. Participants might have been less influenced by gaze duration when there was no eye contact present, and this effect was stronger for autistic people because they did not take repeated gaze into account in the same way as nonautistic participants did.

Finally, as expected, we found no main effect of Agent. While we would argue that this null effect of agent suggests that the effects of gaze dynamics generalize across agents, it may also be related to the relative humanlikeness of our specific robot agent, modelled after the iCub (https://icub.iit.it/). The iCub shows several clearly human-like features, in particular, several "Kindchenschema" features (large eyes, large head, high and protruding forehead, chubby cheeks, small nose, and mouth; Lorenz, 1943). These features might have led to a strong perception of humanlikeness and, thus, no difference in the perception of communicative intent between human and robot conditions. Research has shown, for instance, that large eye whites draw attention to the pupils, which are a prominent social signal that may promote more positive evaluations of the associated interaction partner (Kret & De Dreu, 2019). In line with this assumption, previous work using the same human and robot avatars in a virtual reality study showed that, while the agent's appearance did not affect the extent to which participants used the agent's gaze in a collaborative task, participants looked more frequently at their partner's face when interacting with the robot avatar compared to the human avatar and commented positively on the robot's "cute" face (Hechler, Cross, et al., 2025). Future work could directly test and compare the effects of design features and overall anthropomorphism on the perception of communicative intent by systematically varying human features, such as eye and pupil size. This would help determine whether these gaze effects generalize to robots with a less human-like body form, like the manufacturing robot Baxter (Rethink Robotics: https://rethinkrobotics.com). Alternatively, it is also possible that nonverbal signals inherently associated with human communication, such as eye gaze, generalize to nonhuman agents or even objects because of our profound human expertise for perceiving and responding to face-like stimuli and cues. This broad tuning of visual perception to face-related stimuli is also evidenced in several perception studies of human sensitivity to illusory faces in pareidolia stimuli (e.g., Alais et al., 2021; Caruana, Inkley, et al., 2019; Wardle et al., 2020). A large body of research on gaze cueing, using a wide range of stimuli (e.g., ecologically nonvalid schematic stimuli), also suggests that gaze cues can influence attention and behavior even when the gaze stimuli significantly depart from real eyes/faces (see Chacón-Candia et al., 2023 for a relevant review).

Figure 11
Reaction Times per Gaze Condition



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We found evidence for significant Agent × Eye Contact and Agent × Repeated Gaze interactions on the perception of communicative intent. Specifically, communicative intent was perceived more strongly when the robot displayed eye contact or repeated gaze, compared to when the human did. However, given the very small effect size (Agent × Eye Contact: $d = -0.04$; Agent × Repeated Gaze: $d = 0.29$) and the lack of such an effect in Caruana et al. (2025), we interpret this result with caution. Unless replicated, this effect is unlikely to reflect a functionally meaningful difference in how agent appearance modulates gaze cue processing.

Taken together, the subtly distinct patterns observed between autistic and nonautistic participants suggest that gaze cues may have slightly different implications for social interaction. However, autistic people generally demonstrated the same sensitivity to core signals of communicative intent (e.g., eye contact) to make reliable and rapid evaluations of another agent's communicative intent. That said, we acknowledge that our classification of participants as autistic was based solely on self-reported diagnostic status via the Prolific recruitment platform. Although participants in the self-identified autistic group scored significantly higher on a validated trait measure (CATI), recent work has demonstrated that self-reported autistic traits do not always correspond with clinician-rated diagnostic outcomes or social behavior (Banker et al., 2025). This raises important questions about how closely self-identified samples reflect the cognitive profiles of individuals with a formal clinical diagnosis. While self-identification is a pragmatic approach for large-scale online studies and has been supported in prior work (e.g., English et al., 2021; Hechler, Tuomainen, et al., 2025; McDonald, 2020), future studies should replicate these findings using in-person diagnostic verification (e.g., autism diagnostic observation schedule second edition; Lord et al., 2012) to ensure stronger clinical generalizability.

Conclusion

In summary, this study investigated three key perceptual properties of dynamic eye gaze displays and the extent to which they influence the perception of communicative intent in both autistic and nonautistic participants. Our findings suggest that eye contact, repeated averted gaze displays to the same location, and gaze duration separately and cumulatively enhance the perception of communicative intent. Participants were most likely to perceive communicative intent when the agent displayed eye contact and repeated gaze. Gaze duration was a less potent signal of communicative intent. However, longer gaze durations resulted in increased perceptions of communicative intent in the absence of eye contact and repeated gaze. Autistic and nonautistic participants showed similar overall patterns, challenging the traditional view of autism as a condition in which people have a reduced tendency to understand the social meaning of gaze cues.

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