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Spontaneous lexical alignment in children with an Autistic Spectrum Disorder and their typically developing peers.

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RUNNING HEAD: Lexical alignment in children

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Abstract

It is well established that adults converge on common referring expressions in dialogue, and that such lexical alignment is important for successful and rewarding communication. We show that children with an Autistic Spectrum Disorder (ASD) and chronological- and verbal-age-matched typically developing (TD) children also show spontaneous lexical alignment. In a card game, both groups tended to refer to an object using the same name as their partner had previously used for the same or a different token of the object. This tendency to align on a pragmatically conditioned aspect of language did not differ between ASD and TD groups, and was unaffected by verbal/chronological age, or (in the ASD group) Theory of Mind or social functioning. We suggest that lexical priming can lead to automatic lexical alignment in both ASD and TD children's dialogue. Our results further suggest that ASD children's conversational impairments do not involve an all-encompassing deficit in linguistic imitation.

During dialogue, adult speakers converge, or align, on common ways of speaking (e.g., Pickering & Garrod, 2004). For example, when adults have a choice of how to refer to an object (e.g., to call a creature a *rabbit* or a *bunny*), they tend to use the same name as their interlocutor previously used, even if this would not be their usual choice. Such *lexical alignment* (or *entrainment;* Garrod & Anderson, 1987) is pervasive in adult dialogue and appears important for effective and rewarding communication (e.g., Reitter & Moore, 2014). As such, an important question is how such behaviour develops, and the extent to which it might manifest in populations with communicative difficulties. Here we investigate whether children with an Autistic Spectrum Disorder (ASD) and their typically developing (TD) peers show spontaneous lexical alignment with a conversational partner.

The tendency for adults to align on common referring expressions in dialogue is well-established (e.g., Garrod & Anderson, 1987), and has been explained with reference to three kinds of mechanism. It has been extensively interpreted as a goal-directed behaviour that reflects a reasoned choice between alternatives based on beliefs about what a conversational partner will understand (*audience design*; e.g., Clark, 1996): Speakers re-use their partner's choice of name, even if they would not normally use that name, because their partner has signalled by their use of the name that they understand it (and have a preference for it). Accordingly, higher levels of alignment are associated with more effective communication (e.g., Reitter & Moore, 2014). This explanation implicates an important role for perspective-taking (and hence Theory of Mind [ToM], or the ability to attribute mental states to others, and to understand that others have different mental states from one's own): Speakers must model their listeners' knowledge as distinct from their own, and accommodate it accordingly in their utterances.

Language alignment has also been linked to the pursuit of social-affective goals (van Baaren, Holland, Steenaert, & van Knippenberg, 2003). Under this account, speakers re-use their partner's choice of name to express affiliation and enhance social relations. Alignment can therefore be interpreted as a linguistic manifestation of the well-known phenomenon of behavioural mimicry, whereby people (often non-consciously) mimic their partner's behaviour (e.g., facial expressions, gestures) in order to both express and induce liking, rapport, and affiliation (e.g., Chartrand & Bargh, 1999). Behavioural mimicry is known to be enhanced when people have affiliative goals (Chartrand & Bargh, 1999), and language mimicry specifically is stronger in individuals with a higher need for social approval (Natale, 1975). In turn, such mimicry creates rapport, strengthening social bonds (e.g., Lakin & Chartrand, 2003). This explanation of alignment therefore attributes a critical role to social cognition and social motivation.

Finally, alignment has been interpreted with respect to automatic and non-goal-directed psycholinguistic mechanisms triggered by linguistic stimuli (Pickering & Garrod, 2004). Thus, speakers tend to use the same name as their partner because their partner's initial use of the name automatically facilitates its subsequent re-use via lexical priming. Pickering and Garrod argued that priming-based alignment of linguistic representations causes interlocutors to develop the same semantic representations, and hence plays a causal role in achieving mutual understanding without the involvement of ToM. Basic memory processes may also play a role, with partner and context acting as a compound cue to retrieval of a particular name (Horton & Gerrig, 2005).

Although most research focuses on one or other of these explanatory frameworks, they are not mutually exclusive. As with other aspects of language production, alignment effects may be best explained as the product of multiple interacting factors that together determine speakers' choices. A basic priming-based mechanism might be supplemented to a greater or lesser role by audience design and social-affective mechanisms depending on circumstances (e.g., whether the context triggered affiliative goals; Chartrand & Bargh, 1999). Lexical choices might be particularly affected by audience design and social-affective mechanisms because they are directly related to meaning and the choice between alternatives may be highly salient for speakers (Branigan, Pickering, Pearson, & McLean, 2010).

Perhaps surprisingly – given its potential importance for successful communication – very little research has directly investigated lexical alignment in children. We might expect TD children to show lexical alignment based on priming and social affective mechanisms from a young age: Lexical priming effects emerge early in development (e.g., Mani, Durrant, & Floccia, 2012), and a link between behavioural imitation and social affect also manifests early. For example, 5-year-olds primed with an affiliative goal are more likely to subsequently imitate an adult (Over & Carpenter, 2009). In contrast, we might expect alignment based on audience design to develop later: Although TD children are sensitive from early childhood to the fact that objects can have more than one name (Clark, 1997) and that different speakers may use different names (Matthews, Lieven, & Tomasello, 2010), the ability to effectively model and accommodate partners' knowledge develops more slowly, even into the teen years (e.g., Anderson, Clark, & Mullin, 1994).

Garrod and Clark (1993) reported evidence compatible with these predictions. They found that pairs of children playing a cooperative game implicitly developed a common lexicon during a dialogue (e.g., using *box* vs *square*). Convergence on a common lexicon occurred for the youngest group (7-8 years) as well as older groups (9-10 and 11-12 years). However, it was more closely linked to communicative success in older groups. Garrod and Clark suggested that younger children may have been more susceptible to alignment based on surface form rather than meaning (i.e., using the same words but with different reference), which could be interpreted as a stronger influence of priming mechanisms in younger children versus audience design mechanisms in older children. However, their study did not explicitly manipulate speakers' word choices, and it is not clear how far their results might generalise (e.g., to a wider set of items, or where there was a strong preference for one alternative).

We might expect a very different pattern in children with ASD. ASD is a developmental disorder characterised by impairments in communication, social interaction, and imagination (Rutter, 1978). It is associated with difficulties in many linguistic domains, although some aspects appear relatively intact; for example, children with ASD show similar patterns of immediate lexical priming to TD children, though they show different patterns over longer timecourses (Harper-Hill, Copland, & Arnott, 2014; Henderson, Clarke, & Snowling, 2011). In particular, children with ASD show conversational deficits that have been attributed to impaired ToM and consequent difficulties in perspective-taking (Happé, 1993): They display pragmatic deficits, such as failing to make relevant contributions or engage in reciprocal exchanges, and producing inappropriate content, including referring expressions (Arnold, Bennetto, & Diehl, 2009; Tager-Flusberg, 1996).

ASD is also associated with pervasive social impairments, including reduced social orientation and affiliative behaviour (e.g., Klin, 1991), which have been linked to deficits in social cognition (relating to ToM; Baron-Cohen, Leslie, & Frith, 1985) or social motivation (Chevallier et al., 2012). For example, children with ASD are less likely to engage in cooperative activities (Liebal, Colombi, Rogers, Warneken, & Tomasello, 2008), and less responsive to praise (Demurie, Roeyers, Baeyens, & Sonuga-Barke, 2011). Particularly relevantly, social impairments are also evidenced by deficits in both spontaneous and elicited imitation of behaviour (see Vivanti & Hamilton, 2013, for review), such as a reduced likelihood to spontaneously imitate an interactional partner's actions (Ingersoll, 2008), or copy the style of an action (Hobson & Hobson, 2008). These deficits appear to be more pronounced in naturalistic-spontaneous interactions (McDuffie et al., 2007), and have been attributed to impaired sensitivity to top-down social cues (Wang & Hamilton, 2012). Several studies have suggested a correlation between non-linguistic imitation and language in ASD, including the possibility of a linguistic imitation deficit (e.g., Charman et al., 2000).

Together, these characteristics suggest that children with ASD might not show the same pattern of spontaneous lexical alignment as TD children. Although automatic lexical priming mechanisms might be intact (Harper-Hill et al., 2014), mechanisms associated with the pursuit of social-affective and communicative goals - depending on social cognition/motivation and perspective-taking respectively - might be impaired. Hence, children with ASD might show a weaker tendency (if any) to use the same name for an object as their partner, compared to their TD peers.

If children with ASD show aberrant patterns of lexical alignment, this might go some way to explaining their social and communicative difficulties in dialogue. Most obviously, their language would appear 'odd' to their interlocutors. More concretely, failures to use the same referring expressions as their partners would contribute to their pragmatic impairment, and could cause misunderstanding. Such failures would also contribute to their social-affective impairment, giving an impression of non-responsiveness and a lack of reciprocity that could yield dissatisfying interactions (and correspondingly reduced rapport between partners).

We investigated spontaneous lexical alignment in children with ASD and their TD peers by using a 'snap' paradigm in which a child and an experimenter alternated turning over and naming pictures of familiar objects as part of a matching game. On experimental trials, the experimenter named an object that had two possible names, with one being strongly preferred; two turns later, the child named the same object. We manipulated (within-participants and –items) whether the experimenter named her picture using its preferred or dispreferred name, and whether the child's picture was the same or a different token of the object. We investigated (1) whether TD children spontaneously used the same name as the experimenter to describe their picture; (2) whether children with ASD showed spontaneous lexical alignment; and (3) whether there was any difference in lexical alignment between children with ASD and TD controls who were matched for chronological age (CAM) and verbal age (VAM).

Experiment

Method

Participants

Fifteen children who had previously received a clinical diagnosis of ASD were recruited from specialist ASD units attached to mainstream schools. Teachers identified children for inclusion on the basis of a clinical diagnosis of ASD (with no co-morbidity) and sufficient verbal communication to follow task instructions. For an additional measure of social functioning, the teacher or support assistant also completed the 'Current behaviour' section (19 items) of the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003). Each participant with ASD was individually matched to two TD children (recruited from three mainstream schools and a preschool) on the basis of verbal age and chronological age respectively (Table 1). Caregivers and participants provided informed consent.

All children were tested for: language ability, using the British Picture Vocabulary Scale (BPVS; Dunn, Dunn, Whetton, & Burley, 1997), a standardized measure of receptive vocabulary (a common area of weakness for children with ASD; Jarrold, Boucher, & Russell, 1997); non-verbal IQ, using Raven's progressive coloured matrices, a test for ages 5 upwards, suitable for individuals with mental and physical impairments (Raven, 2000); and ToM, using a role-play version of a first-order false belief task (the Sally Ann task; Baron-Cohen et al., 1985).

Materials

The 20 experimental items comprised pairs of pictures (a *prime* and *target*), each depicting an object with two acceptable names (e.g. *rabbit* and *bunny*), and a scripted *prime name* (*preferred* vs. *dispreferred*).[1] In the *same-token* condition, the prime and target pictures were identical; in the *different-token* condition, the prime picture was a different token of the same category.

We prepared four paired (Experimenter/Participant) lists, each containing one version of each experimental item in a Latin Square design, plus 28 filler pictures. Participants were randomly assigned to lists; item order was individually randomized with constraints that two fillers intervened between the experimenter's prime and the child's associated target, and the eight 'snap' trials (where the experimenter and child's pictures matched) were distributed through the experiment.

Procedure

Children were tested individually. The experimenter and child each had a pile of cards, and alternated turning over and naming the top card. When their cards were identical, the first player to say 'Snap!' won the cards in play. The experimenter always named her prime card first, using the preferred or dispreferred name following her script. After two intervening fillers (one described by the child, one by the experimenter), the child named his or her target card (Figure 1). Following the game, we tested ToM. The BPVS and Raven's matrices were administered in a separate session.

Analysis

Target responses were coded as *Preferred Name, Dispreferred Name* or *Other.* We carried out three sets of analyses. The first two sets were concerned with establishing whether spontaneous lexical alignment occurred in children with ASD and in TD children, and did not seek to compare groups. For these analyses, we therefore collapsed CAM and VAM into a single TD group.

The first set of analyses investigated, for the ASD and TD groups separately, the likelihood of aligning with the experimenter on the preferred name (Preferred Name = 1, else =0). The second set of analyses investigated, for the ASD and TD groups separately, the likelihood of aligning with the experimenter on the dispreferred name (Dispreferred Name = 1, else = 0). Our final set of analyses compared ASD vs. CAM and ASD vs. VAM groups' overall likelihood of aligning with the experimenter (on either name; aligned response = 1, else =0). We also included chronological and verbal age (both groups), and ToM and SCQ (ASD group), as predictors in the analyses.

All analyses used mixed logit models; whenever possible, the maximal by-child and by-item random structure was included (Barr, Levy, Scheepers, & Tily, 2013). All models were fitted using the lme4 package (version 1.1-7; Bates, Maechler, & Bolker, 2013) in R (version 3.2.0; R Code Team, 2014).

Results

In both Prime Name conditions, ASD children and TD children produced almost identical proportions of aligned responses (Preferred name: ASD: 88%; TD: 84%; Dispreferred name: ASD: 47%; TD: 48%; Table 2). Figure 2 shows the observed proportions of aligned responses to preferred and dispreferred Prime Name by Target Picture condition for the three groups of children, against the baseline rates of preferred and dispreferred responses that would be expected on the basis of our pretest. The *alignment effect* in Table 2 shows the increase in percentage points in the observed probability of producing a preferred response after a preferred vs. after a dispreferred prime name, and producing a dispreferred response after a dispreferred vs. after a preferred prime name.

Likelihood to align on the preferred name: **ASD and TD groups** (Table 3)

Here we coded preferred-name response as 1, dispreferred/other = 0. Both groups showed a significant main effect of Prime Name (i.e., lexical alignment): Both ASD and TD children were more likely to produce preferred names after the experimenter had used the preferred name than the dispreferred name. No other predictors significantly interacted with Prime Name in either group: Alignment was not modulated by picture repetition, or any individual difference measures.

Likelihood to align on the dispreferred name: ASD and TD groups (Table 4)

This analysis recoded responses so that dispreferred = 1, preferred/other = 0. Both groups showed a significant main effect of Prime Name: ASD and TD children were more likely to produce dispreferred names after the experimenter had used the dispreferred name than the preferred name.

In the ASD group, TOM did not significantly interact with Prime Name; ASD children who failed ToM produced 32/60 (53%) Dispreferred-Name responses following a Dispreferred-Name prime, and 4/59 (7%) following a Preferred-Name prime; for children who passed ToM, the corresponding numbers were 38/90 (42%) and 4/90 (4%). Model convergence issues precluded including any other individual difference measures. However, a mixed logit model for the ASD group on overall likelihood to align (on either name) showed no significant interactions between Prime Name and any individual difference measures (all p*s* > .4). Together, these results suggest that no age- or ASD-related measures mediated lexical alignment in the ASD group.

In the TD group, no predictors significantly interacted with Prime Name.

Likelihood to align on either name: ASD vs. TD groups (Table 5)

This analysis treated the ASD group's likelihood to align across conditions as the intercept. The TD groups were compared against this intercept: Significant contrast coefficients for the CAM or the VAM group would imply that, compared to the ASD group, the CAM or the VAM group showed a different likelihood to align across conditions. The coefficients for Prime Name, Target Picture, and the Prime Name by Target Picture interaction represent the main effects and the interaction of the two predictors for the ASD group. Their interactions with the CAM and VAM groups represent how these effects change in the CAM and VAM groups compared to the ASD group. For instance, a significant Prime Name by CAM group interaction would imply that, compared to ASD children, CAM children showed a different pattern of alignment on preferred versus dispreferred names.

The contrasts for the CAM and VAM groups were not statistically significant; the two TD groups did not differ from the ASD group in their overall tendency to align. The coefficient of Prime Name was significant; ASD children were more likely to align with the preferred than the dispreferred name. There was no significant interaction between Prime Name and VAM Group, nor Prime Name and CAM Group; the effect of Prime Name did not differ in the TD and ASD groups. No other effect or interaction was significant.

To confirm that our data supported the null hypothesis of no difference in groups' overall tendency to align, we turned to the Bayes Factor, which quantifies the likelihood of observing the data if there were no difference between the TD groups and the ASD group, compared to if there were a difference between the groups (Wagenmakers, 2007). We constructed the null model, a GLMM with only the main effects of Prime Name and Target Picture; this model assumes that the three groups align to the same extent across conditions. We also constructed the alternative model, a GLMM with the main effects of Group, Prime Name and Target Picture; this model assumes that the VAM and CAM group may align to a different extent compared to the ASD group (across conditions). We then used the two models' Bayesian Information Criterion (BIC) values to estimate the Bayes Factor as $e^{(BIC\_alternative - BIC\_null)/2}$ (see Wagenmakers, 2007, and Masson, 2011).

The null model (i.e., without the effect of Group) fit the data better by a Bayes Factor of $e^{(1087.5 - 1074.0)/2} = 854.06$, providing strong evidence against the hypothesis that the TD children showed a different alignment tendency compared to ASD children (posterior probability in favour of the null model BF / (BF + 1) = .99, which represents very strong evidence according to Raftery's categorization; Raftery, 1995).

Discussion

During dialogue, adults implicitly converge on common ways of referring to objects. Such lexical alignment appears important for both communicative and social reasons, by promoting mutual understanding and enhancing positive relationships. Impaired alignment behaviors might therefore explain why some speakers consistently experience unsuccessful and unrewarding interactions. Our experiment investigated lexical alignment in children, and specifically whether children with ASD, a population characterized by communicative and social deficits, would show spontaneous lexical alignment during dialogue, and if so, to the same extent as their TD peers.

In a picture-matching game, TD children showed a strong and reliable tendency to use the same name for an object as their conversational partner had used on an earlier turn. This tendency occurred for both preferred and dispreferred object names (alignment effect: 36.5% in both conditions), over two intervening trials, and without explicit invitation or instruction. It occurred over a range of objects, irrespective of whether the child named the same or a different token, and was unaffected by chronological or verbal age. Our results therefore extend previous research by demonstrating a generalized tendency towards spontaneous lexical alignment in TD children's dialogue that reflects convergence on a way to refer to a category of object, rather than a particular token of that category (i.e., a specific referent).

More importantly, our study also demonstrated strong spontaneous lexical alignment in children with ASD. Strikingly, children with ASD's referential choices were influenced by their partner's language to the same extent as chronological- and verbal-age-matched controls (alignment effect: preferred name: 42.5%; dispreferred name: 41.5%). Moreover, alignment was not mediated by chronological or verbal age, ToM, or level of social functioning (as measured by the SCQ). These results do not appear to be explicable as verbal shadowing or immediate echolalia (Rydell & Mirenda, 1994): Children heard the experimenter's prime name two turns before they produced the target (hence alignment did not arise from immediate repetition of the experimenter's utterance), and used the same names as the experimenter only when it was appropriate and meaningful to do so (i.e., to refer to the same category of object) on all but two occasions (one of which may have reflected misinterpretation of the picture). Instead, these effects reflect a tendency to name objects in the same way as a conversational partner.

These results suggest that children with ASD's conversational impairments cannot be straightforwardly linked to fundamental deficits in converging with a partner's referential expressions. Given that pragmatic impairments are characteristic of ASD (e.g., Tager-Flusberg, 1996), the finding that children with ASD showed intact alignment for an aspect of language that is strongly pragmatically conditioned is striking. We cannot be sure whether our children with ASD would show atypical lexical alignment in other contexts (e.g., natural conversation). Previous research has suggested that differences in language behavior between children with ASD and TD children may be less marked in highly structured contexts (as in our study) than in more open-ended contexts (e.g., Landry & Loveland, 1989; see also Wetherby & Prizant, 2000). Nor do we know whether children with ASD with more profound language difficulties than the average 1.5 year language delay in our sample (spanning a range from a verbal age 73 months below chronological age to a verbal age 42 months above chronological age) might show a different pattern, though we note the absence of any effect of verbal age in any of our analyses.

However, our results suggest that any impairments in lexical alignment in ASD must be more subtle than uniformly reduced (or entirely absent) alignment. This conclusion is consistent with recent findings of intact alignment for syntactic choices that are not pragmatically conditioned in children with ASD's dialogue (Allen, Haywood, Rajendran, & Branigan, 2011; Hopkins, Yuill, & Keller, 2015), as well as evidence for intact lexical and syntactic alignment in adults with Asperger's syndrome (Slocombe et al., 2013; see also Nadig, Seth, & Sasson, 2015, for further evidence of lexical entrainment in adults with ASD). Importantly, these studies show that such alignment occurs in natural dialogue, as well as in task-oriented dialogues that are less highly structured than in the current study.

This conclusion is also consistent with recent research on imitation of non-linguistic behavior in ASD populations, which argues against a uniform imitation deficit in favor of a more nuanced approach whereby the likelihood of imitation is affected by multiple factors (e.g., an imitatee's goals; see Vivanti & Hamilton, 2013). It is not yet clear whether non-linguistic imitation and linguistic imitation (i.e., alignment) are appropriately characterized within a common theoretical framework; such a framework would of course be supported if the same factors were demonstrated to be influential in both. But at the very least, our results - in conjunction with Allen et al. (2011), Hopkins et al. (2015), and Slocombe et al., (2013) - argue against a basic and pervasive imitation deficit for language in ASD.

We now consider the mechanisms underlying lexical alignment in this study. Under a multi-componential account, whereby alignment arises from the interaction of audience design, social-affective and psycholinguistic priming mechanisms, we might have expected TD children to show stronger alignment overall than ASD children, because both social-affective and priming-based mechanisms would (additively) induce TD children to use the same name as their partner. Moreover, this tendency might have been expected to be stronger in older TD children, who should have sufficient perspective-taking skills to use the same name as their partner strategically to enhance communication, in the same way as adults in a similar setting (Branigan, Pickering, Pearson, McLean, & Brown, 2011). Older TD children, but not younger TD children or children with ASD, might therefore have shown an additional audience design effect.

In fact, the pattern of results suggests a critical role for lexical priming. That is, children appear to have used the same name as their partner because their partner's initial use raised its activation in their mental lexicon, facilitating subsequent retrieval. Evidence that audience design mechanisms did not contribute to alignment in this study comes from the absence of any difference between the ASD and TD groups, and the fact that neither chronological age in the TD group, nor ToM in the ASD group, mediated alignment, as would have been expected if audience design, which requires the ability to take a partner's perspective, were implicated. Second, the absence of any difference between the ASD and TD groups argues against any contribution of social-affective mechanisms. This conclusion is strengthened by the fact that the magnitude of alignment in ASD children was not mediated by individual differences in social functioning. Finally, the fact that alignment was unaffected by whether the prime and target involved the same or different pictures (i.e., tokens) suggests that alignment was not the result of memory processes associated with exposure to a retrieval cue; if so, we would have expected stronger alignment when naming the same token.

We therefore conclude that alignment in this study was primarily associated with lexical priming. Previous research has established that both TD children and children with ASD are susceptible to lexical priming in a laboratory setting (e.g., Harper-Hill, Copland, & Arnott, 2014); the current study suggests such effects can also influence their language use in dialogue, across a wide age range. The conclusion that lexical alignment can arise from automatic priming mechanisms is consistent with Garrod and

Clark's (1993) claim that reflexive repetition of a partner's language use is a default behavior occurring from the earliest stages of language development, and with evidence for strong lexical priming in children (Jescheniak, Hahne, Hoffmann, & Wagner, 2006).

Relevantly, Garrod and Clark noted that such automatic alignment may be communicatively maladaptive under some circumstances (e.g., if speakers use the same word, but with different reference). In such cases, ToM may be implicated in detecting and resolving potential or actual miscommunication (Pickering & Garrod, 2004), and successful communication may require speakers to be able to suppress an automatic tendency to align. An important question for future research is whether children with ASD are impaired in this ability to inhibit automatic alignment where relevant.

It is not clear whether different mechanisms would be implicated under other conditions. Our task involved a simple picture-matching game in which the child and experimenter named cards as they competed to identify matching pairs. In these circumstances, there was no additional motivation for social affiliation beyond participating in the game, and naming the pictures was incidental to success in the game. Social affiliative mechanisms might play a stronger role in contexts where affiliative goals were enhanced (Chartrand & Bargh, 1999), and audience design mechanisms might be more likely to be implicated in task-oriented dialogues where mutual understanding (and specifically, successful reference resolution, as in e.g., Slocombe et al., 2013) was more salient (Reitter & Moore, 2014).

Further research is therefore needed to determine whether under different circumstances, differences in alignment might emerge between TD children and children with ASD, and between children within each population with varying characteristics (e.g., individual differences in age, inhibitory control, social functioning), that might implicate contributions of other mechanisms.

In conclusion, our results suggest that the tendency to spontaneously converge with a conversational partner's referring expressions is strong and automatic even in children, and moreover that conversational impairments in ASD do not appear to involve an all-encompassing deficit in linguistic imitation.

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Notes

[1] Pretests established that (1) In a group of 18 TD pre-schoolers, both names were spontaneously produced, but the preferred name was produced at least twice as frequently as the dispreferred name; (2) Of 12 further TD pre-schoolers, more than 70% correctly chose the target (from an array of four including a semantic competitor), given the dispreferred name.

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Table 1: Background measures by group. Means (ranges) [standard deviations]; *frequencies.*

	Groups		
	Children with ASD	**VAM controls**	**CAM controls**
	N=15	*N*=15	*N*=15
Chronological Age	10;10 (5;11 – 13;11) [34.6 months]	10;0 (3;4 –14;0) [44.2 months]	10;10 [6;0 – 14;0] [36.6 months]
Verbal Age *(BPVS)*	9;4 (4;6 – 14;8) [38.3 months]	9;4 (4;7 – 14;8) [37.8 months]	10;2 (5;11 – 14;8) [32.7 months]
Non-Verbal IQ *(Raven's matrix)*	27.13 [5.854]	22 [11.193]	28.60 [5.938]
SCQ [*Current behaviour*]	8.66 [5.28]		
ToM (*Passed/Failed*)	*6/9*	*13/2**	*15/0*

*The two TD children who failed were aged 3;4 and 3;11 years.

Table 2: Frequency (and %) of responses by Group, Prime Name and Target Picture. Alignment effect represents children's increased probability (in percentage points) of producing an aligned name (i.e., producing a preferred name after hearing a preferred prime name compared to after a dispreferred prime name, and producing a dispreferred name after hearing a dispreferred prime name compared to after a preferred prime name).

			Prime Name		
Group	**Target Picture**	**Response**	**Preferred**	**Dispreferred**	**Alignment effect** (95% bootstrapped CI's)
ASD	Same	Preferred	68 (92%)	33 (45%)	47% (28-61)
		Dispreferred	4 (5%)	37 (49%)	44% (27-57)
		Other	2	5	
	Different	Preferred	63 (84%)	34 (45%)	39% (23-48)
		Dispreferred	4 (5%)	33 (44%)	39% (23-45)
		Other	8	8	
VAM	Same	Preferred	65 (87%)	37 (49%)	38% (17-51)
		Dispreferred	6 (8%)	34 (45%)	37% (16-53)
		Other	4	4	
	Different	Preferred	62 (85%)	35 (46%)	39% (26-53)
		Dispreferred	7 (10%)	35 (46%)	36% (19-46)
		Other	4	6	
CAM	Same	Preferred	60 (80%)	33 (45%)	35% (06-55)
		Dispreferred	12 (16%)	40 (55%)	39% (12-58)
		Other	3	0	
	Different	Preferred	62 (83%)	37 (49%)	34% (12-44)
		Dispreferred	10 (13%)	35 (47%)	34% (12-45)
		Other	3	3	

Table 3: Summary of the mixed logit models for the likelihood to produce a preferred name[1]

	ASD children (n = 299)[2]				TD children (n = 597)[3]			
	Parameter estimates		Wald's test		Parameter estimates		Wald's test	
	β	S.E.	z	p(β=0)	β	S.E.	z	p(β=0)
Intercept	1.59	0.53	3.01		1.20	0.32	3.80	
PrimeName (d)	-3.91	0.78	-5.04	<.001	-2.64	0.50	-5.27	<.001
TargetPic (d)	-0.62	0.57	-1.09	>.1	-0.21	0.43	-0.49	>.1
C.Age (s)	0.42	0.49	0.85	>.1	0.26	0.13	1.94	>.1
V.Age (s)	-0.37	0.34	-1.09	>.1	0.61	0.26	2.36	<.05
SCQ (r)	0.07	0.60	0.12	>.1	-	-	-	-
TOM (s)	0.04	0.63	0.06	>.1	-	-	-	-
PrimeName:TargetPic	-1.73	1.43	1.21	>.1	0.41	0.90	0.46	>.1
PrimeName:C.Age	0.29	1.02	0.28	>.1	-0.24	0.42	-0.57	>.1
PrimeName:V.Age	-0.80	0.70	-1.15	>.1	0.15	0.79	0.20	>.1
PrimeName:SCQ	-0.77	1.28	-0.61	>.1	-	-	-	-
PrimeName:TOM	-0.05	1.30	-0.04	>.1	-	-	-	-
TargetPic:C.Age	1.02	0.93	1.09	>.1	-0.46	0.30	-1.53	>.1
TargetPic:V.Age	-0.04	0.59	-0.07	>.1	-0.29	0.58	-0.50	>.1
TargetPic:SCQ	-0.76	1.14	-0.67	>.1	-	-	-	-
TargetPic:TOM	-0.64	1.21	-0.53	>.1	-	-	-	-
PrimeName:TargetPic:C.Age	-1.57	2.24	-0.70	>.1	0.16	0.66	0.24	>.1
PrimeName:TargetPic:V.Age	-0.67	1.61	-0.41	>.1	0.04	1.25	0.03	>.1
PrimeName:TargetPic:SCQ	0.64	2.78	0.23	>.1	-	-	-	-
PrimeName:TargetPic:TOM	1.32	2.87	0.46	>.1	-	-	-	-

[1] PrimeName and TargetPic were deviation-contrast coded (d), with values -.5/.5 for levels Preferred/Dispreferred and Same/Different. ChronoAge was centered and scaled (s) (TD C.Age M = 0, range = [-2.11, 1.08]; ASD C.Age M = 0, range = [-1.71, 1.07]). Verbal Age was centered and scaled, and residualised (r) against ChronoAge (TD V.Age (s) M = 0, range = [-1.09, 1.06]; ASD V.Age (r) M = 0, range = [-1.24, 1.57]) to address the high correlation between the two variables (TD r = .85; ASD r = .69). SCQ was centered and scaled, and residualised (r) against ChronoAge (s) and VerbalAge (r) (M = 0, range = [-0.71, 1.25]). TOM was centered and scaled (s), with values .812/-1.228 for levels passed/failed.
[2] Model converged upon simplifying the random structure by forcing independence between by-item random effects.
[3] Model converged with full random structure justified by the design.

Table 4: Summary of the mixed logit models for the likelihood to produce a dispreferred name[1]

	ASD children (n = 299)[2]				TD children (n = 597)[3]			
	Parameter estimates		Wald's test		Parameter estimates		Wald's test	
	β	**S.E.**	**z**	**p(β=0)**	**β**	**S.E.**	**z**	**p(β=0)**
Intercept	-2.25	0.67	-3.36		-1.54	0.28	-5.59	
PrimeName (d)	4.12	1.29	3.19	<.01	2.84	0.55	5.10	<.001
TargetPic (d)	-0.25	1.33	-0.19	>.1	0.19	0.47	0.40	>.1
C.Age (s)	-	-	-	-	-0.40	0.14	-2.91	<.01
V.Age (r)	-	-	-	-	-0.49	0.30	-1.63	>.1
TOM (c)	-0.65	0.55	-1.16	>.1	-	-	-	-
PrimeName:TargetPic	-0.11	2.71	-0.04	>.1	-0.55	1.01	-0.54	>.1
PrimeName:C.Age	-	-	-	-	0.69	0.43	1.59	>.1
PrimeName:V.Age	-	-	-	-	-0.14	0.86	-0.16	>.1
PrimeName:TOM	-0.05	1.27	-0.04	>.1	-	-	-	-
TargetPic:C.Age	-	-	-	-	0.51	0.27	1.86	=.06
TargetPic:V.Age	-	-	-	-	0.01	0.60	0.02	>.1
TargetPic:TOM	-0.07	1.26	-0.05	>.1	-	-	-	-
PrimeName:TargetPic:C.Age	-	-	-	-	-0.04	0.68	-0.06	>.1
PrimeName:TargetPic:V.Age	-	-	-	-	0.91	1.40	0.65	>.1
PrimeName:TargetPic:TOM	0.82	2.63	0.31	>.1	-	-	-	-

[1] PrimeName and TargetPic were deviation-contrast coded (d), with values -.5/.5 for levels Preferred/Dispreferred and Same/Different; ChronoAge was centered and scaled (s); Verbal Age was centered and scaled, and residualised against ChronoAge (r) to address the high correlation between the two variables (see Table 3 for more details); TOM was centered (c).
[2] Model converged with full random structure.
[3] Model converged with full random structure justified by the design.

Table 5: Summary of the mixed logit model of the likelihood to lexically entrain (on either name), comparing ASD and TD children (n = 896)[1,2]

Predictors (fixed effects)	**Parameter estimates**		**Wald's test**	
	β	**S.E.**	**z**	**p(β = 0)**
Intercept	1.66	0.45	3.70	
CAM-ASD	-0.48	0.55	-0.90	>.1
VAM-ASD	-0.01	0.62	0.99	>.1
PrimeName (d)	-3.80	0.97	-3.92	<.001
TargetPic (d)	-1.14	0.89	-1.28	>.1
CAM-ASD:PrimeName (d)	1.41	0.83	1.70	=.09
VAM-ASD:PrimeName (d)	0.03	1.18	0.02	>.1
CAM-ASD:TargetPic (d)	0.87	0.94	0.93	>.1
VAM-ASD:TargetPic (d)	0.27	1.19	0.20	>.1
PrimeName(d):TargetPic(d)	1.77	1.63	1.08	>.1
CAM-ASD:PrimeName(d):TargetPic(d)	-2.20	1.79	-1.23	>.1
VAM-ASD:PrimeName(d):TargetPic(d)	0.19	2.28	0.08	>.1

[1] Group was dummy coded with ASD as baseline group. PrimeName and TargetPic were deviation-contrast coded (d), with values -.5/.5 for levels Preferred/Dispreferred and Same/Different. The intercept represents the log-odds to align for the ASD group across conditions. PrimeName (d), TargetPic (d) and PrimeName(d):TargetPic(d) represent, respectively, the main effects and the interaction of the two predictors for the ASD group (on the logit scale). The interactions with the CAM and VAM groups represent how these main effects and their interaction change in the CAM and the VAM (respectively) groups compared to the ASD group (on the logit scale).
[2] Model converged with full random structure justified by the design.

Figure 1. Example trial (Dispreferred Name/Different-token condition): The experimenter named an object using the dispreferred name ("bunny"). After two fillers, the child named a different token of the same object. Alignment occurred if the child used the same name as the experimenter previously used ("bunny").

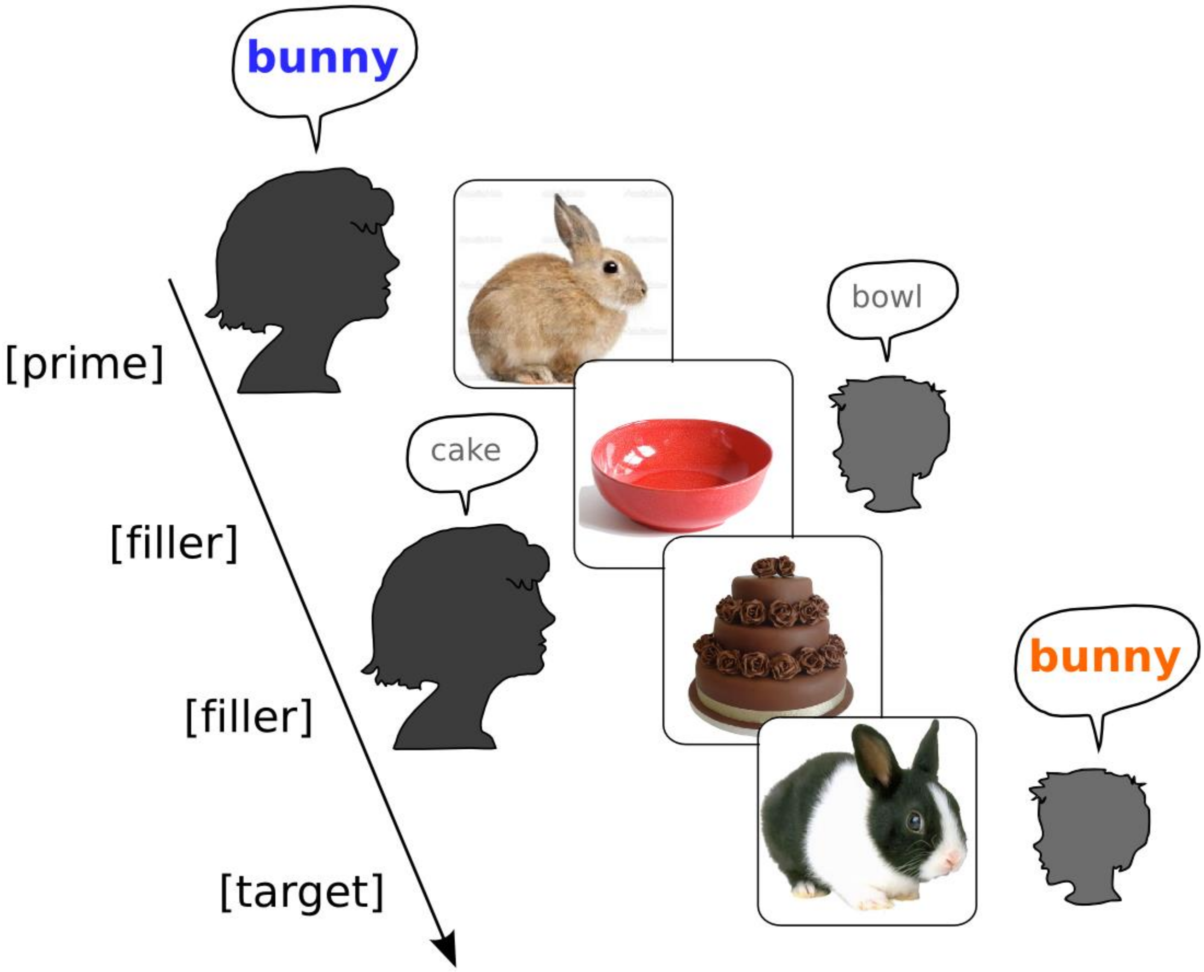

Figure 2: Observed proportions of aligned responses by Group and Target Picture condition. Error bars represent non-parametrically bootstrapped BCa 95% confidence intervals based on subject-wise condition means. Baseline probabilities to produce a preferred (Pr = 0.67) (dotted red line) and a dispreferred (Pr = 0.12) (dashed blue line) name were estimated from the pre-test.