132 (2026) 202844

Contents lists available at ScienceDirect

Research in Autism

journal homepage: www.elsevier.com/locate/rasd

Can autism professionals hear the autism diagnosis at a preverbal stage? A first impression study

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ARTICLE INFO

Keywords:
First impressions
Expert clinician judgements
Autism
Elevated likelihood of autism
Preverbal production
Canonical babbling

ABSTRACT

Autism professionals frequently report being able to rapidly detect autism from hearing an autistic individual's vocal production, even before direct interaction. While vocal characteristics can influence diagnostic judgments, it remains unclear how accurate such spontaneous judgements may be and which characteristics of vocalization drive them. To date, there is no research on first impressions of vocalization of young autistic children. Sixty-one autism professionals categorized around two hundred short vocal samples from 9- and 18-month-old children as 'autistic' or 'non-autistic'. The vocal samples were presented in a random order and were either vocalic or canonical babbling productions. Autism professionals showed an overall modest ability to accurately detect which vocalizations were produced by autistic vs non-autistic children. At both 9 and 18 months of age, classification accuracy exceeded chance level for vocalic productions and for canonical babbling productions produced by non-autistic children, whereas accuracy for canonical babbling produced by autistic children did not exceeded chance level and showed a systematic bias toward non-autistic classification. Autism professionals' first impression based on young children's vocal productions thus appear only moderately reliable. In typical development, canonical babbling corresponds to a more mature speech acquisition stage than vocalic productions. Accordingly, participating in autism professionals' classification are probably based more on the perceived maturity of vocalizations sample than on sensitivity to some feature characteristic of autism.

1. Introduction

The impetus for this study comes from a personal experience that, nonetheless, we trust, will be shared by many readers of this journal: expert clinicians specialized in diagnosing autism often say that they are able to 'hear' autistic children from the waiting room, even before starting the first diagnosis appointment. Many autism professionals also say that they can recognize a vocalization as being produced by an autistic child outside their practice or research lab, while shopping or at the airport, for instance, again without laying eyes on this child.

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https://doi.org/10.1016/j.reia.2026.202844
Received 12 November 2025; Received in revised form 24 January 2026; Accepted 1 February 2026
Available online 6 February 2026

Such anecdotes may be framed as *first impressions* about an individual's diagnosis. First impressions refer to a psychological construct whereby individuals rapidly and unconsciously extract and create information about another person based on behavior perceived during direct or indirect interaction (Reis & Sprecher, 2009). Originally relevant for survival, first impressions emerge automatically as humans process their environment, and impact virtually any social interaction (Ghijsen, 2004; Judd et al., 2012; Rule & Ambady, 2009). First impressions have been shown to affect how people perceive specific traits or conditions, including autism (de Marchena & Eigsti, 2010; Geelhand et al., 2021; Grossman, 2015; Scherer, 1978; Siegman et al., 1987; Wearden et al., 1998). In a typical first impression experimental paradigm, a rater– who may be an expert of a certain condition or a lay person–is asked to make a judgment about another person in a few seconds. The judgment can be made via different modalities (audio, video or photos) and about different traits (voice, behavior, likelihood of becoming friends, etc.). For instance, there is ample literature on how vocal characteristics may exert a strong impact on first impressions of another person's disease or mental health condition, such as Parkinson's disease (Pitcairn et al., 1990), depression (Mundt et al., 2007, 2012), personality-disorder-specific traits (Fowler et al., 2009; Holtzman & Strube, 2010; Tackett et al., 2017) or traits and state of anxiety (Harrigan et al., 1994; Weeks et al., 2016).

In the same vein, there are good reasons to believe that audio recordings of vocalizations or speech could give rise to reliable first impressions of autism. Atypical prosody (pitch and rhythm) and voice quality are an important feature of autism symptomatology (Baltaxe & Simmons, 1985; Diehl et al., 2009; Loveall et al., 2021; Mccann & Peppé; Paul et al., 2005; Peppe et al., 2011; Shriberg et al., 2001). In fact, speech atypicalities must be observed and recorded during the gold-standard Autism Diagnostic Observation Schedule (ADOS-2) (Lord et al., 1989) and Autism Diagnostic Interview-Revised (ADI-R) (Lord et al., 1994). Atypical prosody and voice quality, frequently reported in autism, is thus likely to give rise to rapid first impressions of autism, especially in autism professionals.

Autism is a heterogeneous condition characterized by a complex behavioral expression that requires an extensive diagnostic procedure. However, some autistic individuals seem to present such frank patterns of autistic behaviors that autism professionals may only need a few minutes to form a diagnostic judgment. In a seminal paper, de Marchena and Miller (de Marchena & Miller, 2017) established a list of behaviors, called 'frank features' of autism that could lead to such rapid 'first' impressions of autism diagnosis. They found that atypical or unusual prosody was among the most frequently reported markers of frank autism. Some authors also report that autism professionals, being expert or still in training, can formulate accurate diagnostic hypotheses after watching, during 5-min live interactions, the behaviors of children aged between 15 and 53 months at suspicion of atypical development (de Marchena et al., 2023; Thomas et al., 2024; Wieckowski et al., 2021) or of individuals diagnosed with autism in childhood but who no longer meet diagnostic criteria during or after adolescence (aged between 12 and 39 years) (Canale et al., 2024). Gabrielsen and colleagues (Gabrielsen et al., 2015) asked expert clinicians to judge behaviors of sixty 10-second clips from ADOS-2 assessments of typically developing children, autistic children and non-autistic children with language delays, all aged between 15 and 33 months. Clinicians rated autistic children's vocalizations as a likely sign of autism more often than they did for children with language delay. That said, in study involving 5-minute live interaction with toddlers (mean age 22.9 months), atypical prosody and vocalizations are, in fact, rarely used by expert clinicians and trainees to characterize their diagnostic impressions (Thomas et al., 2024).

However informative about autism professionals' conscious and thoughtful ability to form a rapid diagnostic opinion, the studies just discussed do not constitute first impression studies in the strict sense (i.e. judgment made unconsciously, in just a few seconds). Furthermore, existing first impressions studies on children predominantly relied on video-based stimuli, thus combining visual and auditory modalities. Accordingly, it is not possible to assess the specific contribution of voice characteristics on initial diagnostic impressions.

Indirect support for the idea that autism professionals could form a first impression of autism can be drawn from first impressions studies with non-expert raters. Non-expert raters robustly issued high atypicality ratings based on audio recordings of verbal autistic adults (Geelhand et al., 2021; Grossman, 2015; Sasson & Morrison, 2019) and children (Beccaria et al., 2025). In fact, non-experts are reported to detect vocal atypicalities in autistic adults within one to three seconds (Grossman, 2015). It makes sense, therefore, to expect that professionals specialized in autism, who themselves believe that they can 'hear' an autism diagnosis, should also be able to form reliable diagnostic impressions of a child based on short excerpts of vocal production. However, to the best of our knowledge, no study has specifically investigated whether autism professionals can in fact assign a correct first impression diagnosis based on audio stimuli.

In autism research, it is possible to capture the earliest stages of development by targeting infants who are at an elevated likelihood of autism (ELA) because they have an older autistic sibling (Constantino, 2021; Hansen et al., 2019). There are several developmental and methodological reasons to explore clinician diagnostic impressions using recordings from ELA children. First, prospectively following ELA children allows to gather vocalic productions at an early, pre-diagnostic age, and to later associate them with a diagnostic outcome, i.e. a presence or not of autism at around 36 months. Second, a first impression study which includes productions from ELA children who did not receive a diagnosis of autism (ELA-, henceforth) mirrors autism professionals' experience in diagnostic and therapeutic centers for autism, where ELA- infants are often present, for evaluation or simply accompanying an older sibling. Third, language disability affects all autistic individuals to some degree (Handbook of Autism and Pervasive Developmental Disorders, 2005). In early childhood, language delay is one of the major warning signs of atypical development for caregivers, as well as for education and medical professionals (Coonrod, 2004; De Giacomo & Fombonne, 1998; Mitchell et al., 2006). While early signs of language delay can sometimes be observed around 18 months of age, caregivers' concerns usually begin around 18–24 months (De Giacomo & Fombonne, 1998; Guinchat et al., 2012; Waddington et al., 2023; Young et al., 2003), a developmental stage characterized by the first two-word utterances (simple phrases) as well as by a vocabulary spurt, rather than by single pre-linguistic vocalizations and first words. It is often around this time that the absence or delay of spoken language becomes more apparent to caregivers and prompts further evaluation. Therefore, autism professionals often encounter autistic individuals who are at a vocal or early preverbal stage of language development, out of step with their chronological age. In other words, even older individuals who are referred to an autism diagnosis may display pre-linguistic vocalizations corresponding to a language developmental age of less than 18 months. Focusing on vocalizations produced at such a young age targets a critical pre-diagnostic developmental window, which spans over the emergence of canonical babbling and early spoken language, and which has not been systematically examined in previous first impression studies with vocal stimuli.

That said, not all prelinguistic vocalizations are of the same kind, and their developmental trajectories differ across age and clinical groups in typically developing infants, canonical babbling—with a recognizable consonant-vowel syllables such as 'ba' or 'da'—emerges around 6–7 months of age and is firmly established by 10 months (Oller et al., 1998; Stark, 1980). Prior and after reaching this milestone, infants also produce simpler vocalic sounds which lack consonants. By 9 months, most typically developing infants produce both vocalic and canonical babbling vocalizations. By 18 months, these prelinguistic forms coexist with first words, and the balance between the number of vocalic and canonical productions is expected to shift significantly in favor of the canonical form (Fenson et al., 1994; Nathani et al., 2006a; Xu et al., 2023). In contrast, autistic children—particularly those who are minimally verbal—often show a delayed onset or reduced frequency of canonical babbling, with lower canonical babbling ratios than their typically developing peers (Patten et al., 2014; Paul et al., 2011). In minimally or non-speaking autistic individuals, the vocal output may remain dominated by vocalic or non-canonical forms, regardless of age (Tenenbaum et al., 2020; Yankowitz et al., 2019). The fact that autism professionals are frequently exposed to a population of non-verbal individuals raises the question of whether professionals' experts in autism are forming reliable perceptual cues within the non-linguistic vocalizations, or whether they are biased by routinely being exposed to non-linguistic vocalizations in children older than 18 months.

2. The current study

The current study seeks to contribute to the existing body of literature on the interplay between first impressions and the detection of autism specificities. We aim to evaluate whether autism professionals can form accurate first impressions of a multidimensional and heterogeneous diagnosis like autism from short excerpts of the early vocalic and canonical babbling productions of 9- and 18-month-old children with Elevated Likelihood of Autism (ELA) who go on to receive a diagnosis of autism (ELA+), ELA children who do not receive a diagnosis of autism (ELA-), and children with Low Likelihood for Autism (LLA)—that is, children without an autistic sibling and for whom the probability to receive an autism diagnosis does not differ from that of the general population. Our main research question is whether autism professionals can detect, above chance, audio recordings from autistic children. Furthermore, we also asked whether detection accuracy is influenced by the type of prelinguistic production, vocalic or canonical babbling, and whether detection accuracy improves along with the recorded child's age.

Table 1
Respondents' characteristics.

Respondent	*n* = 61
Gender	
Male: Female: Other Ratio	6: 54: 1
Country	52: 5: 2: 2
French-speaking Belgium: France: Canada (Quebec): French-speaking Switzerland	
Profession	
Educator	5
Secondary/High school teacher	1
Occupational therapist	1
Elementary School teacher	3
Physiotherapist	1
Speech therapist	23
Neuropediatrician	2
Neuropsychologist	3
Education specialist	2
Pediatrician	2
Child psychiatrist	1
Psychologist	12
Psychomotor therapist	3
Other	2
Type of practice	
Diagnostic: Teaching: Support care and treatment	12: 10: 39
Years of experience working with autistic children	
1–3 years	13
4–10 years	23
> 10 years [11-40y]	25
Age range in years of the autistic population respondent works most with	
[0-5]: [6-12]: [13-18]: 18 +	19: 34: 5: 3
Is respondent parent of a child under 36 months?	
Yes: No ratio	14: 47

3. Methods

The experimental protocol was approved the Ethics Committee of the Faculty of Psychology, Université Libre de Bruxelles, Brussels, Belgium. (Project ID: [596/2022] accepted the 2023-02-01). All methods were performed in accordance with the relevant guidelines and regulations. Furthermore, informed consent was obtained from all participants before the beginning of the task (see Table 4: Stage of the First Impression Task).

3.1. Participants

A total of 188 participants took part in an online first impression task, but only 61 (88 % female) completed the entire task. All respondents were specialized professionals working with autistic individuals in the following fields: 12 in diagnosis (20 %), 10 in education (16 %) and 39 in support care and treatment (64 %). Participants' main occupation was pediatric neurologist, child psychiatrist, pediatrician, psychiatrist, speech pathologist, psychologist, neuropsychologist, educator, psychomotor therapist, physiotherapist, occupational therapist, education specialist, teacher, or preschool teacher. All participants were recruited through the first author's professional network across French-speaking Belgium, France, French-speaking Switzerland, and French-speaking Canada. Advertisements via social networks were not used, as they might have attracted participants who did not match the intended target group. Table 1 displays respondents' characteristics.

4. Stimuli and task

4.1. Selection of children's naturalistic vocalization recordings

The stimuli used in this study were young children's vocalizations extracted from 6-hour-long naturalistic speech recordings, collected at home at 9 and 18 months of age. The recordings were initially collected as part of a longitudinal research protocol designed to capture the children's spontaneous vocal behavior in their natural home environments. All recordings were made using the same model of microphone device (Zerone, 48 kHz, 192 kbps) across participants, ensuring consistency in recording quality. The device was placed inside a small chest pocket on a specially designed T-shirt worn by the child, with the microphone positioned at the level of the sternum to optimally capture the child's vocalizations throughout the day. Each session consisted of approximately 6 h of continuous audio, without any specific prompts or experimental manipulation. The recordings captured a wide range of everyday situations, including both interactive (e.g., play, meals, care routines) and non-interactive moments (e.g., rest, independent exploration). These naturalistic conditions allowed for the collection of ecologically valid vocal behavior, representative of each child's typical daily environment. At the time of recording, children were classified according to their autism likelihood status into one of the two groups:

Table 2
Characteristics of all included children contributing recordings at 9 months, 18 months, or both.

		ELA+		ELA-		LLA	
	Sampling moment	N = 14	Mean (SD) Range	N = 10	Mean (SD) Range	N = 11	Mean (SD) Range
Sex ratio (M:F)		9:5		0:10		6:5	
Socioeconomic status	Study entry	13	8.73 (3.76) 3–15.5	10	7.75 (2.63) 5.5–12.5	11	13.41 (2.61) 10–17
Nonverbal IQ	36 months	11	93 (14.93) 55–105	6	106.17 (6.14) 99–113	8	103 (4) 99–110
VABS-II Score Total	18 months	7	92.57 (27.17) 64–143	6	134.33 (16.24) 105–154	9	103.3 (14.93) 71–127
	36 months	5	85.6 (25.95) 56–121	1	82 (NA) 82	7	109.57 (14.36) 81–124
Communication Socialization	18 months		93.11 (17.57) 69–119		124.28 (11.73) 113–144		103.2 (14.33) 82–128
	36 months		82 (15.15) 68–106		106.33 (20.5) 86–127		111.25 (14.03) 81–127
	18 months		99.28 (25.83) 77–147		130.33 (18.36) 97–147		111.3 (15.03) 82–136
	36 months		81.17 (34.97) 35–129		100 (NA) 100		111 (19.02) 81–144
MB CDI Words and utterances Expressive vocabulary	36 months	9	256.78 (178.12) 6–541	4	465.5 (120.25) 297–553	8	507.37 (171.44) 94–616
ADOS-2 SA comparison	36 months	11	5.11 (1.61) 2–7	6	1.17 (0.41) 1–2	8	1 (0) 1–1
RRB comparison	36 months		8.18 (1.6) 5–10		2 (2.45) 1–7		1 (0) 1–1
Total comparison	36 months		5.81 (1.78) 2–9		1 (0) 1–1		1 (0) 1–1

children at elevated likelihood of autism (ELA) and children at low likelihood of autism (LLA). Children from these two groups were then classified into an outcome group based on their score from an ADOS-2 assessment (by a certified ADOS assessor) at 36 months: children at elevated likelihood of autism who later received a diagnosis of autism (ELA+), children at elevated likelihood of autism who later did not receive a diagnosis of autism (ELA−), and children at low likelihood of autism (LLA). The LLA group consisted of children with a low likelihood of autism based on family history (i.e., no autistic sibling), who did not meet diagnostic criteria for autism as determined by the ADOS-2, and who did not show any developmental concerns according to the Vineland-II or signs of intellectual disability on the Leiter-3 (see Table 2 – Characteristics of all included children contributing recordings at 9 months, 18 months, or both).

Stimuli at 9 and 18 months were drawn from a longitudinal cohort in which infants were enrolled at 6 months without knowledge of later developmental outcomes and were recorded repeatedly between 6 and 36 months of age (at 6, 9, 12, 15, 18, 24, and 36 months). Among the 45 infants at elevated likelihood for autism who were recruited at this study onset, some were later were classified as ELA+ and some others as ELA-. In this study, we included all possible available high-quality recordings from these groups and excluded *a posteriori* recordings and stimuli compromised by background noise or recording artifacts. Even though this approach resulted in unequal numbers of participants and stimuli per group, it allowed us to prioritize methodological rigor by selecting participants a priori and preserving naturalistic sample distributions. We initially selected 15 recordings per age group from the same autistic children (ELA+), and 20 recordings per age group from non-autistic children, combining both the ELA- and LLA groups. For 5 and 4 children at 9 and 18 months, respectively, the quality of the audio recording was judged too poor to be used for a first impression audio task based on naturalistic audio recordings. When possible, these missing recordings were replaced with others of acceptable sound quality from different children within the same diagnostic and age group. As a result, 12 recordings of 9-month-old and 14 recordings of 18-month-old autistic children, and 17 recordings of 9-month-old and 18 recordings of 18-month-old non-autistic children were eventually selected for stimulus extraction. The recordings used in this study come from children enrolled in a longitudinal baby-sibling study. Developmental assessments (Vineland-II, language test, ADOS-2, Socio-Economic Status) were conducted at various ages, and Table 2 provides these parameters for informational purposes, organized by diagnosis outcome groups.

4.2. Stimuli selection

First, each 6-hour-long recording was reduced to a 30-minute segment, corresponding to the period in which the child produced the most vocal sounds. To determine this, we used an algorithm to identify the 30 consecutive minutes with the highest number of vocalization units. Second, these 30-minute-long recordings were manually coded according to a scheme inspired primarily from (Nathani et al., 2006b; Oller, 2000) to characterize early (pre)verbal productions collected in natural settings. Children's vocal productions during the recordings were coded as: nonvocalic preverbal productions, vocalic preverbal productions, canonical babbling, proto-word, isolated word, two-word combination or phrase (see OSF link https://osf.io/y2jxm/?view_only=35550286652c4372b004816e596c9461 for a complete description of the coding procedure).

Out of all these coded productions, we selected stimuli that were considered representative of a 9-month-old infant and an 18-month-old toddler. For stimuli selection, three main criteria were applied. First, only productions that did not significantly overlap with background noise or other voices were retained, ensuring clean and unambiguous stimuli for processing. Second, among the different types of productions that a child produced at 9 and 18 months, only those that were coded as 'vocalic preverbal production' or 'canonical babbling production' were selected (see OSF; https://osf.io/y2jxm/?view_only=35550286652c4372b004816e596c9461). Third, to the best of our capacity, we selected productions that were within the most represented length range of all productions in the original recording sample. No previous study has examined first impressions based on preverbal productions, so we could not rely on existing literature to determine stimulus duration. As a result, we aimed for a duration that was representative of children's vocal behaviors within the relevant age ranges for each participant and at each age, two vocalic units and two canonical babbling units were randomly selected. For 9-month productions, two vocalic units that were between 500 ms and 1000 ms long and two canonical babbling units that were between 1000 ms and 1500 ms long were selected for each participant. For 18-month productions, two vocalic units and two canonical babbling units, both between 1000 and 1500 ms long, were selected for each participant. This selection reflects the average temporal properties of these vocalization types as observed in our dataset. From a methodological perspective, manipulating stimulus duration could have compromised their ecological validity and introduced a sense of atypicality in the perception of the vocalizations. Therefore, our approach aimed to strike a balance between consistency across stimuli and fidelity to the natural characteristics of preverbal vocal behavior at each developmental stage. All selected units were extracted as.wav audio files and used as stimuli.

4.3. Task design

The task was implemented in PsychoPy (Peirce et al., 2019) and disseminated online to participants via the Pavlovia platform. The estimated duration to complete the task was 20 min.

Participants listened to vocalic and canonical babbling production excerpts from 9-month-old and 18-month-old children. After each audio stimulus was played, participants were asked to quickly form a 'clinical' judgment of whether the child was more likely to be (a) autistic or (b) non-autistic. The response was a forced choice between *Autistic* ('I think this stimulus comes from an autistic child') and *Non-autistic* ('I think this stimulus comes from a non-autistic child'). The option to include a *Sibling of an autistic child who did not receive a diagnosis of autism* response (i.e., children from the ELA- group) was deliberately excluded to prevent it from becoming a default choice when respondents were unsure about their classification. Finally, participants were not allowed to replay the audio stimuli. This restriction was essential to maintain the integrity of the first impression paradigm we employed. Allowing multiple playbacks would have undermined the spontaneous, intuitive nature of the task, which aimed to capture autism professionals' immediate judgments based on brief and naturalistic vocal samples.

Stimuli from 9-month-old and 18-month-old children were presented in two distinct blocks. Respondents were given an age approximation (i.e., "youngest" vs. "less young") for each block to avoid significant expectation biases based on language development milestones. Mixing 9-month-old and 18-month-old vocalizations in the same block could have led to 9-month stimuli being systemically rated as '*autistic*' due to being less developmentally advanced than 18-month stimuli. Similarly, counterbalancing the order of two blocks across participants could have biased the respondents towards rating the 9-month-old stimuli as more atypical if they would have been exposed to them after having first rated 18-month-old stimuli. Stimuli in both blocks were presented randomly across participants. The distribution of stimuli across vocalization types, diagnostic outcome groups, and age is summarized in Table 3.

The task was completely anonymous and did not collect any identifying data from respondents. Table 4 summarizes the procedure.

5. Planned analyses

All analyses were performed in R (version 4.1.3; (R Core Team. R core team, 2021). For descriptive purposes, we computed, for each participant, a *d'* value, which corresponds to the difference between the z-scores of the Hit Rate (proportion of correct positive identifications (true positives) out of all actual positives) and the False Alarm Rate (proportion of incorrect positive identifications (false positives) out of all actual negatives). A positive *d'* value indicates good discrimination, a negative *d'* value suggests poor discrimination, and a *d'* value of 0 indicates an at-chance discrimination. To assess the variability and uncertainty of the overall *d'* estimate, as well as to compensate for unbalanced sample sizes, a bootstrap analysis was performed using the **boot** package, generating 10,000 resampled datasets to compute the mean *d'* with 95 % confidence intervals (CI).

Next, to evaluate the contributions of different vocalization types to respondents' diagnostic judgments at 9 and 18 months of age, we conducted mixed-effects logistic regression analyses on respondents' accuracy, with the glmer function from the **lme4** package (Bates et al., 2015). Participants' responses were coded as correct (=1) or incorrect (=0) based on the outcome group of the child. Vocalizations of ELA+ children classified as 'autistic' as well as vocalizations of ELA- and LLA children classified as 'non-autistic' were coded as correct responses. Conversely, vocalizations of ELA+ children classified as 'non-autistic' and those of ELA- and LLA children classified as 'autistic' were coded as incorrect responses. Type of production (vocalic vs. canonical babbling) and Diagnostis (ELA+ vs. ELA- vs. LLA) were included as fixed effects and by participant and by recorded child intercepts were included in the random structure.

Finally, to evaluate the contributions of children's age to respondents' diagnostic judgments, age (9 months vs. 18 months) and Diagnosis (ELA+ vs. ELA- vs. LLA) were included as fixed effects, with by participant and by recorded child intercepts included in the random structure.

6. Results

Of the 188 participants who accessed the survey link, 61 (32.4 %) completed all 228 experimental stimuli. Among the remaining 127 dropouts, 75 (39.9 %) opened the survey but did not progress beyond the recruitment page, and 47 (25 %) withdrew during the consent, instructions, or practice-trial stages (i.e., before exposure to any of the 228 vocalization stimuli). Only five participants (2.7 %) exited after seeing some experimental stimuli (having completed 2, 25, 35, 35, and 67 stimuli, respectively). Since the vast majority of dropouts occurred prior to or at the very beginning of the task, there is no evidence that stimulus fatigue would systematically influence responses among those who completed the survey.

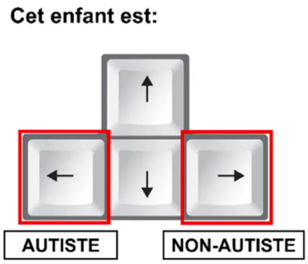
Discriminability (*d'*) for stimuli of 9-month-old infants was 0.08 (95 % CI [0.02:0.15]), indicating a level of detection of productions by autistic children close to chance. Stimuli of 18-month-old children yielded a slightly higher discriminability with a *d'* value of 0.23 (95 % CI [0.17:0.29]). Overall, respondents showed a moderate ability to differentiate between stimuli from children who received a diagnosis of autism and those who did not. While discriminability was not high, it was significantly better for 18 months than 9 months stimuli. The mean difference between the bootstrap distribution is 0.14, with 95 % confidence interval ranging from 0.05 to 0.23, suggesting that the observed difference is statistically significant.

Table 3
Distribution of stimuli across vocalization types, groups and age.

	Vocalic Productions			Canonical Babbling Productions		
	ELA+	ELA-	LLA	ELA+	ELA-	LLA
Block1 (9 months)	20	24	13	18	22	14
	20 (Autistic)	37 (Non-Autistic)		18 (Autistic)	36 (Non-Autistic)	
Total	**57 stimuli**			**54 stimuli**		
Block2 (18 months)	17	24	13	20	28	15
	17 (Autistic)	37 (Non-Autistic)		20 (Autistic)	43 (Non-Autistic)	
Total	**54 stimuli**			**63 stimuli**		

Table 4
Stage of the first impression task.

Screen 1	Presentation of the experimenter in charge of the study, the context of the study and the research question: 'Can we 'hear' the autistic diagnosis early on?'
Screen 2	Presentation of a short literature background of first impression studies and the broad purpose of the study. Information about the time needed to complete the task (~20 min) in order to invite people who would not have this time available to return to the task later.
Screens 3–6	Information about participants' rights such as protection of data, right of withdrawal, etc. in order to get participants to enter in the task voluntarily and knowingly. Participants were then asked to provide consent to pursue the task.
Screen 7	Presentation of all important task instructions: (1) Organization of the task (2) Recommended environment while performing the task: 1. 20 min available in a quiet area; 2. Wearing headphones or earphones; 3. Give spontaneous answers, stimuli are presented quickly; 4. The task cannot be paused, and it is important to complete it to the end in order to validate and record respondents' answers.
Screen 8 **Questions Block 1**	a. What is your profession? Educator/Teacher/Professor/Occupational therapist/Elementary School teacher/Physiotherapist/Speech therapist/Neuropediatrician/Neuropsychologist/Education specialist/Pediatrician/Child psychiatrist/Psychologist/Psychomotor therapist/Other. b. Where do you currently work? French-speaking Belgium/France/Quebec (Canada)/French-speaking Switzerland. c. How many years have you been working with an autistic population? 1–40 +. d. Most of your practice (in time over a week) is dedicated to: diagnosis/teaching/support care and treatment.
Screen 9 **Trial block**	Participants were given two practice trials with two trial stimuli extracted from two participants not included in the study to practice the response key on their keyboard. The following visual reminder of the response key was always visible during Trial and Stimuli blocks.



Screen 10 **Stimuli Block 1**	The first block of stimuli included stimuli extracted from 9-month-old infants and was presented to participants as including the 'youngest children'. Participants were blind as to the exact age of infants in the stimuli in order to avoid expectation bias. Stimuli were randomly presented across participants. In this block, each participant heard a total of 112 stimuli presented randomly. 58 stimuli were vocalic productions and 54 were canonical babbling productions. In total, 46 stimuli from the ELA+ group, 28 stimuli from the ELA- group and 38 stimuli from the LLA group were presented to each participant.
Screen 11 **Questions Block 2**	e. Over the past year, which of the following age group have you worked with the most: autistic preschoolers (0–5 years)/autistic children between 6 and 12 years/autistic adolescents (13–18 years)/autistic adults (+18 years). f. Are you currently the parent of a child who is younger than 36 months? Yes/No c. What gender do you identify with? Male/Female/Other
Screen 12 **Stimuli Block 2**	The second block of stimuli included stimuli extracted from 18-month-old toddlers and was presented to participants as including the 'less young children'. Participants were blind as to the exact age of infants in the stimuli in order to avoid expectation bias. Stimuli were randomly presented across participants. Block 2 corresponded to the 18-month age range. In this block, each participant heard a total of 118 stimuli presented randomly. 54 stimuli were vocalic productions and 64 were canonical babbling productions. In total, 52 stimuli from the ELA+ group, 28 stimuli from the ELA- group and 38 stimuli from the LLA group were presented to each participant.
Screen 13	The last screen includes words of thanks and acknowledgments, as well as the contact information of the study team member responsible for any questions regarding the task or future publications.

6.1. 9-month sample

Stepwise comparison of mixed-effect logistic regressions revealed an effect of Diagnosis ($\chi^2(2) = 38, p < .001$), no effect of Type of production ($\chi^2(1) = 2.35, p = .12$), and a significant Diagnosis x Type interaction ($\chi^2(2) = 230, p < .001$). Next, we conducted pairwise comparisons on Type of production within each level of Diagnosis. For recordings from the ELA+ group, accuracy was higher for vocal than for canonical babbling stimuli ($\beta = .842$, SE = .087, $p < .0001$), whereas for the recordings from the two other groups, vocalic stimuli were associated with lower accuracy compared to canonical babbling stimuli (ELA-: $\beta = -.789$, SE = 0.123, $p < .001$; LLA: $\beta = -.824$, SE = .098, $p < .001$).

Recall that stimuli included 41 % for which the correct response was 'autistic' and 59 % (ELA- and LLA children's recordings) for which the correct response was 'non-autistic'. Accordingly, the chance level for correctly detecting the former as autistic is 0.41, while it is 0.59 for correctly classifying the latter as non-autistic. Fitted accuracy probabilities, displayed along with 95 % confidence intervals in Fig. 1, show that vocalic recordings from ELA+ children are classified at chance level, and that canonical babbling productions from ELA+ children are more frequently misclassified as originating from non-autistic children that would be expected by

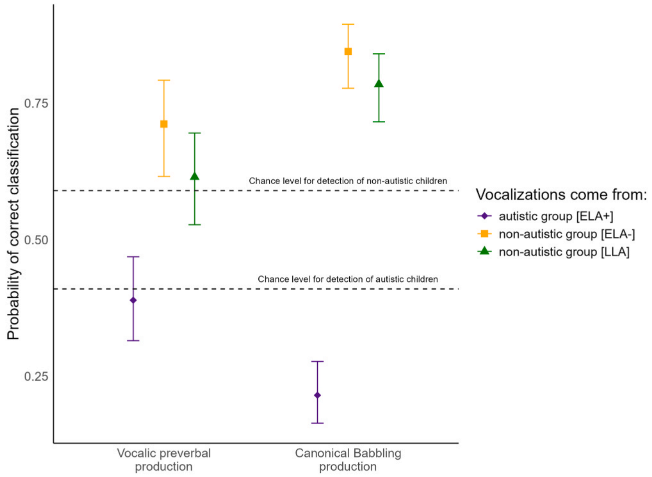


Fig. 1. Interaction between production type and diagnosis at 9 months and at-chance levels.

chance. By contrast, the recordings of ELA- children are correctly classified above chance for both types of production. Finally, correct classification of recordings of LLA children is at chance for vocalic productions, but above for canonical babbling.

6.2. 18-month sample

Stepwise comparison of mixed-effect logistic regressions revealed an effect of Diagnosis ($\chi^2(2) = 37, p < .001$), no effect of Type of production ($\chi^2(1) = .03, p = .85$) and a significant Diagnosis × Type interaction ($\chi^2(2) = 696, p < .001$). Planned pairwise comparisons on Type of production within each level of Diagnosis showed that within the ELA+ group, vocalic production stimuli were recognized with a better accuracy than canonical babbling stimuli ($\beta = -1.57$, SE = .086, $p < .0001$) whereas within non-autistic groups, canonical babbling showed a significantly higher correct response compared to vocalic production (ELA-: $\beta = 1.68$, SE = .12, $p < 0.0001$ and LLA: $\beta = 1.09$, SE = 1.07, $p < 0.0001$).

Stimuli included 44 % for which the correct response was 'autistic' and 56 % (ELA- and LLA children's recordings) for which the correct response was 'non-autistic'. Accordingly, the chance level for correctly detecting the former as autistic is 0.44, while it is 0.56 for correctly classifying the latter as non-autistic. Fitted accuracy probabilities, displayed along with 95 % confidence intervals in Fig. 2, show that vocalic productions by ELA+ children are classified as autistic above chance, but that canonical babbling by ELA+ are consistently classified as non-autistic. Canonical babbling productions by both ELA- and LLA children are correctly classified as non-autistic above chance. Finally, accurate classification for vocalic productions is at chance for recordings by ELA- children, but above chance for recordings by LLA children.

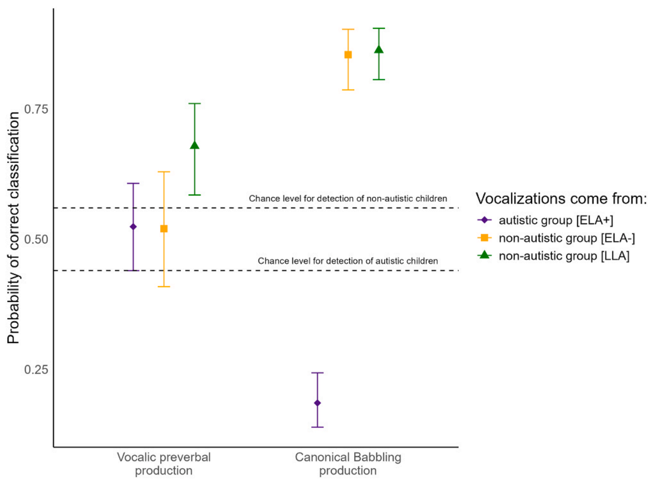


Fig. 2. Interaction between production type and diagnosis at 18 months and at-chance levels.

6.3. Accuracy by age and by diagnosis

Stepwise comparison of mixed-effect logistic regressions revealed that Diagnosis ($\chi^2(2) = 47, p < .001$), Age ($\chi^2(1) = 9.5, p = .002$), and the Diagnosis × Age interaction ($\chi^2(2) = 52, p < .001$) all improved model fit. Post-hoc pairwise comparisons on the best-fitting model of Age within each Diagnosis level revealed no significant accuracy difference for recordings by ELA+ infants ($\beta = -0.05$, SE = .06, $p = .95$). By contrast, accuracy was significantly higher for recordings at 9 than 18 months for ELA- group ($\beta = 0.37$, SE = 0.1, $p = .002$) and higher for recordings at 18 than 9 months for LLA ($\beta = 0.49$, SE = 0.07, $p < .001$) children. Stimuli included 43 % for which the correct response was 'autistic' and 57 % (ELA- and LLA children's recordings), for which the correct response was 'non-autistic'. Accordingly, the chance level for correctly detecting the former as autistic is 0.43, while it is 0.57 for correctly classifying the latter as non-autistic. Fitted accuracy probabilities, displayed along with 95 % confidence intervals in Fig. 3, show that while recordings by LLA and ELA- children are overall correctly classified above chance, accuracy for recordings by ELA+ children is below chance for both age groups.

7. Discussion

Professionals with expertise in autism often report being able to quickly identify autistic traits, especially distinctive vocal characteristics, in professional and personal contexts. The present study sought to experimentally investigate whether frequent exposure to autistic patients enables autism professionals to accurately classify brief vocalizations as produced by an autistic vs. a non-autistic child. Taken together, our results suggest overall modest poor sensitivity in discriminating the vocalizations of autistic children from those of non-autistic peers. These temper the autism professionals' impression to be able to recognize an autistic individual at first sound.

One interpretation of our study could simply be that discrimination decisions based on short audio excerpt are less reliable than judgments based on longer stimuli, coupled with the opportunity to observe multiple different behaviors or to confirm one's judgment through multiple occurrences of the same behavior via a multimodal medium, leads to a more accurate identification of autistic individuals (de Marchena et al., 2023; Thomas et al., 2024; Wieckowski et al., 2021). A central result of our study is that autism detection accuracy was influenced by the type of vocal production—specifically, vocalic production versus canonical babbling production. This difference is most likely explained by the presence of a syllabic structure in canonical babbling, which may provide richer linguistic cues. However, it is also important to consider that the stimuli in our study were matched to the natural duration of preverbal vocalizations. As a result, the durations of vocalic and canonical babbling stimuli differed slightly, which may have contributed to the observed variation in participant responses. This distinction in vocal types also reflects typical developmental trajectories. Vocalic productions, composed exclusively of vowel-like sounds, emerge early in development, within the first few months of life. In contrast, canonical babbling, which involves consonant-vowel combinations and displays syllabic structure, typically begins around six months in typically developing infants. Notably, these two types of productions coexist for a period of time and occur at varying frequencies throughout early linguistic development, persisting until the emergence of spoken language. However, only canonical babbling is considered as a critical precursor of speech. Accordingly, canonical babbling is less present in autistic children with severe language delays or minimally verbal profiles (McDaniel et al., 2018; Yankowitz et al., 2019). Now, for canonical babbling productions, respondents' accuracy was clearly below chance for autistic children and above chance for non-autistic ones, regardless of the children's age. The pattern was less clear for vocalic productions by 9-month-olds, but accuracy tended to be above chance for recordings of non-autistic children, and at-chance for those of autistic children. For 18-month-old trials, respondents' accuracy for vocalic productions was clearly above chance for autistic children and the subgroup of LLA children and at-chance for ELA- children. Overall, these observations indicate better recognition of vocalic production than canonical babbling for stimuli from children who received a diagnosis of autism, whereas the opposite is true for stimuli from children who did not receive a diagnosis of autism. Given that the

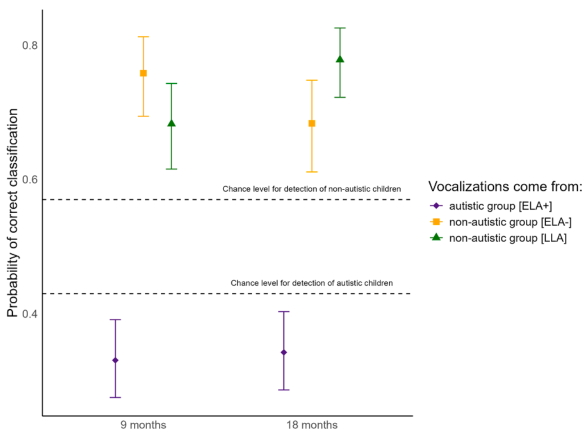


Fig. 3. Interaction between age and diagnosis and at-chance levels.

decision task was binary—autistic and non-autistic being the only choices— one interpretation of these results could be that professionals with expertise in autism may naturally associate vocalic productions with autistic children and canonical babbling with non-autistic ones.

If autism professionals' impression of recognize autism at first sound were based on traits specific to autism, expertise in autism should lead to high accuracy in auditory first-impression tasks. This aligns with the idea that specialized knowledge and experience might uniquely equip autism professionals to detect subtle and autism-specific features from brief behavioral samples. Our findings nuance this assumption and suggest that first impressions of prototypical presentations of autism, at least when it comes to infants or toddlers, do not seem to be based on autism specific characteristics. It makes sense to speculate that vocalic productions and canonical babbling evoke distinct first impressions based on the maturity of linguistic production. Vocalic productions may generate an impression of lower linguistic maturity compared to canonical babbling, which may be perceived as more advanced developmentally. In our experiment, neither the precise ages of the recorded children nor the types of production were disclosed to participating professionals. Accordingly, autism professionals consistently demonstrated a tendency to incorrectly classify canonical babbling production by autistic children as originating from non-autistic groups and experienced difficulties in correctly categorizing autistic canonical babbling production. An alternative interpretation of our findings is that clinicians' judgments were influenced not only by the acoustic properties of the stimuli, but also by the relative maturity of vocalizations within each block. When brief vocalic productions appeared among predominantly canonical babbling samples (as in the 18-month block), they may have been perceived as atypically delayed or underdeveloped, leading to an increased 'autistic' classification. Such a contrast-driven effect would still be consistent with first-impression judgments of preverbal vocal behavior being shaped by contextual expectations about developmental stage.

Why would autism professionals exhibit such a recognition bias? Most diagnostic first impressions occur within professional contexts, where autism professionals are already exposed to populations with specific traits seeking evaluations at autism specialist centers. These frequently encounter a mismatch between an autistic individual's chronological age and the type of linguistic production they exhibit, such as autistic two or three-year-olds who display only preverbal vocalic productions. This setting may inherently prompt autism professionals to associate less mature vocal behaviors with autism. The same kind of selection bias may, in fact, be present in several previous studies on diagnostic first impressions, which take place in diagnostic consultation settings for autism. Autism professionals who take part in such studies of diagnostic first impressions are typically the same individuals who are involved in the final diagnostic evaluations (de Marchena et al., 2023; Thomas et al., 2024; Wieckowski et al., 2021).

Therefore, the categorization decision made by our participating professionals may be partly independent of knowledge of what is specific to autism but rather influenced by their professional context and sensitivity to the clinical profiles they encounter.

Our study thus highlights the importance of considering how exposure to specific populations and professional settings may shape autism professionals' expectations and decision-making processes. There is rapidly growing research on salient frank features of autism, which may enable rapid diagnostic impressions later confirmed by more extensive assessment. Our results show that, for some of these features, autism professionals may in fact be sensitive to a trait associated with the autistic diagnosis (language delay in our case) rather than with the autism phenotype per se (a putatively specific way to produce prelinguistic sounds). Future research should further explore how first-impression judgments are shaped by developmental atypicalities and delays that are a consequence of autism, rather than aligning with traits uniquely or prototypically associated with autism. Better delineating the nature of frank autism features could also explain why studies like de Marchena and colleagues, Wieckowski and colleagues or Thomas and colleagues (de Marchena et al., 2023; Thomas et al., 2024; Wieckowski et al., 2021) report high specificity but only moderate sensitivity. That is, these studies suggested that initial clinical impressions are reliable for confirming that a child is unlikely to have autism (specificity), but less reliable for confidently identifying all children who do (sensitivity). Moderate sensitivity may be explained by autism professionals' tendency to generalize their own clinical experiences to prototypical representations of autism.

Obviously, no diagnostic procedure should only rely on first impressions, and our results showed a low accuracy to detect stimuli from autistic individuals. However, autism professionals' sensitivity to language maturity is noteworthy. Even though language delay is not a marker specific to autism, it is likely that, overall, professionals in autism demonstrate a genuine sensitivity to the impression of linguistic maturity conveyed by a preverbal production. In future, it would be interesting to extend the experimental paradigm to individuals who do not have professional experience with autism, or for that matter with developmental disabilities. Independently of the condition associated with language delay, demonstrating, even modest, sensitivity to the linguistic maturity of a young child could help restore value to the early impressions reported by parents and frontline professionals (pediatricians, childcare workers, preschool teachers) who often the first to raise developmental concerns. Addressing these concerns is frequently dismissed or delayed under the premise that time should be given for development to occur naturally. If replicated with a broader sample of naïve respondents, such findings could support a more nuanced understanding of how early impressions, while devoid of clear diagnostic value, may still reflect subtle developmental signals that warrant attention.

8. Limitations

Due to a small sample size, the influence of respondent characteristics, such as years of professional experience, having a child under 3 years of age, frequent exposition to a specific age range or gender, could not be examined. While the sample was designed to be representative, certain professions, particularly speech pathologists, were overrepresented. Another avenue for future research would be to recruit a more homogeneous sample of children's recordings in terms of autistic symptomatology or to preselect children whose vocalizations are considered clear manifestations of autism. While our goal was to preserve ecological validity by including a heterogeneous sample that mirrors the variability encountered in real-life diagnostic settings, we acknowledge that this heterogeneity limits the ability to draw conclusions about specific language profiles. Dividing our sample based on future language outcomes would not only have exceeded the scope of our study but would also have considerably reduced statistical power. Nonetheless, targeting more homogeneous subgroups based on early vocal predictors of language trajectories certainly is a promising direction for future studies. Furthermore, the stimuli did not allow for analyses of gender effects.

Regarding stimulus presentation, we chose to present all 9-month recordings before the 18-month recordings (grouped into two age-specific blocks with randomized stimuli order within each) in order to minimize maturational-contrast effects and avoid cross-age contamination of first impressions. At the time of study design, we were more concerned about the potential influence of more mature vocal productions on the perception of less mature ones than the reverse. Nonetheless, we acknowledge that future studies may choose to counterbalance stimulus order more fully. This design choice also means that labels such as ‘youngest’ and ‘less young’ may have implicitly revealed age-related information, despite our intention to keep age background minimal. While our goal was to preserve ecological validity by including a heterogeneous sample that mirrors the variability encountered in real-life diagnostic settings, we acknowledge that this heterogeneity limits the ability to draw conclusions about specific language profiles. Dividing our sample based on future language outcomes would not only have exceeded the scope of our study (focused on preverbal features) but would also have considerably reduced statistical power. Nonetheless, targeting more homogeneous subgroups based on early vocal biomarkers predictive of later language trajectories represents a promising direction for future studies

9. Conclusions

The results of the current study indicate that the task was challenging for autism professionals, but their performance was influenced by the type of vocalizations, the child's age, and the diagnosis to which the children belonged. Canonical babbling productions were more often attributed to non-autistic children than to autistic children, regardless of the recorded child’s actual diagnostic status. Autism professionals seemed to rely more significantly on developmental cues rather than autism-specific traits when forming their judgments. This response pattern highlights the insufficient reliability of autism professionals' first impressions for accurately identifying autism in all cases. Interestingly, the findings demonstrate that autism professionals may exhibit sensitivity to linguistic maturity, even in preverbal productions. However, this ability does not translate to high diagnostic accuracy for autism without additional contextual information. Future research should examine whether similar recognition biases are present among lay individuals, as well as the role of developmental factors such as mismatch between the age and the linguistic variability in shaping first impressions, and the broader implications of these biases for diagnostic decision-making in clinical settings.

CRediT authorship contribution statement

Marielle Weyland: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Pauline Maes:** Writing – review & editing, Software, Methodology, Formal analysis, Data curation. **Mikhail Kissine:** Writing – review & editing, Visualization, Supervision, Resources, Funding acquisition, Formal analysis.

Ethics approval and consent to participate

The experimental protocol was approved the Ethics Committee of the Faculty of Psychology, Université Libre de Bruxelles, Brussels, Belgium. (Project ID: [596/2022] accepted the 2023-02-01). Informed consent was obtained from all respondents through the task interface. Additionally, informed consent was obtained from the legal guardians of all individuals from whom the (non-identifiable) stimulus materials originate.

Funding

At the time of the study, MW was supported by a Marguerite-Marie Delacroix Foundation Doctoral Grant, and PM was supported through an Excellence of Science Grant. Currently, MW is supported through an Excellence of Science grant, and PM by a Marie Skłodowska-Curie Actions Postdoctoral Grant. MK and MW research is also supported by the Périer-D’Ieteren Foundation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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