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Exploring Unexpected Bilingualism in Autism: Enhanced Sensitivity to Non-Adjacent Dependencies

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ABSTRACT

Statistical learning refers to the ability to detect regularities from sensory input, including speech. Statistical learning plays a key role in language acquisition, particularly for complex structures, such as nonadjacent dependencies, that are ubiquitous in natural language syntax. This study investigates nonadjacent dependency learning in autistic children who acquire English through screen exposure, a phenomenon known as Unexpected Bilingualism (UB). Unlike their non-autistic peers, autistic-UB children acquire foreign languages with little interactional support. We hypothesize that this intensive experience with linguistic input should be associated in autistic-UB children with enhanced sensitivity to nonadjacent dependencies. An artificial language learning experiment confirmed that both non-autistic and autistic children with close to typical language ranges can learn non-adjacent dependencies from passive exposure to unfamiliar linguistic input. Crucially, autistic-UB exhibited significantly faster learning as compared to their autistic and non-autistic peers. This study documents that UB in autism is associated with distinct cognitive abilities.

1 | Introduction

Statistical learning refers to the acquisition of statistical regularities by mere exposure and without intention to learn (Perruchet and Pacton 2006). This mechanism likely plays a central role in a range of linguistic properties, such as detecting word boundaries, phonetic categories, word order, and syntactic structure (see Romberg and Saffran 2010). The most well-known example in the language domain is infants' sensitivity to transitional probabilities between adjacent syllables, which allows them to identify word boundaries in a continuous stream of pseudo-words (Saffran et al. 1996).

However, detecting the regularities between adjacent sequence elements is clearly insufficient to acquire more complex language properties, such as disjoint AXB contingencies where the element in position B can only be predicted based on the element in position A, but is independent of the one occurring in the intervening position X. These nonadjacent AXB dependencies are ubiquitous in natural language, where they underpin long-distance agreement For instance, third person marking in *She often runs in the park* crosses the intervening material between the syntactic subject and the verb. However, acquiring nonadjacent dependencies is more complex because the relationship between A and B can only be learned by ignoring X, which means neglecting local transition probabilities in favor of distant relationships (Friederici et al. 2011; Newport and Aslin 2004). Whereas sensitivity to adjacent dependencies emerges very early during development (Saffran et al. 1996) and is even present in neonates (Teinonen et al. 2009), the ability to track nonadjacent

Summary

- Autistic children with Unexpected Bilingualism (UB) learn foreign language from screen exposure.
- Autistic-UB children show enhanced sensitivity to nonadjacent dependencies in an artificial language task.
- Autistic-UB children might have a distinct cognitive profile that could bootstrap alternative pathways for language development.

dependencies emerges later, typically after the first year of life (Gómez and Maye 2005).

As the extraction of nonadjacent dependencies is a fundamental property of mature syntax, an important research question is how sensitivity to long-distance relations and the development of linguistic abilities are related. Several studies have found that children's learning of nonadjacent dependencies is predictive of later linguistic abilities, including syntax and morphology (Kidd 2012; Erickson and Thiessen 2015; Frost et al. 2020). Individual differences in nonadjacent dependency learning may thus contribute to variability in language acquisition, not only in typically developing populations, but also in conditions characterized by frequent language acquisition delays and disabilities, such as in developmental language delays, hearing impairments, and autism (Arciuli and Conway 2018).

Research on statistical learning is particularly relevant to the study of language in autism. Autism is characterized by two main nosological signs: (1) significant atypicalities in verbal and non-verbal communication and (2) restricted or stereotypical behaviors and interests (American Psychiatric Association 2013). Delays in the onset of speech and long-lasting language disabilities also constitute a very frequent characteristic of autism and are often the primary concern of caregivers (Wetherby et al. 2004). In around 60% of autistic children, expressive language emerges with a significant delay, and up to 30% of autistic individuals never reach functional verbal communication (Wodka et al. 2013). The etiology of language difficulties in autism has mainly been attributed to socio-communicative atypicalities, such as joint attention skills, which are central to the autism diagnosis and likely have a cascading effect on language (Su et al. 2021). Several longitudinal studies show that difficulties in processing and establishing joint attention indeed raise the risk for an autistic child to remain non- or minimally verbal (Anderson et al. 2009; Luyster et al. 2008; Paul et al. 2008). At the same time, joint attention does not systematically predict language outcomes in autism, with some autistic children reaching typical language levels despite low rates of joint attention behaviors (Ellis Weismer and Kover 2015; Kissine et al. 2023).

The phenomenon of Unexpected Bilingualism (UB) offers another kind of evidence that language acquisition in some autistic children can occur with little reliance on socio-communicative interaction. A small but rapidly growing number of case studies report that some autistic children acquire languages that are not used around them solely through passive exposure to screens—a phenomenon known as UB (Abd El-Raziq et al. 2023; Dumont et al. 2024; Francis et al. 2024; Kissine et al. 2019; Vulchanova et al. 2012; Zhukova et al. 2021). These autistic children thus, by mere screen exposure, reach advanced levels of lexical, phonological and syntactical skills in a language that no one around them uses and, in several cases, even understands. This type of language acquisition is unexpected because active social interaction with communicative partners is considered fundamental for the typical acquisition of linguistic structures (Kuhl et al. 2003). While this unique form of language acquisition raises important questions about the underlying cognitive mechanisms, with the exception of Dumont et al. (2024), the current literature on UB consists only of case studies.

The study of UB is still in its early stages, and it is unclear whether such a non-socially mediated pathway to language results from a particular cognitive predisposition, akin, for instance, to enhanced local processing (Germain et al. 2019; Happé and Frith 2006; Mottron et al. 2006) or intense interest for highly structured abstract objects, akin to interest in calendar calculation or print (Klin et al. 2007; Mottron et al. 2021). Either way, it is likely that the UB children, who reach productive mastery complex morpho-syntactic rules only from passive exposure to linguistic stimuli, unsupported by social cues or action feedback, are exceptionally sensitive to statistical regularities in the language input, including nonadjacent dependencies.

The existing experimental literature on SL mechanisms in autism is relatively scarce, and mostly focused on adjacent dependency learning. Two meta-analyses suggest that SL of adjacent dependency is preserved in autism, with overall no difference at the group level between autistic and non-autistic individuals (Foti et al. 2015; Obeid et al. 2016). Most of the studies included in these meta-analyses have rather modest sample sizes, with 8–26 autistic participants. More importantly, perhaps, these studies included primarily verbal autistic teenagers and adults, usually with language skills within the typical range. But for these verbal individuals, adjacent dependency learning may not be sufficiently challenging to yield any significant variation. By contrast, testing nonadjacent dependencies, which are both more complex and essential to morpho-syntax, may unveil more fine-grained subgroups within autistic individuals. Finally, previous studies relied on offline methods, with statistical learning being assessed after exposure by presenting participants with a familiarity forced choice between two strings. Such offline paradigms do not provide any information on the participants' learning curve. Moreover, offline tasks are not immune from contamination from other cognitive processes such as encoding, verbal memory and decision-making (Siegelman et al. 2017), and are also vulnerable to fatigue and engagement with the task (Arnon 2020).

Because natural languages are rife with nonadjacent dependencies, there is no reason to believe that autistic individuals with language levels within the typical range should significantly differ in the ability to detect and learn such dependencies from their typically developing peers. By contrast, we predict that autistic individuals with unexpected bilingualism (Au-UB henceforth), who acquired structural language skills from passive exposure to screen language input, should be more sensitive to linguistic nonadjacent dependencies than their autistic and non-autistic peers. To test this hypothesis, we adapted the online paradigm developed by Lammertinck et al. (2019). In this task, children are exposed to an artificial grammar composed of 3-word sentences and asked to detect target elements occurring on the third location. In the training blocks, and unknown to the participants, some trials have the underlying AXB structures, such that the target in the third (B) position can be predicted based on the element in the first (A) position. In a disruption block, this underlying rule is cancelled, such that targets are replaced by fillers elements in position B. Throughout the training blocks, reaction times provide an online measure of the nonadjacent dependencies. If participants learn the nonadjacent dependencies, they should exhibit a decrease in reaction time in the training blocks as they can anticipate the occurrence of element B based on element A. On the contrary, in the disruption block, element B cannot be anticipated anymore, and reaction time should therefore increase.

First, we hypothesize that children in all groups will be able to detect and learn nonadjacent dependencies. Accordingly, we expect a *disruption effect* in all groups, that is, an increase in reaction time in the disruption block, where previously learned nonadjacent dependencies are no longer presented. Second, we hypothesize that autistic children who acquire foreign language (English) through screens exposure (Au-UB) will exhibit enhanced sensitivity to nonadjacent dependencies. Accordingly, we expect a faster *learning rate* for Au-UB than for autistic (Au) and non-autistic (Non-Au) children, reflected by a steeper reaction time slope in the Training Blocks.

2 | Methods

2.1 | Participants

A total of 50 autistic and 50 non-autistic participants aged between 9 and 16 years old were initially recruited in the context of a larger study on narratives (Belenger et al. 2025). This age range accommodated task demands (understanding the instructions and maintaining attention) and ensured that UB-participants had already acquired English from exposure to screens. As this was the first study exploring UB in this context, we could not predict the prevalence of autistic-UB profiles a priori. Autistic participants were recruited through our lab database, specialized and ordinary schools, social media, and word of mouth. Non-autistic participants were recruited mainly through schools, word of mouth, and our lab database.

Inclusion criteria for our study were to be aged between 9 and 16 at time of recruitment, to have non-verbal IQ (non-verbal index at the Weschler) above 70, the use of French as primary language in the family and to be sufficiently fluent to perform a narrative task (see Authors, under review). Eight participants (5 autistic and 3 non-autistic) were included in the sample despite missing non-verbal index. As their Full-Scale IQ was above 70, we could reasonably expect that their non-verbal index would meet the inclusion criterion. All autistic participants received a clinical diagnosis of autism from multidisciplinary team (composed of medical doctors, speech therapists, psychologists and social workers) specialized in diagnosing autism and officially licensed to do so by the Belgian State. Autism was ruled out in the non-autistic group using the Social Communication Questionnaire (SCQ; Rutter et al. 2003), a screening questionnaire probing for autism symptoms across the lifespan.

Our final sample (see Table 1) consisted of 47 autistic (19 females; biological sex) and 47 (21 females) non-autistic children. Two of the initially recruited autistic children were excluded from the analysis because they did not complete the task entirely, and one due to below chance performance (<60% accuracy). The final non-autistic group comprised 47 children (21 females), because three participants of the 50 initially recruited non-autistic children were also excluded from the analysis; two because they did not complete the task until the end, and one because of SCQ scores above the 15 thresholds, which may indicate a potential deviation from typical development.

Parents completed a questionnaire on the language development of their child (age of first word and first sentences), language productions (language used by the child, echolalia), language input (languages used by caregivers, siblings, exposure at school) and media exposure (screen time, content). Autistic participants were considered for inclusion in the autistic-UB group if, in this questionnaire, parents reported the use of English in French-speaking households where English was not in daily use or taught at school. To further ensure that the knowledge of English was genuinely productive and not limited to echolalic productions of media input, we administered a formal language assessment in English, using the CELF-5 (Wiig et al. 2013) (see Supp. Mat S1 for individual language performance).

The French version of Communication Evaluation of Language Fundamentals-5 (CELF-F; Wiig et al. 2019) was used to assess core language abilities in French. French language assessment was always administered by second author and English language assessment for the autistic-UB was always administered by first author to avoid testing bias in the UB group. Weschler Intelligence Scale for Children-5th Edition (Weschler 2014) was used to obtain the non-verbal IQ index. Participants' raw scores were converted into standardized scores based on their age.

Parents also responded to questions about their socio-economic background, adapted from the revised Family Affluence Scale (Torsheim et al. 2016) which serves as a proxy for the participant's socioeconomic background. It includes an education score on a 0 to 6 point scale, ranging from 0 (indicating no primary school achievement) to 6 (representing a doctoral degree), and an economic status on a 0 to 13 point scale, where 0 corresponds to very low economic status, and 13 reflects very high economic status. The addition of these two scores is used as an index of families' socio-economic status (SES).

Ethical approval was received for the study from the Erasme-ULB ethics committee in accordance with the Declaration of Helsinki. Participants' parents signed a written consent for their children to be enrolled in this study after being informed of their rights and all aspects of the experimental design. All participants gave written consent to participate in the study, after being informed by the experimenter of the procedure and the goals of the study.

2.2 | Nonadjacent Dependency Task

The task was presented on a Microsoft Surface 4 Tablet using EPrime 3.0 software. Reaction times were recorded with a RB-540 response pad.

TABLE 1 | Participant information.

	AUTISTIC-UB		AU		N-AU		One-way ANOVAs		
	N	**Mean (SD) [Range]**	***N***	**Mean (SD) [Range]**	***N***	**Mean (SD) [Range]**	**AU-UB vs. AU**	**AU-UB vs. N-AU**	**AU vs. N-AU**
Age (months)	11	149.45 (23.96) [119–186]	37	152.62 (27.74) [109–203]	47	147.10 (27.26) [110–200]	ns	ns	ns
SES (1–20)	8	10.5 (3.62) [6–17]	32	9.93 (2.75) [5–17]	33	13.18 (3.15) [7–18]	ns	ns	0.006
SCQ	8	21.25 (8.44) [8–33]	32	22.18 (5.73) [11–33]	39	3.43 (2.99) [0–10]	ns	<0.001	<0.001
WISC-V non-verbal Index score	11	93.81 (14.75) [74–124]	32	98.43 (17.12) [70–134]	44	110.10 (12.67) [78–131]	ns	0.004	0.002
WISC-V full scale IQ score	11	86.54 (15.65) [66–121]	35	96.05 (18.83) [57–129]	45	110.68 (11.54) [82–129]	ns	<0.001	0.001
French core language score (CELF-V)	10	74 (19.49) [46–114]	36	81 (18.52) [52–125]	45	101 (11.97) [70–127]	ns	<0.001	<0.001
English core language score (CELF-V)[a]	9	66.78 (18.90) [45–100]							

Note: Data are shown as *M* (*SD*), range.
Abbreviations: UB = unexpected bilingualism, SES = socio-economic status, SCQ = social communication questionnaire.
[a]Two AUTISTIC-UB children did not wish to complete the CELF-V in English.

TABLE 2 | Example of artificial language for Versions 1 and 2. X represents intervening CVCV X-element.

Trials type	Version 1	Version 2
Target	Fal X nuf	Zir X bep
Non-target	Zir X Bep	Fal X nuf
Filler	Fip X dol Poj X nit	Fip X dol Poj X nit

We used an artificial grammar task in which participants' sensitivity to nonadjacent dependencies learning has been well attested in previous studies (Lammertink et al. 2020; Marimon et al. 2021; van Witteloostuijn et al. 2019; Witteloostuijn et al. 2021).

Participants engaged in a game-based task in which they had to help a monkey character to gather bananas. To do so, they had to listen carefully to utterances composed of three words. They were told to press the green button as quickly as possible when one of the words was a specific target word (e.g., *nuf*) and to press a red button otherwise. Each correct button press earned the child a banana, contributing to the monkey's collection. There was a 1-s interval between each element of the utterance. Children had to press on one of the buttons within 750 ms after the end of each utterance, if they did not do so, a null response was recorded, and the next trial (utterance) began. In each utterance, the first and third element were a one-syllable CVC pseudoword, and the second element was a disyllabic CVCV pseudoword. There were three types of trials. Two types of trials comprised a nonadjacent dependency between the first and the third element: *zir* X *bep* or *fal* X *nuf* with the X element indicating the bisyllabic pseudoword, extracted from a list of 24 different elements. As seen in Table 2, in one version (Version 1) of the experiment the target word was *nuf*, in the other version (Version 2) the target was *bep*. Participants with an even ID number were assigned to the *bep* version of the experiment, the odd ID to the *nuf* version. Nonadjacent dependency types of trials were further divided into two types: target requiring a green press and non-target requiring a red press, according to which element ended the sentence. The third type of trials were filler trials that did not contain any nonadjacent dependency (no *bep* or *nuf*), always requiring a red press.

The original task (Lammertink et al. 2019) has been adapted for the artificial language to respect the phonotactic constraints of French. All the syllables shared the same frequency (0.01–0.03) according to the Lexique3 database (New et al. 2001). The French-POND (the French version of the CLEARPOND online database) was used to control for the pseudowords phonological neighbors (Marian et al. 2012). The words from the artificial language were synthetized in the online IPA reader (http://ipa-reader.xyz/) with the "Celine" voice in French to avoid uncontrolled variation in intensity, duration, or pitch. The experimental instructions were recorded by a female voice who was unaware of the study goals and methods.

The task was composed of a training phase with six blocks, one disruption block, and one recovery block. Each block contained 30 trials separated by short breaks in which participants were told how many bananas they gathered (correct answers) and were asked whether they were ready to continue. An overview of the paradigm and the expected reaction time is provided Figure 1. In the training phase, the third element of each trial, target or non-target, was determined by the first element. The trials of the disruption block contained the same number of target and non-target elements (in third position), but they were not preceded, as in the training phase, by the predictive element in the first position, so that their onset could not be anticipated. If participants were sensitive to the nonadjacent dependencies

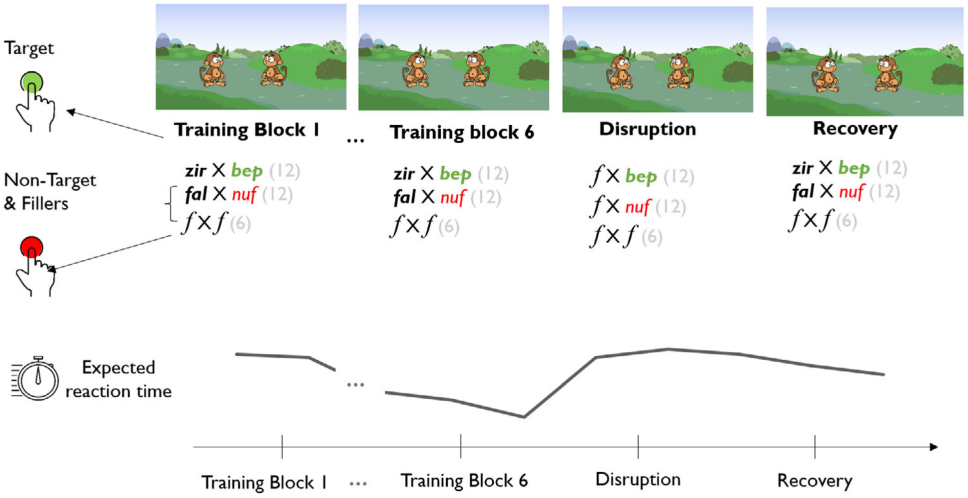

FIGURE 1 | Visual representation of the nonadjacent dependency task with the expected reaction time across blocks. Number of trials per type and block are given in brackets. The target word, which requires a green button press, is highlighted in green; words highlighted in red represent the non-target and filler (f) CVC words, which require a red button press. X represents the intervening CVCV X-elements.

they should display a *learning effect*, that is, a gradual decrease in reaction time, in the training phase, as well as a *disruption effect*, which is a significant increase in reaction time between the last training block and the disruption block. Finally, in the recovery block, the AXB structure of trials was identical to that of the training block. Each training block consisted of 12 target trials that required a green press (e.g., zir X bep) and 12 non-target trials that requiring a red press (e.g., fal X nuf). Each target and non-target trial thus had an intervening CVCV X-element. These X-elements were drawn from a pool of 24 different CVCV sequences, so that within a block each X-element appeared only once, either in a target or a non-target trial. There were six training blocks in total, so that each X-element appeared in a target trial in three blocks and in a non-target trial in three other blocks. Each training block also contained six filler trials, which also required a red press and had the structure *f* X *f*. The *f* elements of these filler trials were drawn from a pool of 24 CVC sequences and the intervening X elements from the same pool of 24 CVCV sequences as for the intervening X-elements of target and non-target elements. Across all blocks, each *f* X *f* combination appeared only once. In the disruption block the first element of the target and non-target trials was replaced by a *f* element (e.g., *f* X bep instead of zir X bep and *f* X nuf instead of fal X nuf), with no *f* item being repeated twice. To avoid accidental adjacent associations between the intervening X-elements and the last element of the modified target and non-target trials, in the disruption block, 12 intervening X-elements were used twice, once in a disrupted target trial (e.g., *f* X bep) and once in a disrupted non-target trial (e.g. *f* X nuf), see Supp Mat (S2) for the X- and *f*- elements.

2.3 | Data Preprocessing

We recorded accuracy and reaction time (in milliseconds) on each trial throughout the experiment. Reaction times were measured from the onset of third word, they could thus be negative if the child anticipated the third element before its occurrence based on the first element. We did try to follow the normalization procedure of Lammertink et al. (2020). We began by sorting all K raw RT observations in ascending order and then assigned to each ranked observation a ranking number r. Each ranked observation was then normalized by replacing it with $(r\text{-}0.5)/K$. This normalization slightly improved the normality of the reaction time data compared to raw reaction times, and the observed effects remained consistent even though statistical models failed to converge. Therefore, we decided to perform our analysis on the raw data.

As in Lammertinck et al. (2019), participants with an overall accuracy below 60% were removed from the analyses (one participant in the Autistic-UB group). Incorrect responses were removed from the analyses.

2.4 | Data Analysis

All analyses were implemented in R (R Core Team and contributor worldwide), using the *psycho*, *lme4*, and *emmeans* packages. We analyzed the raw reaction time using linear mixed-effects model and used a stepwise method to compare our models. The null model included age as fixed effect (to account for the rather wide age range in our sample), random per participant intercepts and random Trial by participant slopes. We gradually augmented the null model by incorporating different independent variables. For the learning rate analysis, we added Trial and Group and their interaction as predictors. For the disruption effect analysis, we added Block, Group, and their interaction. The best fitting model was chosen based on log-likelihood χ^2 comparisons, as well as inspection of AIC and BIC values. Post hoc comparisons were carried out on the best fitting models using the *emmeans* package, with Tukey adjustment. One set of analyses targeted the *disruption effect* and another one the *learning rate*.

The *disruption effect* analysis assessed the learning of nonadjacent dependency rules by identifying the presence of a disruption peak, marked by a significant increase in reaction time between the last Training block and the Disruption block. For the disruption effect analysis, however, we included all trial types (Target,

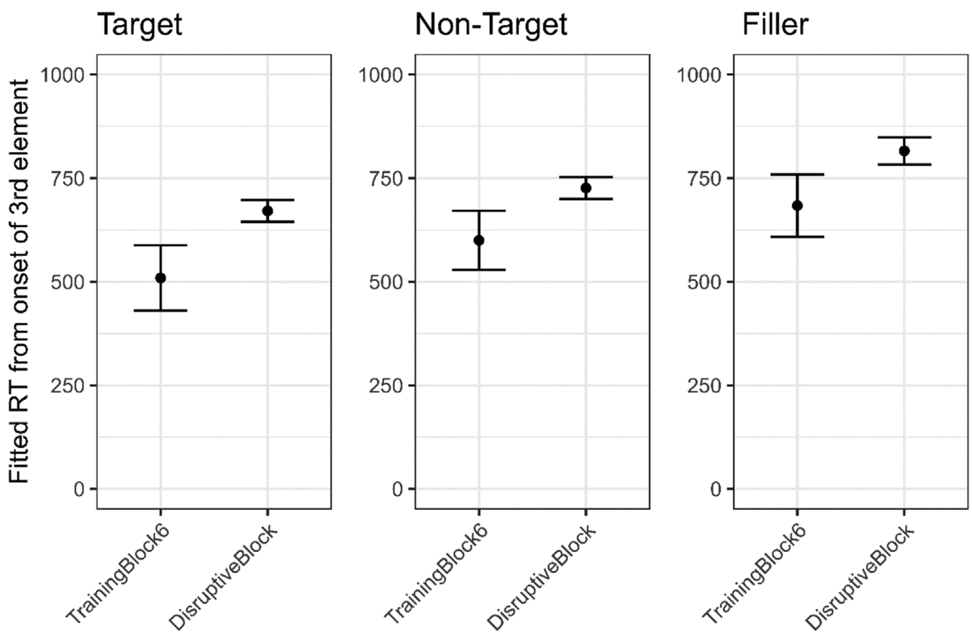

FIGURE 2 | Fitted reaction times with confidence intervals during the last training block and the disruption block.

Non-Target, and Fillers). The disruption effect should manifest across all trials, as the absence of the learned regularity in the Disruption block may affect reaction times in general, not just in Target trials.

The *learning rate* analysis aimed to test whether autistic-UB individuals exhibited faster learning of nonadjacent dependencies during exposure. To do this, we examined the reaction time slope after collapsing all trials across the training blocks into a single continuous Trial variable. In this analysis, we focused exclusively on Target trials. The rationale for this choice was that only the Target trials directly reflected learning of the underlying dependency. By contrast, Non-Target and Filler trials required the same type of response (red press). Accordingly, any decrease in the reaction time slope in Non-Target could either be due to the absence of the target dependency or to the presence of the non-target. By contrast, learning non-target dependencies may increase reaction times in filler items.

3 | Results

3.1 | Disruption Peak

For all trial types, the inclusion of the Group variable or its interaction with the Block variable did not improve the model fit. The best fitting model included only the Block variable (Target: $\chi^2(1) = 19.09$, $p < 0.001$; Non-Target: $\chi^2(1) = 15.91$, $p < 0.001$; Fillers: $\chi^2(2) = 16.37$, $p < 0.001$); see Supp. Mat (S4) for model fit comparisons.

As can be seen from Figure 2, reaction times were faster in the last training block than in the disruption block for all trial types (Target: $\beta = -161.71$, SE $= 35.34$, $p < 0.001$; Non-Target: $\beta = -126.26$, SE $= 30.47$, $p < 0.001$, Filler: $\beta = -132.29$, SE $= 31.44$, $p < 0.001$). That is, for all children a disruption of the underlying nonadjacent dependency resulted in significantly slower reaction times.

3.2 | Learning Rate

The inclusion of the interaction between Trial and Group significantly improved the model fit (Target: $\chi^2(2) = 6.39$, $p = 0.04$) compared to the model with only the fixed effects (Trial and Group); see Supp. Mat. (S5) for model fit comparisons.

As can be seen in Figure 3, the fitted reaction time slope was negative for the Au-UB children (−5.79, 95% CI [−9.39; −2.191]), but flat for Au (−0.77, 95% CI: [−2.74; 1.18]) and Non-Au (−1.05, 95% CI [−2.78; 0.69]).

That is, only the Au-UB became faster to detect the presence of Target pseudo-words based on nonadjacent dependencies.

3.3 | A Posteriori Checks

We performed two a posteriori checks, fully reported in Supp. Mat (S7). First, to ensure that the group effects on reaction time slopes that emerged in our models were not better accounted by IQ or proficiency in French (first language), we replaced the Group factor by these variables in the best fitting models. Children with higher IQ or CELF (French) scores have faster reaction time at the task onset, but none of these variables predicted a negative reaction time slope. Second, to make sure that the effect on reaction times was due to *unexpected* bilingualism and not bilingualism *tout court*, based on parental questionnaires we reclassified all autistic children as bilingual or not, based on whether they were consistently exposed to a second language via live interaction (e.g., with a caregiver) before age three. Bilingualism in autistic groups did not have any effect on reaction times.

4 | Discussion

The present study investigated whether Unexpected Bilingual autistic children, who acquire a language through screen

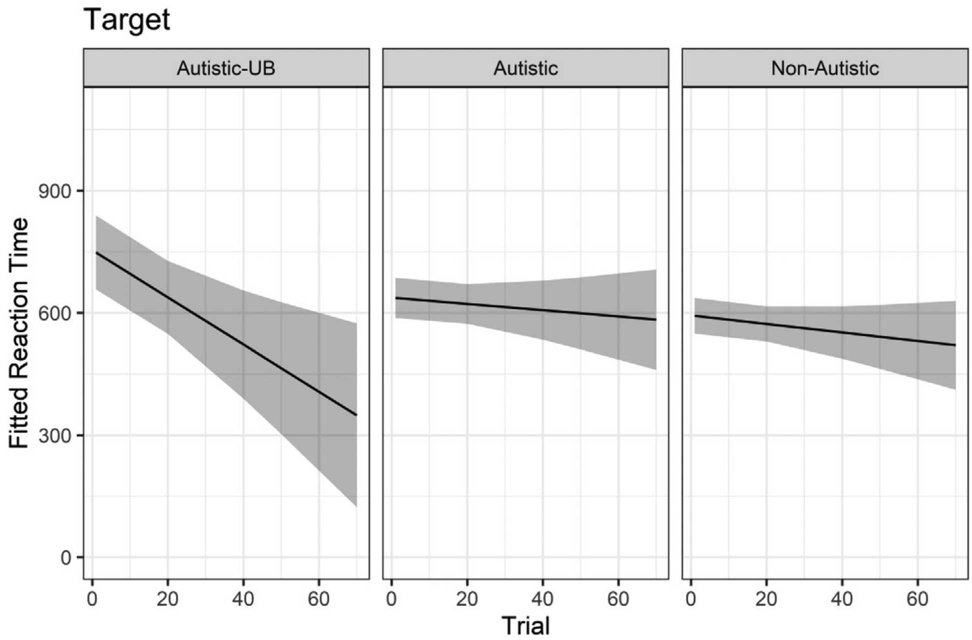

FIGURE 3 | Fitted reaction times (shaded bands represent 95% confidence intervals) across all training trials, and by group to detect target stimuli.

exposure (Au-UB) exhibited heightened sensitivity to nonadjacent dependencies, as compared to their autistic (Au) and non-autistic peers (Non-Au). Nonadjacent dependency learning is crucial to acquire AXB structures, which is, in turn, fundamental for processing syntactic patterns between A and B despite the presence of unrelated intervening material. Given numerous reports of autistic-UB children who acquire advanced language skills without relying on direct social interaction or typical socio-communicative cues (Abd El-Raziq et al. 2023; Francis et al. 2024; Kissine et al. 2019; Vulchanova et al. 2012; Zhukova et al. 2021), it is crucial to understand which mechanisms can be associated with such non interactive language acquisition. In this study, we hypothesized that autistic-UB would demonstrate a heightened sensitivity to unfamiliar nonadjacent dependencies.

To assess sensitivity to nonadjacent dependencies, participants were exposed to structured AXB sequences in a child-friendly task. Learning was measured by tracking participants' ability to anticipate element B based on the preceding element A. The primary finding of our study was that all groups showed a *disruption peak*, which refers to a noticeable increase in reaction time when the expected B element was no longer preceded by the A element in the disruption block. This shows that all participants learned long distance AXB associations. As they were all fully verbal, it is not surprising that children in all groups would demonstrate the ability to detect nonadjacent dependencies, which are central to human morpho-syntax. In this respect, our results extend previous studies on statistical learning in autism (Foti et al. 2015; Obeid et al. 2016) and confirms that statistical learning skills of autistic individuals with (near) typical structural language are comparable to those of their typically developing peers. Interestingly, unlike in autism, there is evidence that statistical learning is impaired in Developmental Language Disorder (Haebig et al. 2017; Lammertink et al. 2020; Obeid et al. 2016), which suggests that language delays in these two conditions may have distinct underlying etiology.

However, the analysis of the learning rate revealed a notable group difference. Only children in the Au-UB exhibited a significant decrease in reaction time, while reaction time slopes remained flat throughout the training in Au and Non-Au. That is, responses in the Au-UB group were consistent with a significantly greater sensitivity to unfamiliar nonadjacent dependencies of an artificial language. To be sure, it is possible that children in the Au-UB group were generally faster at the task, independently of their sensitivity to non-adjacent dependencies. However, such an explanation, in general motor terms, is made unlikely by the absence of group difference in the reaction time intercepts in the training trials, as well as by the fact that in the disruption group children in the Au-UB group were as slow as those in the other ones. A more plausible interpretation is in autistic children with UB, that is, who had previous experience in learning foreign languages with no interactional support, the detection of the underlying structure of the artificial language was faster and, perhaps, more explicit. Children in all groups experienced a significant slowdown when the non-adjacent dependencies underlying training trials were disrupted, which demonstrates that these non-adjacent dependencies have been learned. The absence of negative reaction time slope observed in the Au and non-Au groups in the training trials suggests that these children learned the regularities at a lower level or may have needed more trials to consolidate the regularities and exhibit faster responses.

An additional explanation could be that children in Au-UB group were more engaged with and committed to the task. Such higher motivation would be consistent with a broader interest in language learning in and of itself. Indeed, many parents of Au-UB children in our sample reported that their child shows an interest in languages beyond English. This spontaneous curiosity and engagement with languages could have made them more inclined to quickly detect and internalize the nonadjacent dependencies presented in the task.

Our robustness checks ruled out that the steeper learning rates in the Au-NB group could be simply explained by the fact that they were bilingual. That said, we cannot fully exclude that bilingualism plays some role. Verhagen and Bree (2021), using the same paradigm as in the current study, found that bilingual preschoolers exhibited a stronger decrease in reaction time during the training phase compared to their monolingual peers, while both groups showed a disruption peak effect—a result that somewhat aligns with our findings. This bilingual advantage has been interpreted through the structural sensitivity hypothesis, which posits that bilinguals have a heightened sensitivity to the structural properties of language. In this framework, exposure to more than one language makes properties of the linguistic input more salient (Kuo and Anderson 2008). A limitation of our study is that we relied on parental reports to index bilingualism. Further research should include finer-grained information about language environment and multilingual proficiency.

The reaction time slopes analyses revealed an increased sensitivity to nonadjacent dependencies in Au-UB. The exact origin of this heightened sensitivity remains to be understood. The question of whether this increased sensitivity is the cause, or a result of Unexpected Bilingualism remains open. Not only does our paper confirm that Unexpected Bilingualism in autism may be more common than previously thought, but it also shows that Au-UBs have a specific cognitive profile. Interestingly, Dumont and colleagues (Dumont et al. 2024) recently reported that Au-UB children exhibit enhanced pitch discrimination for pure tones compared to both their autistic and non-autistic peers. These enhanced perceptual skills are consistent with higher sensitivity to language-like structural dependencies we report here. Salient acoustic cues may help segment the linguistic input, and even override statistical regularities (Johnson and Jusczyk 2001; Johnson and Seidl 2009; Thiessen and Saffran 2003). More broadly, Unexpected Bilingualism may bring new, crucial insights into language acquisition in autism, suggesting a qualitatively different acquisition pathway toward language in some autistic children. This pathway might compensate difficulties in detecting socio-communicative cues by relying more heavily on structural properties of the input, such as statistical and acoustic regularities. In this sense, UB represents a significant challenge for empiricist models of language acquisition that take socio-communicative interaction as an absolute prerequisite for the emergence of structural language (see Kissine (2021b, 2021a) and Goldberg and Abbot-Smith (2021), for contrasting opinions). Keeping an open mind toward the possibility of such alternative pathways may yield a more nuanced understanding of the diversity in language learning trajectories in autism and could inform theoretical models of language acquisition (Kissine et al. 2023). Further down the line, it is not impossible that better understanding unexpected bilingualism could lead to specific intervention strategies tailored to autistic children who exhibit strengths in processing structural cues. Such interventions could complement approaches that focus on socio-pragmatic abilities, which are clearly vital for adaptative skills, communication and social inclusion. Another step in understanding Unexpected Bilingualism should be to determine whether the increased sensitivity observed in nonadjacent dependency learning is modality-specific. Comparing nonadjacent dependency learning across visual, verbal auditory, and non-verbal auditory modalities will help clarify whether this sensitivity represents a specialization in processing verbal stimuli.

Author Contributions

Charlotte Dumont conceived the study and adapted the task, led data collection, conceived, and performed the analyses and writing of the manuscript. Marie Belenger led the data collection. Charlotte Dumont conceived and performed the analyses under the supervision of Mikhail Kissine and Arnaud Destrebecqz. Charlotte Dumont led the writing of the manuscript, with critical revisions by Mikhail Kissine and Arnaud Destrebecqz. Mikhail Kissine and Arnaud Destrebecqz secured funding.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

De-identified data and R scripts are available from the corresponding author on request.

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