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RESEARCH ARTICLE

Enhanced pitch discrimination in autistic children with unexpected bilingualism

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Abstract

Some autistic children acquire foreign languages from exposure to screens. Such unexpected bilingualism (UB) is therefore not driven by social interaction, rather, language acquisition appears to rely on less socially mediated learning and other cognitive processes. We hypothesize that UB children may rely on other cues, such as acoustic cues, of the linguistic input. Previous research indicates enhanced pitch processing in some autistic children, often associated with language delays and difficulties in forming stable phonological categories due to sensitivity to subtle linguistic variations. We propose that repetitive screen-based input simplifies linguistic complexity, allowing focus on individual cues. This study hypothesizes that autistic UB children exhibit superior pitch discrimination compared with both autistic and non-autistic peers. From a sample of 46 autistic French-speaking children aged 9 to 16, 12 were considered as UB. These children, along with 45 non-autistic children, participated in a two-alternative forced-choice pitch discrimination task. They listened to pairs of pure tones, 50% of which differed by 3% (easy), 2% (medium), or 1% (hard). A stringent comparison of performance revealed that only the autistic UB group performed above chance for tone pairs that differed, across all conditions. This group demonstrated superior pitch discrimination relative to autistic and non-autistic peers. This study establishes the phenomenon of UB in autism and provides evidence for enhanced pitch discrimination in this group. Acute perception of auditory information, combined with repeated language content, may facilitate UB children's focus on phonetic features, and help acquire a language with no communicative support or motivation.

Lay Summary

In this study, we tested pitch discrimination abilities in a group of French-speaking autistic children who have acquired English solely from exposure through screens (UB, Unexpected Bilingualism). Compared with their autistic and non-autistic peers, UB-autistic children demonstrated enhanced pitch discrimination abilities.

KEYWORDS
autism, enhanced auditory perception, language acquisition, low-level processing, screen exposure, unexpected bilingualism

INTRODUCTION

Autistic children frequently display language delays and difficulties, which are likely linked to early onset socio-communicative atypicalities inherent to the autism diagnosis (Su et al., 2021). Socio-communicative skills play a central role in early typical language development (e.g. Colonnesi et al., 2010), and, accordingly, autistic children with weaker joint attention abilities are more likely to remain minimally verbal (Luyster et al., 2008; Paul et al., 2008; Wodka et al., 2013; Yoder et al., 2015). However, there is also some evidence that socio-communicative abilities do not always predict language growth in autism (Anderson et al., 2007; Ellis Weismer &

Kover, 2015; Kissine et al., 2023), and hence that language acquisition in autism is mediated by communicative interaction to a lesser extent than in typical development. Consistent with this hypothesis is the phenomenon of *unexpected bilingualism* (UB) in some autistic children. Described in multiple, independent case studies to date, autistic UB children learn foreign languages via noninteractive, self-selected exposure to and engagement with content on the internet, television, and computer games (Abd El-Raziq et al., 2023; Kissine et al., 2019; Vulchanova et al., 2012; Zhukova et al., 2021). That is, autistic UB children acquire advanced morpho-syntactic and phonological knowledge through exposure to screen-based media. Ostrolenk et al. (2024) report that some autistic children with an intense interest in letters seem to acquire a foreign language by changing the subtitles of YouTube videos in order to read them. While further research is clearly needed, it is possible that UB may also be based on nonsocially mediated exposure to print materials. Strikingly, learning language from screens has repeatedly been documented as ineffective in typically developing children (Kuhl et al., 2003; Sachs et al., 1981). In fact, early exposure to screens may even have deleterious effects in typical development, with high levels of exposure to screens before the age of 3 related to poor language outcomes (Zimmerman & Christakis, 2005).

To date, UB (in autism) is drastically understudied; the empirical literature is limited to a handful of case studies that report advanced and productive morpho-syntactic skills in the language learned from screens. No study so far has investigated UB as a distinct subgroup on the autism spectrum and compared such children to non-autistic peers. The very existence of UB challenges the overspread idea that social interaction is a prerequisite for language acquisition in autism and raises the question of which less socially mediated mechanisms enable these children to acquire language from screens. A better understanding of the specific characteristics of UB children is thus of paramount importance.

One straightforward hypothesis is that UB children rely heavily on the internal structure of their linguistic input, compensating for reduced socio-communicative bootstrapping. That is, these children acquire language by focusing on the structural properties of the linguistic input from screens to which they are repeatedly exposed. Language learners—typical and atypical alike—use statistical and prosodic cues to parse and segment their linguistic input. Suprasegmental cues such as pitch variation, lengthening, and pausing are crucial for word segmentation (Goodsitt et al., 1993; Shukla et al., 2011) and syntactic parsing (de Carvalho et al., 2016). Furthermore, prosodic cues are preferred over purely statistical ones when the two do not overlap (Jusczyk et al., 1999; Soderstrom et al., 2005; Thiessen & Saffran, 2003). For instance, Thiessen and Saffran (2003) found that 9-month-olds used syllable stress for segmentation, ignoring distributional regularities.

There is extensive converging evidence that auditory processing in autism is enhanced, with more frequent absolute pitch, enhanced pitch discrimination, and enhanced pitch perception in autistic versus non-autistic individuals (Bonnel et al., 2010; Eigsti & Fein, 2013; Haesen et al., 2011; Heaton, 2003, 2005; Heaton et al., 2008; Kellerman et al., 2005). A recent meta-analysis of 22 studies (Chen et al., 2022) found small to medium positive effect size for enhanced pitch perception in autism.

Under the revised version of the Weak Central Coherence (WCC) model (Happé & Frith, 2006), a cognitive processing style specific to autistic individuals is characterized by a preference for bottom-up processing of information, with a tendency to focus on local details—including fine-grained acoustic differences—at the expense of global, top-down processing, based on higher level structure and contextual knowledge. Vulchanova et al. (2012) have used WCC to explain the UB profile of EV, a 10-year-old Bulgarian girl who learned German only via television. Vulchanova et al. (2012) reported that EV demonstrated enhanced local processing on grammar tasks, block design and object assembly tasks, and argued that a local processing bias combined with the massive exposure to input from television may have contributed to EV's UB.

Likewise, according to the Enhanced Perceptual Functioning (EPF) model (Mottron et al., 2006), heightened perceptual functioning in autism results in a focus on local features rather than global configurations. Within the EPF model, the enhanced pitch perception observed in autism is explained by the overdevelopment of low-level perceptual operations (Germain et al., 2019; Mottron et al., 2006). While WCC posits a deficit in top-down processing, the EPF model attributes local bias to superiority in low-level perceptual operations without global perception being necessarily impaired.

In the context of language processing, Chen et al. (2022) argue that the local bias in autism may enhance the extraction of low-level perceptual information (e.g., acoustic cues) at the expense of higher order information, such as linguistic meaning and social functioning. Heightened attention to low-level properties of the speech stream could then impact language acquisition, especially in social communication environments that require the integration of verbal and nonverbal cues and of the nonlinguistic context. Acute auditory perception could have a detrimental effect on language development because the perception of wide range of nonmeaningful auditory contrasts may compromise the emergence of stable phonological categories. Jones et al. (2009) found that enhanced pitch discrimination was linked with a history of language delay; similarly, Eigsti and Fein (2013) reported that better pitch discrimination was associated with both *current* autism symptomatology and with delays in first word production (a critical language milestone). Additionally, studies on tone languages such as

Mandarin Chinese, where pitch changes play a contrastive phonological role, further demonstrate that overly enhanced pitch discrimination may impact the creation of stable phonological categories. There is evidence that in autistic Chinese children, enhanced sensitivity to pitch variation within tone categories might hinder the formation of stable phonological representations (Wang et al., 2017; Yu et al., 2015).

Enhanced auditory perception may prevent autistic children from generalizing across from fine-grained variations in speech input, and hence negatively impact language acquisition. Much of the language content of cartoons, video games, and other screen-based media occurs in the context of interactions between two or more virtual agents, and thus presents verbal and nonverbal information in context. However, repetitive exposure to this prerecorded linguistic input, as is common in autistic UB children, may offset the complexity of communicative language. Caregivers and clinicians report that autistic children watch their favorite cartoons or videos—especially preferred segments—hundreds and hundreds of times. The media to which autistic UB children are exposed offer a means for replaying preferred excerpts, and to focus on a specific aspect of the linguistic input. We speculate that, in attending to screen-based linguistic input, some autistic children may abstract away from the socio-communicative aspects and predominantly focus on structural and phonetic properties. Any difficulty in building stable phonological categories, due to heightened attention to nonmeaningful acoustic contrasts, could be neutralized by the possibility of replaying—and reproducing—a video, reducing the variability in the input. We propose that heightened auditory perception, combined with invariant and repeated screen-based linguistic input, is the mechanism underlying screen-based language acquisition in UB autism.

Consistent with anectodical caregiver reports of absolute pitch and related strengths in the domain of music in autistic UB children, the first author conducted a case study of three UB children. Findings indicated that each child developed distinct phonological categories for the language spoken around them and the language they learned autonomously and without familial or educational support from screen-based media (Dumont et al., 2022). Acute auditory perception could have facilitated the perception of fine contrasts in the foreign language they heard from screens, allowing them to acquire the corresponding phonological categories.

In sum, the unusual acquisition of language not used in the family context via screen-based exposure in some autistic children could be linked to enhanced perception of fine-grained auditory differences. In this study, we tested pitch discrimination abilities among autistic and non-autistic children, with the prediction of heightened pitch perception in UB children relative to children in the two other groups. We compared performance in a pitch discrimination task among Autistic-UB (AU-UB), Autistic (AU), and Non-Autistic (Non-AU) children raised in a French-speaking linguistic environment. The AU-UB children acquired English exclusively through exposure to screens.

METHODS

Participants

We focused on verbal autistic individuals, given challenges in establishing the presence of UB in nonspeaking individuals. Participants were 46 autistic (AU; 19 females) children, including 12 AU-UB (3 females), and 46 non-autistic children (Non-AU; 21 females), ages 9 to 16 years, see Table 1 for Participant information. Inclusion criteria were a Nonverbal Index (NVI) of cognitive abilities above 70 and the use of French as primary language in the family. Four participants were included despite their NVI being not available. As their Full-Scale IQ was above 70, we could reasonably expect that their NVI would meet the inclusion criterion. All autistic participants received a clinical diagnosis of autism from multidisciplinary teams (composed of medical doctors, speech therapists, psychologists, and social workers) specialized and officially licensed in diagnosing autism by the Belgian State. Participants were recruited by first and second authors for a larger study on sex differences in autism and statistical learning in autism. While our primary focus was not explicitly directed toward identifying UB within the autistic cohort, it is noteworthy that a subset of participants exhibiting this unique profile spontaneously emerged within our sample.

Measures

Parents completed the French version of the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003)—Lifetime version, a 40-item questionnaire probing autism symptoms across the lifespan. Autism was ruled out in the non-autistic group using the SCQ, with scores below the threshold of 15. One participant in the Non-AU group was excluded because of an SCQ score above this cutoff.

Parents responded to a questionnaire regarding language development (age of first words and first phrases), language production (languages used by the child), language input (languages used by caregivers, siblings, exposure at school), and media exposure (amount of screen time, type of activities). Given the novelty of the phenomenon of UB, there is neither a commonly accepted definition nor established inclusion criteria. Participants were included in the AU-UB group[1] if, in this questionnaire,

[1]Given missing data from some participants, sample sizes vary from one measure to another. Data were missing because parents did not complete or did not return the questionnaires they received. NVI scores are missing for the participants who had a recent FS-IQ assessment that did not include the two subsets needed to calculate the NVI. Lastly, for one participant, the scores of the French version of the CELF were lost due to experimenter error.

TABLE 1 Participant information.

	AU-UB		AU		Non-AU		One-way ANOVAs		
	N	Mean (SD) [range]	*N*	Mean (SD) [range]	*N*	Mean (SD) [range]	AU-UB vs. AU	AU-UB vs. non-AU	AU vs. non-AU
Age (months)	12	149.84 (23.96) [118–187]	34	151.05 (27.98) [109–203]	45	146.86 (26.53) [110–203]	ns	ns	ns
SES (1–20)	9	11.44 (3.87) [6–17]	30	10.10 (2.62) [6–17]	37	13.13 (3.03) [7–18]	ns	ns	0.003
SCQ	8	21.25 (8.45) [8–33]	33	21.40 (5.37) [11–33]	37	3.14 (2.90) [0–10]	ns	<0.001	<0.001
WISC-V NVIQ score	12	92 (15.18) [74–124]	31	100 (17.43) [70–134]	44	109 (13.35) [78–131]	ns	0.002	0.04
WISC-V FSIQ score	12	85 (15.67) [66–121]	33	98 (18.23) [64–129]	44	109 (12.58) [73–129]	0.03	<0.001	0.01
French core language score (CELF-V)	12	74 (18.62) [46–114]	33	82 (18.99) [44–125]	44	101 (11.95) [70–127]	<0.001	<0.001	<0.001
English core language score (CELF-V)	10	65 (18.21) [45–100]							

Abbreviations: CELF, Communication of the Evaluation of Language Fundamentals-5th version; SCQ, Social Communication Questionnaire; SES, socioeconomic status; UB, unexpected bilingualism; WISC-V FSIQ, Full Scale IQ of Weschler Intelligence Scale for Children-5th Edition; WISC-V NV, Non-Verbal Index of Weschler Intelligence Scale for Children-5th Edition.

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 English version of the CELF-5 (Wiig et al., 2013). Twelve out of the 48 autistic participants were included in the UB group. For six of these AU-UB children, parents reported that their child produced first words in English only, or along with French words, the other six parents reported that the child's first words were in French, with English emerging between one to 6 years of age. Note that many of these parents expressed some discomfort with their child's production in English, because the parents themselves were not fluent or comfortable speaking in English; many asked for clinical guidance about whether they should discourage the child's use of this less-useful communicative modality.

Core language abilities in French were also assessed using the Communication Evaluation of Language Fundamentals-5th version (Wiig et al., 2019, CELF-F[2]). To avoid testing bias, the French and the English versions of the CELF were administered by different examiners (first author for English, and second author for French). A NVI of cognitive abilities was assessed using the Weschler Intelligence Scale for Children-5th Edition (WISC-V; Weschler, 2014), yielding age-based standardized scores.

Parents reported on sociodemographic characteristics on a questionnaire adapted and translated to French from the Family Affluence Scale (Torsheim et al., 2016). This measure, which served as a proxy of socioeconomic status (SES), captures educational attainment on a 0- to 6-point scale, ranging from 0 (indicating no primary school achievement) to 6 (representing a doctoral degree), and economic status on a 0- to 13-point scale, based on indicators such as ownership of assets (e.g., car, dishwasher, frequency of vacations, etc.) with 0 indicating very low economic status, and 13 indicating very high economic status. The education and income (status) scores are added to form a composite measure of SES.

Pitch discrimination task

The pitch discrimination task, adapted from Eigsti and Fein (2013), was programmed in E-Prime 3 (Psychology Software Tools, 2016) and presented on an ASUS ROG STRIX laptop via Bose Quietcomfort 45 headphones. Participants were asked to listen to 112 pairs of tones and to make a same/different judgment in a two-alternative forced-choice task. If the participants judged that the pairs were identical, they had to press on the key of the keyboard with a green sticker; if the pairs were judged to be different, they had to press on the key of the keyboard with a red sticker. Tones were 100 ms long, with a 1000 ms interstimulus interval and a 500 ms intertrial interval. Participants first completed a training block of 16 trials with feedback (at 4% and 1% difference between tones), and then completed three 36-trial blocks at increasing difficulty levels: Easy (in which pairs could differ by 3% Hz), Medium (with a 2% difference), and Hard (1% difference). Each block comprised 36 pairs of tones, 18 of which (50%) were identical. Tones were 500, 750, 1000, or 1500 Hz, chosen to be outside of the typical range for human speech. For additional details, see Eigsti and Fein (2013).

Data analytic plan

All analyses were implemented in R (R Core Team, 2024), using the *psycho*, *lme4*, and *emmeans* packages.

[2]Two AU-UB children refused to complete the CELF-V in English; mastery of English (advanced syntactical and lexical knowledge) was assessed by the first author in informal conversation with the child.

Prior to analysis, anticipatory responses (RT < 70 ms) and trials with a response slower than 7 s were removed; these trials comprised <1% of the data.

Mean accuracy was computed for each group and type of tone (same vs. different) to assess general group differences. Subsequently, we examined participants' discrimination abilities and response biases using Signal Detection Theory (Macmillan, 2002). The d' and c-statistic were calculated using the dprime function of the psycho package in R. Initially, we determined Hits, False Alarms, Correct Rejections, and Misses. Hits were defined as correctly discriminating two different tones, while False Alarms referred to mistakenly identifying identical tones as different. Correct Rejections were instances of correctly identifying two identical tones, and Misses were instances of incorrectly rejecting two different tones. d' serves as a valuable metric, indicating the separation between the signal and noise distributions. d' values close to 0 suggest performance at chance levels, whereas values above 1 are considered evidence of reliable discrimination. Subsequently, we computed the c-statistic to explore any potential response bias. A c-statistic value of 0.5 suggests no bias, while values deviating from 0.5 indicate a bias toward responding "different" (c > 0.5) or "same" ($c < 0.5$).

Accuracy was subsequently modeled using stepwise forward comparisons of multilevel logistic models. In contrast to previous studies where d' was used as the dependent variable, we opted to utilize raw accuracy. This decision aimed to minimize loss of statistical power, as calculating d' involves transformation and loss of information. This ensured a more direct representation of participants' performance and maximized sensitivity to detect group differences and subtle variations in task performance. The baseline model included a random intercept for subject and age as fixed factors; age was centered given the wide age range of the sample and group differences in age. Subsequent models were iteratively expanded by adding predictor variables: Group (AU-UB, AU, Non-AU), Stimulus Type (same/different pairs), and Difficulty level (Easy, Medium, Hard), as well as their interactions. The selection of each model was guided by model fit indices, including AIC (Akaike information criterion) and BIC (Bayesian information criterion), as well as the significance of predictors. The AIC and BIC were used to balance goodness of fit with model complexity, aiming to identify the model that provided the best trade-off. Additionally, significance testing helped ensure that selected predictors contributed meaningfully to the model. The best-fitting model was used for subsequent pairwise Tukey comparisons, implemented with the *emmeans* package.

There were no differences in accuracy as a function of sex (female/male) or SES. As we had no specific predictions for these variables, they were not included in further analyses.

RESULTS

Psychometric measures and autistic symptomatology

One-way ANOVAs showed significant group differences Full-Scale IQ and French language assessments. AU-UB participants had significantly lower Full-Scale IQ and lower language performance in French than the Autistic (AU) and Non-Autistic (Non-AU) groups. Furthermore, AU-UB English CELF scores were significantly lower than French CELF scores. The AU-UB group's core language scores in English were extremely heterogeneous, with scores ranging from 45 to 100. As expected, the Non-AU had lower SCQ scores than both AU groups.

Pitch discrimination results

Looking at descriptive statistics in Table 2, mean group accuracy revealed that AU-UB were more accurate in both "Same" and "Different" pairs of pure tones than AU and Non-AU. Higher d' in the AU-UB indicates a relatively higher sensitivity in discriminating between signal and noise. In all group, the c-statistic indicate a bias toward answering "same," with the AU-UB exhibiting a stronger "same" bias than AU and Non-AU. However, taking the d' and c together, the results suggests that while all groups tend to perceive all pairs as the same, the UB group is better able to effectively discriminate between signal and noise, resulting in higher sensitivity.

For inferential statistics, stepwise forward model comparisons, revealed that the best fitting model included effects of Group, Type, and Difficulty, as well as Type × Difficulty and Group × Type interactions, $\chi^2(2) = 10.66$, $p = 0.004$.; see Table S1 in Supporting Information.

Looking at the significant Type × Difficulty interaction from the best fitting model, post hoc pairwise Tukey-adjusted comparisons showed that, across groups, accuracy differed across each pairing of conditions: accuracy of different pairs was higher in the Easy than in the Medium ($\beta = 0.35$; SE $= 0.08$; $p < 0.001$) and Hard ($\beta = 0.88$, SE $= 0.08$ $p < 0.001$) conditions, and in the

TABLE 2 Mean raw accuracy and standard error as a function of group and stimulus pairings (same, different), and d' and c means and standard errors.

	Accuracy		Signal detection theory	
	Same	Different	d'	c
AU-UB	0.76 (0.18)	0.69 (0.19)	1.52 (1.31)	0.14 (0.36)
AU	0.73 (0.18)	0.53 (0.21)	0.87 (1.06)	0.35 (0.48)
Non-AU	0.74 (0.14)	0.54 (0.18)	0.83 (0.81)	0.30 (0.38)

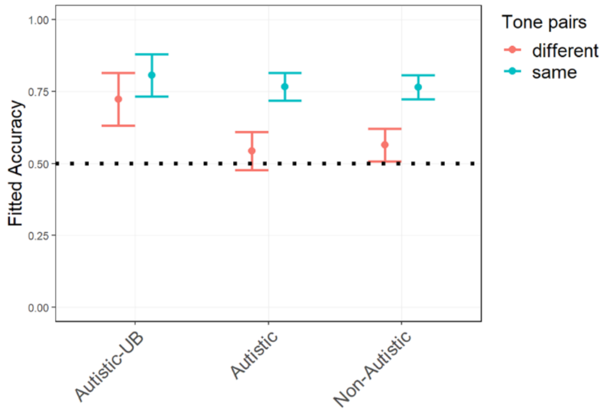

FIGURE 1 Fitted accuracy and 95% CI by group and stimulus type.

Medium than in the Hard condition ($\beta = 0.53$, SE $= 0.08$, $p < 0.001$). For identical tone pairs, accuracy was significantly higher in the Easy condition than in the Medium ($\beta = 0.30$, SE $= 0.09$, $p = 0.002$) and Hard ($\beta = 0.46$, SE $=0.09$, $p < 0.001$) conditions; however, for identical pairs, accuracy in the Medium and Hard conditions did not differ ($p = 0.14$). In all conditions, participants responded with greater accuracy to identical tone-pairs relative to different tone-pairs (Easy: $\beta = -0.49$, SE $= 0.09$; Medium: $\beta = -0.69$, SE $= 0.09$; Hard: $\beta = -1.06$, SE $= 0.09$; all p's < 0.001), reflecting a bias toward "same" responses.

Turning to the significant Group × Type interaction: as shown by the fitted 95% confidence intervals in Figure 1, only the UB group performed above the 50% chance level with different tone-pairs. Post hoc comparisons showed that, for different tone-pairs, children in the AU-UB group had higher accuracy than children in either the AU ($\beta = 0.80$, SE $= 0.27$, $p = 0.009$) or the Non-AU ($\beta = 0.71$, SE $= 0.26$, $p = 0.01$) groups. The AU and Non-AU groups did not differ in accuracy for different tone-pairs and there was no group difference in accuracy for same tone-pairs (all p's > 0.05).

Effects of language performance and bilingualism

We performed an a posteriori check to ensure that group effects were not due to confounding variables such as French (first language) abilities or "expected bilingual" status. We first replaced the group variable in our best-fitting model with French CELF-5 scores. Results indicated that French CELF-5 scores did not predict accuracy ($p = 0.73$). To test whether "expected bilingual" status accounted for differences in pitch performance, any autistic child who was consistently exposed to a second language via live human interaction (e.g., with a caregiver) before age 3 years was coded as bilingual. An analysis compared pitch discrimination by group for Autistic-Bilingual, Autistic-Monolingual, and Non-Autistic groups. Post hoc comparisons revealed no group differences in accuracy, all p's > 0.60.

DISCUSSION

This study is the first to compare a group of autistic children with UB to their autistic and non-autistic peers. The very presence of the largest (to date) group of autistic children with un-taught second language abilities establishes that UB is not limited to isolated and exotic case studies, but is a genuine phenomenon, present in 25% of our total sample of autistic participants. By simply recruiting French-speaking non-autistic (Non-AU) and autistic participants (AU), we identified 12 Autistic-UB (AU-UB) out of 48 autistic children. The selection was based on a parental questionnaire reporting some knowledge of English, without any formal learning or exposure at home, and further established via formal assessment of English language skills.

Understanding the mechanisms that drive UB is crucial; the capacity to acquire fluent language skills via screen-based exposure suggests that language acquisition could, in some cases, be less mediated by socio-communicative abilities. With the exception of the case study by Vulchanova et al. (2012), there is currently no study describing the mechanisms underlying such intriguing language acquisition profiles. Vulchanova et al. (2012) framed their study in terms of the WCC hypothesis (Happé & Frith, 2006). Our hypothesis, aligning with both the WCC and the EPF hypotheses, was that autistic UB children would exhibit enhanced performance in pitch discrimination. Both models predict that heightened perceptual processing, such as pitch discrimination, may be due to enhanced sensitivity and attention to low-level perceptual information.

In addition to establishing the phenomenon of UB in the largest sample to date of autistic children, the primary finding was of superior pitch discrimination abilities in the AU-UB children as compared with both AU and Non-AU participants. The AU-UB children exhibited better accuracy in detecting different pairs of tones across varying difficulty levels, while AU and Non-AU participants performance did not differ from chance. No group differences were found for the pairs of pure tones that were identical; accuracy was very high overall for identical pairs (Means = 0.76, 0.73, and 0.74 for AU-UB, AU, and Non-AU groups). In all groups, the c-statistic from signal detection theory showed a bias toward "same" responses, potentially accounting for the lack of group differences for same pairs of pure tones.

Enhanced pitch discrimination ability in autistic UB children carries significant implications for understanding their language acquisition profiles. Pitch discrimination has been linked to both language acquisition deficits and current autistic symptomatology. Jones et al. (2009) did not find any difference between autistic and non-autistic group at the group level but identified a subgroup of autistic participants with heightened auditory perception and a history of delayed language onset. Bonnel et al. (2010) found that only an autistic group, and not participants with the Asperger syndrome diagnosis who had no history of language or cognitive delays, showed enhanced pitch discrimination. Eigsti and Fein (2013) also reported enhanced pitch discrimination in autistic children, but not in those who were diagnosed as children but no longer met criteria for autism.

Similar to reports from Jones et al. (2009), Eigsti and Fein (2013), and Bonnel et al. (2010), the current study revealed enhanced pitch discrimination in a particular subgroup of autistic children. The subgrouping variable in our sample was not based on language history (as in Jones et al., 2009 and Bonnel et al., 2010) or current autistic symptomatology (as in Eigsti & Fein, 2013), but rather on a unique bilingual language profile. Here, results indicated that the autistic participants with self-taught bilingual language skills displayed significantly better auditory discrimination relative to autistic participants without UB or non-autistic comparison participants. Note, however, that these results are quite compatible with previously reported links between enhanced auditory processing, and language delays; children in the AU-UB group, who displayed heightened pitch perception, also displayed overall lower scores in the language of their linguistic community (French) compared with their autistic peers without the unexpected bilingual profile. Note, however, that overall linguistic skills did not predict pitch discrimination in the totality of our sample; this nonreplication of prior findings may reflect the choice of raw accuracy data instead of d' as the dependent variable.

According to both the EPF and WCC theories (Happé & Frith, 2006; Mottron et al., 2006), autistic individuals have a unique cognitive style that prioritizes lower level perceptual processing. Enhanced auditory processing is plausibly one manifestation of this cognitive style, which, in variable communication environments, may lead to overly detailed phonological representations and thereby to delays in language acquisition. However, in the case of screen-based exposure, the variability of the linguistic input is likely offset by one's ability to replay a video segment over and over again. Repeated exposure to a constrained linguistic input set may allow UB children to attend exclusively only the structural, phonetic properties, and reducing the stress of social interaction. The possibility of acquiring linguistic structures outside a direct interactional frame is further supported by evidence on language acquisition in culture where children tend to be not directly spoken to by adults (Foushee & Srinivasan, 2024) and raises crucial questions about language learnability (Kissine, 2021).

Acute perception in auditory information, such as pitch, vowel contrasts, or relative formant, could also drive a child's interest in language learning *in and of itself*. Restricted and repetitive idiosyncratic interests are central to the autism diagnosis (American Psychiatric Association, 2013). Intense interests often incorporate a sensory dimension (Uljarević et al., 2022), with television and YouTube videos being one of the most common interests in autistic children (Nowell et al., 2021), including those with age-typical cognitive skills (Klin et al., 2007). The local bias observed in autism has also been linked to an advantage in fragmented, featural learning, and may result in a tendency to seek configural patterns, as found in calendar calculations, mathematics, memorization—and language (Klin et al., 2007; Mottron et al., 2021). Many parents of children in our AU-UB sample reported that their child watched content not only in English, but also in Russian, Spanish or Japanese. While it was not possible to assess their abilities in these languages, we speculate that enhanced performance in auditory discrimination and the bias toward low-level processing underlies the children with the AU-UB profile to seek out different languages in order to "crack the code."

To expand our comprehension of UB, future research should focus on higher level auditory discrimination tasks to thoroughly investigate auditory processing profiles in Autistic-UB individuals. For example, more complex auditory stimuli and tasks evaluating higher order auditory features, such as speech intonation, prosodic processing, or phonemic contrasts, would provide a broader perspective on the local-processing bias. A clear limitation of our study is the absence of audiometric data: a baseline of hearing sensitivity would further allow comparing pitch discrimination relative to auditory threshold levels. In this exploratory study, we did not assess other relevant perceptual low-level auditory skills (such as temporal auditory processing). Future studies should recruit larger samples of Autistic-UB children to investigate potential links between pitch discrimination abilities and the age of language onset (see Eigsti & Fein, 2013). Relatedly, it would be important to include younger children to better understand how pitch discrimination may interact with language trajectories in this group. A longitudinal study tracking media use, preferred contents and the watching habits of children with the UB profile, would illuminate the processes underlying this type of language acquisition. Studies utilizing long-format recording tools (e.g., LENA recorders) should also contrast language input in UB children via screens, communicative interactions, and overheard speech.

By investigating UB and understanding the underlying mechanisms and cognitive profiles, we can move closer to providing evidence-based advice to caregivers of autistic UB children, who do not know whether they should encourage the exposure to screens in foreign languages. More broadly, this research informs theoretical models of language acquisition.

AUTHOR CONTRIBUTIONS

Inge-Marie Eigsti provided the task and Marie Belenger and Charlotte Dumont adapted it to French. Charlotte Dumont and Marie Belenger conceived the study and led data collection. Charlotte Dumont conceived and performed the analyses with help from Marie Belenger. Mikhail Kissine secured funding. Charlotte Dumont led writing of the manuscript, with critical revisions by Mikhail Kissine and Inge-Marie Eigsti.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

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. Written consent was obtained from children enrolled in this study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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