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Brief Report

Developmental improvements in talker recognition are specific to the native language

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ABSTRACT

Previous studies have shown that talker recognition by young children continues to improve into late childhood. But why might this be the case? Are children's gradually improving talker recognition abilities driven primarily by general maturational factors in the cognitive or perceptual domain (general maturation hypothesis), or are these improvements primarily linked to children's increasingly sophisticated linguistic knowledge (language attunement hypothesis)? In the current study, we addressed this question by testing monolingual English-speaking 5- and 6-year-olds (N = 80) on their ability to recognize talkers in a familiar language (i.e., English) and in an unfamiliar language (i.e., Spanish) using a "voice lineup" talker recognition task. We predicted two alternative outcomes. According to the general maturation hypothesis, we should see improvements in talker recognition for both the familiar and unfamiliar languages as children grow older. According to the language attunement hypothesis, however, we should see developmental improvements in talker recognition for the familiar language only. Our findings suggest that early developmental improvements in talker recognition are limited to familiar languages, highlighting the potential central role of language-specific knowledge in talker recognition.

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Introduction

The attainment of mature talker recognition abilities follows a protracted period of development. Although young children gradually improve at talker recognition throughout childhood, they fail to demonstrate adult-level skill at recognizing people's voices until they near adolescence. This finding is now well established in the literature (e.g., Creel & Jiménez, 2012; Fecher, Paquette-Smith, & Johnson, 2019; Mann, Diamond, & Carey, 1979). However, the factors driving the improvements in children's talker recognition abilities are still poorly understood. Here, we propose two alternative hypotheses for the protracted development of talker recognition.

According to the first hypothesis—henceforth the *general maturation hypothesis*—the gradual developmental improvements in children's talker recognition abilities are predominantly driven by domain-general cognitive and/or auditory perceptual maturation. This hypothesis is supported by studies showing that many core cognitive processes (e.g., working memory, attentional control, processing speed, other executive functions; Best, Miller, & Jones, 2009; Dempster, 1981; Hale, 1990; Luna, Garver, Urban, Lazar, & Sweeney, 2004) and sensory processing mechanisms (e.g., statistical learning, auditory perception; Halliday, Taylor, Edmondson-Jones, & Moore, 2008; Huyck & Wright, 2013; Moore, 2002; Zaltz, Ari-Even Roth, Karni, & Kishon-Rabin, 2018) are still immature even during late childhood. That is, compared with adults, children might be at a disadvantage in learning to recognize talkers because children are less prepared to stay focused on the task, to attend to relevant talker-specific detail in the speech stream, or to keep indexical cues to talker identity in memory. The general maturation hypothesis is consistent with the classic notion that talker recognition is based on sensitivity to acoustic (rather than linguistic) properties of speech (e.g., Hecker, 1971; see Remez, Fellowes, & Rubin, 1997, for discussion). It also aligns with studies showing that voices that are perceptually distinct from one another (e.g., due to gender differences) are easier to distinguish and recognize than more similar-sounding voices (e.g., Creel & Jiménez, 2012; Fecher et al., 2019).

Alternatively, according to the second hypothesis—henceforth the *language attunement hypothesis*—the protracted development of talker recognition seen in earlier work might be linked less to the gradual cognitive or perceptual maturation and more to the gradual development of linguistic abilities during early childhood (e.g., phonological processing abilities). Indeed, we already know that talker recognition critically depends on linguistic knowledge. This has been demonstrated by the language familiarity effect, whereby adults (e.g., Bregman & Creel, 2014; Goggin, Thompson, Strube, & Simental, 1991; Johnson, Bruggeman, & Cutler, 2018; Levi, 2019; Perrachione, 2019), children (Fecher & Johnson, 2018a; Levi, 2018; Levi & Schwartz, 2013), and infants (Fecher & Johnson, 2018b, 2019b; Johnson, Westrek, Nazzi, & Cutler, 2011) are better at talker recognition in familiar languages than in unfamiliar languages. We also know that as children grow older, they gradually refine their phonetic and phonological processing skills in their native language (e.g., Hazan & Barrett, 2000; Nittrouer, 1992; Ohde & Haley, 1997). Therefore, if talker recognition draws on linguistic knowledge, and linguistic knowledge improves as children grow older, then these two processes might be linked in development, with children's linguistic and talker recognition abilities improving in tandem.

To date, we have very little data available to adjudicate between these two alternative hypotheses. In fact, only two studies have examined talker processing across both ages and languages, and neither study was designed to directly test the two hypotheses presented above. Rather, the primary aim was to compare talker recognition in familiar versus unfamiliar languages in both children and adults, thereby examining whether the typically observed recognition advantage for speakers of familiar languages over speakers of unfamiliar languages was stronger in children than in adults. Levi and Schwartz (2013) tested English-speaking adults and 7- to 12-year-old children on their ability to discriminate between talkers in English and German. Across development, they found an improvement in the discrimination of familiar-language talkers and an inverted U-shaped developmental pattern for the discrimination of unfamiliar-language talkers. The second study had a slightly different goal and it observed a different pattern of results. Fecher and Johnson (2018a) tested English-speaking adults and 5- and 6-year-old children on talker recognition in English and Polish. They hypothesized that the language familiarity effect would be stronger in adults than in children. Importantly, they did not expect the performance of 5-year-olds to differ from the performance of 6-year-olds. To their surprise, however, they found that the language familiarity effect grew stronger from 5 to 6 years of age. Moreover, contrary to their predictions, the effects seen in 6-year-olds and adults were quite similar.

To summarize, children's ability to recognize talkers shows a protracted period of development, but no study to date has directly examined the role of linguistic experience versus general perceptual and cognitive maturation in this process. In the current study, we asked what factors drive improvements in talker recognition during early childhood. In contrast to past studies, we were not merely interested in whether children and adults differ in their talker recognition abilities or at what age children develop differential recognition of speakers of familiar versus unfamiliar languages. Rather, we examined whether developmental improvements in talker recognition are specific to the native language. We made two a priori predictions. First, we predicted that if improvements in talker recognition are driven by general maturation (general maturation hypothesis), then 6-year-olds will outperform 5-year-olds for both a familiar language and an unfamiliar language. Alternatively, if these improvements are driven by language knowledge (language attunement hypothesis), then 6-year-olds will outperform 5-year-olds for the familiar language only.[1] We tested these hypotheses by testing English-speaking adults and 5- and 6-year-old children on a "voice lineup" talker recognition task in a familiar language (English) and an unfamiliar language (Spanish).

Method

Participants

A total of 40 5-year-olds (M_{age} = 5.4 years, SD = 0.3; 18 female) and 40 6-year-olds (M_{age} = 6.4 years, SD = 0.3; 16 female) with self-reported normal hearing and vision from the Greater Toronto Area were tested (none of them had participated in the Fecher & Johnson (2018a) study). Children were monolingual North American English speakers with no knowledge of (or systematic exposure to) Spanish and no reported history of delayed speech and language development. All 80 children completed an engaging "voice lineup" talker recognition task involving their native language (English) and a foreign language (Spanish). A subset of children—20 5-year-olds (M_{age} = 5.4 years, SD = 0.3; 11 female) and 20 6-year-olds (M_{age} = 6.5 years, SD = 0.3; 10 female)—were also tested on the Comprehensive Test of Phonological Processing–Second Edition (CTOPP-2) to assess their phonological awareness and memory abilities. The study was approved by the University of Toronto Research Ethics Board. Caregivers provided written consent for their children's participation, and children verbally assented to taking part in the study.

Stimuli

Stimuli for the talker recognition task consisted of speech recordings of four female English–Spanish bilingual speakers (M_{age} = 20.8 years, SD = 2.2) reading 40 English and 40 Spanish sentences used in previous infant studies (e.g., Fecher & Johnson, 2019a, 2019b). The sentences were read in an adult-directed manner with a 'neutral' tone of voice (see example sentences provided in Appendix A). All four speakers learned both English and Spanish from birth, and none of them had a perceivable Spanish accent when speaking English. Recording bilinguals reduced the likelihood that any performance differences seen across language conditions resulted from the language change rather than a talker change. The recordings for this study were made in the same recording studio using the same equipment as the recordings used in the previous study (Fecher & Johnson, 2018a).

[1] Note that although we made these two distinct predictions, we also readily admit that it is possible that both of these factors (general maturation and language attunement) could play a role in children's improving talker recognition abilities over the course of development and that the contribution of these two factors could shift in weight across development. We highlight these possibilities further in the Discussion.

Procedure

The procedure of the talker recognition task was identical to the procedure in Fecher and Johnson (2018a) except that, as described above, the English–Polish recordings used in the earlier study were replaced by the recordings of the English–Spanish bilinguals (i.e., an entirely new set of talkers and a new foreign language were used here). Children were tested individually in a single session, where they played an interactive computer game presented on a 15-inch touchscreen monitor. In this game, children were exposed to cartoon aliens speaking either English or Spanish and, after a 1-min delay, were asked to identify which of two voices presented to them in a voice lineup matched the voice of the alien from before (see Fig. 1). Specifically, children were first familiarized with the voice of an alien by listening to four sentences spoken by the alien (two repetitions of two different sentences). Next, children watched a cartoon movie (without speech) for 1 min. After that, children saw two spaceships appear on the screen. One spaceship was linked to the voice of the alien from the beginning of the trial, and the other spaceship was linked to a new voice (one sentence spoken per alien). Children could listen to the voices by touching the spaceships. After listening to both voices at least once, children were encouraged to indicate which of them sounded like the voice of the alien from before. To indicate their choice, children dragged the appropriate spaceship onto the image of a planet presented at the top of the screen. Feedback on their performance was provided in the form of a smiling or frowning emoji that popped up on the screen once children had made their selection. Children completed four English and four Spanish trials (languages were never mixed within trials). After four trials, children took a timed 4 min break, during which they played a board game with the experimenter (for additional design details see Fecher & Johnson, 2018a). The experiment took 20 to 25 min to complete.

A subset of children also completed five standardized tests of phonological processing (in English only). These tests were chosen because previous research has implicated the central role of native-language phonology in talker processing (e.g., Creel & Jiménez, 2012; Fecher & Johnson, 2018a; Kadam, Orena, Theodore, & Polka, 2016; Levi, 2019). We speculated that if the findings from our talker recognition experiment were to suggest that the developmental improvements in talker recognition are linked to linguistic knowledge (i.e., if we were to find support for the language attunement hypothesis), then we would be in a better position to speculate on which type of linguistic knowledge might account for this effect. Children who completed these tests were tested individually in the same session following the talker recognition task. Sufficient rest breaks, including games and small motivational rewards, were provided throughout the session. Children were tested on five CTOPP-2 subtests: Elision, Blending Words, and Sound Matching as measures of phonological awareness and Memory for Digits and Nonword Repetition as measures of phonological memory. We compiled

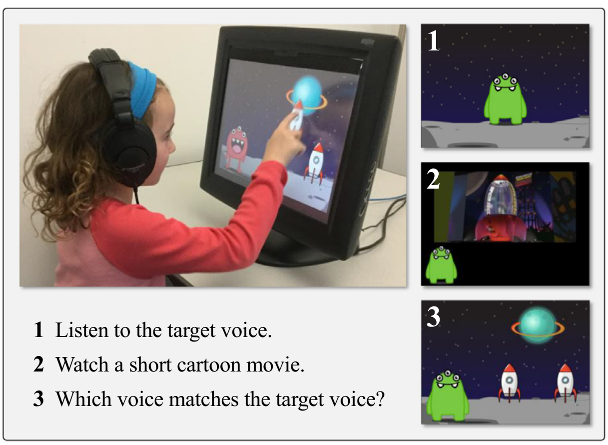

Fig. 1. Experimental procedure used in the “voice lineup” talker recognition task.

two composite scores using the non-age-adjusted developmental scores for each subtest: the Phonological Awareness Composite Score (PACS) and the Phonological Memory Composite Score (PMCS).

Results

To recall, the general maturation hypothesis predicts that 6-year-olds should outperform 5-year-olds for both English and Spanish, and the language attunement hypothesis predicts that 6-year-olds should outperform 5-year-olds for English only (i.e., the latter predicts that developmental improvements should be limited to the familiar language). Whereas Fig. 2A depicts idealized predictions for both hypotheses, Fig. 2B shows the observed results from this study and, for comparison, from Fecher and Johnson (2018a). For clarity of presentation, Fig. 2 shows difference scores, which were calculated by subtracting the mean proportion correct for the 5-year-olds from the mean proportion correct for the 6-year-olds. From looking at the figure, our data clearly support the language attunement hypothesis, with children improving at talker recognition in the familiar language (as indexed by positive scores) but not in the unfamiliar language (as indicated by null or even negative scores).

To assess children's talker recognition performance statistically, we used a generalized mixed-effects model with mean proportion correct talker recognition as the dependent variable and the contrast-coded independent variables age (0.5: 6-year-olds; −0.5: 5-year-olds), language (0.5: English; −0.5: Spanish), and the age × language interaction as fixed effects. We also included random intercepts for participant and talker and a random slope for language by participant. The main effects of age and language did not reach significance ($p > .10$). The lack of an age effect suggests that, averaged across languages, younger and older children performed similarly. Critically, however, a significant age × language interaction was found ($\beta = 0.90$, $SE = 0.34$, $z = 2.69$, $p = .007$), indicating that the test language affected talker recognition differently in 5-year-olds and 6-year-olds.

To further examine the significant age × language interaction, we constructed separate models for the two languages, with age as a fixed effect and random intercepts for participant and talker. For English, we found a significant age effect ($\beta = 0.71$, $SE = 0.24$, $z = 3.00$, $p = .003$), with 6-year-olds performing significantly better than 5-year-olds (see Fig. 3, two leftmost bars). For Spanish, however, the effect of age did not reach significance ($p = .424$), suggesting that 5-year-olds and 6-year-olds performed similarly (and, descriptively speaking, the 6-year-olds even performed worse for Spanish; see Fig. 3, two rightmost bars). Thus, between 5 and 6 years of age, children improved at talker recognition in their native language but not in the foreign language. The developmental patterns seen here and in Fecher and Johnson (2018a) therefore strongly support the language attunement hypothesis.[2] Note that our results provide no support for a hybrid explanation involving both general maturation and language attunement because overall performance did not change between 5 and 6 years of age (i.e., only performance in the familiar language improved).

What type of linguistic knowledge might account for our finding that the 6-year-olds outperformed the 5-year-olds for English but not for Spanish? To examine whether phonological knowledge (as captured by CTOPP-2) was driving children's performance, we correlated children's talker recognition accuracy in English with their performance on the five CTOPP-2 subtests for the 40 children who additionally completed these phonological tests (for detailed results see Table B1 in Appendix B). Both PACS (measure of phonological awareness), $r(38) = .38$, $p = .014$, and PMCS (measure of phonological memory), $r(38) = .38$, $p = .015$, were positively correlated with children's age (as one would expect). However, neither PACS, $r(38) = .15$, $p = .357$, nor PMCS, $r(38) = .17$, $p = .303$, was significantly correlated with talker recognition accuracy. Post hoc comparisons between talker recognition and performance

[2] To facilitate comparisons with Fecher and Johnson (2018a) and other studies focusing on the development of the language familiarity effect, we also constructed separate models for the two age groups, with language as a fixed effect, random intercepts for participant and talker, and a by-participant random slope for language. The 6-year-olds showed a robust language familiarity effect ($\beta = 0.51$, $SE = 0.24$, $z = 2.12$, $p = .034$), with children performing better for English than for Spanish. For the 5-year-olds, the effect of language did not reach significance ($p = .123$). Interestingly, like in Fecher and Johnson (2018a), the 5-year-olds showed a trend to perform better for the unfamiliar language than for the familiar language, but this pattern was not statistically significant (see Discussion).

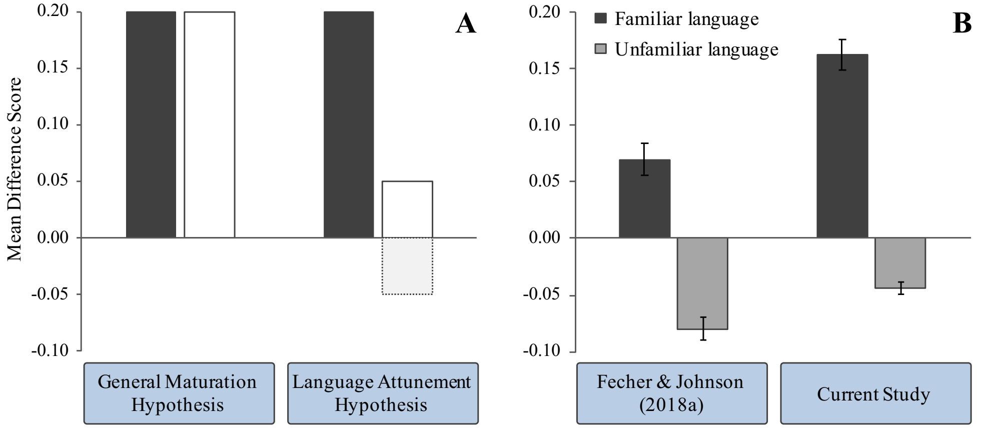

Fig. 2. (A) Idealized mean difference scores as predicted by the general maturation hypothesis and the language attunement hypothesis. (B) Observed mean difference scores from Fecher and Johnson (2018a) and the current study, calculated by subtracting mean proportion correct for the 5-year-olds from mean proportion correct for the 6-year-olds. Positive scores indicate better performance, and negative scores indicate worse performance, at 6 years of age than at 5 years of age. Error bars in Panel B represent standard errors of the mean.

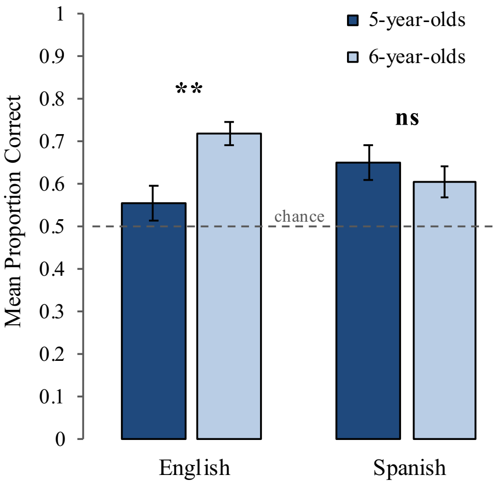

Fig. 3. Mean proportions correct for the 5-year-olds and 6-year-olds. For English, the 6-year-olds performed significantly better than the 5-year-olds, but for Spanish, no statistically significant differences between the age groups were found. Error bars represent standard errors of the mean. $^{**}p < .01$.

on each subtest showed no significant relationships either, and no significant patterns emerged when splitting the dataset by age group (p > .10 for all comparisons).

Discussion

Why does it take children so long to develop adult-like talker recognition abilities? In seeking an answer to this question, this study has brought together two formerly independent lines of research on human talker recognition. The first line of research has shown that it takes children many years to attain mature talker recognition skills, with young children only gradually improving at reliably recognizing talkers (e.g., Bartholomeus, 1973; Creel & Jiménez, 2012; Fecher et al., 2019; Mann et al., 1979). The second line of research, which dates back to early forensic studies on earwitness performance, has demonstrated that both child and adult listeners are better at talker identification in familiar languages than in unfamiliar languages (e.g., Fecher & Johnson, 2018a; Johnson et al., 2018; Köster & Schiller, 1997; Levi, 2019; Levi & Schwartz, 2013; Perrachione, 2019). In the current study, we pulled together these two lines of research by showing that the gradual developmental improvements in talker recognition seen in young children seem to be limited to familiar languages, with children getting better over time at recognizing talkers in familiar languages but not in unfamiliar languages.

Our finding that children developmentally improve at native-language (but not foreign-language) talker recognition strongly suggests that the two factors under investigation here—the listener's age and the language spoken by the talker—not only heavily affect recognition accuracy (as shown in previous research) but also interact in perception in a way that is meaningful for our understanding of how children reach mature talker recognition abilities. Although it has been firmly established that children show a protracted period of development for talker recognition, the current study is the first to provide empirical evidence showing that the improvements in talker recognition during early child development may be linked specifically to children's growing linguistic knowledge rather than general maturational factors in the cognitive or perceptual domain. Two primary observations in our data led us to this conclusion.

First and foremost, we showed that between 5 and 6 years of age, developmental improvements in talker recognition were limited to the familiar language. This finding perfectly aligns with (and conceptually replicates) the finding reported in Fecher and Johnson (2018a) for a different language pairing and a different set of speech recordings. Second, neither in the current study nor in Fecher and Johnson (2018a) did we observe global improvements in talker recognition performance between 5 and 6 years of age. Indeed, the younger children even showed a tendency to perform better than the older children for the unfamiliar language and to perform better for the unfamiliar language than for the familiar language (but note that even when we collapsed the data from both studies, these patterns did not reach statistical significance). The absence of global improvements not only underscores the central role of language knowledge in talker recognition but it also suggests that task difficulty cannot be considered a confound in this study. That is, the task we used (which was exactly the same for both age groups) was not simply more challenging for 5-year-olds than 6-year-olds, and thus this factor cannot explain the older children's superior performance with familiar-language talkers.

Although the current study clearly replicates Fecher and Johnson (2018a) in that both studies showed a strong language familiarity effect in 6-year-olds but not in 5-year-olds, at first glance our results could appear to contradict earlier findings with infants. In the infant literature, even 4.5-month-olds elicit a language effect in a talker discrimination task (e.g., Fecher & Johnson, 2019b; Johnson et al., 2011). Does this mean that the development of the language familiarity effect follows a U-shaped pattern, briefly disappearing at around 5 years of age and resurfacing at around 6 years of age? We find this explanation unlikely. Instead, it seems much more likely that the emergence of the language familiarity effect is highly subject to task demands and that infant studies typically employ discrimination paradigms that are conceptually very different from the recognition paradigms often used with older children (see Fecher & Johnson, 2018a, and Levi, 2019, for further discussion). Therefore, we refrain from concluding that no language familiarity effect exists at 5 years of age—we might have seen an effect with a different experimental approach—and only conclude that the effect appears to grow stronger over time during early childhood. Thus, consistent with our conclusion that increasing linguistic knowledge determines the developmental improvements in talker recognition, the key factor driving the development of the language familiarity effect in talker recognition seems to be the increase in performance for the familiar language rather than the decrease in performance for the unfamiliar language.

So if linguistic knowledge likely drives the improvements in talker recognition in the native language, then what type of linguistic knowledge might account for this effect? One possible explanation previously set forth by Fecher and Johnson (2018a) is that the reported developmental patterns might be linked to literacy education in schools and at home, specifically to children's rapidly improving knowledge of the native-language sound system (phonology) at this particular age (see also Bregman & Creel, 2014; Levi & Schwartz, 2013). Support for this idea comes from studies suggesting that language skill is related to children's talker discrimination performance (e.g., Dailey, Plante, & Vance, 2013) and studies demonstrating a relationship between reading skill and language-specific speech perception (e.g., Burnham, 2003). Here, we tested a subset of children on a standardized test of reading-related phonological processing abilities and then correlated the results of this test with children's talker recognition accuracy. This analysis showed no significant relationship between talker recognition (as captured by a voice lineup task) and phonological awareness and memory (as captured by CTOPP-2). Thus, this aspect of our study does not provide strong support for the notion that phonological awareness and memory drive improvements in talker recognition. Importantly, however, we cannot conclusively state that phonological knowledge does not play a role in the development of mature talker recognition abilities because we might well have seen a relationship between phonological processing and talker recognition if we had used a different talker recognition paradigm, tested a larger sample of children from a wider age range, had more variability in our data, or used a different (potentially more sensitive) measure of phonological ability.[3] That said, we readily admit that some other aspect of linguistic development besides phonological awareness and memory may be driving developmental improvements in talker recognition.

How do we move forward in our goal to understand the factors contributing to the development of familiar-language talker recognition? For one, follow-up studies could examine more directly the relationship between voice learning ability (as captured, e.g., by a training-identification task) and phoneme or word learning ability (as captured, e.g., by a comprehension or classification task involving the same set of voices), or they could test additional populations (e.g., children at risk for speech and language processing difficulties: see, e.g., Kadam et al., 2016; Perea et al., 2014; children growing up in multi-lingual or multi-accented homes: see also Fecher & Johnson, 2019a; Levi, 2018). Moreover, to be better able to distinguish between linguistic and general cognitive influences on talker processing ability, future research on the impact of factors such as working memory and attention span on talker processing is needed. Learning more about the role of these factors in the development of talker recognition is important because, as mentioned earlier, even though the current data lend strong support to the language attunement hypothesis (rather than the general maturation hypothesis), both linguistic and general cognitive/perceptual factors could contribute to the development of talker recognition. That is, we acknowledge that talker recognition might not be tied (exclusively) to increasing language knowledge in development but that various attentional, motivational, and other domain-general factors may be at play as children hone their talker recognition skills.

To conclude, the findings from this study suggest that talker recognition and spoken language processing are integrally related in child development, with both skills requiring significant time and experience to fully develop. We found that children's developmental improvements in talker recognition are limited to the familiar language. This potentially suggests that these improvements are driven primarily by linguistic rather than general cognitive or perceptual development. Based on the current findings, however, we cannot conclusively say what aspect of linguistic development could be driving developmental improvements in talker recognition, especially since we found no correlation between performance on a standardized test of phonological awareness and performance on familiar-language talker recognition. Nonetheless, the current work significantly advances our understanding of (the

[3] Note also that previous studies showing a correlation between phonological processing and indexical processing have reported significant results only for certain CTOPP-2 subtests (e.g., Kadam et al., 2016; Perrachione et al., 2011).

Table B1
Proportion correct talker recognition in each language condition and developmental scores provided by CTOPP-2 for each of five subtests and the two composite scores for the subset of children who completed both the talker recognition and CTOPP-2 parts of the experiment.

Participant	Gender	Age Group	Age in Months	Proportion Correct English	Proportion Correct Spanish	Elision	Blending Words	Sound Matching	Memory for Digits	Nonword Repetition	PACS	PMCS
1	F	5	60.4	0.75	0.75	379	427	309	422	407	372	415
2	F	5	60.8	0.50	0.25	299	271	321	422	331	297	377
3	F	5	61.0	0.75	0.75	356	411	367	396	349	378	373
4	F	5	61.3	0.50	1.00	260	271	367	422	313	299	368
5	F	5	62.4	0.25	0.25	322	382	309	497	407	338	452
6	F	5	62.5	0.75	0.75	299	300	309	422	428	303	425
7	F	5	62.7	0.50	1.00	428	597	486	497	449	504	473
8	F	5	62.8	0.75	0.75	322	382	332	343	331	345	337
9	F	5	63.0	0.00	1.00	299	355	321	473	407	325	440
10	F	5	67.0	0.75	0.50	487	563	486	370	387	512	379
11	F	5	70.8	0.50	1.00	344	397	356	448	387	366	418
12	M	5	60.8	0.25	0.50	415	411	321	497	368	382	433
13	M	5	60.9	0.00	0.50	440	411	460	343	263	437	303
14	M	5	63.5	0.75	1.00	356	286	344	448	407	329	428
15	M	5	63.6	0.25	0.50	344	271	272	370	407	296	389
16	M	5	64.2	0.75	0.50	333	382	321	396	368	345	382
17	M	5	68.5	0.75	0.75	367	313	332	396	368	337	382
18	M	5	69.8	0.25	1.00	428	382	356	422	471	389	447
19	M	5	70.6	0.75	1.00	333	271	321	396	387	308	392
20	M	5	71.3	0.50	0.75	278	397	356	473	407	344	440
21	F	6	72.7	0.50	0.75	415	427	500	370	407	447	389
22	F	6	73.8	0.75	0.25	391	382	424	473	368	399	421
23	F	6	74.1	1.00	0.75	428	469	472	546	349	456	448
24	F	6	74.8	0.75	0.50	415	440	435	497	428	430	463
25	F	6	74.9	1.00	0.50	311	382	356	370	349	350	360
26	F	6	75.5	0.75	1.00	428	531	460	473	471	473	472
27	F	6	76.3	1.00	0.75	367	382	367	473	407	372	440
28	F	6	81.7	0.75	0.25	391	300	259	448	331	317	390
29	F	6	81.7	0.75	0.25	311	286	424	422	407	340	415
30	F	6	83.5	0.75	0.50	596	485	500	546	428	527	487
31	M	6	73.2	0.75	0.50	367	411	332	546	519	370	533
32	M	6	74.1	0.75	1.00	520	515	513	546	543	516	545
33	M	6	76.5	0.75	0.75	379	485	448	546	471	437	509
34	M	6	78.0	0.75	0.50	403	469	297	396	449	390	423
35	M	6	78.3	0.75	0.50	311	368	285	497	387	321	442
36	M	6	79.7	0.75	0.75	391	411	472	473	407	425	440
37	M	6	82.3	0.50	0.25	428	500	435	370	349	454	360
38	M	6	83.0	0.50	0.50	415	485	424	546	407	441	477
39	M	6	83.1	1.00	0.75	452	500	460	546	349	471	448
40	M	6	83.6	0.50	0.75	391	411	401	546	368	401	457

Note. CTOPP-2: Comprehensive Test of Phonological Processing–Second Edition (Wagner et al., 2013); PACS: Phonological Awareness Composite Score; PMCS: Phonological Memory Composite Score; F: female; M: male.

development of) human talker recognition abilities, and it also generates new hypotheses about how different (linguistic and other) experiences might help to explain individual differences in talker recognition across the lifespan.

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Appendix A

Examples of English test sentences
1. The last concert given at the opera was a tremendous success.

2. My grandparents' neighbor is the most charming person I know.
Examples of Spanish test sentences
1. El niño se levantó temprano para ver el sol. (The boy got up early to see the sun.)
2. El nuevo presidente será elegido en mayo. (The new president will be elected in May.)

Appendix B

See Table B1.

Appendix C

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2020.104991.

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