Developmental Psychology

Infants Discriminate Subtle Nasal Contrasts Late: Evidence From Field Psycholinguistic Experiments on Tagalog-Learning Infants in the Philippines

Rowena Garcia, Michael C. Valdez, and Natalie Boll-Avetisyan

Online First Publication, August 28, 2025. https://dx.doi.org/10.1037/dev0002053

CITATION

Garcia, R., Valdez, M. C., & Boll-Avetisyan, N. (2025). Infants discriminate subtle nasal contrasts late: Evidence from field psycholinguistic experiments on Tagalog-learning infants in the Philippines. *Developmental Psychology*. Advance online publication. https://dx.doi.org/10.1037/dev0002053

AMERICAN PSYCHOLOGICAL ASSOCIATION

Developmental Psychology

ISSN: 0012-1649

https://doi.org/10.1037/dev0002053

Infants Discriminate Subtle Nasal Contrasts Late: Evidence From Field Psycholinguistic Experiments on Tagalog-Learning Infants in the Philippines

Rowena Garcia[1, 2, 3], Michael C. Valdez[3], and Natalie Boll-Avetisyan[2]

[1] Language Development and Multilingualism Research Area, Leibniz-Centre General Linguistics, Berlin, Germany

[2] Department of Linguistics, University of Potsdam

[3] Department of Speech Pathology, University of the Philippines Manila

Studies suggest that infants initially show universal discrimination abilities. However, this narrative has been heavily based on Indo-European languages. It has also been proposed that infants' speech sound discrimination is affected by acoustic salience, such that acoustically subtle contrasts are not discriminated until the end of an infant's first year. Furthermore, others have suggested an influence of word position and positional frequency in discrimination abilities. In Study 1, we analyzed a child-directed corpus of Tagalog and found that the /n/-/ŋ/ contrast is more frequent in the word-final than word-initial position, which might make the contrast easier to discriminate in the final than initial position. In three preregistered field psycholinguistic studies, we tested the nasal discrimination abilities of Tagalog-learning infants in the Philippines (total $n = 60$) using a habituation task and the central fixation paradigm. Experiment 1 tested 4- to 6-month-olds' discrimination of /na/ and /ŋa/, while Experiment 2 tested 10- to 12-month-olds. Experiment 3 tested 4- to 6-month-olds' discrimination of /an/ and /aŋ/. We found that only the 10- to 12-month-olds showed discrimination of /na/ and /ŋa/. The 4- to 6-month-olds did not show discrimination of the contrast in the word-initial nor in the final position. These results are in line with the acoustic salience account and with previous findings of studies in Asia showing a late discrimination of native contrasts. We discuss language- and context-specific factors that can explain these results.

Public Significance Statement
This research helps us better understand how infants growing up in the Philippines perceive speech, which is essential for acquiring their ambient language.

Keywords: infant speech perception, acoustic salience, phoneme frequency, habituation, Tagalog

Diana Leyva served as action editor.

Rowena Garcia https://orcid.org/0000-0003-1363-542X

Michael C. Valdez https://orcid.org/0009-0008-3761-0327

Natalie Boll-Avetisyan https://orcid.org/0000-0001-5446-946X

The data and script are available on the Open Science Framework at https://osf.io/8v659/. The corpus analysis was not preregistered, but the experiments were (https://osf.io/82v49 and https://osf.io/3aqwy/). The authors do not have any conflicts of interest. This project was funded by the Deutsche Forschungsgemeinschaft (DFG; German Research Foundation)—Project ID 317633480—SFB 1287 (Project C07), and by the University of Potsdam's Universitäre Forschungsschwerpunkt Kognitionswissenschaften (UFSKW).

The authors thank Chandan Narayan for sharing his experimental stimuli and for his support for the project. They thank Megha Sundara, Sharon Peperkamp, Linda Polka, Reiko Mazuka, Leher Singh, the Potsdam BabyLAB members, and the audience at the 24th International Congress of Infant Studies 2024 for their valuable feedback. They are grateful to Raúl Bendezú Araujo for project support, Alan Langus, Janina Camille Vargas, and Turgut Ağabeyoğlu for helping with experiment preparation, Lea Böhme for the offline coding, Alma Labro for ethics approval assistance, Rhenee Mae Espayos and Julia Garcia for their help in data collection, community members of Bagong Barrio for helping in participant recruitment, and last, to the families who participated in the experiments.

Rowena Garcia played a lead role in data curation, formal analysis, investigation, project administration, visualization, and writing–original draft and an equal role in conceptualization, funding acquisition, and methodology. Michael C. Valdez played a supporting role in project administration and writing–review and editing. Natalie Boll-Avetisyan played a lead role in writing–review and editing and an equal role in conceptualization, funding acquisition, and methodology.

Correspondence concerning this article should be addressed to Rowena Garcia, Language Development and Multilingualism Research Area, Leibniz-Centre General Linguistics, Pariser Street 1, 10719 Berlin, Germany. Email: garcia@leibniz-zas.de

Numerous studies have provided evidence that infants show a universal ability to discriminate phonetic contrasts from birth (Eimas, 1974, 1975; Jusczyk, 1997; Kuhl, 2004; Sundara et al., 2018; Werker, 2018; Werker et al., 1981; Werker & Tees, 1999). However, within their first year of life, they become specialized to their ambient language such that they retain or improve their ability to discriminate phonetic differences that are contrastive in their language, but their ability to discriminate noncontrastive differences declines (e.g., Anderson et al., 2003; Kuhl et al., 2006; Lovčević & Tsuji, 2024; Polka et al., 2001; Werker & Curtin, 2005; Werker & Tees, 1984; for reviews, see Kuhl, 2004; Tsuji & Cristia, 2014; Werker, 2024). This initial ability to discriminate contrasts is claimed to provide infants with the readiness to learn their ambient language, that is, any language of the world (Werker, 2018). However, the empirical evidence for this supposed universal discrimination ability from birth is far from universal (e.g., Kotera et al., 2024; Liu & Kager, 2016; Nam et al., 2025; Rosslund et al., 2024; Schönhuber et al., 2019). First, most of the present studies come from North American and Western European populations growing up with Indo-European languages (Singh et al., 2022). Second, it has been claimed that phonetic discrimination is modulated by other factors such as acoustic salience (Chládková & Paillereau, 2020; Narayan, 2019), phoneme frequency (Anderson et al., 2003), and phoneme position (Zamuner, 2006); resulting in later discrimination of some contrasts.

In this research, we aim to contribute to diversifying our evidence base by testing an understudied Austronesian language and testing infants outside of North America and Western Europe. Particularly, we tested the phonetic discrimination abilities of Tagalog-learning infants in the Philippines, which to our knowledge have not been tested so far. More importantly, given the properties of Tagalog, these field experiments also shed light on the effects of acoustic salience, phoneme frequency, and phoneme position on infants' discrimination abilities.

Sampling Bias in Phonetic Discrimination Research

In a review of phonetic discrimination studies in the past 50 years, Singh et al. (2022) reported that almost 50% of published studies on monolingual infants tested participants who were learning English, and 25% tested infants who were learning other Indo-European languages. This sampling bias is problematic for the generalizability of acquisition theories given the wide variation in the properties of the languages of the world and the manifold contexts in which infants acquire language; making the diversification of our research essential (Aravena-Bravo et al., 2024; Kidd & Garcia, 2022; Singh, 2024; Singh et al., 2022).

Importantly, recent studies conducted in Asia, particularly on infants learning Thai (Kra-Drai), Korean (Altaic), and Japanese (Japonic) crucially show only later discrimination even of native contrasts (Choi et al., 2024; Lovčević & Tsuji, 2024; Mazuka et al., 2022; Sato et al., 2010, 2012; Shin et al., 2018). For instance, Choi et al. found that 4- to 9-month-olds did not show discrimination of native Korean native lenis /p/ and aspirated /p^h/ stop contrast, and only the 10- to 12-month showed a weak sensitivity to the contrast. In Thai, only the 10- to 12-month-olds discriminated the native voiceless /p/ from the voiceless aspirated /p^h/, but not the 4- to 6-month-olds nor the 7- to 9-month-olds (Mazuka et al., 2022). It is striking that these studies conducted in Asia similarly show later discrimination of native contrasts, even though these languages are genetically unrelated and show large differences in their prosody and phoneme inventories. In this research, we expanded our research base by examining another Asian language from another language family (Austronesian), and by testing infants in a Global South country (the Philippines).

Influence of Acoustic Salience

It has been proposed that not all phonetic contrasts are distinguishable in similar ways, but that the trajectory of infant phonetic discrimination is affected by the acoustic nature of the contrast and in particular, the contrast's acoustic salience (Archer & Curtin, 2018; Archer et al., 2016; Chládková & Paillereau, 2020; Narayan, 2019; Narayan et al., 2010; Rosslund et al., 2024). Narayan (2019) explained that phonetic contrasts can be plotted on an acoustic salience scale with complete acoustic separation at one end and acoustic overlap (based on a relevant acoustic dimension, e.g., F2 transition) at the other end. The more the acoustic features or psychophysical properties of a contrast overlap, the lower its salience and thus the more difficult it will be to discriminate (for details on the acoustic cues that affect acoustic saliency of different contrasts, see Narayan, 2019). Aside from the raw acoustic details, salience is also based on how easily a contrast is perceived by adults (Narayan, 2019). In reviews of previous studies, it has been argued that experiments showing discrimination involved contrasts which are acoustically salient (e.g., Eimas, 1974; Moffitt, 1971) while those showing a lack of or difficulty in discrimination (e.g., Bosch & Sebastián-Gallés, 2003; Polka et al., 2001) can be attributed to low acoustic salience of the contrast (Chládková & Paillereau, 2020; Narayan, 2019).

One example of a contrast with low acoustic salience is /n/-/ŋ/. Narayan (2008) showed that the contrast between /na/ and /ŋa/ is less salient compared with the /na/ and /ma/ contrast, for example. In Tagalog, a language which has both these nasal contrasts in the initial as well as final position of a syllable, /n/ and /ŋ/ in the initial position are acoustically very similar in their F2 and F3 values as well as in dynamic energy change. Perceptually, adult native speakers of Tagalog made more mistakes in discriminating /na/ and /ŋa/ compared with /na/ and /ma/. Following up on this with infants, Narayan et al. (2010) tested infants' discrimination of the same nasal contrasts using the central fixation paradigm. In this paradigm, infants sit on their caregiver's lap while facing a monitor. Along with the visual stimulus, an auditory stimulus is presented, and the infants' looks to the screen are taken to indicate the infants' attention to the auditory stimulus. Infants were presented with either /na/ or /ŋa/ until they had habituated (based on a set habituation criterion) to it. After the habituation phase, infants were given one same (same stimulus as in the habituation) and one change (different from the habituation stimulus) test trial. Discrimination was indicated by longer looks to the screen in the change compared with the same test trial. Narayan et al. found that 4-month-old Canadian English-learning infants discriminated the salient /ma/ and /na/ contrast but not the /na/ and /ŋa/ contrast—at an age at which universal discrimination is usually found. They also found that infants in Canada who were also exposed to Philippine languages including Tagalog showed discrimination of the native /na/ and /ŋa/ contrast only at 10–12 months. These results suggest that even if a contrast is present in the ambient language, if acoustic salience is low, discrimination will be difficult for infants. According to Narayan (2019), infants may need enough experience with the ambient language (potentially via exposure to and use of lexical minimal pairs) to be able to discriminate a subtle contrast, that is why only the older age group showed discrimination.

However, Sundara et al. (2018), using a slightly different method but crucially, the same acoustic stimuli, showed countervailing evidence that American English-learning infants can discriminate /na/ and /ŋa/ at the age of 4 and 6 months. They explained that their paradigm (i.e., an infant-controlled paradigm wherein the trial stopped if the child looked away for more than one consecutive second) was more sensitive in capturing infants' discrimination abilities compared with Narayan et al. (2010). Additionally, the two studies differed in the habituation criterion used, trial length, and interstimulus interval within the trials; resulting in longer habituation in Sundara et al.'s study compared with Narayan et al.'s. Sundara et al. predicted that if Tagalog-learning infants would be tested using their more sensitive method, even younger infants will show discrimination of the subtle /na/ and /ŋa/ contrast. This prediction is directly tested in the present study.

Influence of Phoneme Frequency and Position

Other factors, beyond acoustic salience, have been shown to affect infants' discrimination abilities. One such factor is the frequency of the contrast and another factor is the position at which it occurs. Regarding frequency, studies have shown that infants are sensitive to the distributional properties of the speech signal that they are exposed to (Guenther & Gjaja, 1996; Jusczyk et al., 1990, 1994; Kuhl, 1993; Saffran et al., 1996) and that this affects phonetic discrimination (Maye et al., 2002). Anderson et al. (2003) showed that more frequent categories are learned earlier than less frequent ones, resulting in an early decline in infants' ability to discriminate nonnative contrasts which are related to a frequent category in their ambient language. They tested 8.5-month-old infants' discrimination of nonnative contrasts and found that infants performed more poorly in discriminating a nonnative contrast which was related to the more frequent contrast in their language (i.e., coronal stop), compared with a nonnative contrast which was related to the less frequent contrast in their language (i.e., dorsal stop). These previous findings indicate that more frequent contrasts in the ambient language might be learned earlier than less frequent contrasts. Given that infants' phonetic representations are perhaps initially tied to positions instead of being abstract categories that are independent of position or variation (Archer et al., 2016), it is possible that if a contrast occurs more often in the word-final position than in the initial position, infants will show earlier discrimination of the former than the latter.

Regarding the position of phonemes, infants seem to show more sensitivity to contrasts in word-initial compared with word-final position (Archer et al., 2016; Jusczyk et al., 1999; Swingley, 2005; Wang & Seidl, 2015; Zamuner, 2006). For example, Zamuner found that 10-month-old Dutch-learning infants could discriminate a voicing (i.e., /t/-/d/) and a place of articulation contrast (i.e., /p/-/t/, /p/-/k/) in the initial, but not in the final position of words. The author explained that contrasts in the initial position may be at an advantage because of their higher salience and their more consistent production compared with contrasts in the final position. Moreover, position has also been shown to affect phonotactic learning. Wang and Seidl (2015) familiarized 8- and 12-month-olds with bisyllabic nonwords which contained fricatives in either the onset of the second syllable or the coda position of the first syllable. Only the 12-month-olds showed learning of the phonotactic pattern, and crucially, only when the fricative was in the onset position.

To give a preview, in Study 1, we show that in Tagalog, the /n/-/ŋ/ contrast occurs more often in the word-final than word-initial position. Hence, based on positional frequency, it might be easier to discriminate this subtle nasal contrast in the final compared with the initial position. However, given the previous findings on infants' lower sensitivity to speech sounds in the final position, it is also possible that the frequency advantage will not be observed.

Tagalog-Learning Infants in Metro Manila

Tagalog is an understudied Western Austronesian language from the Philippines with almost 33 million native speakers and 54 million second-language users (Eberhard et al., 2025). The language has three nasals, namely /m, n, and ŋ/, which can occur in all syllable and word positions (Bondoc et al., in press; Schachter & Otanes, 1972). Tagalog-learning infants usually grow up in multilingual communities, with exposure to English, and/or additional local languages (Amora et al., 2020; Mahboob & Cruz, 2013; Philippine Statistics Authority, 2023a). Families living in urban communities such as Metro Manila also have good access to English mass and print media (Ledesma & Morris, 2005) as well as to English content on the internet (Philippine Statistics Authority, 2023b). In the Philippines, language dominance is related to socioeconomic status (SES), such that the higher the SES of a family, the more English they speak, and the less Tagalog-dominant they are (Amora et al., 2020; Ledesma & Morris, 2005). In this research, we tested Tagalog-learning infants from Tagalog-dominant families in Caloocan, the city with the fourth highest poverty incidence (i.e., not having sufficient income to meet basic needs; 2%) in the National Capital Region in 2023 (Philippine Statistics Authority, 2024). Testing participants from this population also answers the call for diversification of our science (Kidd & Garcia, 2022; Singh et al., 2022, 2024), which serves as a good test of the supposed universality of our theories on phonological development and brings us closer to identifying the potential causes of differences in the results of previous studies and therefore the conditions under which phonetic discrimination is observed.

The Current Research

In this research, we investigated whether Tagalog-speaking infants can discriminate the subtle nasal contrast /n/-/ŋ/ in the word-initial and word-final position, directly testing if the reason for the lack of discrimination in the Narayan et al.'s (2010) study with Tagalog-learning infants was due to lack of methodological sensitivity, as suggested by Sundara et al. (2018). Through a corpus study and three habituation experiments, we aimed to shed light on the role of acoustic salience, phonemic frequency, and a phoneme's word position on phonetic discrimination. We tested two age groups: 4- to 6-month-olds, the age during which universal discrimination is typically found, as well as 10- to 12-month-olds, an age at which language-specific perception is usually found, following Narayan et al.

Under the acoustic salience account (Chládková & Paillereau, 2020; Narayan, 2019; Narayan et al., 2010), only the older 10- to 12-month-olds will be able to discriminate the subtle /n/ and /ŋ/

contrast, and not the 4- to 6-month-olds. Under the universal discrimination account (Kuhl, 2004; Kuhl et al., 2006, 2008; Sundara et al., 2018), even the younger group will show discrimination of all contrasts. Additionally, if phoneme frequency affects infants' phonetic discrimination (Anderson et al., 2003), the 4- to 6-month-olds might show better discrimination of the /n/ and /ŋ/ contrast in the position where it is more frequent. If contrasts in the word-final position are discriminated later than contrasts in the initial position (Zamuner, 2006), Tagalog-learning infants will show earlier discrimination of the subtle contrast in the word-initial than in the word-final position.

We first present an analysis of Tagalog child-directed speech to have a more precise picture of the input that infants may receive and therefore, to be able to make specific predictions for the frequency account. Experiments 1–3 report field habituation experiments following Sundara et al.'s (2018) procedure, and importantly, using Narayan et al.'s (2010) stimuli that were also used by Sundara et al., to enhance comparability with the two previous studies. Experiment 1 focuses on 4- to 6-month-olds' discrimination of /n/ and /ŋ/ in the word-initial position, that is, /na/ and /ŋa/. Experiment 2 reports on testing the same contrast with 10- to 12-month-olds. Experiment 3 reports on 4- to 6-month-olds' discrimination of the /n/ and /ŋ/ contrast in the word-final position, that is, /an/ and /aŋ/.

It must be noted that the current experiments differed from those of Narayan et al. (2010) and Sundara et al. (2018) in the following ways: first, compared with Narayan et al., the infants presumably had more exposure to Tagalog, and they lived in an urban area in the Philippines instead of in an urban area in North America. Second, as there is currently no psycholinguistic child lab in the Philippines, infants had to be tested in a field context, where noise (e.g., electric fan) and visual distractions could not be controlled as well as in labs used in previous studies on phonetic discrimination. Field-based experiments with infants have worked in other studies including our own (Foushee & Srinivasan, 2024; Omane et al., 2023, 2024), and we built on our prior experience with field-based experiments with older children in the Philippines (Garcia et al., 2020, 2021, 2023; Garcia & Kidd, 2020). This field context also necessitated recruiting a wider age range of participants compared with studies conducted in labs with a database of potential participants.

Corpus Analysis

Method

Corpus Data

To estimate the frequency of occurrence of the nasal phonemes in the input that Tagalog-learning children hear, we analyzed Garcia and Kidd's (2022) Tagalog child-directed speech corpus. An infant-directed corpus would have been more appropriate, but the current corpus was the only one available to us. The corpus comprised 1-hr recordings of interactions between 20 pairs of children (ages: 2.01–3.10) and their caregivers. The participants were recorded at their homes while using a given set of materials including toys and picture books. The corpus was not phonetically transcribed, but since Tagalog has a transparent writing system (Himmelmann, 2005), it was possible to perform calculations on these orthographic transcriptions. The ELAN transcriptions were in a format similar to minCHAT which meant that transcribers wrote what they heard and indicated the dictionary form of this production (e.g., *nandun* vs. *nandoon*), preserving phonetic information in the transcription. However, given that the corpus was not designed for a phonological study, transcribers were not required to indicate phonological processes like assimilation.

Procedure and Preprocessing

The ELAN transcriptions were first converted to .cha format so they could be compatible with CLAN (MacWhinney, 2000). Using CLAN, words that begin and end with a nasal were extracted along with their token frequencies. We acknowledge that a syllable-level analysis would be more informative than our current word-level analysis, but there is currently no automated way to do this for Tagalog. The first author, who is a native speaker of Tagalog, manually marked the proper nouns (e.g., names of the children), sounds (e.g., *hmm*), and errors due to spelling of words (e.g., *ng* was printed out as an output for words that start with /ŋ/, but this word is pronounced as /naŋ/), for these to be excluded.

We found a total of 2,284 word forms that contained nasal consonants in word-initial or word-final position, with a total token frequency of 30,027. Note however that each different spelling or production of a word was considered as different forms (e.g., *nandun* was considered different from *nandoon*), which we did not correct for as this did not influence the frequency counts of our phonemes of interest. A total of 68 forms with 2,973 tokens were excluded because they were proper nouns, sounds, or transparency errors.

Transparency and Openness

The calculations were done in R Version 4.2.2 (R Core Team, 2022). The data and script are available on the Open Science Framework at https://osf.io/8v659/ (Garcia et al., 2025). This study was not preregistered. All data exclusions are reported.

Results and Discussion

Table 1 shows the token frequency of the nasal phonemes in the remaining 2,216 forms, with a total token frequency of 27,054. The results show that the dental /n/ is the most frequent nasal phoneme in both the word-initial and word-final positions. For the word-initial position, /ŋ/ is the least frequent, making up only 4% of the nasal phonemes. However, in the word-final position, /ŋ/ comprised 40% of the nasal phonemes. These indicate that children hear /ŋ/ more in the word-final than in word-initial position, and they receive more input discriminating /ŋ/ from /n/ in the final compared with the initial position. If phoneme frequency affects phonological development (Anderson et al., 2003), it is expected

Table 1
Token Frequency of the Nasal Phonemes in the Word-Initial and Word-Final Positions in Garcia and Kidd's (2022) Tagalog Child-Directed Speech Corpus

Phoneme	Word-initial position	Word-final position
/m/	2,398 (22%)	473 (3%)
/n/	8,088 (74%)	9,275 (57%)
/ŋ/	403 (4%)	6,417 (40%)

Note. The percentage of occurrence for each phoneme at each position is enclosed in parentheses.

that infants will discriminate this subtle contrast earlier in the word-final compared with the initial position.

Experiment 1: 4- to 6-Month-Olds' Discrimination of /na/ and /ŋa/

Method

In this preregistered experiment (https://osf.io/82v49), we investigated 4- to 6-month-old Tagalog-learning infants' discrimination of the subtle /n/ and /ŋ/ contrast in the word-initial position.

Participants

We aimed to reach a total sample size of 20 Tagalog-learning infants on the basis of a power analysis using Sundara et al.'s (2018) data, which showed that 20 participants would be enough to observe a main effect of test trial condition. We had to recruit a total of 30 from Metro Manila (19 boys, 11 girls) with a mean age of 166 days (range = 124–206) in order to reach our target of 20. Ten had to be excluded because of the following reasons: fussiness/crying (one boy), shorter looking times to the posttest trial compared with the average of the last three trials in the habituation phase (three boys, four girls), and for failing the inclusion criteria (one boy was from an English-dominant family, one boy was premature). The rest fulfilled our inclusion criteria: they were born full-term (at least 37 weeks of gestation), came from Tagalog-dominant families, and none had any reported history of hearing impairment or chronic illness. Half the recruited participants also had exposure to other languages through their caregivers (14 to English, one to Bisaya), and 80% had exposure to English through media. The 20 included participants had a mean age of 165 days (range = 124–205). Families were given ₱500 and a small gift for their participation. Additionally, families were provided with flyers containing information on language stimulation techniques and other tips on how to support children's language development. Ethical approval was obtained from the University of the Philippines Manila's Research Ethics Board.

Infants were recruited through advertisements in local health care and birthing (lying-in) centers and on social media, as well as through snowball sampling. Staff of community centers connected us with families of infants. We also distributed flyers among caregivers in the community church, markets, and so forth. The flyers contained information about the study and a link to a short registration form which determined whether they satisfied the inclusion criteria. Whenever families preferred that we register them for the study, we conducted short interviews and filled out the short registration form ourselves. We adjusted to the families' preferred ways of contact (e.g., via Facebook Messenger, SMS), sent them several reminders of the testing appointment, and made appointments flexible.

Materials

We used Narayan et al. (2010) three tokens of /na/ and /ŋa/ produced by a female native speaker of Tagalog (see Appendix A for the acoustic properties of the tokens). On the basis of these, we generated our audio stimuli: one habituation and one test audio stimulus for /na/, and the same for /ŋa/. For the /na/ stimuli, the /na/ tokens were concatenated on R (the three tokens were repeated five times and arranged in random order, resulting in 15 tokens), with each token being played every 1.267 s, resulting in a 19 s. file. The /na/ test trial contained the same 15 tokens, but had a different first token from the /na/ habituation trial. The same was done for the /ŋa/ trials. One salient change test trial was created for /ma/ similarly, using tokens from Narayan et al.

For the pretest and posttest phases, an audio stimulus which was saliently different from the target nasal stimuli was used: three tokens of /bɔk/ spoken by another female native speaker of Tagalog were concatenated. Similar to the habituation and test trials, each token was repeated five times each and arranged in random order, resulting in 15 tokens; but here, each token was played every 1.067 s, resulting in a shorter 16 s long single audio stimulus. The perceived loudness of all the concatenated audio stimuli was normalized to −23.0 Loudness Units Full Scale using Audacity. These resulting audio stimuli were then combined with a static colorful checkerboard picture to create video files, using DaVinci Resolve. These video files served as the experimental trials. Lastly, a chime sound was also combined with a video of moving circles to create an attention getter for the trials.

Procedure

Participants were tested individually in a community hall in Caloocan City, Metro Manila. Given that infant studies are not common in the country, the research needed to be conducted in a location that the community associates with legitimate and trustworthy endeavors. Temporary adjustments were made to make one of the community hall's rooms more suitable for testing, such as the addition of curtains, fans, and room dividers. We also prepared a mat and toys for infants who needed a break.

Infants sat on their caregiver's lap while they were both facing a 15.6 in. laptop monitor with an eye-tracker (Tobii Pro X3-120) on the bottom bezel and a webcam on top. The speakers were hidden behind the monitor, and the keyboard was covered by a piece of cloth to lessen distractions. The experimenter sat behind a wooden panel, controlled the experiment using an external keyboard and another monitor, and observed the participant through the webcam footage. The experimenter pressed and held a button on the keyboard to indicate that the infant was looking at the screen and released this button when the infant was looking away. The webcam footage of the participant was also recorded for offline coding.

We used an infant-controlled central fixation procedure following Sundara et al. (2018), and combined this with mobile eye tracking. Each experiment session started with a 5-point calibration using Tobii Pro Lab 1.118. A video of a moving rattle with sound was used to mark the calibration points. If the accuracy degree was below five, the experimenter proceeded to the experiment. If not, recalibration of all or some of the calibration points was done once. Caregivers wore a darkened pair of sunglasses, so their eyes would not be detected by the eye-tracker. The collection of eye data was needed for a separate study and the results from the eye tracking are not reported here.

The experiment was conducted on Psychopy 2022.2.5 (Peirce et al., 2019) using the Titta toolbox (Niehorster et al., 2020), as it allowed for the simultaneous use of an eye-tracker and the coding of looks and looks away from the screen. Before each trial, the attention getter was presented. Once the infant looked at the screen, the trial started. A trial ended if a child looked away for more than 1 s or upon reaching the end of the video stimulus. In the pretest, test, and posttest phases, if a child accumulated a looking time of less than 2 s in a trial, this trial was repeated once. The visual stimulus presentation covered 1,720 × 880 pixels of the full HD screen.

The pretest phase consisted of a single /bɔk/ trial. The pretest phase was followed by the habituation phase. Half the infants were assigned to the /na/ habituation condition, while the other half were assigned to the /ŋa/ habituation condition. The habituation video stimulus was played multiple times until the habituation criterion was reached (i.e., the sum of the looks to the last three trials was less than 50% of the sum of the looks to the longest three consecutive trials) or a maximum of 25 trials had been played. There were a minimum of six trials before the habituation phase ended. Moreover, because of the difficulty in programming the sliding comparisons in Psychopy for determining if the habituation criterion had been reached, the experiment was programed such that the last three habituation trials might have an overlap with the longest three habituation trials, for example, last three trials were Trials 13–15, and the longest three trials were Trials 11–13. However, there was no instance of this in the analyzed data for Experiment 1. Those who did not reach the habituation criterion within 25 trials were excluded from the analysis. After the habituation phase, the test phase began. The test phase consisted of one "same" (similar stimulus as in the habituation, i.e., /na/ for those who got the /na/ habituation condition) and one "subtle change" trial (i.e., /ŋa/ for those who got the /na/ habituation condition) which were presented in a counterbalanced order across participants, as well as one "salient change" trial (i.e., a /ma/ trial) that always occurred at the end of the test phase. The addition of a final test trial which was not part of the habituation phase for any participant is not typical for this paradigm. We collected this data as an attempt to also get information about the infants' discrimination of a more salient contrast, that is, /m/ versus /n/ or /ŋ/. A separate experiment would have been more appropriate to address this, but given the conditions related to the fieldwork, particularly the restricted time for participant recruitment, we included this additional test item, which arguably did not have any influence on the more crucial test trials. The experiment ended with a posttest phase using the same /bɔk/ trial as in the pretest phase. Those who did not show longer looks to the posttest trial compared with the average of their looks to the last three habituation trials were excluded from the analysis, following Sundara et al. (2018). This exclusion was to ensure that infants included in the analyses dishabituated to the posttest trials and were still paying attention to the stimuli during the latter part of the experiment.

Data Analysis

As preregistered, the dependent variable was the accumulated looking time per test trial (same trial, change trial). Looking behavior was manually coded live during the experiment, and additionally recorded by an eye-tracker. Moreover, all the test trials were also coded frame-by-frame offline by a research assistant who was blind to the conditions. The offline coding accounted for false continuations of the trials (i.e., trial continued even if the child looked away for more than one consecutive second) due to the needed reaction time of the experimenter to indicate a look away; which meant that looks after more than 1 s of look away were not included in the accumulated looking time for a test trial. Here, we present a statistical analysis using the offline coding,[1] but the analysis with the live coding results were very similar and can be found on Open Science Framework at https://osf.io/8v659/. We fitted linear mixed-effects models using the lmer function of the lme4 package (Version 1.1-35.5, Bates et al., 2015). The models included the main effects and interaction of habituation stimulus (/na/ or /ŋa/) and test trial conditions (same, subtle change), and a random participant intercept. To inspect significant interaction of variables, the emmeans package (Version 1.10.5, Lenth, 2024) was used. As an exploratory analysis, we also fitted linear mixed models with the test trial condition being either the same or the salient change trial.

Transparency and Openness

This study's design and analysis were preregistered on the Open Science Framework at https://osf.io/82v49. We report all data exclusions, as well as how we determined the sample size. The manual offline coding was done in ELAN 6.7 (*ELAN*, 2023), and the calculations were done in R Version 4.2.2 (R Core Team, 2022). The data and script are available at the Open Science Framework at https://osf.io/8v659/. The pretest/posttest materials as well as the attention getter can be obtained from the authors upon request. The nasal tokens were generously shared with us by Chandan Narayan.

Results

Table 2 shows the mean accumulated looking times for the pretest, habituation, and posttest phases (based on the live coding), as well as the mean number of habituation trials. The looking times for the same and subtle change test trials are presented in Figure 1.

The linear mixed-effects model showed a main effect of habituation stimulus (see Table 3) such that those who were habituated to the velar /ŋa/ looked longer overall to the test trials compared with those who were habituated to the dental /na/. Neither the effect of the test condition nor any other effect was significant.

Our exploratory analysis comparing the same test trial with the salient change /ma/ trial showed an interaction of habituation stimulus and test condition (see Appendix B). There were no other significant effects observed. Inspection of the significant interaction showed a diverging direction of the looking times for the habituation trials: those who were habituated with /na/ showed more looks to the change compared with the same test trial (Estimate: −0.81, *SE*: 0.67, $p = .24$), while it was the other way around for those who were habituated with /ŋa/ (Estimate: 1.44, *SE*: 0.74, $p = .07$). However, these test condition differences were not significant.

Discussion

The lack of a significant effect of test trial conditions indicate that we have no evidence for 4- to 6-month-olds' discrimination of the subtle /n/ and /ŋ/ contrast in the word-initial position. This result indicates that among the three studies, including the current one, which have tested the subtle /n/-/ŋ/ contrast at this age, only one (Sundara et al., 2018) has found evidence of sensitivity to this subtle contrast.

The significant effect of habituation—with longer looking times for test trials from infants habituated with /ŋa/ compared with those habituated by /na/—might be due to the lower frequency of /ŋ/

[1] Sundara et al. (2018) analyzed the manually coded online data, while Narayan et al. (2010) analyzed offline-coded data.

Table 2
Average Looking Times in Seconds for the Different Experiment Phases and the Average Number of Habituation Trials in Experiments 1–3

Phase	Experiment 1: 4- to 6-month /na/ vs. /ŋa/	Experiment 2: 10- to 12-month /na/ vs. /ŋa/	Experiment 3: 4- to 6-month /an/ vs. /aŋ/
Pretest phase	10.35 (4.30)	10.43 (4.79)	10.58 (4.63)
Habituation phase	64.05 (26.55)	72.41 (50.77)	72.10 (39.54)
Habituation trials	9.15 (3.36)	9.7 (3.36)	10.15 (3.98)
Posttest phase	7.97 (3.93)	8.85 (4.37)	8.88 (4.17)

Note. Standard deviations are enclosed in parentheses.

compared with /n/. It is possible that the former group was more attentive than the latter because their habituation stimulus was more interesting, given that they have lesser chances of encountering /ŋ/ compared with /n/ in daily life. This is in line with previous studies showing that infants generally look longer at novel compared with familiar stimuli (Fagan, 1970; Fantz, 1964). This explanation is also supported by the current finding that infants assigned to the /ŋa/ habituation phase also had a longer mean length of habituation phase compared with those who were habituated to /na/ (/ŋa/: 71.41 s vs. /na/: 56.68 s).

The exploratory analysis indicates that 4- to 6-month-olds also did not show evidence of discriminating the more salient /n/ versus /m/ contrast. Note, however, that no infant group was habituated to /ma/, and the addition of another change trial is not common in this paradigm.

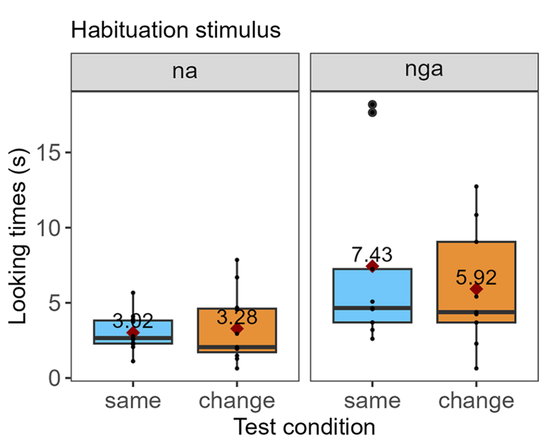
Given these results, we conducted the same experiment on older infants. In Experiment 2, we tested 10- to 12-month-old Tagalog-learning infants on their discrimination of the subtle /n/ and /ŋ/ contrast.

Experiment 2: 10- to 12-Month-Olds' Discrimination of /na/ and /ŋa/

Method

In this preregistered experiment (https://osf.io/3aqwy/), we investigated 10- to 12-month-old Tagalog-learning infants' discrimination of the subtle /n/ and /ŋ/ contrast in the word-initial position.

Figure 1
Average Accumulated Looking Times for the Same and Subtle Change Test Trials per Habituation Stimulus in Experiment 1



Note. See the online article for the color version of this figure.

Participants

The target number of participants and recruitment method were the same as in Experiment 1. We tested a total of 35 Tagalog-learning infants from Metro Manila (21 boys, 14 girls) with a mean age of 362 days (range = 278–396). All were born full-term and did not have any history of hearing impairment or chronic illness. Fifteen had to be excluded for the following reasons: fussiness/crying (two boys), shorter looking times to the posttest trial compared with the average of the last three trials in the habituation phase (four boys, five girls), differing direction of test trial results between manual live data and eye-tracking data (two boys, one girl) and failing the inclusion criteria (one boy was only 9 months). Among the recruited infants, 49% also had exposure to English through their caregivers and 91% through media. Data from 20 infants (M_{age} = 367 days, range = 319–396) were analyzed.

Materials

The same materials as in Experiment 1 were used.

Procedure

The same procedure as in Experiment 1 was followed.

Data Analysis

The same analysis as in Experiment 1 was performed. Additionally, as preregistered, we combined the data from Experiments 1 and 2, and tested for an effect of age on the infants' looking times to the test trials. The additional models included the main effects and interactions of age (4 to 6, 10 to 12), habituation stimulus (/na/ or /ŋa/) and test trial conditions (same, subtle change), and a random subject intercept.

Transparency and Openness

The same procedure as in Experiment 1 was followed. The results of the combined analysis of Experiments 1 and 2 can be found in the study's Open Science Framework at https://osf.io/8v659/. Below, we report the results of Experiment 2.

Results

Table 2 shows the mean accumulated looking times for the pretest, habituation, and posttest phases, as well as the mean number of habituation trials. The looking times for the same and subtle change test trials are presented in Figure 2. The linear mixed-effects model showed a main effect of test condition (see

Table 3
Main Effects and Interaction in Experiment 1

Predictor	Estimate	*SE*	*t*	*p*
(Intercept)	4.91	0.69	7.05	<.01
Habituation trial	−1.76	0.69	−2.54	.02
Test condition	0.31	0.47	0.67	.51
Habit × Test	−0.44	0.47	−0.95	.35

Note. *SE* = standard error.

Table 4), such that there were more looks to the subtle change trial compared with the same trial. There were no other significant effects. Our exploratory analysis comparing the same test trial with the salient change /ma/ trial showed no significant effects (see Appendix C).

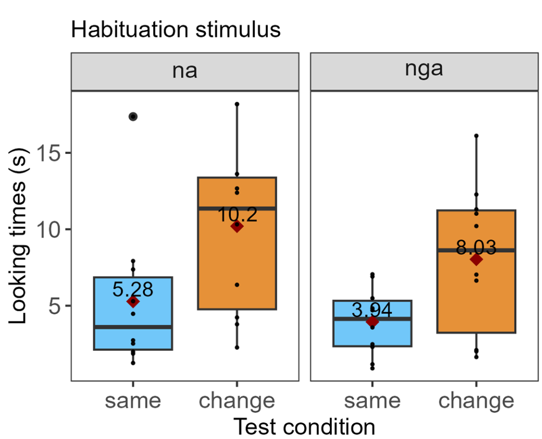
Discussion

The analysis of data from Experiment 2 revealed that 10- to 12-month-olds showed discrimination of the subtle /n/ and /ŋ/ contrast in the word-initial position. Both studies that tested infants' discrimination of this subtle contrast at this age (Narayan et al., 2010, and the present study) have shown that 10- to 12-month-olds can discriminate the /n/ and /ŋ/ contrast. Narayan et al. (2010) argued for an effect of saliency in discrimination, such that discriminating more subtle contrasts takes longer to acquire compared with discriminating more salient contrasts. The data from Experiments 1 and 2 also support this claim.

The finding from the current exploratory analysis showing no discrimination of the salient /na/ versus /ma/ contrast in the 10- to 12-month-olds, despite discrimination of the subtle /na/ and /ŋa/ contrast, seems unlikely. We take this result to suggest that the addition of a salient change trial at the end of the test phase, which was not used for habituation of any group of children, may not be methodologically appropriate for assessing infants' ability to discriminate the contrast.

Because of lack of evidence for 4- to 6-month-olds' discrimination of the subtle /n/ and /ŋ/ contrast in the word-initial position, in Experiment 3, we tested whether the contrast is easier to discriminate and is thus discriminated earlier in the word-final position compared with the initial position. If frequency has an influence on phonetic discrimination (Anderson et al., 2003), and given the higher frequency of the contrast in Tagalog word-final than initial position, it is possible that 4- to 6-month-olds can discriminate this contrast in the word-final position but not in the initial position. However, if infants are more sensitive to contrasts in the initial than in the word-final position (Zamuner, 2006), there might be no advantage of the higher frequency of the /n/ and /ŋ/ contrast in the word-final compared with the word-initial position.

Figure 2
Average Accumulated Looking Times for the Same and Subtle Change Test Trials per Habituation Stimulus in Experiment 2



Note. See the online article for the color version of this figure.

Experiment 3: 4- to 6-Month-Olds' Discrimination of /an/ and /aŋ/

Method

In this preregistered experiment (https://osf.io/3aqwy/), we investigated 4- to 6-month-old Tagalog-learning infants' discrimination of the subtle /n/ and /ŋ/ contrast in the word-final position.

Participants

The target number of infants and recruitment method were the same as in Experiments 1 and 2. We tested a new group of 4- to 6-month-old Tagalog-learning infants from Metro Manila (n = 32, 18 boys and 14 girls) with a mean age of 157 days (range = 120–206). All were born full-term and did not have any history of hearing impairment or chronic illness. Twelve had to be excluded for the following reasons: fussiness/crying (four boys, three girls), and shorter looking times to the posttest trial compared with the average of the last three trials in the habituation phase (two boys, three girls). Among the recruited infants, 53% also had exposure to other languages through their caregivers (14 to English, one to Bisaya, one to Kapampangan, one to Bikol) and 84% had exposure to English through media. Data from 20 infants (M = 157 days, range = 120–196) were analyzed.

Materials

Three tokens each of /an/, /aŋ/, and /am/ from the same speaker as the Narayan et al. (2010) recordings which were used in Experiments 1 and 2, were generously provided to us by Chandan Narayan. These tokens were concatenated to form the habituation and test trials. See Appendix A for the acoustic properties of the stimuli. Note that the F2 offset of /an/ and /aŋ/ are far apart from each other, which might add salience to the contrast. The creation of the stimuli was the same as in Experiment 1.

Procedure

The same procedure as in Experiment 1 was followed.

Data Analysis

The same analysis as in Experiment 1 was performed. Additionally, as preregistered, we combined the data from Experiments 1 and 3, and tested for an effect of word position of the contrast on the infants' looking times to the test trials. The additional models included the main effects and interactions of position (word-initial vs. word-final),

Table 4
Main Effects and Interaction in Experiment 2

Predictor	Estimate	*SE*	*t*	*p*
(Intercept)	6.86	0.85	8.09	<.01
Habituation trial	0.88	0.85	1.03	.32
Test condition	−2.25	0.61	−3.72	<.01
Habit × Test	−0.21	0.61	−0.34	.74

Note. *SE* = standard error.

habituation stimulus (/na/ or /ŋa/), and the test conditions (same, subtle change), and a random subject intercept.

Transparency and Openness

The same procedure as in Experiment 1 was followed. The results of the combined analysis of Experiments 1 and 3 can be found in the study's Open Science Framework at https://osf.io/8v659/. Below, we report the results of Experiment 3.

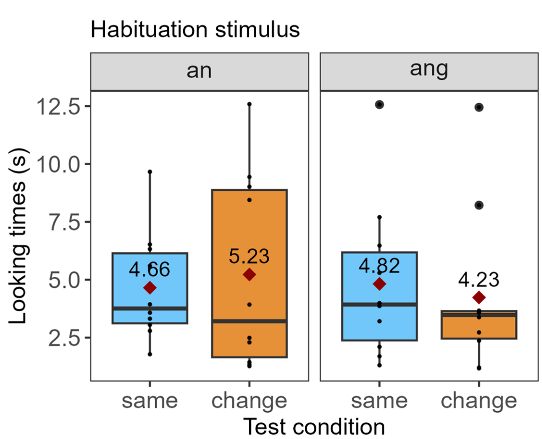
Results

Table 2 shows the mean accumulated looking times for the pretest, habituation, and posttest phases, as well as the mean number of habituation trials. The looking times for the same and change test trials are presented in Figure 3. There were no significant effects observed in the planned (see Table 5) nor in the exploratory analysis comparing the same test trial with the salient change /ma/ trial (see Appendix D).

Discussion

The results showed no evidence that 4- to 6-month-old Tagalog-learning children can discriminate the subtle /n/ and /ŋ/ contrast in the word-final position. Because of the null result, we do not have evidence to show that the higher frequency of this contrast in the word-final than in the word-initial position makes it easier to discriminate. It is possible that there was no frequency advantage because infants are also more sensitive to contrasts in the word-initial than in the final position (Zamuner, 2006). From the current findings, we also do not have evidence that 4- to 6-month-olds can discriminate /n/ and /m/ in the word-final position.

Figure 3
Average Accumulated Looking Times for the Same and Subtle Change Test Trials per Habituation Stimulus in Experiment 3



Note. See the online article for the color version of this figure.

General Discussion

Through a corpus analysis and three field habituation experiments closely following Sundara et al.'s (2018) method, we tested Tagalog-learning infants' ability to discriminate the subtle /n/-/ŋ/ contrast in the word-initial and word-final positions. In doing so, we tested the universal discrimination account (Kuhl, 2004; Kuhl et al., 2006, 2008; Sundara et al., 2018), which predicts that infants can discriminate all contrasts at birth, and the acoustic salience account (Chládková & Paillereau, 2020; Narayan, 2019; Narayan et al., 2010), which predicts that subtle contrasts take long to acquire, and are not discriminable at birth. Additionally, we tested if phoneme frequency affects infants' phonetic discrimination (Anderson et al., 2003), such that contrasts in the more frequent position are acquired earlier than contrasts in the less frequent position; and last, if contrasts in the word-final position are discriminated later than contrasts in the initial position (Zamuner, 2006). Our results indicate that the 10- to 12-month-old group was able to discriminate the subtle /n/ and /ŋ/ contrast. However, the younger 4- to 6-month-old group did not show discrimination of the subtle contrast in either word-initial or word-final position. These results have both methodological and theoretical implications that we discuss below.

From a methodological perspective, the present study was among the very first that probe infants' speech sound discrimination in infants growing up in the Global South, particularly in Southeast Asia. One reason for the lack of infant perception studies in these regions of the world might be the lack of availability of babylabs. With the present result of 10- to 12-month-olds showing discrimination of a subtle contrast, we demonstrate that the methodology of setting up a mobile lab for experimental field studies can be successfully applied.

From a theoretical perspective, the current data best support the acoustic salience account. It is possible that infants need enough experience with their ambient language (Narayan et al., 2010), namely exposure and use of lexical minimal pairs to be able to discriminate a subtle contrast (Narayan, 2019). Because of the need for experience, only older infants show evidence of discrimination. The current findings are more in line with Narayan et al. (2010) data from Tagalog-learning infants in Canada than with Sundara et al.'s (2018) data from English-learning infants in the United States of America. As we closely followed Sundara et al.'s method, the present study suggests that the lack of discrimination in the Narayan et al.'s study may not solely be attributed to lack of methodological sensitivity.

Our current data do not provide evidence supporting the frequency-based phonetic discrimination account (Anderson et al., 2003), as we did not find an earlier discrimination of the more frequent /n/-/ŋ/ contrast in the word-final position compared with the word-initial position. As the younger group did not show discrimination of the contrasts, we also do not have evidence that contrasts in the word-final position are discriminated later than contrasts in the initial position (Zamuner, 2006). It is possible that we did not observe

Table 5
Main Effects and Interaction in Experiment 3

Predictor	Estimate	*SE*	*t*	*p*
(Intercept)	4.73	0.55	8.56	<.01
Habituation trial	0.21	0.55	0.37	.71
Test condition	0.01	0.53	0.01	.99
Habit × Test	−0.29	0.53	−0.54	.59

Note. *SE* = standard error.

a frequency advantage, as this was canceled out by the lack of sensitivity of infants to contrasts in the word-final position. The effect of phoneme frequency and position can potentially be answered by testing an older group on discriminating the /n/-/ŋ/ contrast in the word-final position. If older infants show discrimination of the subtle contrast only in the initial position (as in Experiment 2), but not in the word-final position, this will suggest that contrasts in the word-final position are discriminated later than those in the initial position, even if the contrast is more frequent in the final than initial position. This awaits further research.

Cumulatively, the previous and current findings indicate that infants aged 4 to 6 months can discriminate the subtle /n/-/ŋ/ contrast under certain conditions, although it is more challenging for them compared with infants aged 10 to 12 months. The big question remains—how come the 4- and 6-month-old English-learning infants in Sundara et al.'s (2018) study showed discrimination of the same subtle nasal contrast which does not exist in the word-initial position in their language, but not the younger Tagalog-learning infants whose language natively has this contrast? One possibility is that the English-learning infants were processing the stimuli at a more surface, acoustic level. This follows one of Zamuner's (2006) explanations for the discrepancy in their finding of lack of discrimination of Dutch-learning 10-month-olds of stops in the final position, compared with Jusczyk's (1977) finding of discrimination in English-learning 2-month-olds. Zamuner explained that the English-learning infants might have discriminated the stimuli based solely on auditory cues, while the older Dutch-learning infants might have tried to access a phonetic mechanism to process the stimuli. This implies that the infants were paying attention to different cues, with the Tagalog-learning group potentially trying to identify words during the task.

A second possibility is that cross-linguistically and/or cross-culturally, infants differ in their developmental trajectory of showing sensitivity to specific aspects contained in the speech signal. Interestingly, our findings are in line with studies conducted in Asia which show late discrimination of native contrasts (/p/-/p^h/ in Korean: Choi et al., 2024; /p/-/p^h/ in Thai, /p/ vs. /b/ in Japanese: Mazuka et al., 2022; /a/-/aː/ in Japanese: Sato et al., 2010; /t/-/tt/ in Japanese: Sato et al., 2012; /s/-/s^*/ in Korean: Shin et al., 2018). It might be straightforward to assume that potential language similarities could be the common ground for why speech sound development in infants in Asia would be different. However, these languages are not genetically related and they differ in structural characteristics. For example, their phoneme inventories differ both in number and types of phonemes, and their prosodic structures are different too. Tagalog neither has lexical tone (unlike Thai) nor pitch accents (unlike Japanese). The only notable similarity relates to the syllable structure: all languages prefer simple syllables (mostly CV, V, VC, CVC; even if some consonant clusters are allowed in Thai and Korean, and in loanwords in Tagalog). The reasons for the later discrimination found in studies in Asia compared with others can only be answered by future research. Notably, to get a deeper understanding of similarities and differences, it is important to conduct controlled cross-linguistic comparisons, as in the present study, where the method was nearly identical to Sundara et al. (2018) yet the results were different. Cross-linguistic differences in controlled comparative settings have also been reported in the past, for example, by Piot et al. (2024) who found differences in sensitivity to low-salient consonant cluster contrasts in French and German-learning infants. Such results show that developmental paths may differ between infants learning different languages and in different environments. For now, the studies in Asia indicate that if we test beyond the small set of Indo-European languages reported in prior studies, the theories based on these latter findings may no longer hold. In the next subsection, we discuss other factors that might affect phonetic discrimination.

In terms of broader phonological development theories, the current findings are compatible with both attunement and perceptual learning theories (Aslin & Pisoni, 1980). Attunement claims that innate sensitivities are enhanced by experience, while perceptual learning theory claims that experience is required to induce the sensitivities in the first place. Following Narayan et al. (2010), it is possible that infants are initially only sensitive to more salient contrasts which they refine by experience. However, teasing these two theories apart would require further testing, particularly covering nonnative contrasts, as well as more salient native contrasts. The current findings do not provide evidence to fully support the native language magnet theory-expanded (Kuhl et al., 2008) which states that during the first year of life, infants' learning of the statistical and prosodic distributions of their language alters their neural structure, leading to stronger neural connections for these ambient regularities, and eventual use of these learned patterns in more complex linguistic tasks such as word learning (Kuhl, 2004). This model predicts universal discrimination of contrasts before 6 months and improvement in infants' ability to perceive native contrasts during the remaining half the first year. The current results do show improvement as only the older group showed discrimination of the subtle contrast, but they do not provide evidence for universal discrimination at a younger age.

Other Factors Affecting Phonetic Discrimination

Another potential explanation for the lack of evidence for nasal discrimination in the younger group in the current research is their low SES (Gonzalez-Gomez et al., 2021; Singh et al., 2022). Singh et al. (2022) showed that 6- to 12-month-old infants' discrimination of a native contrast (i.e., /ba/-/da/) was predicted by the family's SES, such that the higher the family SES, the better the discrimination of a native contrast. In particular, maternal occupation predicted discrimination, which the authors proposed to be due to different factors. One of these is mother–child engagement, with mothers with higher education or who work in higher status professions providing more stimulation to their children, resulting in better language sensitivity. Another is the increased financial capital of families with a mother who works in higher status professions. This higher income provides families with access to resources that stimulate language development (e.g., books) and allows them to engage with the infants to a greater extent, enabling parents to provide higher quantity and quality of infant-directed speech to their children, compared with families with lower SES (see Melvin et al., 2017, for how a linguistically rich environment may be more critical for early phonetic discrimination compared with a high family SES). We did not have information on maternal occupation in the current research, but the experiments were conducted in the city with the 4th highest poverty incidence in the National Capital Region in 2023 (Philippine Statistics Authority, 2024). Additionally, 84% of the mothers and 88% of the fathers in the current research did not have a college diploma, which severely limits one's chance of getting a job, more so, one that pays more than the minimum wage in the country (Philippine Business for Education, 2024).

Aside from the family SES, infants' bilingualism might have also influenced the current results. While some studies suggest similarities in phoneme development for monolingual and bilingual infants (Fennell & McDonald, 2024; Mousley et al., 2024), others have shown differences (Bosch & Sebastián-Gallés, 2003; Burns et al., 2007; Garcia-Sierra et al., 2011; Liu & Kager, 2016; Singh et al., 2017, 2018). For instance, Garcia-Sierra et al. (2011) found that only the 10- to 12-month-old Spanish English bilinguals and not the 6- to 9-month-olds showed evidence of neural discrimination of Spanish and English contrasts. The authors explained that this late discrimination of native contrasts by bilinguals might be because bilinguals have to remain more open to variations (e.g., a variation may be contrastive in one of their languages, but not in the other) and less neurally committed, given the higher variability in the input that they receive, compared with monolinguals of the same age. Bilinguals would need enough exposure to their languages to be able to identify the areas where their languages have opposing or the same rules (Singh et al., 2024). Although the participants of the present study are from Tagalog-dominant families, 47% had exposure to English through their caregivers and 91% through media.

Although we found significant effects of test conditions for the older group, indicating that the method worked, the field conditions in the current experiments might have affected the results. For example, it was quite hot in the testing room. Despite the use of electric fans, some infants became irritable and cried because of the heat (as explained by their caregivers) leading to dropout. Compared with most studies on phonetic discrimination, the current experiments were not conducted under lab conditions. This situation means that there were more external noise (e.g., electric fans) and distractions during the experiments, compared with those in other studies. On the one hand, such a situation is possibly more ecologically valid, as it is more similar to the infants' daily environment than lab conditions. On the other hand, the settings used in the paradigm were based on lab studies. For example, the field distractions could have potentially affected when infants habituate to the stimuli, and in this case, perhaps the set habituation criterion based on lab studies was inappropriate. One way to test this is by creating similar nonlab conditions in labs which have previously shown discrimination of subtle contrasts.

Despite the nonlab conditions of our experiments, we were able to address our research questions and to identify potential future directions of study. Conducting such field experiments in low-resource countries and populations without developmental labs can be one of the ways to address the lack of diversity in infant research (Singh et al., 2022) and language acquisition (Kidd & Garcia, 2022) and developmental science (Singh et al., 2025) in general. We believe that if developmental science is serious in making our science more diverse and inclusive, we should embrace the imperfect conditions of field psycholinguistic research for now, and recognize such studies as an informative first step into understanding how infants around the world, and not just in the Global North, acquire language.

Conclusion

Overall, we found discrimination of the subtle /n/-/ŋ/ contrast only in 10- to 12-month-old Tagalog-learning children and not in 4- to 6-month-olds. Our findings provide supporting evidence to the claim that acoustic salience has an influence on infant phonetic discrimination. The current research underlines the importance of conducting studies in underrepresented populations, which in the future will hopefully be able to show the exact conditions under which infants show sensitivity to a phonetic contrast.

References

Amora, K. K., Garcia, R., & Gagarina, N. (2020). Tagalog adaptation of the Multilingual Assessment Instrument for Narratives: History, process and preliminary results. *ZAS Papers in Linguistics*, *64*, 221–233. https://doi.org/10.21248/zaspil.64.2020.577

Anderson, J. L., Morgan, J. L., & White, K. S. (2003). A statistical basis for speech sound discrimination. *Language and Speech*, *46*(2–3), 155–182. https://doi.org/10.1177/00238309030460020601

Aravena-Bravo, P., Cristia, A., Garcia, R., Kotera, H., Nicolas, R. K., Laranjo, R., Arokoyo, B. E., Benavides-Varela, S., Benders, T., Boll-Avetisyan, N., Cychosz, M., Ben, R. D., Diop, Y., Durán-Urzúa, C., Havron, N., Manalili, M., Narasimhan, B., Omane, P. O., Rowland, C., … Woon, F. T. (2024). Towards diversifying early language development research: The first Truly Global International Summer/Winter School on Language Acquisition (/L+/) 2021. *Journal of Cognition and Development*, *25*(2), 242–260. https://doi.org/10.1080/15248372.2023.2231083

Archer, S. L., & Curtin, S. (2018). Fourteen-month-olds' sensitivity to acoustic salience in minimal pair word learning. *Journal of Child Language*, *45*(5), 1198–1211. https://doi.org/10.1017/S0305000917000617

Archer, S. L., Zamuner, T., Engel, K., Fais, L., & Curtin, S. (2016). Infants' discrimination of consonants: Interplay between word position and acoustic saliency. *Language Learning and Development*, *12*(1), 60–78. https://doi.org/10.1080/15475441.2014.979490

Aslin, R. N., & Pisoni, D. B. (1980). Some developmental processes in speech perception. In G. YeniKomshian, J. F. Kavanagh, & C. A. Ferguson (Eds.), *Child phonology: Perception and production* (pp. 67–96). Academic Press.

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Bondoc, I. P., Garcia, R., & Garcia, F. D. (in press). Tagalog. In S. Mcleod (Ed.), *The Oxford handbook of speech development in languages of the world*. Oxford University Press.

Bosch, L., & Sebastián-Gallés, N. (2003). Simultaneous bilingualism and the perception of a language-specific vowel contrast in the first year of life. *Language and Speech*, *46*(2–3), 217–243. https://doi.org/10.1177/00238309030460020801

Burns, T. C., Yoshida, K. A., Hill, K., & Werker, J. F. (2007). The development of phonetic representation in bilingual and monolingual infants. *Applied Psycholinguistics*, *28*(3), 455–474. https://doi.org/10.1017/S0142716407070257

Chládková, K., & Paillereau, N. (2020). The what and when of universal perception: A review of early speech sound acquisition. *Language Learning*, *70*(4), 1136–1182. https://doi.org/10.1111/lang.12422

Choi, Y., Nam, M., Yamane, N., & Mazuka, R. (2024). Lack of early sensitivity and gradual emergence of native phoneme categories: A pattern from underrepresented language learners. *Developmental Science*, *27*(5), Article e13422. https://doi.org/10.1111/desc.13422

Eberhard, D. M., Simons, G. F., & Fennig, C. D. (2025). *Ethnologue: Languages of the world* (28th ed.). SIL International. https://www.ethnologue.com/

Eimas, P. D. (1974). Auditory and linguistic processing of cues for place of articulation by infants. *Perception & Psychophysics*, *16*(3), 513–521. https://doi.org/10.3758/BF03198580

Eimas, P. D. (1975). Auditory and phonetic coding of the cues for speech: Discrimination of the [r-l] distinction by young infants. *Perception & Psychophysics*, *18*(5), 341–347. https://doi.org/10.3758/BF03211210

ELAN (Version 6.7) [Computer software] (2023). Max Planck Institute for Psycholinguistics, The Language Archive. https://archive.mpi.nl/tla/elan

Fagan, J. F., III. (1970). Memory in the infant. *Journal of Experimental Child Psychology*, *9*(2), 217–226. https://doi.org/10.1016/0022-0965(70)90087-1

Fantz, R. L. (1964). Visual experience in infants: Decreased attention to familiar patterns relative to novel ones. *Science*, *146*(3644), 668–670. https://doi.org/10.1126/science.146.3644.668

Fennell, C. T., & McDonald, M. (2024). Distributional learning of bimodal and trimodal phoneme categories in monolingual and bilingual infants. *Infant Behavior and Development*, *77*, Article 101983. https://doi.org/10.1016/j.infbeh.2024.101983

Foushee, R., & Srinivasan, M. (2024). Infants who are rarely spoken to nevertheless understand many words. *Proceedings of the National Academy of Sciences of the United States of America*, *121*(23), Article e2311425121. https://doi.org/10.1073/pnas.2311425121

Garcia, R., Albert, H. M. D., Bondoc, I. P., & Marzan, J. C. B. (2023). Collecting language acquisition data from understudied urban communities: A reply to Cristia et al. *Journal of Child Language*, *50*(3), 522–526. https://doi.org/10.1017/S0305000922000721

Garcia, R., Garrido Rodriguez, G., & Kidd, E. (2021). Developmental effects in the online use of morphosyntactic cues in sentence processing: Evidence from Tagalog. *Cognition*, *216*, Article 104859. https://doi.org/10.1016/j.cognition.2021.104859

Garcia, R., & Kidd, E. (2020). The acquisition of the Tagalog symmetrical voice system: Evidence from structural priming. *Language Learning and Development*, *16*(4), 399–425. https://doi.org/10.1080/15475441.2020.1814780

Garcia, R., & Kidd, E. (2022). Acquiring verb-argument structure in Tagalog: A multivariate corpus analysis of caregiver and child speech. *Linguistics*, *60*(6), 1855–1906. https://doi.org/10.1515/ling-2021-0107

Garcia, R., Roeser, J., & Höhle, B. (2020). Children's online use of word order and morphosyntactic markers in Tagalog thematic role assignment: An eye-tracking study. *Journal of Child Language*, *47*(3), 533–555. https://doi.org/10.1017/S0305000919000618

Garcia, R., Valdez, M. C., & Boll-Avetisyan, N. (2025, May 22). *Phonetic discrimination in Tagalog-learning infants*. Open Science Framework. https://osf.io/8v659/

Garcia-Sierra, A., Rivera-Gaxiola, M., Percaccio, C. R., Conboy, B. T., Romo, H., Klarman, L., Ortiz, S., & Kuhl, P. K. (2011). Bilingual language learning: An ERP study relating early brain responses to speech, language input, and later word production. *Journal of Phonetics*, *39*(4), 546–557. https://doi.org/10.1016/j.wocn.2011.07.002

Gonzalez-Gomez, N., O'Brien, F., & Harris, M. (2021). The effects of prematurity and socioeconomic deprivation on early speech perception: A story of two different delays. *Developmental Science*, *24*(2), Article e13020. https://doi.org/10.1111/desc.13020

Guenther, F. H., & Gjaja, M. N. (1996). The perceptual magnet effect as an emergent property of neural map formation. *The Journal of the Acoustical Society of America*, *100*(2), 1111–1121. https://doi.org/10.1121/1.416296

Himmelmann, N. P. (2005). Tagalog. In K. A. Adelaar & N. P. Himmelmann (Eds.), *The Austronesian languages of Asia and Madagascar* (pp. 350–376). Routledge.

Jusczyk, P. W. (1977). Perception of syllable-final stop consonants by 2-month-old infants. *Perception & Psychophysics*, *21*(5), 450–454. https://doi.org/10.3758/BF03199501

Jusczyk, P. W. (1997). *The discovery of spoken language*. MIT Press.

Jusczyk, P. W., Bertoncini, J., Bijeljac-Babic, R., Kennedy, L. J., & Mehler, J. (1990). The role of attention in speech perception by young infants. *Cognitive Development*, *5*(3), 265–286. https://doi.org/10.1016/0885-2014(90)90018-O

Jusczyk, P. W., Goodman, M. B., & Baumann, A. (1999). Nine-month-olds' attention to sound similarities in syllables. *Journal of Memory and Language*, *40*(1), 62–82. https://doi.org/10.1006/jmla.1998.2605

Jusczyk, P. W., Luce, P. A., & Charles-Luce, J. (1994). Infants' sensitivity to phonotactic patterns in the native language. *Journal of Memory and Language*, *33*(5), 630–645. https://doi.org/10.1006/jmla.1994.1030

Kidd, E., & Garcia, R. (2022). How diverse is child language acquisition research? *First Language*, *42*(6), 703–735. https://doi.org/10.1177/01427237211066405

Kotera, H., Khattab, G., Boll-Avetisyan, N., & Höhle, B. (2024). German infants' discrimination of the English /æ/-/ɛ/ contrast: Evidence from a cross-sectional and a longitudinal study. *Infant Behavior and Development*, *77*, Article 101984. https://doi.org/10.1016/j.infbeh.2024.101984

Kuhl, P. K. (1993). Early linguistic experience and phonetic perception: Implications for theories of developmental speech perception. *Journal of Phonetics*, *21*(1–2), 125–139. https://doi.org/10.1016/S0095-4470(19)31326-9

Kuhl, P. K. (2004). Early language acquisition: Cracking the speech code. *Nature Reviews Neuroscience*, *5*(11), 831–843. https://doi.org/10.1038/nrn1533

Kuhl, P. K., Conboy, B. T., Coffey-Corina, S., Padden, D., Rivera-Gaxiola, M., & Nelson, T. (2008). Phonetic learning as a pathway to language: New data and native language magnet theory expanded (NLM-e). *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1493), 979–1000. https://doi.org/10.1098/rstb.2007.2154

Kuhl, P. K., Stevens, E., Hayashi, A., Deguchi, T., Kiritani, S., & Iverson, P. (2006). Infants show a facilitation effect for native language phonetic perception between 6 and 12 months. *Developmental Science*, *9*(2), F13–F21. https://doi.org/10.1111/j.1467-7687.2006.00468.x

Ledesma, H. M. L., & Morris, R. D. (2005). Patterns of language preference among bilingual (Filipino–English) boys. *International Journal of Bilingual Education and Bilingualism*, *8*(1), 62–80. https://doi.org/10.1080/jBEB.v8.i1.pg62

Lenth, R. V. (2024). *emmeans: Estimated marginal means, aka least-squares means* [Computer software]. https://rvlenth.github.io/emmeans/

Liu, L., & Kager, R. (2016). Perception of a native vowel contrast by Dutch monolingual and bilingual infants: A bilingual perceptual lead. *International Journal of Bilingualism*, *20*(3), 335–345. https://doi.org/10.1177/1367006914566082

Lovčević, I., & Tsuji, S. (2024). The developmental pattern of native and non-native speech perception during the 1st year of life in Japanese infants. *Infant Behavior and Development*, *76*, Article 101977. https://doi.org/10.1016/j.infbeh.2024.101977

MacWhinney, B. (2000). *The CHILDES project: Tools for analyzing talk* (3rd ed.). Lawrence Erlbaum.

Mahboob, A., & Cruz, P. (2013). English and mother-tongue-based multilingual education: Language attitudes in the Philippines. *Asian Journal of English Language Studies*, *1*, 1–17. https://doi.org/10.59960/1.a1

Maye, J., Werker, J. F., & Gerken, L. (2002). Infant sensitivity to distributional information can affect phonetic discrimination. *Cognition*, *82*(3), B101–B111. https://doi.org/10.1016/S0010-0277(01)00157-3

Mazuka, R., Choi, Y., & Onsuwan, C. (2022, July). *Developmental trajectory of infants? Discrimination of stop-contrasts revisited: New data from Korean-, Thai- and Japanese-learning infants* [Conference session]. International Congress of Infant Studies, Ottawa, Canada.

Melvin, S. A., Brito, N. H., Mack, L. J., Engelhardt, L. E., Fifer, W. P., Elliott, A. J., & Noble, K. G. (2017). Home environment, but not socioeconomic status, is linked to differences in early phonetic perception ability. *Infancy*, *22*(1), 42–55. https://doi.org/10.1111/infa.12145

Moffitt, A. R. (1971). Consonant cue perception by twenty- to twenty-four-week-old infants. *Child Development*, *42*(3), 717–731. https://doi.org/10.2307/1127443

Mousley, V. L., MacSweeney, M., & Mercure, E. (2024). Revisiting perceptual sensitivity to non-native speech in a diverse sample of bilinguals. *Infant Behavior and Development*, *76*, Article 101959. https://doi.org/10.1016/j.infbeh.2024.101959

Nam, M., Yamane, N., Hwang, H. K., Onsuwan, C., Choi, Y., & Mazuka, R. (2025). Early influence of language experience in non-native speech perception: Discrimination of three-way Thai stop contrasts by Korean and Japanese infants. *Infant Behavior and Development*, *78*, Article 102005. https://doi.org/10.1016/j.infbeh.2024.102005

Narayan, C. R. (2008). The acoustic–perceptual salience of nasal place contrasts. *Journal of Phonetics*, *36*(1), 191–217. https://doi.org/10.1016/j.wocn.2007.10.001

Narayan, C. R. (2019). An acoustic perspective on 45 years of infant speech perception, Part 1: Consonants. *Language and Linguistics Compass*, *13*(10), Article e12352. https://doi.org/10.1111/lnc3.12352

Narayan, C. R., Werker, J. F., & Beddor, P. S. (2010). The interaction between acoustic salience and language experience in developmental speech perception: Evidence from nasal place discrimination. *Developmental Science*, *13*(3), 407–420. https://doi.org/10.1111/j.1467-7687.2009.00898.x

Niehorster, D. C., Andersson, R., & Nyström, M. (2020). Titta: A toolbox for creating PsychToolbox and Psychopy experiments with Tobii eye trackers. *Behavior Research Methods*, *52*(5), 1970–1979. https://doi.org/10.3758/s13428-020-01358-8

Omane, P. O., Benders, T., & Boll-Avetisyan, N. (2024). Vowel harmony preferences in infants growing up in multilingual Ghana (Africa). *Developmental Psychology*, *60*(8), 1372–1383. https://doi.org/10.1037/dev0001776

Omane, P. O., Benders, T., Duah, R. A., & Boll-Avetisyan, N. (2023). Diversifying language acquisition research can be (partly) achieved in urban societies and with simplified methodologies: Insights from multilingual Ghana. *Journal of Child Language*, *50*(3), 532–536. https://doi.org/10.1017/S0305000923000090

Peirce, J., Gray, J. R., Simpson, S., MacAskill, M., Höchenberger, R., Sogo, H., Kastman, E., & Lindeløv, J. K. (2019). PsychoPy2: Experiments in behavior made easy. *Behavior Research Methods*, *51*(1), 195–203. https://doi.org/10.3758/s13428-018-01193-y

Philippine Business for Education. (2024). *2024 jobs outlook study: Survey and analysis on the inclination of companies to directly hire senior high school graduates*. https://pbed.ph/

Philippine Statistics Authority. (2023a). *2020 census of population and housing: Number of households by language/dialect generally spoken at home and highly urbanized city/municipality*. https://psa.gov.ph/content/tagalog-most-widely-spoken-language-home-2020-census-population-and-housing

Philippine Statistics Authority. (2023b). *2020 census of population and housing: Households using internet by location and region*. https://psa.gov.ph/statistics/population-and-housing/stat-tables

Philippine Statistics Authority. (2024). *2023 poverty statistics: Annual per capita poverty threshold and poverty incidence among families with measures of precision, by region, province and highly urbanized cities: 2018, 2021, and 2023*. https://psa.gov.ph/sites/default/files/phdsd/2023%20FY%20Official%20Poverty%20Statistics%20Publication_15August2024.pdf

Piot, L., Nazzi, T., & Boll-Avetisyan, N. (2024). Infants' sensitivity to phonotactic regularities related to perceptually low-salient fricatives: A cross-linguistic study. *Frontiers in Psychology*, *15*, Article 1367240. https://doi.org/10.3389/fpsyg.2024.1367240

Polka, L., Colantonio, C., & Sundara, M. (2001). A cross-language comparison of/d/-/th/perception: Evidence for a new developmental pattern. *Journal of the Acoustical Society of America*, *109*(5), 2190–2201. https://doi.org/10.1121/1.1362689

R Core Team. (2022). *R: A language and environment for statistical computing* [Computer software]. R Foundation for Statistical Computing. https://www.R-project.org/

Rosslund, A., Mayor, J., Cristia, A., & Kartushina, N. (2024). Native and non-native vowel discrimination in 6-month-old Norwegian infants. *Infant Behavior and Development*, *77*, Article 101992. https://doi.org/10.1016/j.infbeh.2024.101992

Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science*, *274*(5294), 1926–1928. https://doi.org/10.1126/science.274.5294.1926

Sato, Y., Kato, M., & Mazuka, R. (2012). Development of single/geminate obstruent discrimination by Japanese infants: Early integration of durational and nondurational cues. *Developmental Psychology*, *48*(1), 18–34. https://doi.org/10.1037/a0025528

Sato, Y., Sogabe, Y., & Mazuka, R. (2010). Discrimination of phonemic vowel length by Japanese infants. *Developmental Psychology*, *46*(1), 106–119. https://doi.org/10.1037/a0016718

Schachter, P., & Otanes, F. T. (1972). *Tagalog reference grammar*. University of California Press.

Schönhuber, M., Czeke, N., Gampe, A., & Grijzenhout, J. (2019). Infant perception of VOT and closure duration contrasts. *Journal of Phonetics*, *77*, Article 100916. https://doi.org/10.1016/j.wocn.2019.100916

Shin, M., Choi, Y., & Mazuka, R. (2018). Development of fricative sound perception in Korean infants: The role of language experience and infants' initial sensitivity. *PLOS ONE*, *13*(6), Article e0199045. https://doi.org/10.1371/journal.pone.0199045

Singh, L. (2024). Generalizability and representation in studies of infant perceptual narrowing: Considerations for future research. *Infant Behavior and Development*, *77*, Article 101998. https://doi.org/10.1016/j.infbeh.2024.101998

Singh, L., Barr, R., Quinn, P. C., Kalashnikova, M., Rocha-Hidalgo, J., Freda, K., & D'Souza, D. (2024). Effects of environmental diversity on exploration and learning: The case of bilingualism. *Journal of Experimental Psychology: General*, *153*(11), 2879–2898. https://doi.org/10.1037/xge0001562

Singh, L., Basnight-Brown, D., Cheon, B. K., Garcia, R., Killen, M., & Mazuka, R. (2025). Ethical and epistemic costs of a lack of geographical and cultural diversity in developmental science. *Developmental Psychology*, *61*(1), 1–18. https://doi.org/10.1037/dev0001841

Singh, L., Fu, C. S. L., Seet, X. H., Tong, A. P. Y., Wang, J. L., & Best, C. T. (2018). Developmental change in tone perception in Mandarin monolingual, English monolingual, and Mandarin-English bilingual infants: Divergences between monolingual and bilingual learners. *Journal of Experimental Child Psychology*, *173*, 59–77. https://doi.org/10.1016/j.jecp.2018.03.012

Singh, L., Loh, D., & Xiao, N. G. (2017). Bilingual infants demonstrate perceptual flexibility in phoneme discrimination but perceptual constraint in face discrimination. *Frontiers in Psychology*, *8*, Article 1563. https://doi.org/10.3389/fpsyg.2017.01563

Singh, L., Rajendra, S. J., & Mazuka, R. (2022). Diversity and representation in studies of infant perceptual narrowing. *Child Development Perspectives*, *16*(4), 191–199. https://doi.org/10.1111/cdep.12468

Sundara, M., Ngon, C., Skoruppa, K., Feldman, N. H., Onario, G. M., Morgan, J. L., & Peperkamp, S. (2018). Young infants' discrimination of

subtle phonetic contrasts. *Cognition*, *178*, 57–66. https://doi.org/10.1016/j.cognition.2018.05.009
Swingley, D. (2005). 11-month-olds' knowledge of how familiar words sound. *Developmental Science*, *8*(5), 432–443. https://doi.org/10.1111/j.1467-7687.2005.00432.x
Tsuji, S., & Cristia, A. (2014). Perceptual attunement in vowels: A meta-analysis. *Developmental Psychobiology*, *56*(2), 179–191. https://doi.org/10.1002/dev.21179
Wang, Y., & Seidl, A. (2015). The learnability of phonotactic patterns in onset and coda positions. *Language Learning and Development*, *11*(1), 1–17. https://doi.org/10.1080/15475441.2013.876270
Werker, J. F. (2018). Perceptual beginnings to language acquisition. *Applied Psycholinguistics*, *39*(4), 703–728. https://doi.org/10.1017/S0142716418000152
Werker, J. F. (2024). Phonetic perceptual reorganization across the first year of life: Looking back. *Infant Behavior and Development*, *75*, Article 101935. https://doi.org/10.1016/j.infbeh.2024.101935
Werker, J. F., & Curtin, S. (2005). PRIMIR: A developmental framework of infant speech processing. *Language Learning and Development*, *1*(2), 197–234. https://doi.org/10.1080/15475441.2005.9684216
Werker, J. F., Gilbert, J. H. V., Humphrey, K., & Tees, R. C. (1981). Developmental aspects of cross-language speech perception. *Child Development*, *52*(1), 349–355. https://doi.org/10.2307/1129249
Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development*, *7*(1), 49–63. https://doi.org/10.1016/S0163-6383(84)80022-3
Werker, J. F., & Tees, R. C. (1999). Influences on infant speech processing: Toward a new synthesis. *Annual Review of Psychology*, *50*(1), 509–535. https://doi.org/10.1146/annurev.psych.50.1.509
Zamuner, T. S. (2006). Sensitivity to word-final phonotactics in 9- to 16-month-old infants. *Infancy*, *10*(1), 77–95. https://doi.org/10.1207/s15327078in1001_5

Appendix A

Average Acoustic Measurements of the Stimuli Tokens Used in Experiments 1–3

Item	Nasal duration (ms)	Total duration (ms)	F2 onset/offset (Hz)	F3 onset/offset (Hz)	F1 midpoint (Hz)	F2 midpoint (Hz)
/na/	122.42	506.56	1799.71	2816.14	948.97	1505.88
/ŋa/	121.98	485.56	1592.70	2599.66	924.10	1496.41
/ma/	132.40	501.60	1365.19	2531.27	937.42	1437.45
/an/	253.57	440.36	1897.64	2649.53	333.78	1505.43
/aŋ/	242.78	430.51	1265.44	2752.02	289.04	1205.22
/am/	243.72	418.39	1345.13	2580.06	304.88	1383.33

Note. The values for the word-initial nasals reported here differ slightly from those reported in Narayan et al. (2010), which is probably due to a difference in how these properties were measured.

(*Appendices continue*)

Appendix B

Main Effects and Interaction in the Exploratory Salient Change Analysis in Experiment 1

Predictor	Estimate	*SE*	*t*	*p*
(Intercept)	4.91	0.83	5.93	<.01
Habituation trial	−1.08	0.83	−1.31	.21
Test condition	0.32	0.5	0.63	.53
Habit × Test	−1.13	0.5	−2.25	.04

Note. *SE* = standard error.

Appendix C

Main Effects and Interaction in the Exploratory Salient Change Analysis in Experiment 2

Predictor	Estimate	*SE*	*t*	*p*
(Intercept)	5.08	0.56	9.11	<.01
Habituation trial	−0.01	0.56	−0.01	.99
Test condition	−0.47	0.56	−0.85	.40
Habit × Test	0.68	0.56	1.22	.23

Note. *SE* = standard error.

Appendix D

Main Effects and Interaction in the Exploratory Salient Change Analysis in Experiment 3

Predictor	Estimate	*SE*	*t*	*p*
(Intercept)	4.81	0.65	7.43	<.01
Habituation trial	0.19	0.65	0.29	.77
Test condition	−0.07	0.41	−0.17	.87
Habit × Test	−0.27	0.41	−0.66	.52

Note. *SE* = standard error.

Received December 12, 2024
Revision received April 15, 2025
Accepted June 23, 2025 ■