The Flower Crown Task: Categorical Perception of VOT in Multilingual K2 Children in Singapore

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Background. Phonological perception develops with linguistic experience. In tests of phoneme identification, there is typically a graded switch from responses at one end of a spectrum of speech sounds to the other (e.g., /b/ to /p/), resulting in a characteristic s-shaped psychometric function, which is taken as evidence of categorical perception (Lisker & Abramson, 1964). Most adults show a steep slope at the transition from one category to the other. Atypically shallow slopes have been linked to reading difficulties in children (Noordenbos & Serniclaes, 2015). However, there is limited knowledge about how children growing up in multilingual environments resolve phonological categories in the presence of two-or-more linguistic systems. Singapore has English, Mandarin Chinese, Malay, Tamil as official languages. Most Singaporeans grow up with more than one language at home and in school (See '**Language Context**', below). To measure categorical perception in multilingual Singaporean children, we developed a new task called the Flower Crown Task. Here we present preliminary evidence about the distribution of multilingual children's scores on this task, and our preregistered plan to link each child's English language phoneme perception with a detailed inventory of their language background.

Methods. We recorded a Singaporean native speaker of English and Chinese saying the words 'beach' and 'peach', and edited the audio to create a Voice Onset Time (VOT) continuum from pre-voiced (-60ms) to aspirated (+90ms), in 10 milliseconds steps, resulting in 16 tokens. During the task, two images are presented on either side of the screen (a peach, a beach), in the guise of a game where children help a Monkey to collect flowers for his crown. Each trial, participants hear an audio file drawn randomly from the VOT continuum, and are asked to select the named picture. Ten decisions are made for each of the 16 VOT steps in the continuum, allowing a psychometric function to be fitted for each individual. Following the statistical procedure of Boets et al 2011, the slope value from the individual's logistic regression is taken as an index of sharpness of the transition from the /b/ to the /p/ category. All participants' parents also complete a detailed language inventory including a multilingual catalogue of input (CLIP) and output (CLOP). The task script was developed on an open source experiment platform OpenSesame (Python 2.7 version). The analysis script was written in R (R Core Team, 2019). The task and analysis plan were pre-registered on the Open Science Framework (https://osf.io/67f3v/?view_only=04ce6b0f14b249b69ae0a1f43b78dc58), with a target N of 150 children.

Project Progress. To date, 120 Singaporean children (5.5 to 6 years-of-age) were recruited and tested from bilingual Chinese/English backgrounds. Figure 1 shows psychometric functions for the children tested so far, where a range of slope values can be observed (Range: Min=-0.01, Max=0.21). When testing concludes, we will report norms for performance on this task, with interim results shown in Table 1. In addition, we will analyze the relationships between language backgrounds and performance in this task, using a combination of exploratory factor analysis and GLMM. As preregistered, the fixed effect(s) of language input will be implemented using the significant factor(s) arising from the PCA of CLIP and CLOP as predictor(s) of an individual's slope value, along with random effects for each participant. This analysis will reveal whether patterns of bilingual language exposure in early childhood are related to individual differences in phonetic perception at age 5.5-6 years.

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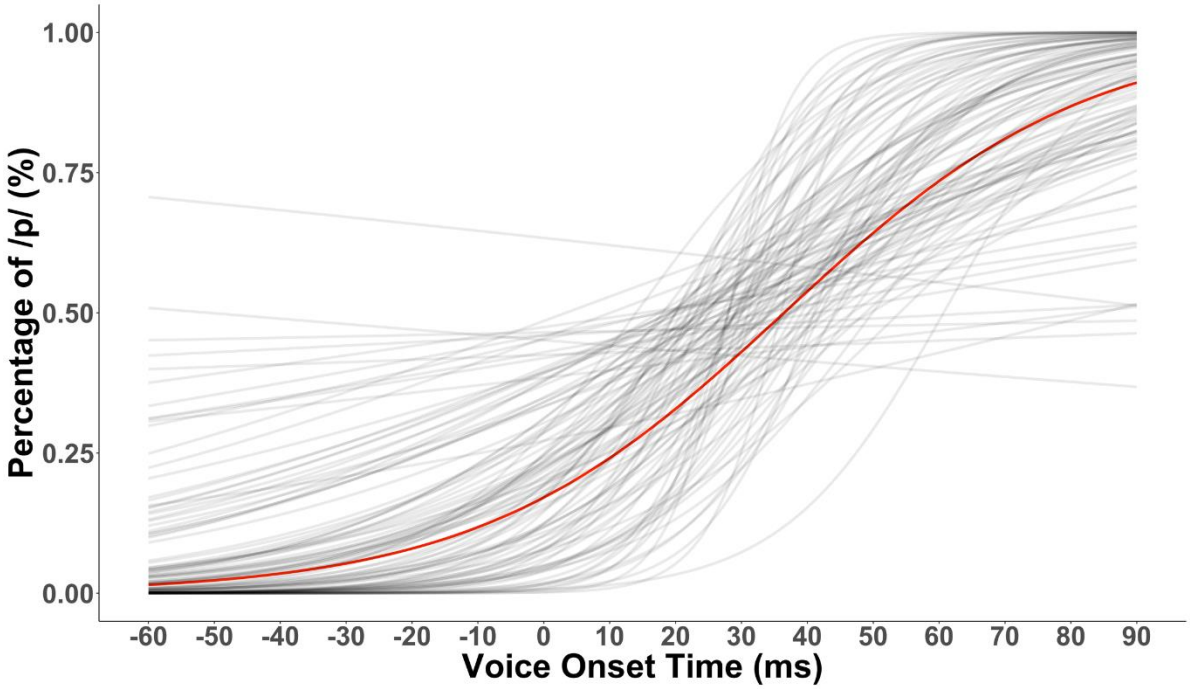

Figure 1. Percentage of /p/ identifications for each step of the VOT from 'beach' to 'peach'. Grey lines show individual psychometric functions (N=120) derived using logistic regression. Thick red line represents the middle of the distribution: the individual with the median slope.

Percentile	5	10	15	20	25	50	75	80	85	90	95
Slope (Scaled)	0.01	0.06	0.08	0.11	0.17	0.43	0.88	1.10	1.15	1.36	1.71

Table 1. Preliminary percentile thresholds for distribution of phoneme identification slope for bilingual Singaporean speakers of English and Chinese at 5.5 to 6 years-of-age. Scaling factor: 10. Larger slope values indicate a steeper transition between categories. A slope of zero indicates at-chance identification of the audio tokens as exemplars of 'beach' or 'peach'.

Language Context. Singapore has a rich multi-lingual landscape, supported by inter-generation multilingualism, and active bilingual education policies. English is the primary language of education, commerce and governance, with active policies to encourage bilingualism. The overwhelming majority of Singaporeans grow up in multilingual households, where an ethnically linked 'Mother Tongue' is spoken, resulting in more than 90% of Singaporean young people reporting literacy in English and another language (Wu, O'Brien, Styles, & Chen, in press 2020). The largest linguistic group in Singapore is ethnically Chinese Singaporeans, making up 73% of the population resident in Singapore at the time of the last census. The most common pattern of language exposure for children growing up in these families is a mulit-lingual mix of Mandarin Chinese and English (along with other Chinese varieties in some households – including Hokkien, Teochew, Cantonese, Hainanese and Hakka) (Woon 2018).

The mixed language environment in Singapore has produced language-specific phoneme targets in the spoken languages of Singapore. Acoustic measurements of speech have shown that Singapore English (Huang, 2003) and Singapore Mandarin (Ng, 2005) have quite different VOTs for their stop consonants, with typical /b, d, g/ occurring at +9ms VOT for Singapore Mandarin and +4ms for Singapore English, while typical /p, t, k/ occurs at +90ms for Singapore Mandarin, +25ms for Singapore English. Other languages in Singapore such as Singapore Malay have 11ms VOT for /b, d, g/ and 16ms VOT for /p, t, k/, while Singapore Hokkien has 8ms VOT for /b, d, g/ and 77ms for /p, t, k/. These are all very different from British English's VOTs for the same consonants (21ms and 56ms). This variation means that a child growing up in Singapore would hear a variety of different VOT contrasts, and their development of phonetic categories may differ depending on the pattern of linguistic exposure in their childhood. One possibility is that children exposed to high variation in VOT develop generally shallow slope values (i.e., fuzzier category boundaries), to cope with the variability. Another possibility is that children develop tightly formed categories for each of the linguistic patterns they hear. Since shallower slope is associated with poorer outcomes in reading (for monolinguals), it is important to understand whether a shallower slope might index something different in bi-/multilinguals.