

Supplementary material 1

French-learning 30-month-olds fail to learn pairs of Cantonese words differing by either a consonant, a vowel or a tone

Given the findings from Experiment 2 that French-learning 30-month-olds can learn pairs of phonetically very different Cantonese words (at least when no tone variability is present during the learning phase), we explored whether they could also learn minimal pairs of Cantonese words differing by either a consonant, a vowel or a tone. The current study is an extension of Chen et al. (2021), in which Cantonese-learning 30-month-olds were tested in their native language. Chen et al. (2021) found that Cantonese-learning 30-month-olds could learn pairs of words that contrasted by a vowel, but failed to do so when the words contrasted by either a consonant or a tone, revealing a vowel bias (V-bias) in word learning. Given that a consonant-bias (C-bias) is expected in French based on prior studies (Nazzi, 2005; see Nazzi & Cutler, 2019, for a general review of the C-bias in lexical processing in adults and infants across languages), the goal of the study was to determine whether French-learning toddlers can use fine phonetic details when learning words in an unknown, non-native language, and if so, whether they have the same bias as when processing native speech, hence a C-bias, or whether they would have the same bias as the Cantonese-learning toddlers in Chen et al. (2021), hence a V-bias. Finding a C-bias would support the notion that these toddlers use native language-specific top-down knowledge to start learning words in an unknown language, while finding a V-bias would support bottom-up effects, suggesting that there are acoustic cues in the Cantonese stimuli making the vowel contrasts easier to process.

The methods were identical to those of Experiment 1, except for the speech stimuli that were taken from Chen et al. (2021). More specifically, we used eye-tracking to test French-learning toddlers' ability to learn pairs of Cantonese pseudowords while processing fine phonetic information (consonant versus vowel versus tone information) at 30 months. On each of 8 trials, there was a word learning phase, during which each child saw a pair of cartoons. In each cartoon, an unfamiliar object was presented visually while 6 sentences in Cantonese, each containing a pseudoword labeling that object, were heard. Within each pair, the pseudowords differed by either a consonant (e.g., /tœ6/ vs. /kœ6/), a vowel (e.g., /khim3/ vs. /khem3/), or a tone (e.g., /tɛ3/ vs. /tɛ6/), depending on the condition to which the child was assigned (between-participant design). Following this short learning phase, the children were tested on whether they had learned the words by presenting them with the two unfamiliar objects side-by-side. As in Chen et al. (2021) and Experiment 1, learning was first

assessed by analyzing changes in proportion of looking times at the target object before (prenaming phase) and after (postnaming phase) it was named. Second, to determine whether word learning performance is linked to vocabulary size, as found in some studies on the processing of phonological information in word learning (e.g., Graf-Estes, Edwards & Saffran, 2011; May & Werker, 2014; Werker, Fennell, Corcoran, & Stager, 2002), we evaluated children's vocabulary size using a parental report.

Methods

Participants

Ninety-six monolingual French-learning 30-month-olds were tested and included in the analyses (mean age = 30 months, 19 days; range: 29 months, 28 days – 31 months, 10 days; 50 girls, 46 boys). All toddlers tested were receiving at least 80% of French input. Thirty-two toddlers were randomly assigned to each of the 3 testing conditions: C-contrast, V-contrast or T-contrast condition. Across the different conditions, the toddlers were matched for age and vocabulary outcomes/CDI (all $t_s < 1$), and female/male ratio. Thirty additional toddlers were tested and excluded from the analyses due to fussiness/crying ($N = 14$), technical problems ($N = 2$), otitis ($N = 6$) or because they did not meet the inclusion criteria ($N = 8$; see paragraph on data analysis for details).

All toddlers were tested in Paris. Parents of all participants provided written informed consent prior to the experiment. The experiment was approved by the CER (Comité d'Evaluation Ethique) of the Université Paris Cité. All data were obtained according to the principles expressed in the Declaration of Helsinki.

Stimuli

All stimuli were identical to those used in Chen et al. (2021).

Apparatus and Procedure

The Apparatus and Procedure were identical to those used in Chen et al. (2021) and in current Experiment 1.

Data Analysis and Exclusion Criteria

The Data analysis pipeline and the exclusion criteria were identical to those used in Chen et al. (2021) and in current Experiment 1.

Accordingly, to ensure that the toddlers were sufficiently engaged in the task, we excluded 93 trials (10 % of total) with less than 50% on-screen data during the test phase. We also excluded 54 additional trials (5.8% of total) in which the toddlers had a strong object bias in the pre-naming phase (>90% looking at one object). Additionally, we excluded 4 outliers, for which the criteria was defined before data collection and analysis as subjects whose average proportion of target looking (logit-transformed PTL – see results section for a complete definition) difference (i.e. PTL in the post-naming phase – PTL in the pre-naming phase) was 2.5 standard deviations away from the mean PTL difference across subjects. Finally, 4 toddlers with less than 4 analyzable trials were excluded. In the final sample, each participant provided, on average, 6.75 trials out of 8.

Vocabulary Measure

To determine the size of the toddler' receptive vocabulary, parents were asked to fill out the vocabulary part of the French equivalent (Kern, 2003) of the MacArthur Communicative Development Inventory: Toddlers (Fenson et al., 1991).

Results

Target looking: Window analysis

We calculated the mean proportion of target looking (PTL = total looking time to target/ total looking time to both objects) on each trial for both the pre- and postnaming phases. Time stamps that were not in any of the AOIs were treated as missing data, so that the calculated proportion of looking to one AOI is always relative to both AOIs, resulting in values between 0 and 1 (i.e., a proportion value of 0.5 means that each AOI was looked at equally long). These proportions were then logit-transformed for the analyses. Because the logit transformation for the values of 0s and 1s is undefined, we applied a small adjustment of 0.025 to the raw proportions before transforming them, as commonly done in this context (Fox & Weisberg, 2019). Logit-transformed looking estimates above 0 indicate greater proportion of looks to the target, while estimates below 0 indicate greater proportion of looks to the distractor.

We conducted a linear mixed-effect model using data from all 8 trials per condition, with *logit-transformed PTL* as the dependent variable, *naming* (pre- vs. post-naming phase) as the within-subject factor and *condition* (consonant- vs. vowel- vs. tone-contrasted) as the

between-subject factor, in interaction. Individual participant intercepts and item intercepts were included in the random effects structure. The full equation was:

$PTL \sim \text{Condition} \times \text{Naming} + (1 | \text{Item}) + (1 | \text{Participant})$.

None of the main effects nor interactions reached significance, including the effect of *Naming* ($\beta = 0.073$, $SE = 0.071$, $p = .303$) and the *Consonant-Vowel* ($\beta = 0.018$, $SE = 0.086$, $p = .836$) and *Vowel-Tone* ($\beta = -0.051$, $SE = 0.086$, $p = .555$) contrasts, indicating no significant increase in target looking between the pre-naming and the post-naming phase, as well as no significant differences in overall target looking between conditions.

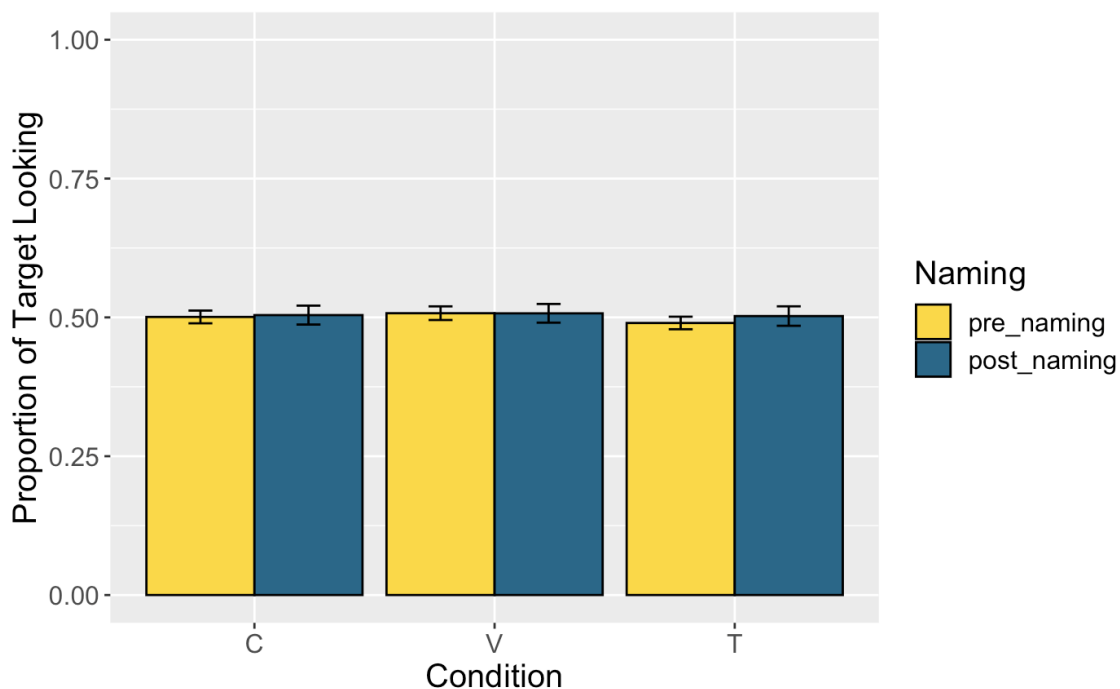


Figure 2. Results for the PTL analysis (Means and SEs), broken down by condition (C: consonant; V: vowel; T: tone). Values were logit-transformed for statistical analyses.

Correlation between PTL difference and CDI

CDIs were returned for 88 of the 96 children. The children produced a mean of 469 French words ($SD = 138$), with no difference between the 3 conditions ($F(2, 85) = .417$, $p = .661$). To determine whether learning performance is linked to the number of words produced, we performed Spearman's correlations between the recognition effect (logit-transformed $PTL_{\text{postnaming}} - \text{logit-transformed } PTL_{\text{prenaming}}$) and the number of words at test, for the 3 conditions. All correlations failed to reach significance (all $ps > .184$, value found for participants in the consonant condition).

Time course Analysis

As in the main experiments and in Chen et al. (2021), we had planned to conduct a growth curve analysis. Yet, upon visualization of the plot showing the raw averaged target looking data for the entire test phase broken down by condition (Figure 3), it appeared that the logit-transformed PTL fluctuated around 0 during the entire trial and that the amount of noise in the dataset was high, leading us to drop this analysis.

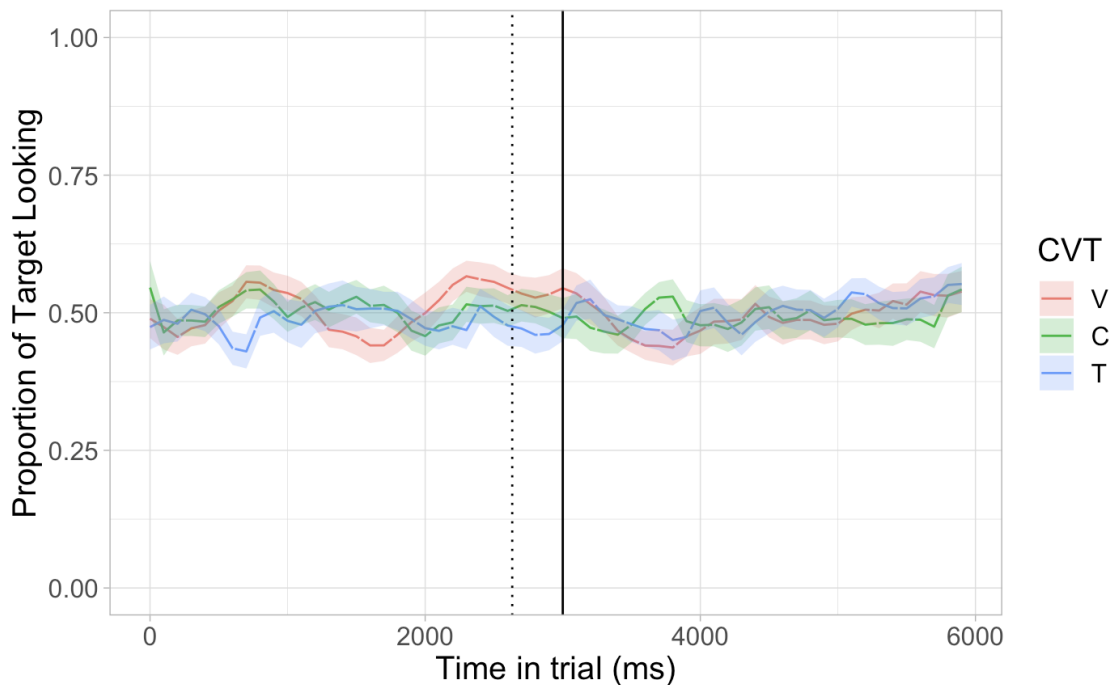


Figure 3. Averaged target looking data (on the raw proportion scale) for the entire test phase, broken down by condition. The dotted black line represents word-onset, the solid black line the beginning of the postnaming phase.

Discussion

In this study, we investigated whether French-learning 30-month-old toddlers can quickly learn new minimal pairs of words in an unfamiliar language, Cantonese. The words in each pair differed minimally in either a consonant, a vowel, or a tone, in order to assess these toddlers' ability to use phonological information in the process of learning words. The results establish that at 30 months, these children fail at the word learning task. Given that the experimental task was identical to the one used in Experiment 1, in which French-learning 30-month-olds could learn pairs of phonologically very different Cantonese words, failure here is likely due to the phonological similarity of the words within each pair, and this appeared to be the case for all three types of contrasts (consonants, vowels and tones). Lastly, we found no

evidence that performance correlated with French vocabulary size in any condition. Moreover, while a few prior studies have reported a link between the ability to learn new words and concurrent vocabulary size (e.g., Graf-Estes et al., 2011; May & Werker, 2014; Werker et al., 2002), we did not find such effects, which might be another sign of the difficulty of the task. Future studies will be needed to evaluate whether learning could be found in other experimental situations, for example if using live tasks which have sometimes be found to lead to better learning (e.g., Kuhl, Tsao & Liu, 2003), or if the words to be learned were presented in isolation rather than in sentences (although results from Experiment 1 establish that French-learning 30-month-olds can segment new words from fluent speech).

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