Supplemental Materials

The Development of Spontaneous Sound-Shape Matching in Monolingual and Bilingual

Infants During the First Year

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Method

Auditory Material

Several productions of the non-words 'buba' and 'kike' were recorded from a native Basque-Spanish bilingual female speaker. Three productions of each item were selected and matched on duration ('buba': M= 560 ms, range: 550-570; 'kike': M= 570 ms, range: 560-570), pitch ('buba': M= 163 Hz, range: 161-166; 'kike': M= 160 Hz, range: 160-166). The items were also normalized for amplitude (70 dB) using Praat (Boersma & Weenik, 2010). Finally, 40-second long stimuli strings were created using the items 'kike' and 'buba' separately, with the inter-stimulus intervals varying between 1000 and 1500 ms.

Detailed Testing Procedure

First, infants were seated on their caregiver's lap in a testing booth facing a screen and speakers, which were positioned 1 meter away. Infants' looking behavior was observed on camera and coded by an experimenter in a separate room. To avoid caregivers' non-verbal biases during the experiment, the caregiver holding the infant wore noise-cancelling headphones and listened to music. The trial presentation was fully infant-controlled. Before the presentation of each trial, a red flashing light appeared on the screen to attract the infant's attention. Once the infant oriented themselves toward the screen, the trial presentation began. If the infant looked away for at least 2 seconds during trial presentation, the trial ended, and the flashing light appeared on the screen again. The maximum trial duration was 40 seconds. To verify infants' general attention to the task, one pre- and one post-test trial were presented before and after the test trials, respectively. For those trials, the visual stimulus was a

combination of a round and a spiky shape presented with some baby-friendly music. All the tested infants were attentive to the task.

Stimuli validation with adults

We run a simple cross-modal matching preferences task in adults, to verify that the auditory stimuli 'kiki' and 'bubu' used in Ozturk et al (2013), and 'buba' and 'kike' used in current study, elicited the same matching preferences by adulthood. Twenty-four adults were presented with two outline drawings of a spiky and a rounded shape on a paper (see Figure 1). Half of the participants were asked to name which of the two shapes was 'buba' and which was 'kike', while other half named objects as 'bubu' and 'kiki'. Participants wrote their responses under each figure.
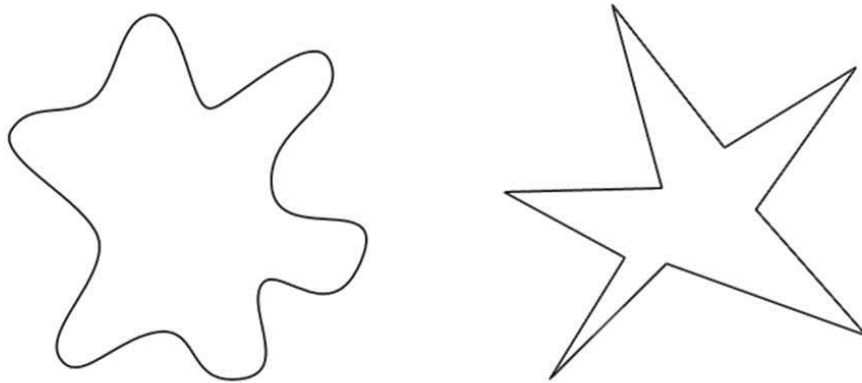

Figure 1. Two shapes were presented to adults. The side position (left or right) was counterbalanced.

Assessing the language exposure of infants

During an interview with one of the primary caregivers, infants' exposure to Spanish and/or Basque was measured using a detailed language background questionnaire. The questionnaire assessed everyday exposure to the two languages from the primary caregivers, family members, and other individuals who regularly spent time with the infant. The language exposure assessment questionnaire and instruction to parents were given in the language of the caregivers' preference. Table 1 presents the language exposure characteristics for each language and age group separately.

Age group	Language Group	Mean (%)	Standard Deviation	Range (%)
4	Monolingual	97.3	3.02	91 -100
(Experiment 1)	Bilingual	52.2	19.46	18- 86
12	Monolingual	98.3	1.8	96 - 100
(Experiment 2)	Bilingual	65.7	20.6	10- 87.6

Table 1. Mean, standard deviation and range of exposure to Basque in percentages across two age and two language groups.

Results

Comparing Experiment 1 and Experiment 2

To determine whether the matching effect is observed in older, but not in younger age group, a mixed repeated ANOVA was conducted on infants' average looking time. *Age* (4 and 12 months) was a between and *Condition* (congruent and incongruent) as a within factor. The analysis revealed only a significant main effect of *Age* ($F_{(1, 50)}$ = 8.02 , p = 0.007; all other effects p > 0.1), where younger infants (Experiment 1) revealed longer looking times (M = 15.1, SD = 5.93) than older infants (Experiment 2; M = 11.0, SD = 4.4), revealing that the two age groups are indeed very different in their looking behavior (i.e., younger infants look longer in response to both trial types than their older peers).

Additionally, a linear mixed effect analysis was conducted to further explore the relation of *Age*, and *Language group* on response to congruent and incongruent trials. Thus, we modeled *Condition* (Congruent and Incongruent), *Age* (4 and 12 months) and *Language group* (monolingual and bilingual) as fixed effects *Intercept of Subjects* was modeled as a random effect. Incongruent condition in monolingual 12-month-olds was set as a reference level for the model. Only the effect of *Age* reached significance ($F_{(1, 49)}$ = 7.9; p = 0.07), specifically, *Age* at the 4-month level was different than the reference (*Intercept* = 11.54; Age 4 b = 3.83, t = 2.37). Other comparisons did not reach significance (all p > 0.2). To account for the strong impact of the *Age* effect, we built a model similar to the previous one, but we excluded the *Age* from the main effects. This time, only *Condition x Age* interaction reached significance ($F_{(1,90.6)}$ = 4.0, p = 0.021), specifically, both Congruent and Incongruent at 4 months levels were significantly different from the reference (Congruent-4months: b = 4.4, t = 2.7; Incongruent-4month: b = 3.83, t = 2.3). Other comparisons did not yield any significance (all p > 0.1). Crucially, in both models *Language* x *Condition* never reached significance (all F < 1, all p > 0.1), demonstrating that the

sound symbolism effect is not affected by different language experience across monolingual and bilingual infants.