

## REPORT

# The shape of boubas: sound–shape correspondences in toddlers and adults

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### Abstract

*A striking demonstration that sound–object correspondences are not completely arbitrary is that adults map nonsense words with rounded vowels (e.g. bouba) to rounded shapes and nonsense words with unrounded vowels (e.g. kiki) to angular shapes (Köhler, 1947; Ramachandran & Hubbard, 2001). Here we tested the boubalkiki phenomenon in 2.5-year-old children and a control group of adults (n = 20 per age), using four pairs of rounded versus pointed shapes and four contrasting pairs of nonsense words differing in vowel sound. Overall, participants at both ages matched words with rounded vowels to the rounder shapes and words with unrounded vowels to the pointed shapes (both  $p < .0005$ ), with no significant difference between the two ages ( $p > .10$ ). Such naturally biased correspondences between sound and shape may influence the development of language.*

### Introduction

Except for onomatopoeia, the mapping of specific sounds to specific objects is assumed to be arbitrary and to vary accordingly from language to language. As a result, the child learning language must master a large number of arbitrary sound–shape associations. In languages with ideographic scripts, they must also master seemingly arbitrary mappings between specific written characters and the objects to which they refer. Surprisingly, in some circumstances adults are able to guess at rates exceeding chance the meaning of words and orthographic characters in foreign languages not closely related to their own. For example, in one study English-speaking adults heard words in Huambisa (a Jivaroan language from north central Peru) and sorted them into those naming birds and those naming fish at rates above chance (Berlin, 1994). Similarly, Hebrew-speaking adults matched Chinese characters to their corresponding Hebrew words with an accuracy above chance (Koriat & Levy, 1979). Such cross-language accuracy suggests that there are some naturally biased mappings between objects and the sounds and orthographic characters used to represent them.

A well-known demonstration of the naturally biased mappings is Köhler's (1947) finding that, given two novel shapes and the nonsense words 'maluma' and 'takete',

English-speaking adults chose 'maluma' as the label for the round shape formed from overlapping ellipses and 'takete' as the label for the angular, star-like shape. Similarly, Ramachandran and Hubbard (2001) found that 95% of English-speaking adults matched 'bouba' with a round, amoeboid shape and 'kiki' with an angular figure (see also Holland & Wertheimer, 1964). Davis (1961) found similar patterns when he asked school children to label Köhler-type drawings with the word 'takete' or 'uloomo'. This was true both for English-speaking children aged 11 to 14 residing in England and for children aged 8 to 14 living in an isolated peninsula of Lake Tanganyika in central Africa who spoke Swahili and the Bantu dialect of Kitongwe, but not English. There are numerous other examples of consistent mapping between vowel sounds and properties of objects. For example, English-speaking adults asked to make sub-vocal pronunciations of nonsense words judge those containing an 'i' as smaller in magnitude than those containing an 'a' (Vetter & Tennant, 1967; see also Koriat & Levy, 1977).

Ramachandran and Hubbard (2001) speculate that the bouba/kiki phenomenon arises from cortical connections among contiguous cortical areas that unite the visual percept of the nonsense shape (round or angular), the appearance of the speaker's lips (open and round or wide and narrow), and the feeling of the phonemic inflection and movement

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of the tongue when one says the words (rounded lips, large mouth opening or lips stretched to produce a small mouth opening). In fact, within linguistics, the vowels [u] (as in ‘Sue’) and [o] (as in ‘bode’) are labelled as rounded vowels and [i] (as in ‘bead’) and [ʌ] (as in ‘sun’) are labelled unrounded or non-rounded vowels. Ramachandran and Hubbard argue that these connections among sensory cortical areas and between sensory and motor areas constrained the evolution of language, influence its development in the individual child, and sometimes lead to synesthesia, a phenomenon affecting 1–2% of the population in which a stimulus induces not only the normal percept but also a second percept in a second modality or along a second dimension (e.g. the sound of ‘a’ looks red or tastes like oranges not quite ripe) (reviewed in Maurer & Mondloch, in press). Indeed recent imaging studies have confirmed that synesthetic percepts are correlated with activity in the expected primary and secondary sensory cortical areas. For example, in synesthetes with coloured hearing or coloured graphemes, hearing or seeing an ‘a’ is correlated with activity not only in the ‘normal’ cortical areas such as the auditory cortex, but also in area V4v in the visual pathway, an area known to be involved in processing form and colour, and to a lesser extent, activity in lower visual areas including the primary visual cortex (Hubbard, Arman, Ramachandran & Boynton, 2005; see Maurer & Mondloch, in press, for a review of earlier studies).

Although the findings with adults and in groups of children as young as 8 to 14 years are consistent with Ramachandran and Hubbard’s hypothesis that connections between neighbouring cortical areas are present early in development and influence the child’s learning of language, there is an alternative explanation: it is their knowledge of language that allows adults and older children to generalize from the corpus of word–object mappings they have learned to nonsense and foreign words. By this account, there are some preexisting patterns in English and the other studied languages such that words with rounded vowels (a round sound and/or a curved grapheme) label round objects and words with non-rounded vowels label pointed objects. In other words, language-learning comes first, and the bouba/kiki phenomenon develops later. Consistent with this alternative account is a report of random responding when the Songe of Papua New Guinea were tested with Köhler-like figures and ‘maluma’ and ‘takete’ – perhaps because sound/shape correspondences are not biased in the same way in Songe as in the other languages that have been tested (Rogers & Ross, 1975).<sup>1</sup>

<sup>1</sup> The results might have been random because the study was conducted through a translator.

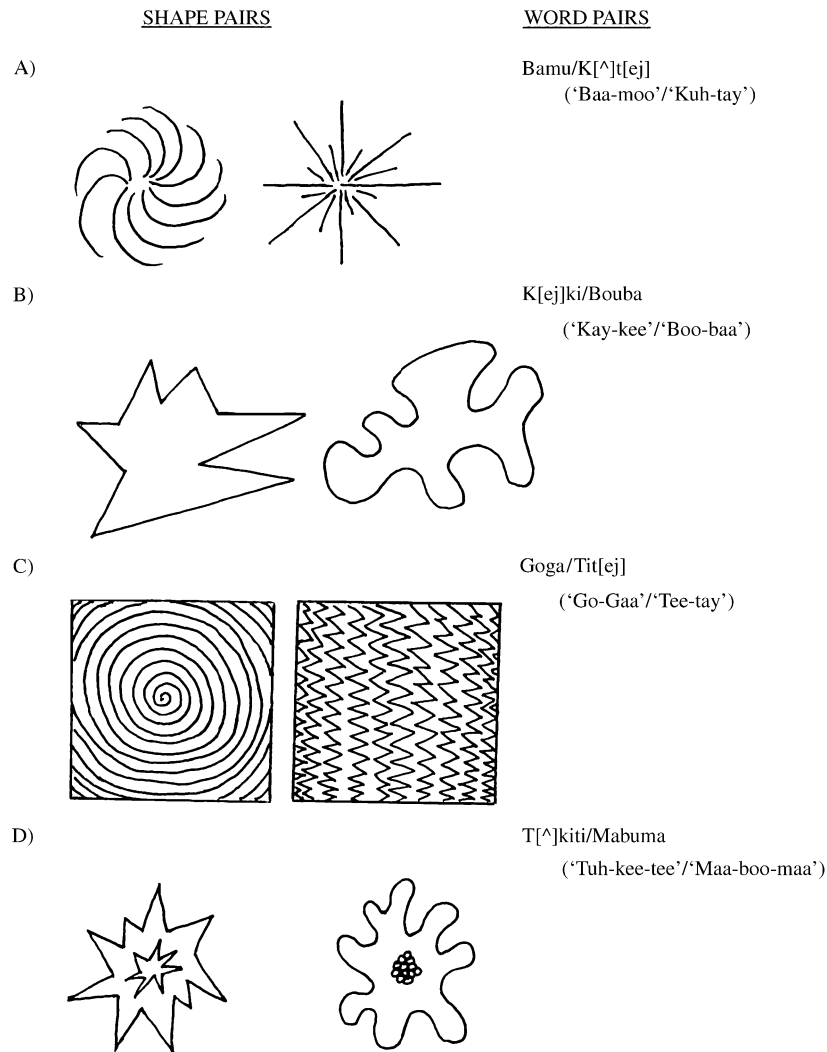
The purpose of our study was to test for the bouba/kiki phenomenon in young children and, thus, to test whether it is present early enough in development that it may indeed influence the learning of language. Although by age 2.5 years, mappings from oral sounds to object shape may have been influenced by language-learning, children at this age have far fewer words in their vocabulary from which to generalize, they have not yet mastered the correspondence between the sound of letters and their grapheme, and they are still in the age period when influences among contiguous brain areas appear to be even stronger than in adults (Neville, 1995). Between ages 2–2.5 and 3 years, spoken language stops eliciting event-related responses over visual cortex (Neville, 1995) and language comprehension begins to alter visual-visual mappings (Smith & Sera, 1992; see Discussion for elaboration).

To test for the bouba/kiki phenomenon in language-learning children, we chose four pairs of shapes, such that in each pair one shape was round and the other one was angular. In addition to the pair of shapes used by Ramachandran and Hubbard (2001), we used three pairs of contrasting shapes that are optimal for stimulating V4v, the area active during forms of synesthesia that involve language (hearing sounds or seeing graphemes) (Gallant, Connor, Rakshit, Lewis & Van Essen, 1996; Kobatake & Tanaka, 1994). For each shape pair, we constructed a pair of two- or three-syllable words in which one word contained rounded vowels (e.g. bouba, pronounced ‘boo-bah’) and the other, non-rounded vowels (e.g. k[ej]ki, pronounced ‘keh-key’) (see Figure 1). The word pairs were constructed to emphasize the vowel difference between the two members of a pair both in sound and in the appearance of the experimenter’s lips as she pronounced the nonsense words. We designed a game that allowed us to assess whether 2.5-year-old children consistently map words with rounded vowels to rounded shapes and words with non-rounded vowels to angular shapes. The game included four validation trials in which we tested a known mapping between a word and an object to assure that the children were ‘playing the game’ and hence that the data from experimental trials were interpretable. A group of non-synesthetic adults was tested for comparison.

## Method

### *Participants*

The participants were 20 preschool children (*M* age = 2.8 years; range 2.6–2.10 years) and 20 undergraduate students (*M* age = 20.3 years; range 18–24 years). Child participants were recruited from names on file of parents



**Figure 1** The pairings of shapes used for the four experimental trials and the choice of words that accompanied them. In order to match the storyline, the shapes in pair A were drawn on construction paper; the shapes in pair B were cut to form holes in the top of a cardboard box; the shapes in pair C were drawn on separate sheets of white paper and glued onto Bristol board; and the shapes in pair D were made into three-dimensional objects using red clay. The shapes in pair B are those used by Ramachandran and Hubbard (2001). The words in parentheses indicate the pronunciation for each word pair.

who had volunteered their child at birth for participation in later studies. Adult participants were students enrolled in an introductory psychology course and received course credit for participation. Half the participants in each group were female. An additional two children were tested but not included in data analysis because they did not meet the criterion on validity trials (see Procedure).

### *Stimuli*

The four pairs of contrasting shapes are shown in Figure 1. Each of the shape pairs was matched with a pair of

contrasting words containing rounded versus non-rounded vowels (see Figure 1). We used varied shapes and sound contrasts and tied them to a storyline to maintain children’s interest and so as to assess the generality of the phenomenon. For the validation trials, we used four pairs of objects that would be readily identified by toddlers: a cut-out drawing of a blue dog without polka dots and a red dog with polka dots, a cut-out drawing of a yellow rabbit without polka dots and a green rabbit with polka dots, a miniature plastic dog and a miniature plastic rhinoceros, and drawings of a bird cage and dog dish.

### Procedure

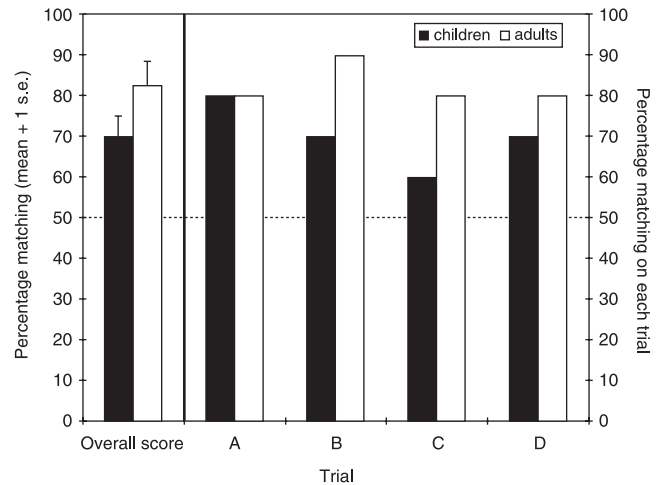
The protocol and procedures were approved by the McMaster Research Ethics Board. After the procedures were explained and a parent gave written consent, the child and the experimenter sat across from each other, with the child's parents sitting behind the child. The experimenter played with the child through stuffed toys called 'Mr Mouse' and 'Mr Bear'. She said 'Hi Mr Mouse! My name is Mr Bear. I can't see that well. Would you be my helper today? You would? Yayy!' This pre-test play, which lasted from 15 to 50 minutes, continued until the child consistently brought the experimenter's puppet objects when asked and the child appeared comfortable with the task.

The study consisted of eight forced-choice trials (four experimental trials and four validity check trials). On the first validity trial the experimenter said: 'This is fun. But I'm a little sad because I can't find my other friends. Mr Mouse, can you help me find them? OK let's look! I have a friend, he is a green rabbit.' The experimenter showed the child the pictures of the green and yellow rabbits and continued 'Do you see him? Can you bring me my friend, the green rabbit? He has polka-dots on him.' If the child picked the correct one, the experimenter said, 'Yayy! I'm so happy that you found my friend', or if the child picked the incorrect picture, the experimenter said, 'Are you trying to trick me? You're funny!' Scripts along similar lines were used for the other three validity trials.

On the first experimental trial, the experimenter continued the story, 'My friend Mr Green Rabbit drew pictures of his favourite toys. He calls them funny names. One is called Bamu and the other is called K[<sup>^</sup>]t[ej].' The experimenter showed the child the drawings labelled A in Figure 1 and asked 'Which one do you think is Bamu?' Regardless of how the child responded on the experimental trials the experimenter responded with 'good job!' The three other experimental trials followed a similar script.

Trials were presented in the same order to all children: validity 1, experimental 1, validity 2, experimental 2, validity 3, validity 4, experimental 3 and experimental 4. The experimenter made sure the child was looking at her face when she recited the nonsense words. On the experimental trials, half the children were asked to pick the shapes for the words Bamu, Bouba, Tit[ej] and T[<sup>^</sup>]kiti and the other half were asked to pick the shapes for the words K[<sup>^</sup>]t[ej], K[ej]ki, Goga and Mabuma. To be included in the final analysis, participants needed to correctly answer three out of four validity check trials.

The props were constructed so that the experimenter could not see which side contained the expected choice before the child responded. Adults were tested with the same method (not including pre-test play). They were



**Figure 2** The proportion of participants choosing the word with the rounded vowels for the round shape and the word with unrounded vowels for the angular shape. Data for the 2.5-year-olds are shown by black bars and data for adults by white bars. The overall score is based on the mean across all four experimental trials for each participant and represents the mean and standard error for each age group. The bars labelled by letters show the proportion of each age group choosing in the expected direction for each of the experimental trials, with the labels corresponding to those in Figure 1. The dotted line shows the chance level of responding (50%).

told that this study was made for preschool children and adults were being tested to use as a comparison.

### Results

Children were correct on three ( $n = 4$ ) or four ( $n = 16$ ) of the four validity trials. No adult made an error on the validity check trials.

For the experimental trials, we calculated a matching score for each subject based on choosing the rounded shape for the words with rounded vowels and the angular shape for the words with non-rounded vowels, such that a score of 4 indicates choosing in the expected direction on every trial and a score of 2 represents random choices. The scores for both children and adults were significantly greater than chance (see Figure 2): children chose in the expected direction on a mean of 2.8 trials,  $t(19) = 4.00$ ,  $p < .0005$ , against an expected value of 2, one-tailed, and adults did so on a mean of 3.3 trials,  $t(19) = 5.64$ ,  $p < .0001$ , one-tailed. The matching scores of children and adults were not significantly different from each other,  $t(19) = -1.697$ ,  $p > .10$ , two-tailed.

Analyses of individual trials indicated that adults matched in the expected direction for each of the four

pairs (all  $ps < .005$  by one-tailed binomial tests) (see Figure 2). The data for individual trials were less consistent in the children: one pair was significant at the .005 level (matching the pictures to bamu/k[<sup>^</sup>]t[ej]), two were significant at the .05 level (matching the hole shape and the toy to bouba/k[ej]ki and mabuma/t[<sup>^</sup>]kiti, respectively) and one was not significant (matching the drawing to goga/tit[ej]).

## Discussion

Like adults, children as young as 2.5 years old showed the bouba/kiki phenomenon: they matched rounder shapes to words containing the vowels [ah] and [u] and pointed shapes to words containing the vowels [i], [ej] and [ʌ]. This pattern was evident in the children's overall matching score and in the analysis of three of the four individual trials. It may not have been significant on the third trial (matching the drawing to goga/tit[ej]) because the storyline may have been less effective for this pair (*find the drawing I made*), because the effect is stronger for some consonant/vowel pairings than others, and/or because the two contrasting shapes in this pair, unlike the three other pairs, did not look like objects and differed only in the shape of internal details within identical external contours (see Figure 1). Nevertheless, it is clear that there is consistent sound–shape mapping present by 2.5 years of age. The results lend support to the hypothesis that naturally biased sound–shape correspondences influence the development of language in the individual child and may have influenced its evolution across time.

Such natural biases can explain adults' ability to guess the meaning of words across languages, at least in some cases. For example, English-speaking adults' correct sorting of words for birds and fish in Huambisa (see Introduction) may be related to the fact that birds are more angular than fish and birds' names are more likely to contain high front, non-rounded vowels [i] and [ej] (Berlin, 1994; Day, 2004). In Huambisa, 40% of bird names have [i] in the first syllable, while this is true for only 8% of fish names. In contrast, 60% of fish names contain an [a] in the first syllable. In fact, there are consistencies across languages in using words containing the vowel [i] for objects that are smaller, brighter, closer and/or associated with higher pitch and words containing the vowels [a] and [o] for objects that are larger, darker, farther away and/or associated with lower pitch (e.g. Day, 2004; Koriat & Levy, 1977; Tanz, 1971). In English, for example, many adjectives denoting large objects contain rounded vowels and involve widening the vocal tract and lips (e.g. LARGE, HUGE) whereas many adjectives

describing small objects often contain non-rounded vowels and involve narrowing the vocal tract and lips (e.g. TINY, TEENY). Systematic studies indicate that such patterns are not universal, but are found for many languages including English, Japanese, Maori, Mandarin, a number of African languages, and even African click languages (Day, 2004; Nuckolls, 1999). These patterns support Ramachandran and Hubbard's claim that naturally biased sound–shape correspondences influenced the evolution of language (Ramachandran & Hubbard, 2001). In other words, the evolution of language may have been influenced by the types of sound–shape correspondences that are easily learned by young children.

The naturally biased sound–shape mappings we documented in young children may facilitate the learning of the many languages where word mappings share this bias. However, the learning of language can modify the mappings. This is clearly evident in a study by Smith and Sera (1992). Like adult synesthetes (Marks, 1974), 2-year-olds mapped larger to darker: they chose the larger of two mice as going with a dark grey model. In contrast, unlike 3-year-olds, they were inconsistent in mapping louder to bigger, despite the fact that larger things usually do make louder sounds. Three-year-olds, who were more accurate on a test of language comprehension for the polar adjectives used in the study, consistently mapped larger to louder, but, like adults and unlike 2-year-olds, performed inconsistently in mapping larger to darker. These results suggest that the relationship between naturally biased sound–object correspondences and language development is one of mutual influence: natural sound–object correspondences bias language development but vocabulary growth can alter perceptual matching. Such altering may explain why the bouba/kiki phenomenon was not observed among the Songe of Papua New Guinea (Rogers & Ross, 1975).

The neural substrate for the sound–shape correspondences is unknown. One possibility is that they are based on connections between primary sensory cortical areas that are contiguous to each other and between sensory and motor areas (Ramachandran & Hubbard, 2001). Consistent with this view is emerging anatomical evidence of connections between the primary auditory and visual sensory cortices in adult animals (Falchier, Clavagnier, Barone & Kennedy, 2002; Wallace, Ramachandran & Stein, 2004), evidence that sound activates primary and extrastriate visual areas in adult synesthetes with coloured hearing (Gray, Williams, Nunn & Baron-Cohen, 1997; Hubbard *et al.*, 2005; Nunn, Gregory, Brammer, Williams, Parslow, Morgan, Morris, Bullmore, Baron-Cohen & Gray, 2002), and evidence that the primary sensory cortical areas are initially less specialized in humans (Neville, 1995; reviewed in Maurer &

Mondloch, in press). A second, and not mutually exclusive, possibility is that mirror neurons play a role in mediating the sound–shape correspondences by connecting the lip shape observed when someone else says the vowels to the feeling of voicing them oneself (reviewed in Blakemore & Frith, 2005; see also Ramachandran & Hubbard, 2001). Note that although our data are consistent with theories based on connections between neighbouring sensory cortical areas and theories based on mirror neurons, our study was not intended as a direct test of those theories.

Because the children in this study were 2.5 years old, we cannot rule out the possibility that the vocabulary they had already learned influenced their sound–shape mappings for the nonsense sounds and shapes used here. Future studies are needed to investigate whether such sound–shape mappings are evident even before infants begin to speak, as would be predicted by Ramachandran and Hubbard's model and our own postulation of neonatal synesthesia (Maurer & Mondloch, in press). Nevertheless, the current study is the first to demonstrate that the bouba/kiki phenomenon exists early enough in development that it can indeed facilitate the learning of languages in which rounder objects tend to be labelled with rounded vowels.

In this study, the experimenter called attention to her mouth as she spoke the nonsense words. Therefore, we cannot disentangle whether the child matched the sound to a shape based on its sound, the shape of the experimenter's lips as she spoke the word, and/or the feeling in the child's mouth of mimicking the sound. Future studies could isolate the influence of lip shape and sound heard, as well as investigate whether there are natural mappings between consonant sounds and specific shapes that also influence the development of language, as suggested by some studies with adults (Holland & Wertheimer, 1964; Westbury, 2005).

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