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Parsing the Role of Consonants Versus Vowels in the Classic Takete-Maluma Phenomenon

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Wolfgang Köhler (1929, *Gestalt psychology*, New York, NY: Liveright) famously reported a bias in people's choice of nonsense words as labels for novel objects, pointing to possible naïve expectations about language structure. Two accounts have been offered to explain this bias, one focusing on the visuomotor effects of different vowel forms and the other focusing on variation in the acoustic structure and perceptual quality of different consonants. To date, evidence in support of both effects is mixed. Moreover, the veracity of either effect has often been doubted due to perceived limitations in methodologies and stimulus materials. A novel word-construction experiment is presented to test both proposed effects using randomized word- and image-generation techniques to address previous methodological concerns. Results show that participants are sensitive to both vowel and consonant content, constructing novel words of relatively sonorant consonants and rounded vowels to label curved object images, and of relatively plosive consonants and nonrounded vowels to label jagged object images. Results point to additional influences on word construction potentially related to the articulatory affordances or constraints accompanying different word forms.

Keywords: sound symbolism, language structure, Bouba-Kiki, name–shape biases, artificial language learning

In 1929, Wolfgang Köhler reported a curious linguistic phenomenon, originally dubbed the Takete-Maluma effect (Köhler, 1929) but, following Ramachandran and Hubbard (2001), more generally known now as the Bouba-Kiki effect. The effect involved people consistently matching particular forms of nonsense words to particular kinds of unfamiliar objects. Specifically, people matched nonsense words like *takete* or *kiki* to an image of a jagged, star-like object and words like *maluma* or *bouba* to an image of a rounded, cloud-like object. This finding was curious because, following Saussure (1916), a central tenet of modern linguistics is that "the form of the symbol is arbitrary"—there is no systematic connection between the form of words and the objects they denote—hence, there should be no reason to prefer one word label over another to name novel object shapes. Yet the consistency of people's matching responses suggested that, in fact, they had some inherent sense of the suitability of particular words as labels for certain objects.

The Saussurean dictum of arbitrariness is still accepted by many, at least for most word forms, and for good reason (Gasser, 2004; Monaghan, Christiansen, & Fitneva, 2011). However, in the years since Köhler's (1929) seminal study, many exceptions to strict arbitrariness have been documented. These have included additional demonstrations of the specific effect Köhler described and subsequent studies extending the findings to include images of additional object forms and additional nonsense words (Davis, 1961; Maurer, Pathman, & Mondloch, 2006; Nielsen & Rendall, 2011; Tarte & Barritt, 1971; Westbury, 2005). They have also included demonstrations of systematic relationships between the structural forms of real phonemes, words, or longer constructions of language and the semantic constructs they convey (reviewed in Hinton, Nichols, & Ohala, 1994). Among the best-known examples concerns the vowel-specific marking of size diminution or augmentation (Sapir, 1929) observed in English and a variety of other languages (Huang, Pratoomraj, & Johnson, 1969; R. C. Johnson, 1967), where words denoting small size more commonly contain high, front vowels (e.g., *bit*, *chip*, *teeny*), whereas words denoting large size more commonly contain low, back vowels (e.g., *block*, *hunk*, *chunk*). Additional widespread forms of nonarbitrariness include mimetic word forms and ideophones common in East Asian and African languages (Diffloth, 1976; Traunmüller, 1994; Itkonen, 2004; Ivanova, 2006). These phenomena and others like them are often grouped together under the banner of "sound symbolism" to reflect the possibility that language constructions may not always be entirely arbitrary. The variety of potential sound-symbolic relationships has grown steadily since Köhler's time such that some now view the classic Saussurean dictum of arbitrariness as largely overturned (reviewed in Ahlner & Zlatev, 2010). Nevertheless, the phenomena of sound symbolism still tend to be marginalized in mainstream linguistics and psycholinguistics,

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treated as curiosities and overshadowed by the continuing presumption of arbitrariness in language.

Leaving aside lingering disagreement on the relative arbitrariness of language, there has certainly been a surge of interest in sound symbolism in the last decade, reflecting three parallel research developments. The first of these is a renewed interest in the origins and evolution of language. Here, one focus has been on the potential connections between human language and animal communication systems, where signal form and function are very clearly related (Owren & Rendall, 2001). A variety of such structure–function relationships are well established in animal signalling and, importantly, have been shown to characterise certain speech sounds in humans as well. For example, nonhuman primates produce a variety of vocalizations that are relatively vowel-like in acoustic structure, with a clear fundamental frequency with harmonic overtones shaped by the resonance properties of the vocal tract (Owren, Seyfarth, & Cheney, 1997; Rendall, Owren, & Rodman, 1998). In addition, the pitch and formant profiles of these vowel-like calls are affected by the length and mass of the vocal folds of the larynx and the size of the resonating cavities of the vocal tract, which, in turn, have been shown to track variation in the overall body size of the signaler (Fitch, 1997; Rendall, Owren, Weerts, & Hienz, 2004). These same size-based acoustic relationships characterise human vowel sounds as well (Rendall, Kollias, Ney, & Lloyd, 2005), and the similarities reflect commonalities in the general anatomy and functioning of the vocal tract in the two groups (Ghazanfar & Rendall, 2008). Furthermore, perceptual studies have shown that this size-related variation in vowels and in vowel-like calls in nonhuman primates is salient to listeners in both groups (Pisanski & Rendall, 2011; Rendall et al., 2004; Rendall, Vokey, & Nemeth, 2007). In humans, the natural size-related variation in vowels (the so-called "frequency code," Ohala, 1994) is, as noted, specifically exploited in some languages to convey size-semantic information. Taken together, findings like these suggest that the structure of at least some speech sounds is not entirely arbitrary but rather is meaningfully related to underlying mechanisms of sound production continuous with those of closely related nonhuman primates, and further, that it sometimes represents the basis for semantic distinctions in the words of language.

A second and important recent development involves sophisticated models and experimental studies demonstrating the value of sound-symbolic relationships for language learning. For example, both Nygaard, Cook, and Namy (2009) and Imai, Kita, Nagumo, and Okada (2008) have demonstrated that sound-symbolic words are easier to learn than non-sound-symbolic ones, even when they are taken from another language and are thus entirely unfamiliar to listeners (see also Ozturk, Krehm, & Vouloumanos, 2012). Furthermore, Monaghan and Christiansen (2006; and see Monaghan et al., 2011) have developed a model of language learning that proposes that an optimal language system would involve a mix of nonarbitrary and arbitrary relationships. More specifically, it would entail a systematic (nonarbitrary) relationship between word structure and word class generally, but within word classes, the structure of individual symbol tokens would be arbitrary.

A final area of work spurring renewed interest in sound symbolism has been extensive recent research in neuroscience on cross-modal perceptual experiences, where, for example, individuals experience percepts in one modality in concert with input from another. Historically, such cross-modal perceptual experiences, often referred to as synesthesia, were thought to be rare and therefore peculiar or aberrant. However, more recent research suggests that the prevalence of cross-modal perceptual experiences is approximately 100 times more common than previously believed (Simner et al., 2006). This has led some researchers to propose that cross-modal perceptual processing might actually be normative (Ward, Huckstep, & Tsakanikos, 2006), at least early in development, after which connections across perceptual domains are gradually pruned (Maurer & Mondloch, 2004). One corollary of this view is that so-called synaesthetes might simply be individuals who retain exaggerated levels of cross-modal neural connectivity into adulthood. Although not yet conclusive, normative cross-modal neural processing offers a plausible mechanistic account of how sound-symbolic relationships might arise by naturally connecting sounds with visual or spatial percepts. In support of this account, some of the sound-symbolic relationships demonstrated to hold broadly in the population at large can also be seen in synaesthetes to an exaggerated degree (Callejas, Acosta, & Lupianez, 2007). In addition, there is evidence that, among synaesthetes, certain graphemes and phonemes are associated with certain colours and that the patterns are similar to worldwide sound-symbolic trends (Day, 2004).

Taken together, the convergence of work in these different areas suggests that language might incorporate a variety of nonarbitrary structure–function relationships that are important to investigate further for their potential insight both into the origins and evolution of language and into the developmental processes involved in children's acquisition of language. To contribute to this effort, we report research further exploring the classic Takete-Maluma effect.

Reexamining the Takete-Maluma Effect

The classic Takete-Maluma effect first reported by Köhler (1929, 1947) and subsequently replicated and extended by others (Davis, 1961; Maurer et al., 2006; Westbury, 2005; Ahlner & Zlatev, 2010) is a productive potential example of naïve expectations that people have about the structure of language. However, interpretations of the effect are varied and past experiments have often been criticised for potential methodological shortcomings (reviewed in Westbury, 2005). For example, the typical experimental paradigm has involved side-by-side presentation of two line drawings, one with a jagged, angular shape and one with a curvier, more cloud-like shape (see Figure 1), along with two contrasting nonsense words (e.g., *takete* and *maluma*; see Table 1). Using this paradigm, researchers have found that words like *takete* or *kiki* are consistently associated with jagged figures and words like *maluma* and *bouba* with curvier figures. However, one concern has been that most experiments have used only a small number and range of stimuli that were also selected subjectively by experimenters, which might virtually guarantee the kind of matching patterns subsequently observed (with the specific form of images potentially matching the orthography of associated letters; Cuskley, Kirby, & Simner, 2010). There has been some question, therefore, about whether the biased matching patterns are robust or are largely limited to specific words and images, perhaps involving quite exaggerated form differences.

Recent efforts have attempted to resolve these issues. For example, both Maurer et al. (2006 and Westbury (2005) have used

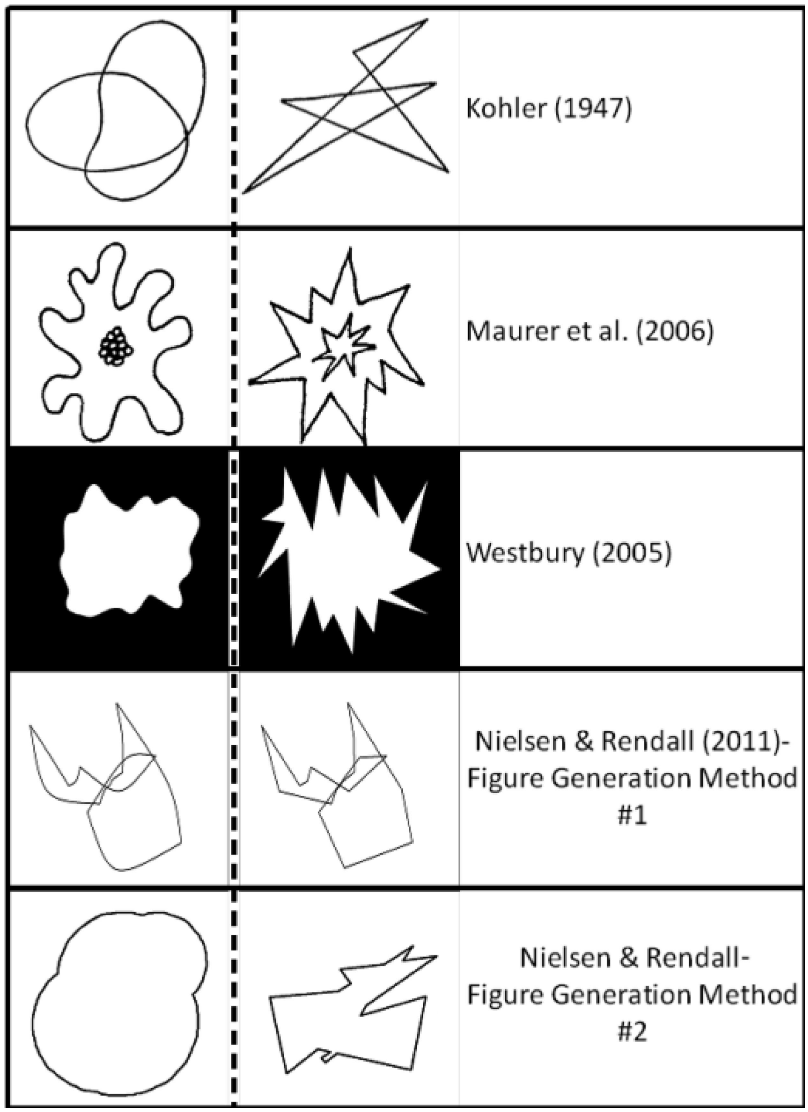

Figure 1. Sample of unfamiliar curved (left) and jagged (right) images used in previous Takete-Maluma experiments and in the experiment presented here.

larger sets of images and words. Nielsen and Rendall (2011) also used comparatively large corpuses of both images and words and took the additional precaution of generating both image and word stimuli using randomization techniques that controlled potential biases in researchers' selection of them and also potential orthographic confounds.

At the same time, different accounts have been offered to explain the source of the matching biases, with some researchers tracing them primarily to the vowel content of words (Tarte & Barritt, 1971; Ramachandran & Hubbbard, 2001; Maurer et al., 2006) and others attributing them to the consonant content (Westbury, 2005; Nielsen & Rendall, 2011). For example, Ramachandran and Hubbard (2001) proposed that the object-shape:word-form matching bias is mediated by synesthesia-like coactivation of the motor or somatosensory areas involved in articulating different sounds and the visual areas associated with the perception of object shape. Thus, the word *maluma*, which requires a rounding of the mouth to produce the "oo"-like vowel sound, is naturally matched to the curved or rounded object, whereas the word *takete*, which does not involve mouth rounding to produce, is matched instead to the jagged object.

In contrast, others have emphasised the possibility that the consonant content of words might play a role. For example, in the words *takete* and *maluma*, there are very clear differences in spectral density and attack between the consonants */t/* and */k/* compared with */m/* and */L/*, which make the first two consonants relatively harsh and the second two relatively mellifluous. This acoustic difference between *takete* and *maluma* might naturally encourage matching of these words to jagged and rounded objects that mirror this distinction in the visual domain. Westbury (2005) provided the first direct test of this alternative and argued that the resulting consonant-based effects observed were based on the

Table 1
Sample of Nonsense Words Used in Previous Takete-Maluma Experiments (Columns 1 and 2) and the Experiment Presented Here (Column 3), and Their Classification Based on Consonants and Vowels

Köhler (1929)		Maurer et al. (2006)		Current experiment	
Maluma (S-R)	Takete (P-NR)	Baamoo (P/S-R)	Kuhtay (P-NR)	Tookah (P-R)	Teekay (P-NR)
Davis (1961)		Gogaa (P-R)	Teetay (P-NR)	Nohmoo (S-R)	Naymuh (S-NR)
				Keemay (P-NR:S-NR)	Mootoh (S-R:P-R)
Uloomu (S-R)	Takete (P-NR)	Westbury (2005)			
Ramachandran & Hubbard (2001)		Loum (S-R)	Bobe (P-R)		
Bouba (P-R)	Kiki (P-NR)	Moom (S-R)	Deeb (P-NR)		

Note. Some word pairs used in past studies have involved systematic confounds of consonant and vowel content (e.g., constructing words only of sonorant consonants paired with rounded vowels or plosive consonants paired with nonrounded vowels) or have used pairs of words both containing plosive consonants. NR = nonrounded vowels; P = plosive consonants; R = rounded vowels; S = sonorant consonants.

association between the chaotic spectral structure of words containing relatively harsh consonants. Nielsen and Rendall (2011) also confirmed a role for consonants and extended Westbury's (2005) interpretation of the effect. They attributed it to inherent differences in the affective valence of plosive or strident consonants versus consonants that are relatively sonorant or mellifluous—differences that imbue words containing these different consonant types with some natural semantic potential, at least in the context of matching them as labels to jagged versus smooth object forms. Nielsen and Rendall (2011) ultimately traced these effects to broader affective–semantic relationships common in the vocal communication systems of nonhuman primates, where harsh, noisy, and punctuate (i.e., strident) sounds are commonly produced in situations of high arousal and often also hostility and aggression, whereas smoother more harmonic (i.e., sonorant) sounds are associated with situations of lower arousal and also positive affiliation and contact (reviewed in Morton, 1977; Owren & Rendall, 1997, 2001). In the cognitive semiotic framework recently proposed by Ahlner and Zlatev (2010), the latter types of association would likely be both iconic and indexical, with some built-in, primary iconic salience of the sounds in their differential effects on attention and arousal being further shaped by temporospatial (indexical) association with aggressive or affiliative behaviours.

In fact, such vocal-affect relationships are continuous with effects also known in human voice production. For example, young infants variously produce either sonorant-type coos or relatively strident loud and abrasive screeches and screams in situations reflecting, respectively, relative comfort or contentment versus hunger or distress. And signals of these two types tend to induce very different affective and behavioural responses in caretakers and other adult listeners. Similarly, adult voicing patterns can be relatively punctuate, harsh, and noisy in situations of high arousal (whether related to fear or anger) compared with that during normative relaxed speech (reviewed in Bachorowski & Owren, 2008; Rendall, 2003). Taken together, there appear to be some very broad relationships between strident and sonorant sounds and the contexts they mediate that have different social and behavioural salience for listeners. It is possible that these relationships might extend, at least in a limited way, to certain consonant sounds of language that exemplify this same strident-sonorant distinction and that thus inherit some natural semantic potential.

Two main issues thus remain regarding the Takete-Maluma effect. The first is whether the effect is traceable more to the effect of vowels and the visuomotor associations proposed to account for them, or to the acoustic quality of consonants and the differential affective influence they have, or whether consonants and vowels both play a role. A second outstanding issue concerns the extent to which the effect is driven by particular and exaggerated object stimuli that are widely divergent in form, and thus whether there are likely any real-world implications. In this article, we attempt to address both issues by testing the role that vowels and consonants each have in combination with one another. In line with our previous work, we attempt to address and mitigate problems of experimental design and stimulus construction that have been leveled at previous studies.

Experiment: The Relative Roles of Consonants and Vowels in the Takete-Maluma Effect

Previous work has shown that consonants can play a role in the Takete-Maluma effect (Nielsen & Rendall, 2011; Westbury, 2005) and that previous results interpreted to reflect an influence specifically of vowels actually reflected an inadvertent coupling between particular types of vowels and specific types of consonants that are established to exert an influence (Nielsen & Rendall, 2011). As a result, there is actually little clear evidence that the naïve expectations about word structure potentially revealed in people's matching biases include a role for vowels (but see Tarte & Barritt, 1971, for a possible exception). To confound interpretation of the source of the effect further, little work has been done that systematically varied both vowel and consonant content to tease apart their individual and joint contributions (see Ahlner & Zlatev, 2010, for an exception). To examine this possibility more systematically, an experiment was designed to test the independent and joint effects of consonants and vowels in the biased matching of novel word forms to unfamiliar object shapes exemplified in the Takete-Maluma effect. The experimental protocol presented here allowed participants to construct words that they thought best matched novel object images, using a large corpus of syllable component options. Further, the presentation of only a single image on any given trial is an important improvement on previous methodologies, as it eliminates analogous Piercian common ground on each trial as an explanation for the observed sound-symbolic associations (see Ahlner & Zlatev, 2010).

Method

Participants

Participants were 22 undergraduate students (14 female, 8 male) enrolled in introductory psychology courses at the University of Lethbridge who received partial course credit for their participation.

Image and Syllable Stimuli

A total of 45 different image pairs were used in this experiment. The images used were a combination of those used in our previous work (Nielsen & Rendall, 2011), supplemented by a set of images used by Westbury (2005) and by a set of new images created based on a modification of the technique described in Nielsen and Rendall (2011).

Briefly, the procedure used in Nielsen and Rendall (2011) used a radially constrained mathematical formula that populated a field of a finite size (see Figure 2A), with either 5 or 10 sequentially ordered, randomly generated calculus points. The location of these points was determined by creating vectors that departed from the centre of the field at random magnitudes and directions (constrained by the overall radius of the field). These points were sequentially numbered and, subsequently, a second vector was generated from the midpoint of the line connecting sequential points, yielding a calculus point for rendering simple curves. Individual line segments were defined by their two original points and the generated curvature point (Figure 2B). These point fields were then joined with either straight (Figure 2C) or curved (Figure 2D) lines. The resulting images were identical to one another except for the curvature of their lines, which produced only subtle differences between the two images in a pair (see Figures 1 and 2).

The new technique was identical to the procedure just described in that it populated a field with randomly generated and radially constrained calculus points (Figure 3A). It departed from the original procedure in how line segments were joined. For curved images, a single number was generated that represented the radius of a circle whose centre point was the generated calculus point (Figure 3B). For straight images, the circle generated at each point (Figure 3C) for curved images was used as the boundary for the generation of a triangle whose three angles were each generated to fall along the circumference of the circle (Figure 3D). At each of the calculus points generated in Step A, either a circle or triangle was drawn, and then the lines that fell inside of the shapes were erased, producing bounded two-dimensional shapes that were either curved (Figure 3E) or jagged (Figure 3F). Unlike the previous method, these figures were only equivalent to one another in the broadest sense that their initial calculus points were identical and the circles of the curved figures served as boundaries for generation of triangles for jagged images. This produced curved images that were, on average, larger than their jagged counterparts and that were much more cloud-like in appearance and thus more similar to the kinds of curved images used in previous studies.

The image sample thus constructed contained the single image pair used originally by Köhler (1929), the four image pairs used by Maurer et al. (2006), four images pairs from Westbury (2005), 18 image pairs created from the first random image generation technique described, and 18 new image pairs created from the modified random image generation technique just described (see Figure 1 for examples).

Syllables for this experiment were created using the voiceless obstruents */t/*, */k/*, and */p/* as the plosive consonants and voiced */m/*, */n/*, and */L/* as the sonorant consonants, as in Nielsen and Rendall (2011). For vowels, we copied the selections of most previous authors and used, as rounded vowels, the vowels */oo/* and */oh/*, and as nonrounded vowels, the vowels */ee/* and */ay/*. Following the predictions of these authors, the former rounded vowels would be predicted to be matched to curved object images, whereas the latter nonrounded vowels would be predicted to be matched to jagged object images. In this experiment, we added the vowel */ah/* as another curve-associated vowel and the vowel */uh/* as another jagged-associated vowel, which follows the vowel type classifications used specifically by Maurer et al. (2006). All vowels were presented textually in the phonetic form presented here to standardize participants' interpretation and pronunciation of them.

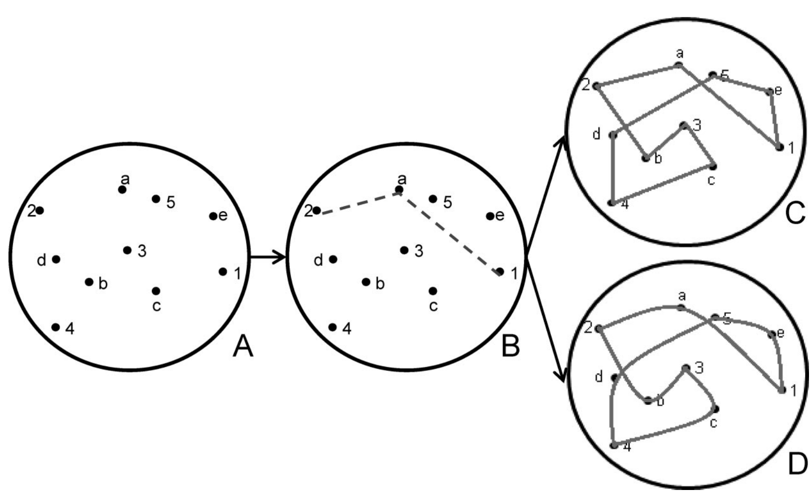

Figure 2. Schematic illustrating the process used to create curved and jagged versions of the same image based on randomization Technique 1.

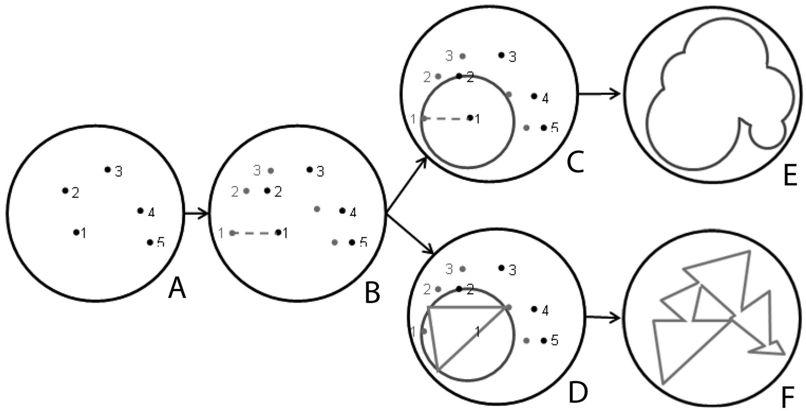

Figure 3. Schematic illustrating the process used to create curved and jagged versions of the same image based on randomization Technique 2.

Additionally, all letters were presented in their capitalized form in an attempt to ameliorate confounds due to orthographic form. In their capitalized forms, in the font presented, the plosive consonant letters are, if anything, less jagged than their sonorant counterparts (T, K, P vs. L, M, N). The orthographic form of the rounded vowels /OO/ and /OH/ were curvier than their nonrounded counterparts /EE/ and /AY/. Unfortunately, this potential confound was unavoidable in constructing a task where participants could create their own labels from a stock of available syllables. Furthermore, as we have stressed elsewhere (Nielsen & Rendall, 2011), even when no orthographic forms are presented at all, because words are presented aurally, one cannot eliminate the possibility that orthography is nevertheless implicated in participants processing of words (see Nielsen & Rendall, 2011, for further discussion).

Syllables constructed of these specific consonants and vowels were able to vary simultaneously according to both vowel and consonant content and could thus be of four general types, as noted: plosive consonant with rounded vowel (P-R), plosive consonant with nonrounded vowel (P-NR), sonorant consonant with rounded vowel (S-R), and sonorant consonant with nonrounded vowel (S-NR). Within each of these general syllable types, there were nine possible combinations of specific consonants ($n = 3$) and vowels ($n = 3$). Participants were exposed to all nine combinations with equal frequency.

To facilitate aural presentation of word material and to standardize the pronunciation of all words that participants heard, we used a commercial text-to-speech program (Swifttalker) to generate synthetic spoken versions of each word from their associated text forms. Spoken versions of each word were generated in a realistic sounding synthetic male voice ("David"). This synthetic voice was developed using the parameters and standard phoneme pronunciations for American English without any strong regional accent.

Experimental Design

The experiment was conducted on computer via a graphical interface created using Runtime Revolution version 2.8.1. On each trial, participants were shown a single image of a novel object form with two columns of syllables below it (see Figure 4). Their task was to construct a two-syllable word from the available single-syllable options that they thought best matched the novel object image. Each column contained four syllables representing all of the possible configurations of consonant–vowel types, as defined in the previous section: P-R, P-NR, S-R, and S-NR.

Participants were required to choose one specific syllable from these general syllable classes from each of the two columns, resulting in standardized two-syllable words. When participants selected a particular syllable option, by clicking on it, the syllable was then played to them over headphones and that syllable was added to a "final word" display. Participants were free to sample and hear any of the possible syllable options and thus change their response for either syllable as many times as they liked. After converging on agreeable options for both syllables, they heard the "final word" they had constructed before proceeding to the next trial. There were a total of 90 trials, with each image drawn from

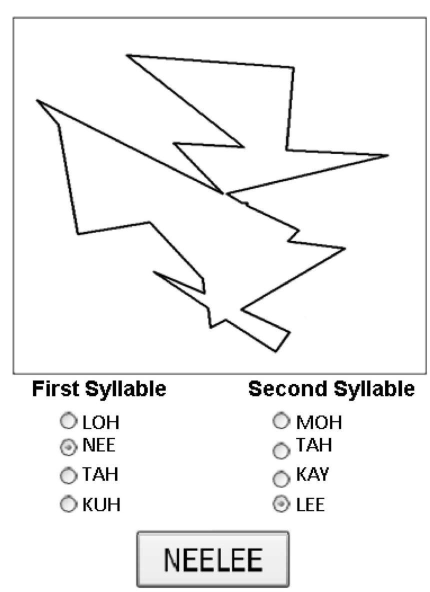

Figure 4. Example of a typical interface for an experimental trial.

the 45 pairs of randomly generated curved and jagged images presented only once. Each of the 9 possible specific combinations of consonants and vowels within the syllable classes was viewed a total of 10 times and randomized between trials. Additionally, the order in which the syllable types were presented from top to bottom in each column was counterbalanced between trials.

Data Analysis

Potential biases in participants' construction of words were first analysed for overall effects using logit analysis to simultaneously assess their selection of particular syllable types for both Syllable1 and Syllable2 on each trial as a function of the image type presented (jagged or curved). In follow-up tests of the specific consonant and vowel effects manifest in participants' syllable choice biases, responses were scored as "correct" based on consonants if they involved matching syllables containing a plosive consonant (*/t/*, */k/*, or */p/*) to jagged images or matching syllables containing a sonorant consonant (*/m/*, */n/*, or */L/*) to curved images. Responses were scored as "correct" based on vowels if they involved matching syllables containing a rounded vowel (*/oo/*, */oh/*, or */ah/*) to curved images or matching syllables containing a nonrounded vowel (*/uh/*, */ee/*, or */ay/*) to jagged images. Participant responses were then analysed separately for each syllable using repeated measures ANOVA with image type (curved or jagged) as a within-subjects factor, and deviation from chance performance (50%) was subsequently tested against the binomial distribution. Image source (see Figure 1) was also included as a factor in each ANOVA but was found to have no significant main effects or interactions. We explicitly included this factor, given that, for the second figure generation method, curved images were larger than their jagged counterparts, which could have had effects based on previously established size–sound correspondences (Sapir, 1929). However, because image source was not significant in any analysis, we do not consider it further in the results.

Results

Logit analysis revealed a statistically significant two-way model (Likelihood ratio chi square = 64.99, df = 15, $p < .01$) attributable to significant main effects for both Syllable 1 and Syllable 2 choices as a function of image type (Syllable 1: partial chi square = 24.41, df = 3, $p < .01$; Syllable 2: partial chi square = 16.08, df = 3, $p < .01$) and a significant interaction between Syllable 1 and Syllable 2 choices independently of image type (partial chi square = 21.89, df = 9, $p < .01$). For Syllable 1, the effect was driven by preferential selection of P-NR (plosive consonant, nonrounded vowel) syllable types for jagged object images and S-R (sonorant consonant, rounded vowel) syllable types for curved object images. For Syllable 2, the effect was driven by preferential selection of P-NR syllable types for jagged object images.

Follow-up analyses further revealed that, for Syllable 1, the main effect was driven by biased selection of both the consonant and the vowel content. Thus, syllables were constructed with plosive consonants for jagged images 54.9% of the time and with sonorant consonants for curved images 52.4% of the time ($F_{1,21}$ = 6.79 p = .016). Only the plosive consonant bias here was significantly different from chance using the binomial test (plosive consonant, $p < .01$; sonorant consonant, p = .068; Figure 5). For

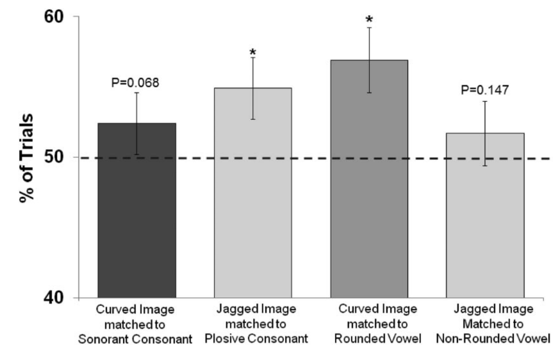

Figure 5. Participants' image-shape, word-form matching responses for Syllable 1. Data plotted represent the mean ($\pm SEM$) percentage of trials in which participants selected the combinations shown. * $p < 0.05$.

vowel content, syllables were constructed with nonrounded vowels for jagged images 51.7% of the time and with rounded vowels for curved images 56.9% of the time ($F_{1,21}$ = 6.65, p = .017). Only the rounded vowel bias was significantly different from chance (rounded vowel, $p < .01$; nonrounded vowel, p = .147; Figure 5).

For Syllable 2, follow-up analyses could not definitively attribute the significant overall main effect identified in logit tests of association to either the consonant or vowel content of syllables. Syllables were constructed with plosive consonants for jagged images 54.2% of the time and with sonorant consonants for curved images 51.1% of the time, and syllables were constructed with nonrounded vowels for jagged images 53.1% of the time and with rounded vowels for curved images 53.0% of the time. These outcomes exactly paralleled those observed for Syllable 1, and most deviated significantly from chance performance when tested individually in binomial tests, but they were not statistically significant in overall repeated measures ANOVA tests for Syllable 2 (Consonants: $F_{1,21}$ = 2.91, p = .102; Vowels: $F_{1,21}$ = 3.51, p = .075; Figure 6).

Additional Effects

Examining the specific syllables chosen in word construction, there was significant variation in participants selection among the 36 possible syllable options on each trial for both Syllable 1 (chi square: 78.82, df = 35, $p < .01$) and Syllable 2 (chi square: 94.50, df = 35, $p < .01$). Thus, in making their specific syllable choices, participants were significantly attracted to some specific syllable contents and they avoided others. Specifically, *koo*, *tee*, and *too* were consistent for both Syllable 1 and Syllable 2 in being chosen at rates well above chance (individual chi-square contributions, respectively, for Syllable 1 and Syllable 2: *koo* = 7.30 and 4.67; *tee* = 7.30 and 4.67; *too* = 8.04 and 4.67), and *nuh*, *pee*, and *poo* were consistent for both syllables in being chosen at rates well below chance (individual chi-square contributions, respectively, for Syllable 1 and Syllable 2: *nuh* = 4.64 and 4.64; *pee* = 5.88 and 6.55; *poo* = 5.24 and 8.00).

Discussion

Our results confirm a role for both consonants and vowels in the matching of novel word forms to unfamiliar object images. Al-

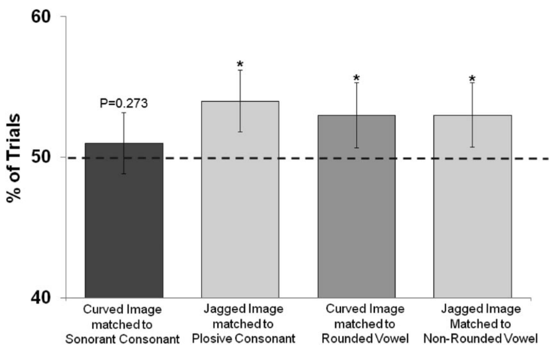

Figure 6. Participants' image-shape, word-form matching responses for Syllable 2. Data plotted represent the mean (±*SEM*) percentage of trials in which participants selected the combinations shown. Note that significance outcomes depicted for each condition are for individual binomial tests but that overall ANOVA tests did not reveal significant differences among conditions (see text for statistics).

though effects for both consonants and vowels have been proposed previously, concerns over the diversity and form of stimulus materials used in many previous studies have made results for one or the other difficult to interpret and have yielded broader concerns over the veracity of the effects and their generalizability. The effects observed here for consonants are thus important in confirming their role in the Takete-Maluma effect, which has been downplayed historically but emphasised recently (Nielsen & Rendall, 2011; see also Westbury, 2005). The results for vowels are also important. There have been many previous studies focused on the role of vowels; however, the proposed effects have been largely one-sided, proposing that words containing rounded vowels that require a round-mouth articulation to produce should promote matching to novel object images with rounded visual forms, but offering no similar account for why words containing nonrounded vowels should be matched to jagged images. Furthermore, we have shown (Nielsen & Rendall, 2011) that studies focusing on the role of vowels sometimes actually entailed critical confounds between the consonant and vowel content of experimental word stimuli, making it difficult to attribute effects to the vowel content per se. Hence, it is important to demonstrate that, with appropriately controlled and balanced word materials, and allowing participants free choice of syllable content in word construction, rounded and nonrounded vowels do indeed appear to have their own effects. Taken together, these outcomes demonstrate that consonants and vowels each seem to be responsible for a portion of the bias, an outcome also reported recently by Ahlner and Zlatev (2010), thereby helping to reconcile what seemed previously to be largely competing explanations of the source of the Takete-Maluma effect (Nielsen & Rendall, 2011).

It is important to note that we have focused on relatively coarse, but motivated, distinctions between broad classes of consonants (obstruents and sonorants) and vowels (rounded and nonrounded). As a result, our work does not address the possibility of other, subtler distinctions within these consonant and vowel classes. For example, there may be salient differences in effects observed among specific subcategories, such as among sonorant consonants between the liquids /*L*/ and /*r*/ and the nasals /*m*/ and /*n*/. Work that deals more directly with a larger corpus of phonemes will ultimately be necessary to tease apart such potential distinctions and the features that account for them. All that can be confidently concluded is that the coarse distinctions we have used here and elsewhere (e.g., Nielsen & Rendall, 2012) are salient in participants' word form preferences.

It is also important to note that our understanding of the types of associations underlying the Bouba-Kiki effect are potentially aided by the experimental methodology we adopted here, which involved serial presentation of only a single image per trial rather than simultaneous presentation of two contrasting images. As Ahlner and Zlatev (2010) point out, the presentation of two images concurrently with two potential labels effectively establishes that there is an analogous common ground between them upon which to base secondary iconic associations. The fact that there are two images varying along one dimension (e.g., curviness) and two labels varying along another dimension (phonology) cues participants to map those dimensions onto each other (with their cross-modal biases helping to determine the specific way in which they do so). By contrast, the method of serial presentation avoids drawing attention to that common ground of images and allows participants to select between multiple common grounds for labelling stimuli. Hence, our results suggest that, in the cognitive semiotic framework of Ahlner and Zlatev (2010), the sound-symbolic effects observed are truly cross-modally iconic.

In addition to effects for both the vowel and consonant content of individual syllables, our experiment revealed, for the first time, a significant interaction in participants' choices of material for Syllable 1 and Syllable 2. This outcome suggests that, in constructing novel word forms, participants were influenced not just by the perceived congruence between the vowel and consonant content of the individual syllables and the form of the object image to be named, as previously proposed in these kinds of experiments; they were also influenced by some additional perceived congruence between the two syllable forms. There are several possibilities that might account for this effect. For example, some of the interaction effect might have reflected participants' attraction to, or avoidance of, certain constructions that would involve syllable reduplication (e.g., *booboo*, *teetee*), which is variously argued either to be avoided cross-linguistically, or to be especially appropriate and common in highly stylized, child-directed speech and in ideophones (Ferguson, 1983; McCarthy, 1986; Ivanova, 2006; cf. Gervain, Macagno, Cogoi, Pena, & Mehler, 2008). Certain such constructions might also have created mildly taboo semantic content (e.g., *peepee*, *poopoo*), and, indeed, results did show that participants avoided the *pee* and *poo* syllables on their own.

A further possibility is that participants' choices were influenced by the relative ease of articulation or coarticulation of different syllable combinations. For example, for the strident consonants /t/ and /k/, the most commonly selected following vowel was the frontal vowel /ee/ and the least commonly selected following vowel was the back vowel /uh/. This describes a pattern of syllable construction in favour of vowels whose articulation is relatively close to the coarticulated consonant sound and against vowels whose articulation is further from the coarticulated consonant sound. Exactly the same pattern was observed for sonorant consonants where the frontal vowel /ee/ was again the most commonly selected vowel following the relatively frontal consonants /m/ and /n/ (excluding the frontal consonant /p/, which was avoided in association with the vowel /*ee*/ for reasons already noted), whereas the back vowel /*uh*/ was the least commonly selected vowel for these consonants. Factors like these are difficult to evaluate in any very credible way post hoc, but they are additional potential sources of bias that might profitably be investigated more systematically in future research. Certainly, they are an additional potential source of systematicity or nonarbitrariness in word forms.

One important remaining question is whether the biases observed in the Takete-Maluma effect reflect natural outcomes of the perceptual organisation of humans and possibly other animals, or whether they are learned through experience with a given language. This is difficult to assess, but research in animal communication suggests that call types analogous to the distinction between plosive and sonorant consonants in language are consistently used in different circumstances (e.g., agonism vs. affiliation, respectively) because of their distinctive inherent salience to conspecifics in ways that are not learned (reviewed in Owren & Rendall, 2001). For example, starlings are unable to learn to ignore their own species-specific distress calls, although they can learn to ignore other types of sounds (R. J. Johnson, Cole, & Stroup, 1985) and experientially naïve infant squirrel monkeys inherently avoid novel objects when they are paired with novel, harsh sounds, but readily approach those same objects when they are paired with novel sounds that are relatively sonorant (Herzog & Hopf, 1983). Such findings raise the possibility that at least some of the biases evident in the Takete-Maluma effect might be rooted in broader, evolutionarily conserved structure–function relationships in communication. Additionally, recent work on both human infants (Imai et al., 2008; Ozturk et al., 2012) and toddlers (Maurer et al., 2006; Nygaard et al., 2009) provides further suggestive evidence that these are learning biases rather than learned biases (cf. Nielsen & Rendall, 2012). This conclusion is further buttressed by studies showing that participants can guess the meaning of foreign words at rates above chance when presented with two contrasting alternatives (e.g., Brown, Black, & Horowitz, 1955; cf. Hunter-Smith, 2007).

In this respect, articulatory effects like those just proposed could be learned through a history of experience with a particular language that embodies such regularities of articulation and coarticulation, which might be the default assumption, but equally those regularities might themselves reflect inherent constraints on articulatory dynamics that hold broadly across languages (MacNeilage & Davis, 2000). Likewise, the avoidance of mildly taboo constructions might reflect language-specific semantic experience, or it might be rooted in inherent structure–function relationships of the sort just outlined and that make such words taboo. Certainly, swear words and other forms of profanity are documented to contain a greater proportion of fricative and plosive (strident) consonants (Van Lancker & Cummings, 1999), similar to those sounds in animals that are likewise proposed to have greater affective valence (Owren & Rendall, 2001).

These potential sources of systematicity or nonarbitrariness are important to consider for their role in processing artificial word material, but they are even more important to consider for their influence on real-language processing and learning (Imai et al., 2008). Importantly, here, it has been demonstrated through modelling and analysis of extant languages that sound-symbolic relationships and other forms of nonarbitrariness are potentially beneficial in language acquisition and transmission (Gasser, 2004; Monaghan et al., 2011; Monaghan, Mattock, & Walker, 2012; Nielsen & Rendall, 2012). At the same time, these same efforts have shown that, as lexicon size increases, nonarbitrary relationships begin to hamper language processing and learning, at which point systematicity wanes and arbitrariness becomes increasingly important. The future of research in language structure thus appears to hinge on a better understanding of the interface between arbitrariness and systematicity.

Résumé

Wolfgang Köhler (1929, *Gestalt psychology*, New York, É.-U. : Liveright) est reconnu pour avoir rapporté un biais dans le choix des gens de mots dépourvus de sens pour désigner des objets nouveaux, soulignant ainsi les attentes peut-être naïves au sujet de la structure de la langue. Deux explications de ce biais sont offertes, l'une axée sur les effets visuomoteurs de formes différentes des voyelles, l'autre, sur la variation de la structure acoustique et la qualité perçue de diverses consonnes. À ce jour, les preuves appuyant les deux effets sont inégales. En outre, la véracité de chaque effet a souvent été mise en doute en raison des limites perçues sur les plans de la méthodologie et des stimuli utilisés. L'expérience de la construction d'un mot nouveau est ici présentée pour vérifier les deux effets proposés, en utilisant au hasard des techniques de génération de mots et d'images afin de remédier aux préoccupations méthodologiques exprimées antérieurement. Les résultats révèlent que les participants sont sensibles à la fois aux voyelles et aux consonnes, ayant construit des mots nouveaux avec des consonnes relativement sonorantes et des voyelles arrondies pour désigner des images d'objets courbés, et des mots aux consonnes relativement plosives et des voyelles non arrondies pour désigner des images d'objets aux rebords dentelés. Les résultats suggèrent des influences additionnelles pour la construction de mots, qui pourraient être reliées aux possibilités ou aux contraintes phonologiques accompagnant les différentes formes de mots.

Mots-clés : symbolisme des sons, structure de langage, Bouba-Kiki, biais forme-nom, apprentissage d'un langage artificiel.

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