Phonemes as images

An experimental inquiry into shape-sound symbolism applied to the distinctive features of French*

Luca Nobile
Université de Bourgogne

This paper attempts to improve the understanding of shape-sound symbolism by isolating the phonological features of the pseudo-words used in the experiments and the graphic features of the figures matched with them. In a first section, it analyses the classic *maluma-takete* effect from both an articulatory and acoustical point of view, showing that it is determined by several phonological features operating simultaneously. In a second section, two new experiments are presented to isolate, first, vowels and consonants and, second, the consonant features of [voicing], [manner of articulation], [nasality] and [place of articulation] in relation to the graphic features of {acuity}, {continuity}, {curvature}, {regularity}, and {density}. The main result is that each phonological feature shows a different pattern of correlations with the graphic features, determined by its subtle phono-articulatory and phono-acoustic structure.

1. Introduction

Most of the experimental literature on "synaesthetic sound symbolism" (Hinton et al. 1994: 4) shows that people tend to establish analogies between phonological and visual distinctions. A strong connection has been found for example between the [front : back] articulatory opposition in vowels (that is an F2 [acute : grave] acoustic opposition) and such visual pairs as "bright" *vs* "dark" (Newman 1933; Fischer-Jørgensen 1967; Peterfalvi 1970; Marks 1982 and 1989) and "small" *vs* "large" (Newman 1933; Johnson 1967; Klank et al. 1971; Thompson & Estes 2011). Among consonants, associations have been established particularly between the [voiceless : voiced] articulatory opposition (which is an [acute : grave] acoustic opposition)

* I would like to thank Pilar Mompeán Guillamón and Lucy Michel for their valuable contribution in the bibliographical research and for kindly reviewing this text.

doi 10.1075/ill.14.04nob

and the visual pairs "bright" *vs* "dark" (Newman 1933; Peterfalvi 1970), "sharp" *vs* "rounded" (Fox 1935; Davis 1961; Holland & Wertheimer 1964; Westbury 2005) and "small" *vs* "large" (Taylor & Taylor 1962; Lapolla 1994; Thompson & Estes 2011). This type of results (see Spence 2011 for a review) seem to play today an important role in the debate on the origin, evolution, and functioning of language (Fitch 2000; Ramachandran & Hubbard 2001; Rizzolatti & Craighero 2007).

This paper sets out to explore such crossmodal correspondences between linguistic sounds and visual experience by examining the role of the distinctive phonological features as constituents of the phono-articulatory gestures. We will try to understand whether voicing, manner of articulation, nasality and place of articulation play distinct or overlapping roles in shape-sound symbolism and whether they have similar or different sound-symbolic values. To do this, we will first analyse the *maluma-takete* experiment, one of the most famous experiments on the topic. Then, we will propose two new experiments designed to isolate the behaviour of the distinctive phonological features used by French speakers.

2. The *maluma-takete* experiment

The *maluma-takete* experiment is a classic of the experimental research in psycholinguistics. It was conceived first by Wolfgang Köhler (1929, 1947),[1] one of the founders of the *Gestalt* psychology, and then often repeated by linguists and psychologists. R. Davis (1961) was one of the first to test it on different languages and, in particular, on a non-Indo-European language, Swahili of Tanzania. It was first repeated on French participants by Jean-Michel Peterfalvi (1964). The experiment has recently re-emerged thanks to the work by Ramachandran and Hubbard (2001), who renamed it "*bouba-kiki*" and used it to support their hypothesis of a synaesthetic origin of language.

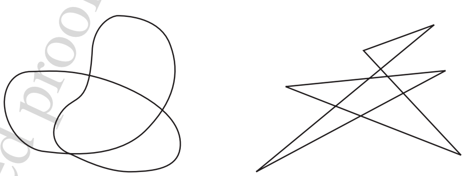

Figure 1. Images associated with the pseudo-words *maluma* and *takete* in Köhler (1947)

1. In the first edition of Köhler's *Gestalt Psychology* (1929: 242–243) the first pseudo-word was *baluma*; it was then changed to *maluma* (1947: 254–255) to avoid any association with *balloon* (according to Earl Anderson 2001: 124).

How does it work? A pair of figures, one curved and the other angular, are presented to the participants who are asked to associate them with the pair of invented words *maluma* and *takete* (see Figure 1). The result is that the vast majority of respondents associate the curvilinear figure to *maluma* and the angular shape to *takete*. It is a very strong result: it generally collects about 90% of the consensus of the participants. We can formally represent it by means of the following sound-symbolic relationship between visual and phonological oppositions:

{rounded} : {angular} ≈ /maluma/ : /takete/

It seems interesting to analyse this result in depth from a phonological point of view. This will allow us to better understand the functioning of the distinctive features in order to devise new experiments to isolate their behaviour.

Some recent, interesting studies have already attempted to meet these kinds of needs. For example, Nielsen and Rendal (2011) first replicated the traditional *maluma-takete* experiment and then changed some experimental conditions in order to distinguish the role of vowels and consonants as well as to test the effects of different types of curved and angular shapes. Their findings suggest that consonants play a predominant role (in particular the [obstruent] *vs* [sonorant] feature) and that specific details of the visual objects could influence subjects' choices. Although independent, our approach is an attempt to develop the research in this direction: instead of testing a single phonological feature ([obstruent : sonorant]) on a single graphic-visual feature ({angular : curved}) we try to test all the consonant features of the French language in relation with different types of graphic-visual contrasts, to see if they tend to exhibit different behaviours.

Another remarkable work on the topic has been carried out by D'Onofrio (2013) who tried to identify the phonological features that play an iconic role in the *bouba-kiki* experiment (a recent reformulation of the *maluma-takete* experiment by Ramachandran & Hubbard 2001). Her results highlight the importance of vowel backness, consonant voicing and consonant place of articulation in representing the {rounded : angular} graphic opposition. Our work goes in a similar direction, trying to analyse separately the distinctive features but, on the one hand, we focus our analysis on consonants in order to be able to analyse systematically all their distinctive features and, on the other hand, we explore also different types of graphic oppositions, in order to test, not only which phonological features are involved, but also if they carry different graphic 'meanings'.

In a contiguous field, that of motion-sound symbolism, and with an inverse method, that is, asking subjects not to evaluate those proposed by the experimenter but to produce new pseudo-words, Saji et al. (2013) have also attempted to distinguish the role of different phonological and semantic features (in Japanese and English). Their data show that certain groups of semantic features tend to appear together with each other and with certain groups of phonological features. For example, in Japanese, the semantic features {heavy : light}, {slow : fast}, {large : small} and {jerky : smooth} (in order of importance) tend to appear together when the subjects describe walking styles, and they tend to be associated to the phonological features (in order of importance) {voiced : voiceless}, {not-palatalized : palatalized}, {nasal : oral} and {sonorant : obstruent}, when the subjects propose sound-symbolic pseudo-words to imitate them. Moreover, if one excludes the semantic feature {heavy : light} and considers instead {non-energetic : energetic}, a corresponding change takes place among the phonological features: the importance of {voicing} and {palatalization} decreases, while that of the [manner of articulation] and the vowel [height] increases. Our research has very similar goals, but it adopts a different method (the evaluation of pseudo-words built by the experimenter) on a different type of phenomenon (shape-sound symbolism). Moreover, we try to provide a fine qualitative analysis of our results to understand exactly what physic characteristics of the phonological distinctive features determine the crossmodal correspondence with certain graphic-visual features and not with others.

More generally, our inquiry is based on a differential and systematic approach to the phonological system. It must be remembered that, according to Jakobson and Waugh (1979), the lack of this type of approach has been the main source of problems for the traditional research on the significant value of sounds, a field represented in France primarily by the works of Maurice Grammont (1901, 1933), Maxime Chastaing (1958, 1962, 1964, 1966) and Jean-Michel Peterfalvi (1964, 1965, 1970; see Nobile 2014 for a critical and historical review of their contributions). This differential approach aims to avoid some of the most typical conceptual and methodological difficulties in the field, proposing a reconciliation between arbitrariness and motivation, not through an attenuation, but through a radicalization of both (see Nobile 2008 and 2011 for a descriptive application of this perspective on Italian grammatical monosyllables).

3. Analysing the distinctive features

Our first aim is thus to question the experimental data of psychology about the *maluma-takete* phenomenon from the theoretical and technical perspective of linguistics.[2] We will ask what phonological properties (and particularly what distinctive features) make us perceive the crossmodal correspondence between the couple of invented words *maluma* and *takete,* on the one hand, and the couple of Köhler's curvilinear and angular pictures. We will try to answer this question firstly, from an articulatory point of view, and secondly, from an acoustic perspective.

3.1 Articulatory analysis

From an articulatory point of view, the opposition between /maluma/ and /takete/ can be analysed as follows (see Figure 2).

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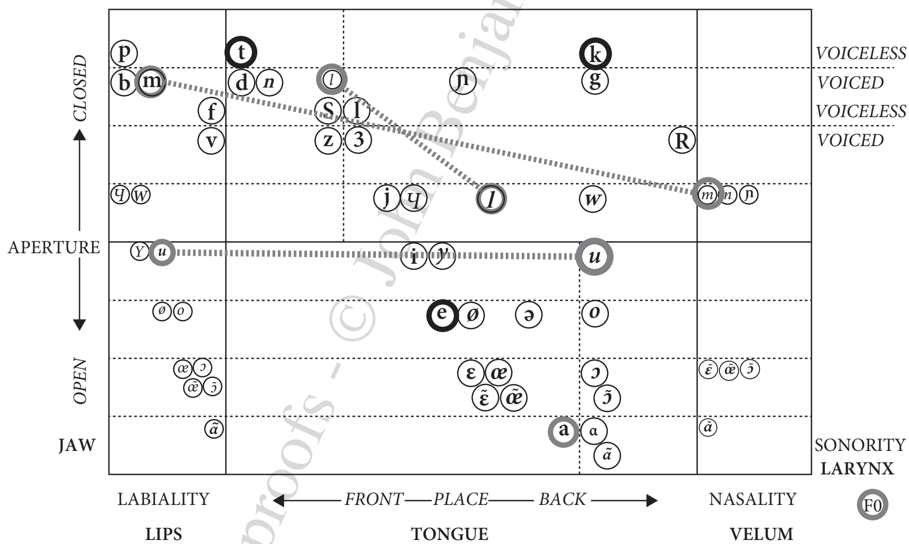


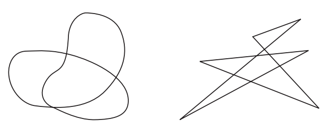
Figure 2. The /maluma/ vs /takete/ opposition (gray vs black circles) in the phono-articulatory system of French

2. Other attempts to provide solid linguistic foundations to this kind of research are D'Onofrio (2013), Saji et al. (2013) and Shinoara et al. (in this volume).

First, the initial (and final) consonant /m/ is opposed to the initial (and final) consonant /t/. The /m/ is a [labial], [nasal], and then necessarily [voiced] consonant, which is articulated by three different simultaneous gestures: (a) completely blocking the exit of air from the mouth through the lip closure; (b) emitting a laryngeal tone through the tensioning of the vocal cords to the air passage from the larynx; and (c) allowing the release of the air from the nose through the lowering of the velum of the palate.[3] On the contrary, /t/ is a [dental], [oral] and [voiceless] [plosive], which is thus articulated by one single gesture: completely blocking the air flow into the mouth by pressing the tip of the tongue against the gums to cause a small explosion.

On the other hand, the internal consonant /l/ is opposed to the internal consonant /k/. The consonant /l/ is a [lateral, voiced, approximant], which is a phoneme produced by three different gestures: (a) pressing the gums with the tip of the tongue; (b) lowering the two sides of the tongue to make the air flow escape; and (c) stretching the vocal cords to produce a laryngeal tone. On the contrary, /k/ is a [velar, voiceless, plosive], articulated by one single gesture: completely blocking the air flow into the mouth by pressing the back of the tongue against the velum to cause a small explosion.

If we compare therefore the three consonant oppositions distinguishing /maluma/ *vs* /takete/ we find several features which could evoke the opposition between the rounded figure and the angular figure. We can say at least that, concerning the articulation of consonants, /maluma/ is to /takete/ what [open-relaxed] is to [closed-tense], what [continuous] is to [explosive], what [voiced] is to [voiceless] and what [distributed] is to [concentrated]:



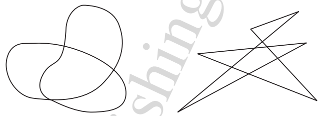
/m…l…m…/ : /t…k…t…/	≈	[open-relaxed]	:	[closed-tense]
		[continuous]	:	[explosive]
		[voiced]	:	[voiceless][4]
		[distributed]	:	[concentrated]

3. It is well known that the velum is normally lowered and opened when we do not speak. Hence we consider the lifting and closing of the velum as a distinctive gesture of the act of speaking in general, while the lowering and the opening of the velum that characterizes the nasal phonemes is considered a secondary gesture, performed not in continuity with the position of non-speech, but in opposition with the position of speech, in order to distinguish the small group of the nasal phonemes from the majority of the other, oral phonemes.

4. As we will see soon, the consonant feature [voiced] means the continuity of the laryngeal tone across vowels and consonants, while the [voiceless] consonant feature represents its discontinuity.

If we look at vowels, the first /a/ of /maluma/ and /takete/ is neutralised, while /u/ is opposed to /e/. The phoneme /u/ is a [labio-velar] vowel, articulated by two different gestures: (a) lips protrusion and (b) tongue retraction. On the contrary /e/ is a [palatal] vowel, articulated in one single gesture: pushing the tongue forwards.

The distinctive features opposing /u/ *vs* /e/ are therefore [back] *vs* [front], [rounded] *vs* [unrounded] and [distributed] *vs* [concentrated]:



		[back]	:	[front][5]
/…u…/ : /…ɛ…/	≈	[rounded]	:	[unrounded]
		[distributed]	:	[concentrated]

3.2 Acoustic analysis

From an acoustic point of view, we can say that /maluma/ is to /takete/, first, what the continuity of the laryngeal tone is to its discontinuity (see Figure 3a). In fact, because vowels are by definition always voiced, that is they are produced by the vibration of the larynx, where the consonants are also voiced (as in *maluma*), the acoustic profile of the word is continuous. Conversely, if the consonants are voiceless (as in *takete*), the laryngeal tone stops before each consonant and restarts at each vowel, thus giving the whole word a discontinuous acoustic profile.

This opposition between continuity and discontinuity is clearly similar to that which distinguishes the curvilinear figure from the angular shape, where a continuous change of the direction of the lines is in opposition with a discontinuous change.

We can now analyse the consonants (Figure 3b and 3c). When comparing the syllable /ma/ to the syllable /ta/, and the consonant /l/ to the consonant /k/, in both cases, we have the opposition between a continuous articulation and a plosive articulation. In the first picture we can see that the continuous initial consonant /m/ has a progressive onset while the initial plosive /t/ has an abrupt onset, with a sharp passage from silence to noise. One can also see that the voiced consonants /l/ and /m/ have periodic structures, which are cyclic and regular, while the voiceless consonants /t/ and /k/ have aperiodic, irregular structures. Finally, we can observe that the sounds of /l/ and /m/ are more grave than the noises of /k/ and

5. The [back] vs [front] opposition can be viewed as a « non prominent » vs « prominent » tongue gesture opposition.

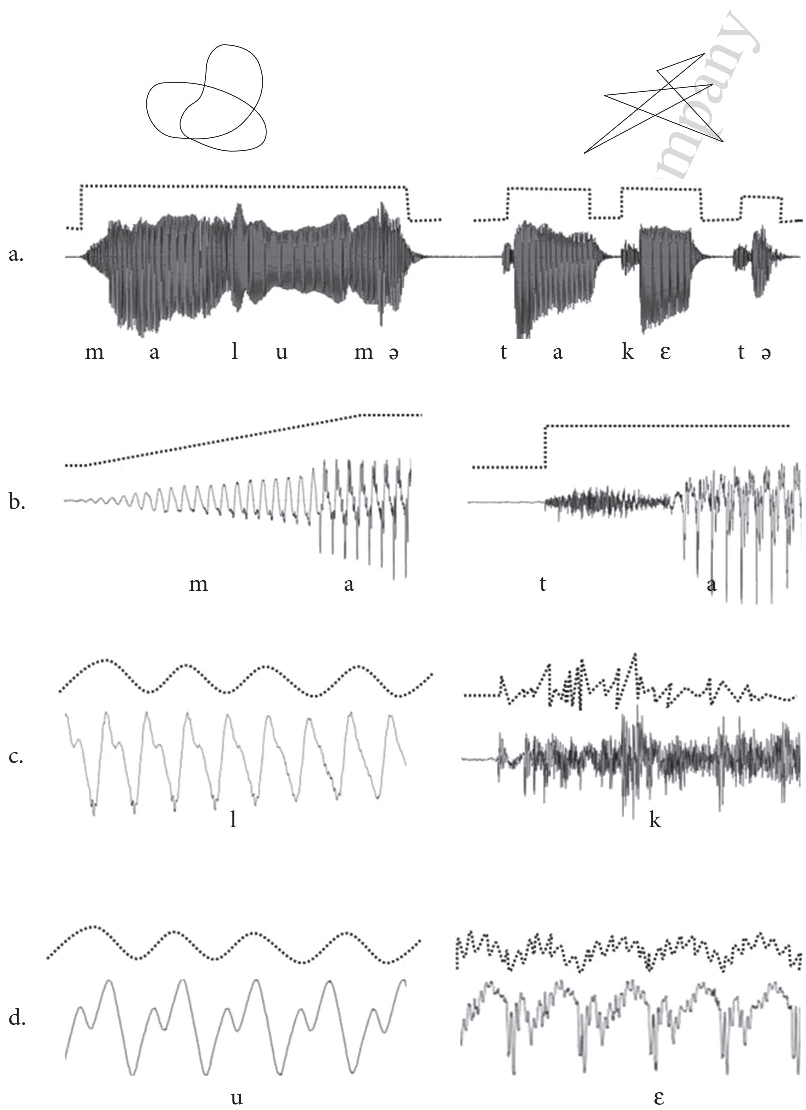


Figure 3. Acoustic oppositions between /malumə/ and /takɛtə/

/t/: the peaks of the former are more widely spaced and relatively less sharp than those of the latter.

Such a property is also seen very clearly in the distinctive feature of the vowels, [grave] *vs* [acute] (Figure 3d). The grave sound /u/ has a more smooth and rounded profile, while the acute sound /ɛ/ has a sharper profile. In fact we know that the wave length of the F2 formant of /u/ (750 Hz) is about 45 cm (or 17.7

inches), while the wave length of the F2 formant of /ɛ/ (1800 Hz) is about 18 cm (7 inches).[6] So, the waveform of the F2 of /u/ is physically two and a half times larger than that of /ɛ/.

3.3 Results of the analysis of the features

Let's summarize the analysis of the phonological distinctive features. All have strong analogies with the visual-graphic features {rounded : angular} distinguishing the figures. Regarding the articulation, /maluma/ and /takete/ are in opposition as a muscle relaxation against a muscle tension, a continuous constriction of the air flow against an obstruction and explosion of the air flow, a dispersion of the points of effort against a concentration of just one effort point. Concerning audition, we have continuity against discontinuity of the laryngeal tone, periodicity of sounds against aperiodicity of noises, and the grave frequencies contained in voicing, with their long, smooth waveforms, against the acute frequencies contained in the hiss and the crackles of the consonants, with their sharp waveforms.

4. Isolating the distinctive features

Starting from the previous analysis, we can ask another question. Do these phono-articulatory features necessarily operate collectively or can we distinguish their relative importance and their specific values in reference to the graphic-visual features of the figures? This question is justified, on the one hand, by the fact that we can see many different features operating concurrently and, on the other hand, by the fact that the result of 90% is statistically very significant; so we can hope to obtain significant results also weakening the stimuli to test more specific properties. To answer this question, two new experiments were conceived to isolate, on the one hand, the graphic features of the figures and, on the other hand, the phonological features of the words.

4.1 First experiment

The first experiment, carried out on a class of 42 students ignoring the classic *maluma-takete* experiment, aimed to test the traditional opposition between a curvilinear and an angular figure with new pseudo-words, built to isolate certain

6. These are the physical distances in the air between two successive relative maximums of the air pressure in the sound waves of /u/ and /ɛ/.

distinctive phonological features. A pair of figures was projected in front of the class and each student received a form containing the same pair of images, printed horizontally on the top; under the images were five pairs of pseudo-words, listed vertically in one central column, randomly ordered, and written accordingly to French spelling. Each pseudo-word had two boxes, left and right, printed perpendicularly under the left and right figures. The experimenter read aloud each pair of pseudo-words and the participants checked the box of each pseudo-word to assign it to the right or the left picture.

Table 1. Results of the first experiment (N = 42; p < 0.001)

				
1.	/maluma/	:	/takete/	97.6%
2.	/nilu/	:	/kitu/	95.2%
3.	/gavada/	:	/kafata/	92.8%
4.	/dugo/	:	/degi/	83.3%
5.	/meli/	:	/toku/	80.9%

The results are summarized in Table 1. The first pair (1), which just tests the traditional words /maluma/ and /takete/ cumulating several distinctive features, obtains the traditional, strong result (97.6%). The second pair (2) /nilu/ vs /kitu/ neutralizes all the oppositions between the vowels, which remain the same in the two words, and keeps only the consonant oppositions of [manner], [voicing] and [nasality]. It shows that these consonant features are enough to get an almost identical result (95.2%, only one person less out of 42), which seems to confirm the data of Nielsen and Rendall (2011) about the primacy of consonants. The third pair of words (3) /gavada/ vs /kafata/ isolates the consonant feature of [voicing]: the articulations of /g/, /v/ and /d/ are exactly the same as those of /k/, /f/ and /t/, with the addition of the laryngeal vibration. Note that the loss of consensus is minimal: the [voicing] of consonants, alone, is enough to collect 92.8% of the votes. This prominent role of [voicing] among consonant features (confirmed, as we shall see, in our second experiment) seems to corroborate the similar results obtained by D'Onofrio (2013) and Saji et al. (2013). The fourth pair, (4) /dugo/ *vs* /degi/ neutralizes, on the contrary, the consonant oppositions and retains only the vowel oppositions of [place] and [labiality]. Here we see a rather clear loss of consensus, although the result remains very strong (83.3%) and highly significant (p < 0.001). This confirms similar results by D'Onofrio (2013) and Saji et al. (2013) and allows to qualify the previously cited result by Nielsen and Rendal (2011), by showing that vowels in themselves are also sufficient to determine the *maluma-takete* effect, although apparently in a weaker way than consonants. One might wonder, however, to what extent this relative weakness of vowels would be confirmed, if the pseudo-words were built with initial vowels. Finally, in the fifth pair, /meli/ vs /toku/, we mixed the [grave] consonants of /maluma/ with [acute] vowels (/e/ and /i/), and the [acute] consonants of /takete/ with [grave] vowels (/o/ and /u/). The result is another reduction of consensus, but it is above all remarkable that the consonant features alone, also against the vowels, still generate a strong (80.9%), highly significant result ($p < 0.001$).

4.2 Second experiment

In the second experiment we tried to isolate in a more systematic way both the distinctive phono-articulatory features of the pseudo-words, focusing our attention on the consonants, and the distinctive graphic-visual features of the figures. To do this, we used a special type of minimal pairs, distinguished not by a single phoneme, but by a single distinctive feature repeated in three different phonemes. This allowed us to test each distinctive feature by just one pair of pseudo-words, neutralising as far as possible the features we were not looking for. For example, the pair /gavada/ *vs* /kafata/ tests the [voicing] distinctive feature in the velar plosives /g/ and /k/, in the labio-dental fricatives /v/ and /f/ and in the dental plosives /d/ and /t/. This test of the [voicing] feature is thus relatively independent from the [place of articulation] and the [manner of articulation] of the phonemes where it appears.

Three different groups of participants were tested under the same conditions described above.

First group
In the first group (N = 45; see Table 2), we studied the {acuity} of the corners of the figure (or the {obtuse : acute} graphic opposition) and the {continuity} of its drawing (or the {continuous : discontinuous} graphic opposition) in relation to four isolated phonological features of consonants (while the graphic properties of {curvature} and {regularity} were neutralized as far as possible). Apart from the usual traditional words, (1 & 6) /maluma/ *vs* /takete/ and /buba/ *vs* /kiki/, characterized by the accumulation of several features, the isolated phonological features are: (2 & 7) [voicing] that is the [voiced : voiceless] phonological opposition, within the pairs /gavada/ *vs* /kafata/ and /vadaga/ *vs* /fataka/; (3 & 8) consonant opening or [manner of articulation], that is the [fricative : plosive] phonological opposition, within the pairs /suʒaf/ *vs* /tugap/ and /suʃav/ *vs* /tukab/; (4 & 9) [nasality] or [sonorancy], that is the [nasal : oral] opposition, which is a particular case of the [sonorant : obstruent] phonological feature, with the couples /nimuɲ/

vs /zivuʒ/ and /meɲan/ *vs* /veʒaz/; and (5 & 10) [place of articulation], particularly the [palato-velar : alveo-dental] phonological opposition, within /gokuʃ/ *vs* /dotus/ and /gakiʃ/ *vs* /datis/.[7] Except labiality, all of the major distinctive features of the French consonant system are then analysed separately.

Table 2. Results of the second experiment, first group (N = 45). The total is other than 100% because it was possible to abstain

			%	vs %	p ≤				%	vs %	p ≤
1.	/maluma/	: /takete/	88.8	11.1	.001	6.	/buba/	: /kiki/	82.2	15.5	.001
2.	/gavada/	: /kafata/	82.2	17.7	.001	7.	/vadaga/	: /fataka/	75.5	20.0	.001
3.	/suʒaf/	: /tugap/	68.8	24.4	.005	8.	/suʃav/	: /tukab/	68.8	24.4	.005
4.	/nimuɲ/	: /zivuʒ/	80.0	17.7	.001	9.	/meɲan/	: /veʒaz/	64.4	28.8	.01
5.	/gokuʃ/	: /dotus/	44.4	28.8	.05	10.	/gakiʃ/	: /datis/	44.4	42.2	NS

The results show that the two graphic oppositions behave similarly: they are both associated with the same phonological oppositions, in similar proportions. Particularly: (1 & 6) the accumulation of different phono-articulatory features increases the consensus; among the isolated features, (2 & 7) [voicing] shows the maximum degree of analogy with the tested graphic features: the [voiced] (grave, continuous) consonants are to the [voiceless] (acute, discontinuous) consonants what the {obtuse} corners are to the {acute} corners and also what the {continuous} lines are to the dashed, {discontinuous} lines; also (3 & 8) the [manner of articulation] significantly correlates to {acuity} and {continuity}: the [fricative] consonants are to the [plosives] what the {obtuse} corners are to the {acute} and what the {continuous} lines is to the {discontinuous}. This is an interesting result because, unlike the other features, [manner of articulation] cannot be easily reduced to the [acute] *vs* [grave] "frequency code" suggested by John Ohala (1984) to explain a large set of sound-symbolic effects, and it requires to take into account other dimensions of the sound physics, such as intensity and duration. Also the opposition between [nasality] and [orality] (or [sonorancy] and [obstruency]: 4 & 9) seems to behave like the [voicing] feature, although asymmetrically: in the case of the {acuity} graphic feature, [nasality] (4) has approximately the same importance than [voicing] (2) while in the case of the {continuity} graphic

7. I call here [palato-velar] the posterior region of the French consonant system, going from the place of articulation of the pre-palatal fricatives /ʃ/ and /ʒ/, through the palatal place of the nasal /ɲ/, to the place of the velar plosives /k/ and /g/.

feature it appears significantly less important. A possible explanation could be that, acoustically, syllables containing [nasals] are not more [continuous] than syllables containing [voiced fricatives] (both are voiced and do not interrupt the vowel laryngeal tone) while the former are significantly more [grave] than the latter (the nasals have a larger sounding box). It should also be noted that the figure representing the {obtuse} graphic feature is the darkest and largest in this group, which may have accentuated the tendency to associate it with the particularly grave timbre of the [nasal] consonants (as a strong correlation between [grave : acute] and {large : small} or {dark : bright} is well known in the literature; see the Introduction). Finally, (5 & 10) we find weak or no significant correlation between the graphic feature of {acuity} and {continuity}, on the one hand, and the phono-articulatory feature of [place]. The [place of articulation] is not related to graphic {continuity} and is just weakly correlated to graphic {acuity}. This could be explained by the fact that the acoustical [continuity] of the dental consonants is not different from that of the pre-palatals and the velars, while their acoustical [acuity] is slightly higher (most of the acoustic energy in the alveo-dentals is around 5000 Hz, whereas in the palato-velars it is around 3000 Hz).

Second group
In the second group (N = 69; see Table 3) we studied the correlation between the same phonological features seen above and two new graphic features: {curvature} (that is the {curved : angular} opposition) and {regularity} (that is the {regular : irregular} opposition), while {acuity} and {continuity} are neutralized as far as possible.

Table 3. Results of the second experiment, second group (N = 69)

			%	vs %	p ≤				%	vs %	p ≤
1.	/maluma/	: /takete/	100	0	.001	6.	/buba/	: /kiki/	46.3	46.3	NS
2.	/gavada/	: /kafata/	91.3	8.6	.001	7.	/vadaga/	: /fataka/	55.0	40.5	NS
3.	/suʒaf/	: /tugap/	76.8	18.8	.001	8.	/suʃav/	: /tukab/	49.2	47.8	NS
4.	/nimuɲ/	: /zivuʒ/	60.8	28.9	.005	9.	/meɲan/	: /veʒaz/	46.3	46.3	NS
5.	/dotus/	: /gokuʃ/	57.9	30.4	.01	10.	/datis/	: /gakiʃ/	60.8	33.3	.01

The first result is that the graphic feature of {curvature} correlates strongly with [voicing] (2, /gavada/ *vs* /kafata/, 91.3%) and [manner] (3, /suʒaf/ *vs* /tugap/, 76.8%): the [voiced] and [fricative] consonants are to the [voiceless] and [plosive] consonants, respectively, what the {curved} lines are to the {angular} lines. Moreover, {curvature} correlates (more weakly) with [nasality] (4, /nimuɲ/ *vs*

/zivuʒ/, 60.8%) and [place of articulation] (5, /dotus/ *vs* /gokuʃ/, 57.9%) so that [nasals] and [alveo-dentals] are to [orals] and [palato-velars], respectively, what the {curved} lines are to the {angular} lines. The second result is particularly interesting. Contrary to what one might expect on the basis of the other results and the previous literature, the [places of articulation] do not combine with the {curvature} graphic feature according to their internal differences in acoustic [acuity]: the [alveo-dental] consonants, which are slightly more [acute], are associated with {curved} lines, while the [palato-velar] consonants, [graver], are associated with {angular} lines. This is a difference from the results of D'Onofrio (2013) which may depend on differences in the figures and pseudo-words we used. It suggest, however, that other articulatory or acoustic properties overlap and overtake the influence of the acoustic [acuity]. These may be, on the one hand, the greater average acoustic intensity of the [palato-velars] and, on the other hand, their "dirtier" or more irregular timbral quality (their acoustic energy tends to be more widespread, between 2000 Hz and 9000 Hz, whereas that of the alveo-dentals tends to be concentrated between 4000 Hz and 9000 Hz) which may evoke the less harmonious, and the more broken, of the two figures. Except for this aspect, however, it should be noted that {curvature} behaves very similarly to the two previous graphic features, {acuity} and {continuity}.

In contrast, the graphic feature of {regularity} behaves in a completely different way. It shows no correlation with the traditional pair /buba/ *vs* /kiki/ (cumulating labiality, sonority and the place of articulation of vowels, 46.3%), nor with the isolated features of [voicing] (7, /vadaga/ *vs* /fataka/, 55%), [manner] (8, /suʃav/ *vs* /tukab/, 49.2%) and [nasality] (9, /meɲan/ *vs* /veʒaz/, 46.3%), while it shows a significant correlation with the [place of articulation] (10, /datis/ *vs* /gakiʃ/, 60.8%). So the [place of articulation] shows a relatively strong correlation with the graphic feature of {regularity}, with which other phonological features do not correlate, while it shows relatively weak or no correlation with the graphic features of {acuity}, {curvature} and {continuity} that correlate significantly with [voicing], [manner] and [nasality]. In other words, we have a quasi-complementary distribution between the [place of articulation] and the other consonant features.

Third group

This relative division of labor seems to be confirmed by the third survey of the same experiment (N = 26; see Table 4), which concerns, on the one hand, the accumulation of the graphic features in the traditional figures and, on the other hand, the graphic feature of {density} (that is the {dense : sparse} opposition).

In this case (where results are a bit less accurate because of the smaller number of participants), traditional figures correlate strongly with the traditional

Table 4. Results of the second experiment, third group (N = 26)

			%	vs %	p ≤				%	vs %	p ≤
1.	/maluma/	: /takete/	84.6	3.8	.001	6.	/buba/	: /kiki/	53.8	42.3	NS
2.	/gavada/	: /kafata/	91.6	3.8	.001	7.	/vadaga/	: /fataka/	53.8	42.3	NS
3.	/suʒaf/	: /tugap/	61.5	30.7	.05	8.	/tukab/	: /suʃav/	50.0	38.4	NS
4.	/nimuɲ/	: /zivuʒ/	57.6	34.6	NS	9.	/meɲan/	: /veʒaz/	65.3	30.7	.05
5.	/gokuʃ/	: /dotus/	50.0	38.4	NS	10.	/gakiʃ/	: /datis/	61.5	30.7	.05

pseudo-words (1, /maluma/ *vs* /takete/, 84.6%) and with [voicing] (2, /gavada/ *vs* /kafata/, 91.6%), they correlate weakly with [manner] (3, /suʒaf/ *vs* /tugap/, 61.5%) and do not correlate with [nasality] (4, /nimuɲ/ *vs* /zivuʒ/, 57.6%) and [place of articulation] (5, /gokuʃ/ *vs* /dotus/, 50%).

On the contrary, the graphic feature of {density} does not correlate with the traditional pseudo-words (6, /buba/ *vs* /kiki/, 53.8%), nor with [voicing] (7, /fataka/ *vs* /vadaga/, 53.8%) or [manner] (8, /tukab/ *vs* /suʃav/, 50.0%), while it shows a (weak) correlation with the [nasality] (9, /meɲan/ *vs* /veʒaz/, 65.3%) and the [place of articulation] (10, /gakiʃ/ *vs* /datis/, 61.5%), so that [nasal] and [palato-velar] consonants are to [oral] and [alveo-dental] consonants, respectively, what a {dense} set of concentric spikes is to a {sparse} one. This might be explained, on the one hand, by the fact that the acoustic opposition [grave : acute], shared by the [nasality] and the [place of articulation] features, may be easily associated to the graphic opposition {dense : sparse} (for example via the well known value {thick : thin}). On the other hand, one could consider that, perceptually, the {dense} figure is not as defined as the {sparse} one because its number of spikes, greater than 10, exceeds our ability to perceive its numerosity without counting, and we are led to perceive it as an object with "a lot" of spikes. This is why, for example, such a figure can be perceived as a schematic representation of a flying seed or of a lock of fur: it seems to have an undefined number of spikes. This could be another factor that associates the {dense} figure to the [palato-velar] consonants, given that, acoustically, the latter are less defined than the [alveo-dentals].

Once again, however, it should be noted that the [place of articulation] seems to work in a very singular manner, combining with graphic features that are not concerned by [voicing] and [manner of articulation].

5. General discussion

Our data confirm the traditional results concerning [voicing]. This is the most significant phonological feature for the crossmodal correspondence with the graphic features of {acuity}, {curvature} and {continuity}:

[voiced : voiceless]	≈	{curved : angular}	91.3%
		{obtuse : acute}	82.2%
		{continuous : discontinuous}	75.5%

We can add now that the phonological features of [manner of articulation] and [nasality] are also regularly correlated with these same graphic characteristics:

[fricative : plosive]	≈	{curved : angular}	76.8%
		{obtuse : acute}	68.8%
		{continuous : discontinuous}	68.8%
[nasal : oral]	≈	{obtuse : acute}	80.0%
		{dense : sparse}	65.3%
		{continuous : discontinuous}	64.4%
		{curved : angular}	60.8%

However, we have also noticed that [nasality], unlike [voicing] and [manner of articulation], shows a stronger correlation with {acuity} than with {curvature} and has a significant correlation with {density} which is not concerned by [voicing] and [manner].

On the other hand, we saw that [place of articulation] does not correlate with the graphic feature of {continuity} and correlates weakly with {acuity} and {curvature}, while it exhibits a unusual link with {regularity} and {density}:

[palato-velar : alveo-dental]	≈	{dense : sparse}	61.5%
		{irregular : regular}	60.8%
		{angular : curved}	57.9%
		{obtuse : acute}	44.4%

While [voicing], [manner of articulation] and partly [nasality] seem thus to behave in a similar way (at least with regard to the examined graphic features), [place of articulation] shows a fundamentally asymmetric behaviour. Not only does it correlate with graphic properties which are weakly concerned by other phonological features, but, in the case of the {curved : angular} graphic opposition, which is the most important for [voicing] and [manner], it even goes against the [grave : acute] acoustical opposition which drives the behaviour of the other features.

The strong similarity between the behaviour of [voicing] and that of [manner of articulation] despite the diversity of their acoustic properties (the opposition [grave : acute] in the case of [voicing] and the opposition [continuous : discontinuous] in the case of [manner]) seems to be due to the fact that these different properties both give rise to a similar effect, that is a [continuous : discontinuous] acoustic opposition. In the case of [manner of articulation], this takes place at the level of the phoneme and it is intrinsic to the very definition of the feature itself: [fricatives] are [continuous] while [plosives] are [discontinuous]. In the case of [voicing], on the contrary, the opposition [continuous : discontinuous] emerges as a secondary effect at the level of the syllable: [voiced] consonants, sharing the laryngeal vibration with vowels, determine a syllabic [continuity] with them, while [voiceless] consonants, interrupting the laryngeal vibration, determine a syllabic [discontinuity]. This may explain not only the similarities in the behaviour of [voicing] and [manner of articulation], with respect to the {curvature}, the {acuity} and the {continuity} graphic features (given that all three can be viewed as oppositions between a greater or a lesser continuity of the lines), but also their differences. In particular, [voicing] obtains a larger consensus than [manner]: this may be explained by the fact that it cumulates the [grave : acute] and the [continuous : discontinuous] acoustic features, while [manner] works only with the [continuous : discontinuous] feature. Moreover, this gain of consensus is significant in the case of the {curvature} and the {acuity} graphic features, while it is negligible in the case of {continuity}: this may depend on the fact that {curvature} and {acuity} are the features in relation to which the acoustic [acuity] can play its iconic role, while in the case of the {continuity} graphic feature only acoustic [continuity] can work as an icon. On the other hand, this kind of explanation implies that the similarity between the behaviours of [voicing] and [manner] has a contingent origin and it should be possible to dissociate them by an appropriate manipulation of the experimental conditions.

In the case of [nasality], the [grave : acute] acoustic feature is more important than the [continuous : discontinuous] feature because the latter cannot exploit the syllabic mechanism of [voicing] (both nasals and orals are indeed voiced in our pseudo-words) nor the phonemic mechanism of the [manner] (both nasals and orals are continuous). The only (weak) acoustic discontinuity is determined, at the syllabic level, by the activation or deactivation of the turbulences characterizing the timbre of the fricatives (which are absent in nasals and vowels). On the contrary, the influence of the [acuity] acoustic feature is very important, because [nasals] are characterized by a very [grave] timbre, distinguishing them strongly from [fricatives]. As we previously observed, this could explain why the consensus for the [nasal : oral] opposition grows in the case of the {obtuse : acute} graphic opposition. In fact, this is the only pair where the difference concerning the continuity of the lines also involves a {large : small} and a {dark : bright} opposition in the figures. Nowadays, {large : small} and {dark : light} are well known visual correlates of the [grave : acute] acoustic feature. Their accidental presence in the {obtuse : acute} figures determines thus a gain of consensus for the [nasal : oral] phonological feature.

In the case of [place of articulation] ([palato-velar : alveo-dental]), the [continuous : discontinuous] acoustic feature has no relevance at all and this explains the lack of crossmodal correspondence with the {continuity} graphic feature. On the other hand, the [grave : acute] acoustic feature has limited importance. Of course, the [alveo-dentals] (about 4000 Hz–9 000 Hz) are more acute than the [palato-velars] (about 2000 Hz–9000 Hz), and this explains why the [palato-velar : alveo-dental] phonological opposition correlates positively with the {obtuse : acute} graphic feature (where the {large : small} and the {dark : bright} accessory graphic features strengthen the crossmodal link with [grave : acute]). Nevertheless, such a [grave : acute] opposition is less perceptible than that between [voiced] and [voiceless] or between [sonorant] and [obstruent] because it is a difference between two noises, not between a sound and a noise, and because the distribution of the frequencies in these noises is not complementary, but largely overlapped. This weak [grave : acute] feature may thus be overcome, under certain conditions, by other acoustic properties of the pair [palatovelar: alveodental], such as the opposition mentioned above between a more 'irregular', 'indefinite' and 'dirty' noise and a more 'regular', 'defined' and 'clean' noise. This could explain, on the one hand, the correlation between [place of articulation] and {regularity} and, on the other hand, the link between [palatovelar : alveodental] and {angular : curved} contradicting the general tendency to associate [grave] to {curved} and [acute] to {angular}, if one admits that the {angular} figure can be perceived as more 'irregular' or 'dirty' than the {curved} figure.

Taken together, these results suggest that different phono-articulatory features tend to be associated to different graphic-visual properties and that their acoustic characteristics play an important role in determining these associations. In particular, the acoustic feature [grave : acute], inherent to the articulatory features [voiced : voiceless] and [nasal : oral] (as well as, to a lesser extent, [palato-velar : alveo-dental]), seems to respond in particular to graphic properties such as {large : small}, {dark : bright} and {thick : thin}, confirming a correspondence well-known in the literature. The acoustic feature [continuous : discontinuous], determined at the level of the phoneme by the articulatory feature [fricative : plosive] as well as, at the level of the syllable, by the feature [voiced: voiceless] (and, to a lesser extent, by [sonorant : obstruent]), seems to be particularly sensitive to graphical characteristics of the lines such as {continuous : discontinuous}, {curved : angular} and {obtuse : acute}. Finally, the acoustic feature that we could call [clean : dirty], inherent to the articulatory feature [alveo-dental : palato-velar] seems to relate to general properties of the figures such as {regular : irregular} or {sparse : dense} (and also, to a lesser extent, {curved : angular}).

To our knowledge this is the first attempt, in the field of shape-sound symbolism, to test the hypothesis of different sound-symbolic values carried by different phono-articulatory features. This is a crucial question because only the simultaneous existence of various sound-symbolic dimensions in the same phonological system can allow us to imagine, through their intersection, the emergence of the semantic variety that characterizes natural languages. On the contrary, as long as the sound-symbolic values belong (or can be reduced) to a single dimension (typically, [grave : acute] = {large : small}), sound symbolism remains a phenomenon constitutively different from the semantics of natural languages, and can be treated as an accessory or residual element, not as a key factor to explain their origin and development. It seems to us that the collected results constitute significant clues in favour of the hypothesis of the multi-dimensionality.

References

Anderson, E. R. 2001. Old English poetic texts and their Latin sources: Iconicity in Cædmon's *Hymn* and *The Phoenix*. In *The Motivated Sign* [Iconicity in Language and Literature 2], O. Fischer & M. Nänny (eds), 109–134. Amsterdam: John Benjamins. DOI: 10.1075/ill.2.11and

Chastaing, M. 1958. Le symbolisme des voyelles: Significations des 'i'. *Journal de psychologie normale et pathologique* 51(3): 403–423 & 461–481.

Chastaing, M. 1962. La brillance des voyelles. *Archivium Linguisticum* 14(1): 1–13.

Chastaing, M. 1964. L'opposition des consonnes 'sourdes' aux consonnes 'sonores' a-t-elle une valeur symbolique? *Vie et langage* 147: 367–370.

Chastaing, M. 1966. Si les R étaient des L… *Vie et langage* 159: 311–317.

Davis, R. 1961. The fitness of names to drawings: A cross-cultural study in Tanganyika. *British Journal of Psychology* 52: 259–268. DOI: 10.1111/j.2044-8295.1961.tb00788.x

D'Onofrio, A. 2013. Phonetic detail and dimensionality in sound-shape correspondences: Refining the *bouba-kiki* paradigm. *Language and Speech* 57(3): 367. DOI: 10.1177/0023830913507694

Fischer-Jørgensen, E. 1967. Perceptual dimensions of vowels. In *To Honor Roman Jakobson: Essays on the Occasion of his Seventieth Birthday*, Vol. I, 667–671. The Hague: Mouton.

Fitch, W. T. 2000. The evolution of speech: A comparative review. *Trends in Cognitive Sciences* 4(7): 258–267. DOI: 10.1016/S1364-6613(00)01494-7

Fox, C. 1935. An experimental study of naming. *American Journal of Psychology* 47: 545–578. DOI: 10.2307/1416003

Grammont, M. 1901. Onomatopées et mots expressifs. *Revue de Langues Romanes* 44(4): 97–158.

Grammont, M. 1933. *Traité de phonétique*. Paris: Delagrave.

Hinton, L., Nichols, J. & Ohala, J. J. 1994. Introduction: Sound-symbolic processes. In *Sound Symbolism*, L. Hinton, J. Nichols & J. J. Ohala (eds), 1–12. Cambridge: CUP.

Holland, M. & Wertheimer, M. 1964. Some physiognomic aspects of naming, or *maluma* and *takete* revisited. *Perceptual and Motor Skills* 19: 111–117. DOI: 10.2466/pms.1964.19.1.111

Jakobson, R. & Waugh, L. 1979. *The Sound Shape of Language*. Bloomington IN: Indiana University Press.
Johnson, R. 1967. Magnitude symbolism of English words. *Journal of Verbal Learning and Verbal Behaviour* 6: 508–511. DOI: 10.1016/S0022-5371(67)80008-2
Klank, L., Huang, Y. & Johnson, R. 1971. Determinants of success in matching word pairs in tests of phonetic symbolism. *Journal of Verbal Learning and Verbal Behaviour* 10: 140–148. DOI: 10.1016/S0022-5371(71)80005-1
Köhler, W. 1929[1947]. *Gestalt Psychology*. New York NY: Liveright.
Lapolla, R. 1994. An experimental investigation into phonetic symbolism as it relates to Mandarin Chinese. In *Sound Symbolism*, L. Hinton, J. Nichols & J. J. Ohala (eds), 130–147. Cambridge: CUP.
Marks, L. 1982. Bright sneezes and dark coughs, loud sunlight and sift moonlight. *Journal of Experimental Psychology [Human Perception and Performance]* 8: 177–93. DOI: 10.1037/0096-1523.8.2.177
Marks, L. 1989. On cross-modal similarity: The perceptual structure of pitch, loudness and brightness. *Journal of Experimental Psychology: Human Perception and Performance* 15: 586–602. DOI: 10.1037/0096-1523.15.3.586
Newman, S. 1933. Further experiments on phonetic symbolism. *American Journal of Psychology* 45: 53–75. DOI: 10.2307/1414186
Nielsen, A. & Rendall, D. 2011. The sound of round: Evaluating the sound-symbolic role of consonants in the classic *takete-maluma* phenomenon. *Canadian Journal of Experimental Psychology* 65: 115–124. DOI: 10.1037/a0022268
Nobile, L. 2008. The grammatical monophonemes of standard Italian: A structural isomorphism between phonological and semantic oppositions? *Cognitive Philology* I(2). <http://ojs.uniroma1.it/index.php/cogphil/article/view/8819>
Nobile, L. 2011. Words in the mirror: Analysing the sensorimotor interface between phonetics and semantics in Italian. In *Semblance and Signification* [Iconicity in Language and Literature 10], P. Michelucci, O. Fischer & C. Ljungberg (eds), 101–131. Amsterdam: John Benjamins. DOI: 10.1075/ill.10.06nob
Nobile, L. 2014. L'iconicité phonologique dans les neurosciences cognitives et dans la tradition linguistique française. *Le Français Moderne* 82(1): 131–169.
Ohala, J. J. 1984. An ethological perspective on common cross-language utilization of F0 of voice. *Phonetica* 41: 1–16. DOI: 10.1159/000261706
Owren, M. J. & Rendal, D. 2001. Sound on the rebound: Bringing form and function back to the forefront in understanding nonhuman primate vocal signaling. *Evolutionary Anthropology* 10: 58–71. DOI: 10.1002/evan.1014
Peterfalvi, J.-M. 1964. Etude du symbolisme phonétique par l'appariement de mots sans signification à des figures. *L'année psychologique* 64(2): 411–432. DOI: 10.3406/psy.1964.27255
Peterfalvi, J.-M. 1965. Les recherches expérimentales sur le symbolisme phonétique. *L'année Psychologique* 65(2): 439–474. DOI: 10.3406/psy.1965.27443
Peterfalvi, J.-M. 1970. *Recherches expérimentales sur le symbolisme phonétique*. Paris: CNRS.
Ramachandran, V. & Hubbard, E. 2001. Synaesthesia – A window into perception, thought and language. *Journal of Consciousness Studies* 8(12): 3–34.
Rizzolatti, G. & Craighero, L. 2007. Language and mirror neurons. *The Oxford Handbook of Psycholinguistics*, G. Gaskell (ed.), 781–785. Oxford: OUP.

Saji, N., Akita, K., Imai, M., Kantartzis, K. & Kita, S. 2013. Cross-linguistically shared and language-specific sound symbolism for motion: An exploratory data mining approach. In *Proceedings of the 35th Annual Meeting of Cognitive Science Society, Berlin, 31 July–03 August 2013*, 1253–1258. <http://mindmodeling.org/cogsci2013>

Spence, C. 2011. Crossmodal correspondences: A tutorial review. *Attention Perception Psychophysics* 73: 971–995. DOI: 10.3758/s13414-010-0073-7

Taylor, I. & Taylor, M. 1962. Phonetic symbolism in four unrelated languages. *Canadian Journal of Psychology* 16: 344–356. DOI: 10.1037/h0083261

Thompson, P. D. & Estes, Z. 2011. Sound symbolic naming of novel objects is a graded function. *The Quarterly Journal of Experimental Psychology* 64(12): 2392–2404. DOI: 10.1080/17470218.2011.605898

Westbury, C. 2005. Implicit sound symbolism in lexical access: Evidence from an interference task. *Brain and Language* 93: 10–19. DOI: 10.1016/j.bandl.2004.07.006