The Power of Words in the Brain: Systematic Sound-Meaning Associations in Novel and Existing Words

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Abstract

In a series of experiments conducted with Dutch native speakers, we explored systematic size/power sound-symbolic associations in novel and existing words. In Experiment 1 (*N* = 64), participants associated vowel-intrinsic fundamental frequency with size/power, disregarding the modality of stimuli presentation (spoken, written), but depending on the lexical status of the stimulus (more strongly for novel then for existing words). In Experiment 2 (*N* = 56), we explored the idea that the order of vowels in a word affects sound-symbolic associations, as pitch contours emerge from a sequence of vowel-intrinsic fundamental frequencies. Participants perceived stimuli with 'rising' combinations of front-back vowels as less powerful than stimuli with 'falling' combinations. This finding indicates that even in non-tonal languages, sound symbolism is not bound to a single segment (phoneme). We compared the effect to the perception of tones in a tonal language, which we explored in Experiment 3 with Mandarin native speakers (*N* = 96) judging the perception of power in monosyllabic novel brand names with four different tones (rising, falling, level and fall-rise). In Experiment 4 (*N* = 146), we examined the effect of vowel-intrinsic intensity, which has previously remained un-noted. The results showed that like fundamental frequency, also intrinsic intensity influences size/power-symbolic associations.

Keywords: **S**ound Symbolism; Cross-modal Correspondence; Form-Meaning Arbitrariness; Frequency Code; Intrinsic Intensity; Intrinsic Fundamental Frequency.

Introduction

A series of relatively recent experiments has shaken one of the most fundamental postulates about human language, namely the arbitrariness assumption regarding the relation between the sound structure of a word and its meaning. Originating with de Saussure, it has long been presumed that the number of pictorial, imitative, or onomatopoetic words in any language is very small (Hockett, 1958; de Saussure, 1916/1959). However, in violation of de Saussure's arbitrariness assumption, many studies confirm that both existing words and non-words in different languages evoke connotations based on their sound structure (Klink, 2000, 2001, 2003; Yorkston & Menon, 2004; Lowrey & Shrum, 2007; Shrum et al., 2012; Kovic et al., 2010; Coulter & Coulter, 2010; Aveyard, 2012; Parise & Spence, 2012; Spence, 2011; Baxter & Lowrey, 2011). The sound-meaning link appears to facilitate both L1 and L2 learning (Nygaard et al., 2009; Imai et al., 2008) by helping to solve the "cross-modal correspondence problem" (which stimuli to link to link together across the senses; Spence, 2011; Bremner et al., 2012) and has been claimed to hold universally (Ultan, 1978; Ramachandran & Hubbard, 2005).

On the one hand, languages encode crossmodal relationships by mapping phonemes to specific *shapes*. For example, by virtue of the so-called "Bouba-Kiki" effect, round vowels are typically linked to rounded objects, whereas high-pitched un-round vowels bring to mind angularity (Köhler, 1929; Ramachandran & Hubbard, 2001; Westbury, 2005; Bremner et al., 2012). The effect seems to hold for children as young as 2-2.5 years and concerns both objects and visual actions (Maurer, Pathman, & Mondloch, 2006; Imai et al., 2008). On the other hand, sound-symbolic phenomena might give rise to a visual *size/power* association (Sapir, 1929). In various languages, words containing vowels with high intrinsic fundamental frequency, the acoustic correlate of pitch, (e.g., front vowels such as /ɪ, i, ɛ/; Lehiste & Peterson, 1961; Whalen & Levitt, 1995) are perceived as referring to lighter, thinner, smaller, less powerful and more feminine entities/individuals and, possibly, prickly, sour taste (Crisinel & Spence, 2009) as opposed to words containing vowels with low intrinsic fundamental frequency (e.g., back vowels such as /ʊ, o, ɔ/). A similar effect can be achieved by using different types of consonants that can influence fundamental frequency either directly, or by raising the frequency of the accompanying vowel (cmp. voiceless *vs.* voiced consonants, fricatives *vs.* plosives). The effect has primarily been observed for non-words (e.g., invented brand names; Klink, 2000, 2001, 2003; Yorkston & Menon, 2004; Lowrey & Shrum, 2007; Shrum et al., 2012) but appears to hold for existing words as well, at least in limited domains: In a study in the area of consumer psychology, Coulter & Coulter (2010) reported that vowel pitch in numerals can influence the perception of price discounts in English and Chinese.

The association between pitch and size/power can, for the most part, be explained by the mechanism of the Frequency Code (Ohala 1994; Gussenhoven, 2004), a psycholinguistic principle primarily used to account for interpretational effects of rising and falling utterance contours in different languages (Chen, 2004). According to the Frequency Code, high pitch is linked to smaller immature speakers (with thinner, smaller vocal folds and shorter vocal tracts producing higher fundamental frequency) and, hence, utterances carrying high and/or rising pitch are interpreted as less dominant, more uncertain, friendlier and questioning. Presumably, the effects of the Frequency Code can be translated from the suprasegmental domain (utterance prosody) to the micro-prosodic, segmental domain, and affect meaning with the help of motor-imitative mechanisms associated with speech perception.

Current Study

In our current study, we attempted to explore further the effect of phonetic segment-intrinsic properties on interpretation of words and non-words. Surprisingly, past research of the sound-referent cross-modal mappings mostly involved written presentation of stimuli. Given that the Frequency Code is grounded in principles of speech production, the question arises what role the modality of presentation plays in the sound-size association. Are sound symbolic effects stronger if words are presented aurally rather than visually? Moreover, according to most models of reading (Coltheart, 2006; Coltheart, 2012), unlike existing words, pseudo-words and non-words can only be pronounced with the help of a system that associates visual segments (i.e., graphemes) with sounds. Are sound-symbolic effects stronger for pseudo-words and non-words than for existing words? We addressed these two questions in Experiment 1 conducted with Dutch native speakers.

Existing research in the area of phonetic symbolism has, so far, disregarded the possibility that not just individual phonemes, but also their sequences, might create meaningful associations between phoneme-intrinsic fundamental frequency and meaning, by virtue of producing a micro-prosodic contour. For example, in words consisting of two syllables, a sequence of high-low vowels (e.g., /CɪCɔ/) produces a "falling contour", while the opposite sequence (/CɔCɪ/) produces a "rising contour". In accordance with the predictions of the Frequency Code (Gussenhoven, 2004; Chen, 2004), these two contours should receive different interpretations (*big/powerful* and *small/powerless*, respectively). Do sound-symbolic associations vary with different sequencing of high- and low-pitched phonemes in a word? We explored the issue in Experiment 2 and compared the outcomes collected for a non-tonal language (Dutch) with perceptions of lexical tones in a tonal language (Mandarin Chinese) in Experiment 3.

The last issue raised in the current study concerns the effect of other segment-intrinsic prosodic features apart from fundamental frequency, in particular, segment-intrinsic intensity (Lehiste & Peterson, 1959). As observed in prosodic studies of interpersonal influence, intensity (loudness) is positively associated with judgments of dominance and potency (Scherer, 1974; Aronovitch, 1976; Buller & Burgoon, 1986). If size/power-symbolic relations arise by transfer from the suprasegmental to the segmental domain, we might expect sounds with intrinsically higher intensity to have an effect comparable to that of low intrinsic fundamental frequency. To our knowledge, sound-symbolic associations of intrinsic intensity have not been explored in the past. Given the frequent co-occurrence of high intrinsic intensity and low intrinsic pitch, it might, in fact, be the case that at least some of the sound-meaning associations reported in the literature might be due to intrinsic intensity, rather than intrinsic fundamental frequency. Therefore, we also examined the interplay of the two acoustic features in Experiment 4.

To sum up, in our study, we addressed the following research questions:

1. Are sound symbolic effects stronger if words are presented aurally rather than visually? Are they stronger for pseudo-words than for existing lexemes? (Experiment 1)
2. Do sound-symbolic associations vary with different sequencing of high- and low-pitched phonemes in a word? (Experiment 2 and 3)
3. Are sound-symbolic associations affected by segment-intrinsic intensity? (Experiment 4)

Experiment 1

In the first experiment, we addressed the question whether or not the modality in which stimuli are presented can affect sound-symbolic interpretation of vowel-intrinsic fundamental frequency. Given that most studies of cross-modal correspondences make use of non-words and pseudo-words, we were also interested to find out if the effect is weaker (or perhaps absent) for items with denotative components.

Participants and Design

Sixty-four native speakers of Dutch (32 male; M_{age} = 25.3, *SD* = 10.5) participated in the experiment on a voluntary basis. The experiment had a 2 x 2 x 2 mixed within-between design. The between-participant variable was Modality in which participants perceived the stimuli (reading or listening). The participants were randomly assigned to the reading or listening condition (32 in each). The within-participant variables were Denotation (stimuli consisting either of existing words or pseudo-words) and Vowel-Intrinsic Fundamental Frequency (High or Low). The dependent variable was Perceived Power/Size.

Material

The stimuli were either pseudowords consisting of phoneme and syllable combinations that are possible in Dutch but meaningless (e.g., *Boloem, Wabboelan, Piripi* and *Kenep*) or pseudowords composed of meaningful morphemes (e.g., *Zondaar, Godenbad, Tinteling* or *Kietelkit*). In total, 160 bi- and tri-syllabic stimuli were systematically divided into four variants, resulting in lists of 40 items (20 existing words or compounds, 20 pseudo-words). For the listening condition, the stimuli were recorded in a soundproof booth by a native Dutch female speaker (50y) without any detectable dialect or speech habits.

Procedure and Instrumentation

The experiment was cast as a marketing study of brand names for a generic type of shampoo. In the listening condition, the stimuli were presented on a Philips Go Gear MP4 with a headset. In the reading condition, the participants filled out a pen-and-paper form. Each experimental session lasted 6-10 minutes. Participants indicated their perception of the brand names on 4 VAS scales each 7.5 cm long (*male/female, big/small, dominant/not dominant* and *unfriendly/friendly*). The Cronbach's alpha coefficient of the four scales was .8 and the scales were reduced to a single Perceived Power/Size measure.

Results

A mixed analysis of variance was used to explore the effect of the independent variables on the Perceived Power/Size. Stimuli with low intrinsic vowel frequency scored higher on the Power/Size scale than stimuli with high frequency vowels, $F(1,62) = 326.77$, $p < .001$, $\eta_p^2 = .79$. The interaction effect of Denotation and Vowel-Intrinsic Fundamental Frequency was also significant, $F(1,62) = 41.29$, $p < .001$, $\eta_p^2 = .40$; the interpretation of pseudo-words was more sensitive to the intrinsic vowel properties and their size/power-symbolic associations. Than the interpretation of existing words. There was no effect of modality of presentation.

Discussion

The results of the first experiment show that the perception of pseudowords consisting of both meaningful and meaningless morphemes is influenced by vowel-intrinsic fundamental frequency: in accordance with the predictions of the Frequency Code, front vowels are associated with less power/smaller size than back vowels. The effect was found to be independent of the modality in which stimuli were presented. The effect was stronger for meaningless pseudowords than for those composed of existing morphemes, suggesting that the phoneme-to-grapheme route (Coltheart, 2006; Coltheart, 2012) might play a role.

Experiment 2

In the second experiment, we addressed the question of the scope of vowel-intrinsic fundamental frequency effects: Are they bound strictly to the individual phonemes or can they combine into tones with different sound-symbolic interpretations, akin to lexical tones in tonal languages?

Participants and Design

The experiment was conducted among 56 participants (25 male, $M_{age} = 35.9$, $SD = 13.0$), all native speakers of Dutch, taking part on a voluntary basis. The independent variable was Vowel-Intrinsic Fundamental Frequency (High, Low, Falling and Rising and the dependent variable was perceived Power/Size of the stimulus (brand name).

Materials

The stimulus list contained 32 meaningless pseudowords, 16 experimental and 16 fillers. The experimental items consisted of 8 bisyllabic and 8 monosyllabic meaningless pseudowords with either the sequence front vowel – back vowel or the opposite, or just a front or a back vowel, with a systematic variation of voiced and voiceless plosives and fricatives (see Table 1).

Procedure and Instrumentation

The experiment was cast as a marketing study for a new product name and presented online via the LimeSurvey platform. The stimuli were presented in a visual modality only. Participants evaluated the stimuli on four 7-point scales (*male/female, big/small, thick/thin and heavy/light*). The mean Cronbach's alpha coefficient was .8 and for the purpose of the statistical analyses, the scales were thus reduced to a single Power/Size measure.

Table 1: Examples of experimental stimuli.

C-Type	Voicing	High	Low	Falling	Rising
Plosive	-	*Ti*	*To*	*Tito*	*Toti*
	+	*Bi*	*Bo*	*Bibo*	*Bobi*
Fricative	-	*Vie*	*Voe*	*Vievoe*	*Voevie*
	+	*Soe*	*Sie*	*Siesoe*	*Soesie*

Results

A repeated-measures ANOVA showed a significant effect of Vowel-Intrinsic Fundamental Frequency on the Perceived Power/Size of the novel product name, $F_1(3, 165) = 47.59$, $p < .001$, $\eta_p^2 = .46$, $F_2(3, 31) = 4.23$, $p < .05$, $F'_{min}(3, 37) = 3.88$, $p < .05$. A post-hoc analysis indicated that the front-back (intrinsically falling) sequence was evaluated as more powerful ($M = 4.23$, $SD = .74$, $p = .017$) than the back-front (intrinsically rising) sequence ($M = 3.92$, $SD = .68$, $p < .001$) and monosyllabic front-vowel stimuli (intrinsically high; $M = 3.00$, $SD = .66$, $p < .001$). The monosyllabic back-vowel stimuli (intrinsically low) were perceived as the most powerful product names ($M = 4.33$, $SD = .66$) compared to the other three types ($p < .001$).

Discussion

In the second experiment, we tested the interpretation of vowel-intrinsic F_0 in combinations of two syllables, using the dimensions 'front-back' (/ɪ-ɔ/ and /i-u/). The vowel order had a large significant effect on the perception of Power/Size. Stimuli with 'rising' combinations of front-back vowels (e.g., /kuki/) were perceived as less powerful than stimuli with 'falling' combinations (e.g., /kiku/); they were also judged as being less powerful than monosyllabic stimuli with a high (front) vowel. This finding indicates that sound symbolism that arises due to vowel-intrinsic fundamental frequency is not bound to a single phoneme but may be the result of combining the acoustic values for sequences of syllables.

Experiment 3

In the third experiment, we explored sound-symbolic interpretations of tones in a tonal language (Mandarin Chinese). In spite of the long tradition of phonetic and phonological research into tone perception and use in tonal languages, no experimental studies have laid an explicit link between the Frequency Code and lexical tones (for a general overview, see Lapolla, 1994).

Participants and Design

Ninety-six graduate and undergraduate Chinese students (39 male) from a university in Beijing participated in the study, 11 participants were excluded from the analysis due to incomplete data caused by server problems. The study was conducted in Mandarin Chinese and had a 2 x 4 design mixed within-between participant design. The within-participant variable was Tone (Tone 1 in high pitch height (H) - Level, Tone 2 in half-high pitch height (LH) - Rising, Tone 3 in half-low pitch height (L(H)) – Low-Rising, and Tone 4 in low pitch-height (HL) - Falling; Gussenhoven, 2004; Wiedenhof, 2004). The between-participant variable was the writing system (Chinese characters or Pinyin); participants were randomly divided into one of the two conditions (45 in the character-written group and 40 in the Pinyin-written group).

Material

Sixteen non-existent brand names (pseudowords) were written in matched Chinese characters and in Pinyin with four different tones (e.g., *lū*, *lú*, *lǔ* and *lù*). A pretest conducted with the Pinyin transcriptions showed that Chinese readers (same population, different group than the participant group) did not have any meaningful associations with the stimuli outside of the context of the experiment.

Procedure and Instrumentation

Participants evaluated the visually presented stimuli on a 7-point scale using the anchors “not powerful at all” (1) and “very powerful” (7). The study was conducted online with help of the Qualtrics platform.

Results

There was a significant main effect of the type of tone on the average perceived power of brand names, $F(1.88, 156.71) = 79.297$, $p < .001$, $\eta_p^2 = .49$, with degrees of freedom corrected using Huynh-Feldt estimates of sphericity. Post-hoc comparisons revealed that the Tone 4 (Falling) was more powerful than the other three Tones. Tone 2 (Rising) and Tone 3 (Low-Rising) were more powerful than Tone 1 (Level/High); the perception of Tone 2 was not different from the perception of Tone 3, see Fig. 1. The writing system used for the presentation of stimuli did not have a significant effect.

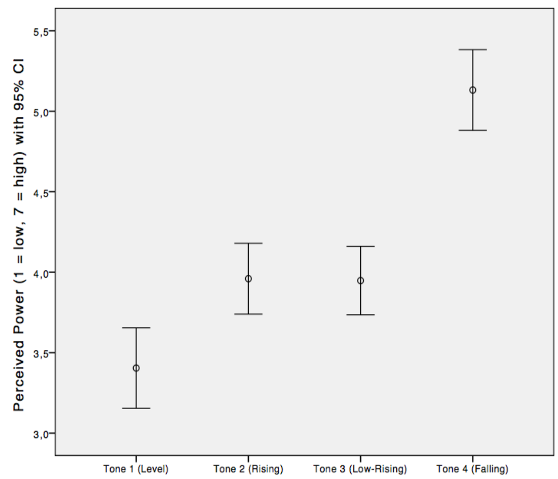

Figure 1: Perception of Chinese lexical tones in novel brand names.

Discussion

The results of the experiment show that the lexical tones in Mandarin Chinese are interpreted in a similar way as segmental and suprasegmental pitch (fundamental frequency) in non-tonal languages. Along the lines predicted by the Frequency Code, high (level) and rising tones are associated with less powerful brand names than falling tones.

Experiment 4

In the fourth experiment, we identified another intrinsic acoustic property of vowels, namely intensity, as a feature that might play a role in cross-modal relationships. Given that the two acoustic values often correlate, it could be that at least some of the sound-symbolic effects discussed in the literature are caused by perceptions of intensity. Therefore, we were interested in a possible interplay of the two acoustic properties.

Participants and Design

The participants were 146 native Dutch speakers (84 male, $M_{age} = 40.39$, $SD = 13.5$) who took part in the experiment on a voluntary basis. The experiment had a 2 x 2 within-participant design, with Fundamental Frequency (High, Low) and Intensity (High, Low) as independent variables and Perceived Power/Size as the dependent variable.

Material

We used 40 fictitious brand names (pseudowords) as stimulus material. The brand names were constructed in accordance with the measurements of intrinsic fundamental frequency and intrinsic intensity of vowels (Lehiste & Peterson, 1959; 1961) and within the limits of the Dutch phonemic inventory in the following way: we selected four vowels as the most extreme representatives of the two acoustic dimensions (/u/ ~ [+ Fundamental Frequency, + Intensity], /i/ ~ [+ Fundamental Frequency, - Intensity], /ɑ/ ~ [- Fundamental Frequency, + Intensity] and /ɪ/ ~ [- Fundamental Frequency, - Intensity]), see Fig. 2. The four vowels were systematically combined with both voiced and voiceless consonants in bi-syllabic non-words ("company names"), e.g. *Manan, Doedoer, Tipit* and *Liediel.*

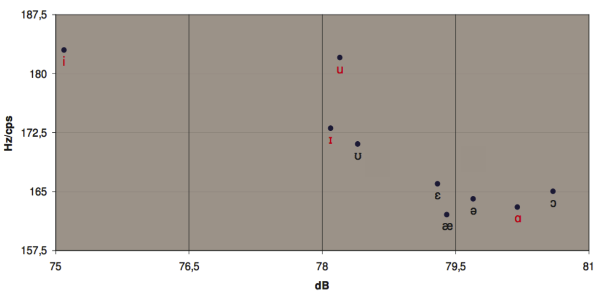

Figure 2: Intrinsic fundamental frequency and intrinsic intensity of vowels (after Lehiste & Peterson, 1959, 1961).

Procedure and Instrumentation

The material was presented visually via the LimeSurvey platform as a part of a marketing study conducted on behalf of a foreign company in the Netherlands. Participants evaluated possible company names on four 5-point scales: *male/female, big/small, dominant/submissive and strong/weak.* On the basis of the Cronbach's alpha (.9 on average), the measures were reduced to a single scale.

Results

The results of a repeated measures ANOVA show a significant effect of Fundamental Frequency, $F_1(1, 145) = 223.44$, $p < .001$, $\eta_p^2 = .61$, $F_2(1, 36) = 73.75$, $p < .001$, $F'_{min}(1, 62) = 55.45$, $p < .001$, and a slightly weaker significant effect of Intensity, $F_1(1, 145) = 155.17$, p < .001, $\eta_p^2 = .52$, $F_2(1, 36) = 49.47$, $p < .001$, $F'_{min}(1, 61) = 37.51$, $p < .001$, as well as a trend of an interaction effect, $F_1(1, 145) = 26.66$, $p < .001$, $\eta_p^2 = .17$, $F_2(1, 36) = 3.76$, $p < .001$, $F'_{min}(1, 47) = 3.30$, $p = .08$ on the perceived Power/Size, see Table 2.

Table 2: Mean Perceived Power/Size.

Fundamental Frequency	Intensity	*M*	*SD*
High	High	2.34	.75
	Low	2.01	.58
Low	High	3.00	.65
	Low	2.43	.60

Discussion

The results of Experiment 4 indicate that sound-size/power correspondence can arise not just thanks to vowel-intrinsic fundamental frequencies but also as a result of intrinsic intensity. Given that the two acoustic values appear to be in a negative correlation, it was not possible to pry apart their effects using written stimuli. In a follow-up study, their contribution could be explored in detail with the help of artificially synthesized stimuli. Another issue to explore in the future concerns individual differences in vowel pronunciation. As noted by Lehiste & Peterson (1959, 1961), different speakers, in fact, vary in their use of the vowel space. The question thus arises if the sound-symbolic effects found in various studies are linked to speakers' own prototypical production targets or based on previous perceptual experience.

General Discussion and Conclusion

In our study, we addressed a number of important questions regarding cross-modal correspondences in the auditory domain. We conducted a series of experiments under the assumption that the size/power sound-symbolic relations are due to intrinsic acoustic properties of phonemes captured by the psycholinguistic principle of the Frequency Code, rather than by idiosyncratic mechanisms akin to weak synaesthesia (see Parise & Spence, 2012, for a discussion). The results of the experiments indicate that sound symbolic effects are not necessarily stronger when words are presented aurally rather than visually, however, the cross-modal sound-size correspondences are stronger for pseudo-words than for existing words. The intrinsic fundamental frequency effects are not bound to individual phonemes but can combine into tones with different sound-symbolic interpretations. In a sense, non-tonal languages thus resemble tonal languages where different lexical tones appear to be interpreted differently (at least on pseudo-words). Finally, other acoustic features apart from fundamental frequency may co-determine the cross-modal sound-based associations: in particular, intrinsic intensity seems to play a significant role.

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