Synthesized size-sound sound symbolism

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Abstract

Studies of sound symbolism have shown that people can associate sound and meaning in consistent ways when presented with maximally contrastive stimulus pairs of nonwords such as bouba/kiki (rounded/sharp) or mil/mal (small/big). Recent work has shown the effect extends to antonymic words from natural languages and has proposed a role for shared cross-modal correspondences in biasing form-to-meaning associations. An important open question is how the associations work, and particularly what the role is of sound-symbolic matches versus mismatches. We report on a learning task designed to distinguish between three existing theories by using a spectrum of sound-symbolically matching, mismatching, and neutral (neither matching nor mismatching) stimuli. Synthesized stimuli allow us to control for prosody, and the inclusion of a neutral condition allows a direct test of competing accounts. We find evidence for a sound-symbolic match boost, but not for a mismatch difficulty compared to the neutral condition.

Keywords: sound symbolism; iconicity; ideophones; cross-modal correspondences; language

Introduction

Research into iconicity, where aspects of a word's form reflect aspects of its meaning, has considerably nuanced the classical view of words as wholly arbitrary (Dingemanse, Blasi, Lupyan, Christiansen, & Monaghan, 2015; Lockwood & Dingemanse, 2015; Perniss, Thompson, & Vigliocco, 2010). Iconicity is found across languages, both spoken (Dingemanse, 2012) and signed (Emmorey, 2014; Perniss & Vigliocco, 2014), and plays a significant role in language acquisition (Imai & Kita, 2014; Perry, Perlman, & Lupyan, 2015; Yoshida, 2012), language evolution (Cuskley & Kirby, 2013; Verhoef, Kirby, & de Boer, 2015; Zlatev, 2014), and language processing (Lockwood & Tuomainen, 2015; Meteyard, Stoppard, Snudden, Cappa, & Vigliocco, 2015; Westbury, 2005); but it is still unclear exactly how.

Studies have shown that people are sensitive to the meanings of sound-symbolic words in a foreign language, associate certain artificial words (henceforth nonwords) with certain properties depending on their vowels and consonants, and learn new words better when there is a sound-symbolic relationship between form and meaning (Aveyard, 2012; Davis, 1961; Dingemanse, Schuerman, Reinisch, Tufvesson, & Mitterer, in press; Kovic, Plunkett, & Westermann, 2010; Lupyan & Casasanto, 2015). The general consensus is that cross-modal correspondences and perceptuo-motor analogies between sounds and meanings provide a way of bridging the two domains in consistent ways (Perniss & Vigliocco 2014). However, there is not yet a satisfactory answer to which cross-modal correspondences are implicated in sound symbolism or how exactly these correspondences help people to make mappings. Many experiments have relied on forced choice decisions where participants judge which nonword goes with which property (Bremner et al., 2013; Davis, 1961; Köhler, 1929; Nielsen & Rendall, 2011, 2013; Sapir, 1929). This sets up a paradigm where participants consistently identify sound-symbolically matching sets of stimuli (e.g. the nonword *bouba* and the round shape, the nonword *kiki* and the spiky shape). The combined weight of these experiments is an affirmation of the existence and prevalence of sound symbolism. However, these studies do not address how the associations affect the participants' choices: does a sound-symbolic match provide a mapping boost helping the participant to choose the matching set of stimuli, or does the sound-symbolic mismatch provide a cue to exclude that set of stimuli, or is it a combination of both? Moreover, it is not always clear whether a mismatch is an actual clash or whether mismatch is simply taken to mean "not matching".

Other experimental designs suggest that it is not as simple as the two-alternative forced choice literature makes out (Monaghan, Mattock, & Walker, 2012; Westbury, 2005).

Rating experiments which vary sound-symbolic representations of size along a graded scale have shown that people judge sound symbolism in a graded fashion rather than simply as being there or not (Thompson & Estes, 2011). A graded model of sound symbolism is more detailed, but leaves the same question open: is it driven equally at both ends of the graded spectrum? Learning experiments have shown that it may be one end of a graded spectrum which drives sound-symbolic associations, such as an association between labial sounds and roundness creating an incidental association between non-labial sounds and spikiness (Jones et al., 2014). While it appears that the spiky—round spectrum does not map directly onto the labial/voiced—non-labial/voiceless spectrum suggested by two-alternative forced-choice studies, it remains to be seen whether this imbalance holds for other domains. Finally, other learning experiments suggest there is a sound-symbolic processing bias, but that it is weak and can be overcome with training (Nielsen & Rendall, 2012).

We ran a similar learning experiment with Japanese ideophones (Lockwood, Dingemanse, & Hagoort, 2016) rather than nonwords. In this study, we taught the ideophones to a group of Dutch participants with no knowledge of Japanese. For half the ideophones, the participants learned the real Dutch translations (e.g. *dik*, or fat, for *bukubuku*, which means fat); for the other half, the participants learned the opposite Dutch translations (e.g. *verdrietig*, or sad, for *ukiuki*, which means happy). In a recognition task, participants remembered the ideophones in the real condition far better than the ideophones in the opposite condition (86.1% recognition accuracy vs. 71.1%). When we repeated the experiment with a set of arbitrary adjectives and another group of participants, there was no sound-symbolic effect across the two conditions (79.1% recognition accuracy in the real adjective condition, 77% in the opposite adjective condition). This is in line with the nonword studies that show a mapping boost for sound-symbolically matching stimuli and a mapping difficulty for sound-symbolically mismatching stimuli, although it is not possible to say whether the effect is driven by one or both of these mapping strategies.

In another sound symbolism study with real words, Nygaard et al. (Nygaard, Cook, & Namy, 2009) found a different result. Participants learned Japanese words with their real translations and their opposite translations equally well, but learned words with random translations less well. They proposed that cross-modal correspondences help sound-to-meaning mappings for both matching and mismatching words, as antonym pairs are conceptually very close. Under this interpretation, sound symbolism in learning tasks is not a graded effect. Rather, the lack of any sound-to-meaning correspondence makes word learning harder than having a mismatching or counterintuitive cross-modal clash to build upon.

While using real words from real languages avoids the ecological validity problem of nonwords, there are other confounds which cannot be completely be ruled out. Firstly, sound-symbolically congruent and incongruent prosody has been shown to affect meaning judgement (Nygaard, Herold, & Namy, 2009). It is possible that our Dutch participants were just picking up on the prosody of the Japanese ideophones rather than the sounds themselves. Secondly, orthography is a constant confound in tasks with both nonwords and real words (Cuskley, Simner, & Kirby, 2015).

This paper builds on Lockwood et al. (2016) by creating nonwords in the shape of Japanese ideophones, synthesizing the sound stimuli, and limiting the meanings to a simple size contrast. This lets us investigate a spectrum of sound-symbolically matching, mismatching, and neutral stimuli. Here, we take neutral to mean that a relation that is neither an obvious match nor an obvious mismatch. The use of a speech synthesizer to generate the sounds eliminates possible prosodic differences which in natural speech may indicate sound-symbolic contrasts (Dingemanse et al. in press). Keeping translations to "big" and "small" lets us work within a well-attested sound-symbolic framework where participants' subjective ratings are constrained and predictable.

Including a neutral condition while ensuring that the mismatch condition is a cross-modal clash (rather than just a lack of cross-modal correspondence) allows us to adjudicate between different theoretical accounts for sound-symbolic effects. If the participants learn matching nonwords better than neutral nonwords, but there is no difference between neutral and mismatching nonwords, this is evidence for a sound-symbolic match boost as in Lockwood et al. (2016) and Jones et al. (2014). If participants learn matching nonwords better than neutral nonwords and neutral nonwords better than mismatching nonwords, this is evidence for a graded sound-symbolic rating effect as in Nielsen and Rendall (2012) transferring to sound-symbolic learning. Finally, if participants learn the neutral nonwords worse than both the matching and mismatching nonwords, this is evidence for cross-modal correspondences boosting learning regardless of whether the associations correspond or clash, as in Nygaard et al. (2009).

Methods

In the main experiment, 30 participants learned 36 nonwords in three learning rounds, and were tested immediately afterwards. We first describe the stimuli design and selection.

Stimuli design

We created nonwords in the CVCV-CVCV pattern found in Japanese ideophones. These nonwords were deliberately created in order to sound big, neutral, or small, based on attested cross-modal correspondences between sound and size. Big-sounding nonwords featured voiced stops and mid/low back vowels. Small-sounding nonwords featured voiceless stops and high front vowels. Neutral-sounding nonwords featured mid-vowels, and had either all voiced, all unvoiced, or a mix of voiced and unvoiced stops. Table 1 shows the distribution of vowels and consonants used in each word type.

Table 1: sound distributions across nonword types

Nonword type	Consonants	Vowels
big-sounding	[b] [d] [g]	[a] [o]
small-sounding	[p] [t] [k]	[i] [ʏ]
neutral-sounding	[p] [b] [t] [d] [k] [g]	[ɛ] [ə]

We wrote a Matlab script to generate all possible combinations of words according to this pattern where the consonant was not repeated (e.g. *bobaboba*), and this resulted in 192 possible nonwords.

We then synthesized the nonwords using the Dutch voice nl2 from the diphone synthesizer MBROLA (Dutoit, Pagel, Pierret, Bataille, & van der Vrecken, 1996). All nonwords were given the same pitch, vowel durations, and prosodic contours.

Stimuli rating pre-test

28 native Dutch speakers listened to each synthesized nonword under the impression that they were size adjectives from a real language. Participants rated how big the word sounded on a Likert scale of 1-7, where 1 represented really small, 4 neutral, and 7 really big. Participants were also told to indicate whether their rating was influenced by a similar-sounding Dutch word in order to detect lexical confounds. We removed 17 nonwords where at least four participants indicated that it reminded them of something.

In the remaining 175 nonwords, participants consistently judged the big-sounding words as big (mean=5.57), the neutral-sounding words as neutral (mean=3.90), and the small-sounding words as small (mean=2.68). This was a highly significant effect according to a one-way ANOVA ($F=694.3$, $p<0.001$), and post-hoc Bonferroni tests showed that this difference was significant between each condition (all ps <0.001). This is shown in Figure 1.

We selected 36 nonwords for the full experiment according to their mean ratings. For the big-sounding nonwords, we chose the 12 highest-rated nonwords; for the small-sounding nonwords, we chose the 12 lowest-rated nonwords; and for the neutral-sounding nonwords, we chose the 12 nonwords which were rated most closely to 4. All 36 nonwords were from the originally designated condition, i.e., all 12 big nonwords were nonwords which we designed to sound big, and so on.

All nonwords meant either *groot* (big) or *klein* (small). This set up three conditions: nonwords that meant big (or small) and sounded big (or small) were sound-symbolically matching, nonwords that meant big (or small) but sounded small (or big) were sound-symbolically mismatching, and nonwords that meant big or small but neither obviously matching nor mismatched were neutral. This is illustrated in Table 2. Correspondences between onsets in the nonwords and translations were controlled across conditions.

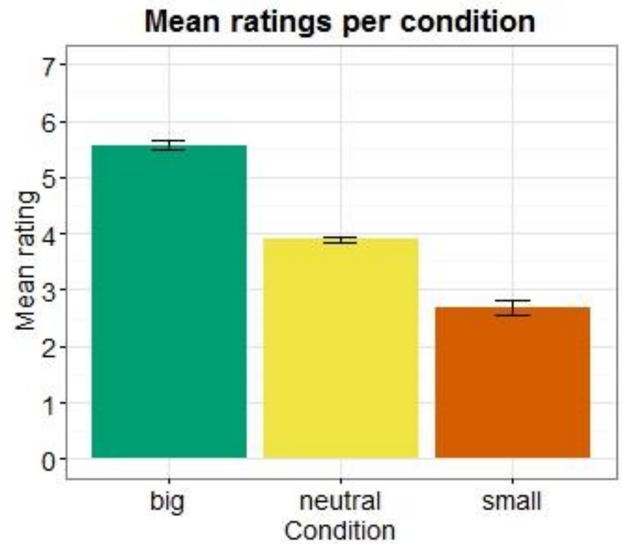

Figure 1: Size ratings per condition

Table 2: examples of learning conditions and nonwords

Condition	Nonword	Translation
Match	badobado	groot
	tʏpitʏpi	klein
Neutral	detədetə	groot
	gɛpɛgɛpɛ	klein
Mismatch	gogagoga	klein
	tipitipi	groot

Main experiment

Participants had three learning rounds in which to learn the nonwords, and then a test round immediately afterwards. They were told that the words came from an African language with a complicated adjective agreement system; in a post-experiment debriefing they were informed that the words were artificial. Item translations were counterbalanced across participants. The procedure is illustrated in Figure 2.

We used Presentation to present the stimuli and record responses. In the learning round, the initial Dutch word was presented for 1000ms with 100ms of jitter, followed by a fixation cross for 1000ms with 100ms of jitter. As the nonword was played over the speakers, a blank screen was presented for 2000ms with 200ms of jitter. This was again followed by a fixation cross. The final screen with the nonword and its Dutch meaning was presented until participants were happy to move onto the next item. Between trials, a blank screen was presented, followed by a fixation cross to announce the beginning of the next trial. Timings in the test round were identical, except that a question mark was presented instead of a blank screen while the nonword played. Participants responded by button press for yes/no answers.

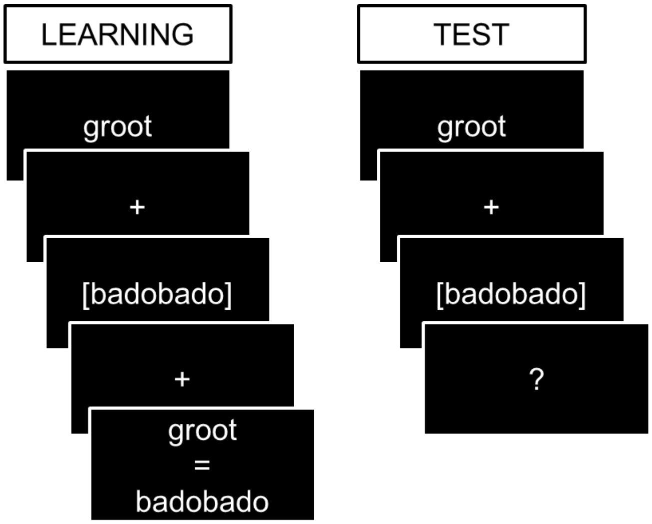

Figure 2: Learning and test round procedures.

We tested 33 native Dutch speaking participants (4m, 29f) aged 18-26 (mean: 21y 4m) with normal or corrected-to-normal vision, recruited from the MPI participant database. Three were discarded due to issues with the Presentation script, leaving us with 30 participants in total. This sample size is identical to Lockwood et al. (2016). However, the reduction in the number of items to learn per condition means that more participants are needed to match the power of that study. Therefore, this experiment is intended as an initial experiment to be replicated with a larger sample size.

Results

Participants identified nonwords at 75.56% accuracy in the match condition, at 66.11% accuracy in the neutral condition, and at 62.50% accuracy in the mismatch condition. This is shown in Figures 3 and 4. Error bars in Figure 4 represent standard error. Mean accuracy was consistent across antonym meanings (match: big = 74.44%, small = 76.67%; neutral: big = 70.56%, small = 61.67%; mismatch: big = 63.89%, small = 61.11%. All ps>0.1).

As the dependent variable was binary—correct or incorrect—we analyzed the responses using a mixed-effects logit model with the glmer function of the lme4 (versions 1.1-8) package in R. The data was modelled by including a per-participant and per-nonword random adjustment to the fixed intercept with a random slope for the fixed effect by participant. The condition was sum contrast coded to compare match to neutral and neutral to mismatch.

Model comparison between a model with condition as a fixed effect and a model with no fixed effect showed that condition was a significant fixed effect (χ^2=8.36, p=0.015). Secondly, the best model included a fixed effect of condition, a random effect by participant with random intercepts and random slopes by condition, and random intercept by nonword. This model showed that participants did better in the match condition than the neutral condition (β=0.48, SE=0.20, p=0.017), but found no evidence for a difference in performance in the neutral and mismatch conditions (β=-0.11, SE=0.21, p=0.60).

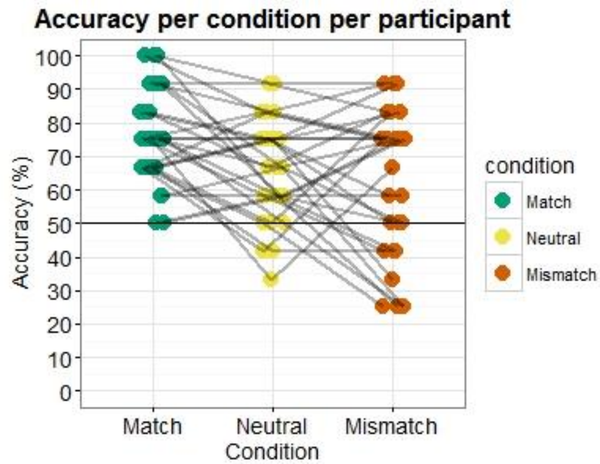

Figure 3: test round results per participant

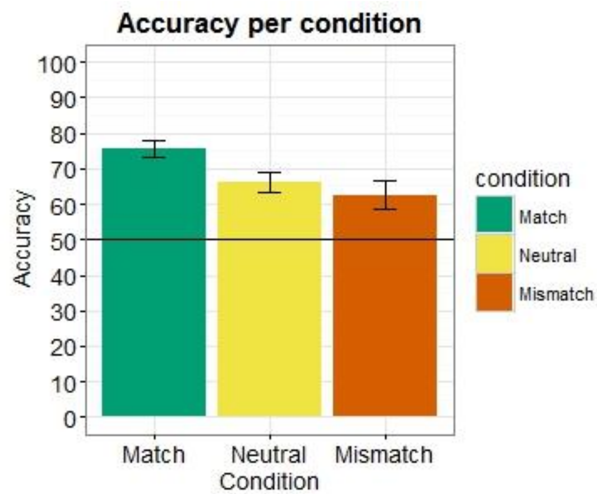

Figure 4: overall test round results

Discussion

Sound symbolism research has shown that cross-modal correspondences help people make mappings between sound and meaning. However, it is unclear whether this is because cross-modal correspondences provide a mapping boost or because a lack of a correspondence causes a mapping difficulty. In this study, we build on previous sound-symbolic word learning research by explicitly controlling the type of sound-symbolic relationship in each condition. Participants learned nonwords which had a variety of sound-symbolic cues to help scaffold word learning. Nonwords in the match condition had cross-modal correspondences between their sounds and meaning; nonwords in the mismatch condition had cross-modal clashes between their sounds and meaning; and nonwords in the neutral condition had neither matching nor mismatching cross-modal information.

Participants learned the nonwords in the match condition better than the nonwords in the neutral condition, but there was no difference in participants' performance in the neutral and mismatch conditions, and nor was there any difference between how well participants learned nonwords meaning big and small. This suggests that sound-symbolic effects in learning, and perhaps other behavioural tasks, are due to cross-modal correspondences providing a mapping boost. It also suggests that cross-modal mismatches do not provide a mapping boost, but nor do they provide an increased mapping difficulty (although mean scores suggest a possible graded effect, which will be examined in a replication with a larger sample size). This provides initial support for Lockwood et al. (2016), Jones et al. (2014), and Imai et al. (2014; Imai, Kita, Nagumo, & Okada, 2008), whose learning experiments have previously suggested that sound-symbolic bootstrapping depends on the boost effect from matching cross-modal correspondences. It also suggests that the graded perception of sound symbolism in rating tasks (such as in Nielsen & Rendall, 2011; Thompson & Estes, 2011, and indeed, the stimuli selection pre-test for this study) does not extend to a graded learning effect. Finally, it provides some evidence against the proposal that any kind of cross-modal associations, corresponding or clashing, are better for facilitating sound-symbolic mappings than no cross-modal associations at all. However, this does not rule out the findings of Nygaard et al. (2009). In their experiments, the learning phase was far longer and continued until participants reached a ceiling effect in their accuracy responses. It is possible that there is an initial sound-symbolic match boost during the first stages of word learning, while any kind of cross-modal association can help scaffold word learning during later stages of learning and consolidation.

A replication of this study with a larger sample size will provide further evidence of whether sound symbolism boosts word learning through cross-modal correspondences rather than other factors. Moreover, it will allow us to explore individual differences in sound symbolism during learning. This study shows that participants learned the matching nonwords better than the neutral nonwords, while there was no evidence for a difference in how well the participants learned neutral and mismatching nonwords. This is most obviously shown in Figure 4. However, the dotplots in Figure 3 suggest that it may not quite be so simple. Participants appear to be split, where approximately half learn the neutral nonwords better than the mismatching nonwords, and approximately half learn the mismatching nonwords better than the neutral nonwords. It is possible that some participants learn words better when there is a cross-modal association between sound and meaning, whether corresponding or clashing, while other participants learn in a way that reflects the graded effect of sound-symbolic perception. A larger sample size in a follow-up replication can explore these individual differences fully.

Finally, this study only addressed size symbolism for consonant voicing and vowel position, and we cannot assume that sound symbolism works this way for all form-meaning mappings.

In summary, we conducted a learning task equally inspired by findings from natural language iconicity and nonword studies. Using synthesized words in a constrained semantic space allowed us to adjudicate between different proposals about how sound symbolism affects learning. The evidence points to a match boost but not a mismatch difficulty, clarifying the role of cross-modal correspondences in sound-symbolic word learning.

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