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The shape of words in the brain

Vanja Kovic [a,*], Kim Plunkett [b], Gert Westermann [c]

[a] Department of Psychology, University of Novi Sad, Dr. Zorana Djindjica, 21000 Novi Sad, Serbia
[b] Department of Experimental Psychology, University of Oxford, South Parks Rd., Oxford OX1 3UD, UK
[c] Department of Psychology, Oxford Brookes University, Gipsy Lane, Oxford OX3 0BP, UK

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ABSTRACT

The principle of arbitrariness in language assumes that there is no intrinsic relationship between linguistic signs and their referents. However, a growing body of sound-symbolism research suggests the existence of some naturally-biased mappings between phonological properties of labels and perceptual properties of their referents (Maurer, Pathman, & Mondloch, 2006). We present new behavioural and neurophysiological evidence for the psychological reality of sound-symbolism. In a categorisation task that captures the processes involved in natural language interpretation, participants were faster to identify novel objects when label–object mappings were sound-symbolic than when they were not. Moreover, early negative EEG-waveforms indicated a sensitivity to sound-symbolic label–object associations (within 200 ms of object presentation), highlighting the non-arbitrary relation between the objects and the labels used to name them. This sensitivity to sound-symbolic label–object associations may reflect a more general process of auditory–visual feature integration where properties of auditory stimuli facilitate a mapping to specific visual features.

1. Introduction

The way we link labels to their referents is a matter of convention according to Saussure (1959), who established arbitrariness as one of the crucial characteristics of language. For instance, the label 'dog' has no intrinsic relationship with the animal to which it refers. Saussure claimed that even onomatopoeic words are no more than conventionalised forms and denied any natural expressiveness of words. Since then the principle of arbitrariness has been widely accepted in the linguistic community. However, a growing body of sound-symbolism research demonstrates that adults and even 2.5-year-old children prefer nonsense words with round vowels (such as 'maluma' or 'bouba') for round-shaped objects and nonsense words with unrounded vowels (such as 'takete' or 'kiki') for pointy objects (Holland & Wertheimer, 1964; Köhler, 1947; Maurer et al., 2006; Ramachandran & Hubbard, 2001; Wertheimer, 1958). Sapir (1929) suggested that word sounds can also capture the magnitude of the objects to which they refer: when asked to decide which of the two sounds 'mil/mal' referred to the larger of two tables, 80% of the participants chose the label 'mal'.

Further support for the psychological reality of sound-symbolism comes from cross-linguistic studies in which participants demonstrated an ability to use the set of label–object mappings they had learnt in their mother tongue to generalise to foreign words (Japanese and English (Kunihira, 1971); Chinese, Czech, and Hindi and English (Brown, Black, & Horowitz, 1955); South Malaita, Kiwai, Tongan, Finnish, and English (Gebels, 1969); and Hebrew and English (Brackbill & Little, 1957). Participants' ability to guess the meanings of foreign words above chance level has led some researchers (e.g., Brown et al., 1955) to conclude that speech itself must have originated from imitative connections between sounds and meaning and that these connections are universal.

* Corresponding author. Tel.: +381 11 2779 749.
E-mail address: vkovic@ff.uns.ac.rs (V. Kovic).

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According to Ramachandran and Hubbard (2001), sound-symbolism is based on the shape of the lips (open and round vs. wide and narrow) when producing labels for certain objects. Ramachandran and Hubbard (2001) argued that *if* sound-symbolism is caused by the link between mouth shape and word sound then objects that in some sense correspond to the mouth shape used to articulate a certain word would be linked with the sound of this word more easily/strongly. In fact, Ramachandran and Hubbard (2001) even speculated that connections among sensory cortical areas and between sensory and motor areas constrained the evolution of language. We do not have experimental evidence for such a claim. However, there is ample opportunity for cross-modal mappings between the shape of the vocal tract (including the mouth) and sound characteristics to be formed early on infancy, either through observational learning, feedback from self-produced sounds or both (see Westermann & Miranda, 2004 for a plausible, neuro-computational account).

More recently, Imai, Kita, Nagumo, and Okada (2008) have demonstrated that 3-year old children are able to generalise the meaning of novel sound-symbolic words, but not of non-sound-symbolic words, in a verb learning task. Nygaard, Cook, and Namy (2009) showed that native English-speaking monolinguals learned the English equivalents and antonyms for Japanese words more accurately and responded faster than when learning random word-meaning pairs. Finally, in a statistical analysis of the English language, Farmer, Christiansen, and Monaghan (2006) demonstrated a probabilistic relationship between the sound of a word and its lexical category.

Many of these studies require adults (and young children) to make forced-choice responses that potentially highlight the sound-symbolic nature of the task. The sound-symbolic choices that participants make in these experiments may therefore not reflect the processes that are involved in normal language interpretation. The aim of our study was to investigate whether sound-symbolic preferences could be demonstrated in a complex categorisation task in which the sound-symbolic relationships were incidental to task performance and where participants were unlikely to be aware of such contingencies during the study.

We designed a set of objects based on the "5-4" categorisation task (Medin & Schafer, 1978; Rehder & Hoffman, 2005) and trained a group of participants in a first study to classify rounded-featured objects as 'mots' and jagged-featured objects as 'riffs' in a congruent sound-symbolic condition. In an incongruent sound-symbolic condition, the label assignment was reversed, i.e., rounded objects were labelled 'riffs' and pointed objects 'mots'. During a subsequent test phase, participants in both the congruent and incongruent conditions were presented with 160 label–objects pairs, half of which matched the previously learned mapping and half of which did not, and were asked to detect label–object matches and mismatches. The question of interest was: given a set of new objects, and equal experience categorising them, are people who have learned sound-symbolic label–object associations faster at categorising them than people who have learned label–object associations that are incongruent at the sound-symbolic level? Furthermore, in a second study we tried to maximise the sound-symbolism effect by varying both roundness and voicing of the sounds. Selected labels in this case were 'dom' and 'shick'. This study involved recording ERP (event-related potentials) from participants to investigate if the effects of sound-symbolic congruency in a categorisation task are apparent in the learner's brain activity.

We predicted that the participants in the sound-symbolic condition would be faster to respond in comparison to the participants in the non-sound-symbolic condition. On the assumption that sound-symbolism is a special case of multi-sensory integration, in accordance with prior studies (Giard & Peronnet, 1999; Molholm, Ritter, Javitt, & Foxe, 2004; Molholm et al., 2002; Shams, Iwaki, Chawla, & Bhattacharya, 2005; Yuval-Greenberg and Deouell, 2007; Widmann, Gruber, Kujala, Tervaniemi, & Schroger, 2007; Widmann, Kujala, Tervaniemi, Kujala, & Schroger, 2004), we also predicted early brain-wave differences between the congruent and incongruent sound-symbolic conditions, resulting from the different degrees of binding between auditory and visual modalities in both conditions. Different ERP signatures arising in the sound-symbolic and non sound-symbolic conditions and faster response times in the sound-symbolic condition can provide direct evidence for the psychological reality of sound-symbolic label–object contingencies.

2. Experiment 1

2.1. Participants

Thirty-seven right-handed, native English speakers with normal or corrected-to-normal vision took part in the study. They were all first-year undergraduate psychology students from the University of Oxford who signed a consent form and received course credit for their participation. Five participants were excluded from the analysis due to failure to learn the task successfully.

2.2. Stimuli

Visual stimuli were schematic animal-like drawings created in Adobe Photoshop CS software (see Fig. 1).

Each object was composed of four binary-valued features (rounded/pointy head, crescent/triangle-shaped wing, rounded/bushy tail and three/five legs) and could be classified as belonging to one of two categories. All of

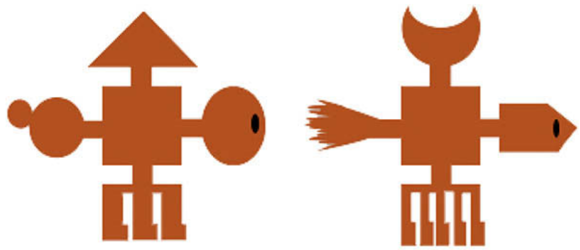

Fig. 1. Schematic drawings based on the 5-4 categorisation task.