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The aim of the present paper was to experimentally test whether sound symbolism has a different effect in labels with different range-of-reference within a simple noun-hierarchy. In two experiments, adult participants learned the makeup of two categories of unfamiliar objects (‘alien life forms’), and were passively exposed to either category-labels or item-labels, in a learning-by-guessing categorization task. Following category training, participants were tested on their visual discrimination of object pairs. In each of the two experiments, for different groups of participants, the labels were either congruent or incongruent with the objects. When trained on items in labeled categories, participants were faster at detecting a match if the labels were congruent, and faster at detecting a mismatch if the labels were incongruent. When trained on items with individual labels, participants were better at detecting a mismatch when trained on incongruent labels. This pattern of results suggests that sound symbolism in category labels enhances similarity judgment when congruent, and enhances discrimination when incongruent. These findings reveal, that the systematicity brought about by shared sound symbolic congruence has a different outcome at different levels of labeling within a noun hierarchy, and that the effect of sound symbolic labeling not only influences mapping between labels and their referents, but also influences object processing in the absence of the label itself.

To call a cloud ‘cirrus’: Sound symbolism in names for categories or items.

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Abstract:

The aim of the present paper was to experimentally test whether sound symbolism has a different effect in labels with different range-of-reference within a simple noun-hierarchy. In two experiments, adult participants learned the makeup of two categories of unfamiliar objects (‘alien life forms’), and were passively exposed to either category-labels or item-labels, in a learning-by-guessing categorization task. Following category training, participants were tested on their visual discrimination of object pairs. In each of the two experiments, for different groups of participants, the labels were either congruent or incongruent with the objects. When trained on items in labeled categories, participants were faster at detecting a match if the labels were congruent, and faster at detecting a mismatch if the labels were incongruent. When trained on items with individual labels, participants were better at detecting a mismatch when trained on incongruent labels. This pattern of results suggests that sound symbolism in category labels enhances similarity judgment when congruent, and enhances discrimination when incongruent. These findings reveal, that the systematicity brought about by shared sound symbolic congruence has a different outcome at different levels of labeling within a noun hierarchy, and that the effect of sound symbolic labeling not only influences mapping between labels and their referents, but also influences object processing in the absence of the label itself.

Keywords: categorization, category label, item label, sound-symbolism

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Introduction:

When cloud watchers talk about a ‘cirrus’ or a ‘cumulus’, they are naming cloud types which can be distinguished by their visual form. The cirrus, its name full of high vowels and sibilant-rich consonants, refers to a high-altitude ice cloud, with a typically thin, wispy form. The culumus, with its rounded vowels and sonorant consonants, refers to a puffy, low-altitude cloud, prone to rising muffin-tops. Do the sounds encoded in the names of the clouds enhance visual differences between the clouds’ shapes? And if so, does the influence of sounds on visual forms differ when labels are used to at different levels of description (e.g., cloud versus cirrus)?

Since the first systematic studies into sound symbolism in linguistic labeling, most research has tended to focus on labels for a small number of individual items (usually a pair), which can be discriminated on some visual dimension. For example, Sapir (1929) asked people which of the word-forms ‘mil’ and ‘mal’ would be a better label for a small or large table, and Köhler (1929:1947) asked whether a curved or an angular line-drawing would be a better match for word forms like ‘baluma’ and ‘takete’. The majority of the literature on sound symbolism (for recent reviews see Imai & Kita 2014; Lockwood & Dingemanse 2015) has followed a trend for contrastive label-stimulus mappings for a small number of items, usually two-dimensional line drawings, usually presented in pairs (prominent examples include Maurer et al. 2006; Ramachandran & Hubbard 2001). While some researchers have expanded the field into other domains such as flavor (Ngo et al. 2011; Spence & Gallace 2011), the majority of research has focused on the mapping between a single experimental stimulus and a single label. It is therefore difficult to interpret what range-of-reference these novel labels might play in a naturalistic noun-labeling hierarchy – do they refer to abstract superordinate category concepts (e.g., animal), basic-level categories (e.g., dog), subordinate-nouns (e.g., Labrador), or even proper nouns for individual exemplars (e.g., Fido).

Research using words from unfamiliar languages provides a ready-made range-of-reference, since participants will likely bootstrap the novel word to its translation equivalent. For example, in a study by Berlin (1995), English speaking participants were above chance at guessing which label in a pair was a type of fish, and which a type of bird, for stimuli from an unfamiliar language. Studies of this kind demonstrate that sound symbolism can reside in labels for categories of natural objects, not just as one-off names for arbitrary experimental tokens.

Similarly, sound-symbolism can enhance word learning for antonym pairs in unfamiliar languages (e.g., 'fast'/'slow') (Nygaard et al. 2009), and sound symbolism can facilitate word learning, in tasks where adults and infants from two different language groups were able to learn action descriptions and extend them to new action events (Imai et al. 2008; Kantartzis et al. 2011). It is therefore clear that sound symbolism is not limited to arbitrary lab-based labels for abstract items, but is evident in descriptive phrases, category labels, and action descriptions. However, it remains unclear whether sound symbolism plays different roles at different levels of labeling within a single hierarchy.

To the best of our knowledge, only one study has investigated sound symbolism in labels which explicitly refer to whole categories of novel objects, where multiple members of the category are available to the participant. In Kovic, Plunkett and Westermann's (2010) study, participants learned to sort two classes of novel, schematic creatures, by allocating them to named categories. Participants began by guessing which creature belonged to which category, and with feedback, gradually refined their answers as they learned which items belonged to which category. The creatures differed according to a number of schematic dimensions (e.g., number of legs, shape of tail), but no single feature was solely responsible for which item belonged to which category. Two groups of participants learned to form categories with labels which were sound-symbolically congruent or incongruent with the typical shape of the creatures' head (e.g., 'dom' or 'shick' for mostly-round or mostly-pointy heads). In two separate behavioural tasks, sound symbolism for head shape did not influence training speed or recall accuracy. However, during the test phases (in which people heard a label, then decided whether a subsequently presented picture matched) the congruence of the shape of the creatures' heads with the newly learned labels influenced the *speed of decisions*. This finding suggested that although the efficiency and success of word learning did not differ between conditions, links between the auditory label and the category members were more efficiently accessed for participants who had learned sound symbolically congruent labels.

The same study also reported electrophysiological evidence of differences between responses of the two groups of participants – during the test phase, ERPs showed characteristics of enhanced visual object processing for people who had learned the congruent category labels. Taken together, these findings suggest that when sound symbolism is present for a recently

acquired category label, it enhances our ability to access information relevant to the mapping between form and meaning. In terms of mechanisms, this finding could suggest that a congruent label invokes (primes) salient features of its member items prior to their visual appearance, thus enhancing object recognition. Alternatively, encoding with symbolism may cause the individual items to be represented with richer feature representations, meaning that their individual shapes were recognized more efficiently.

However, notable questions still remain about the limits of sound symbolism in naturalistic language environments. As argued in a recent review (Dingemanse et al. 2015), if all concepts with similar meanings had similar-sounding names, the phonological space for semantically related items would become extremely crowded, leading to high confusability between related items, thereby necessitating a tug-of-war between arbitrariness and systematicity in natural language systems. It has been suggested that systematicity plays a strong role at the level of grouping together categories, rather than distinguishing between exemplars. Although this claim has been tested in relation to different grammatical categories (Monaghan & Christiansen 2006; Monaghan et al. 2011), it remains to be tested for labels at different levels of noun taxonomy.

The aim of the present paper was to experimentally test whether sound symbolism has a different effect in labels with different range-of-reference within a simple noun-heirarchy. We conducted a study in which people learned the makeup of two categories of unfamiliar objects (‘alien life forms’), and were passively exposed to either labels for the categories, or labels for each item, while they learned. Within this framework, for different groups of participants, the labels were either congruent or incongruent with the objects. We asked whether congruence between the label and the visual form of the objects might cause people to attend to the objects differently, if they were trained under different conditions. Since previous research (Kovic et al. 2010) has demonstrated that sound symbolism does not alter the speed or the accuracy of category formation, we expected to see the influence of sound symbolism in tests conducted after category learning. As previous research did not make clear whether sound symbolism altered connections between the word-form and the visual features of the object, or representation of the visual objects themselves, the test phase was implemented as a silent, visual same/different judgement.

We predicted that if sound symbolism is effective in highlighting featural similarities among members of a category, then the advantage of sound-symbolism will be observed for category-label learning, but not item-label learning. On the other hand, if the effects of sound symbolism are pervasive wherever they arise, we predict that the influence of sound symbolism will be present in all labeling conditions.

Method

Participants

Eighty-two participants, students from a local Science Center and second-year undergraduate students at the Department of Psychology, of the University took part in the present experiment and received course credit for their participation. All participants reported normal or corrected-to-normal vision.

Stimuli

Visual stimuli were abstract pencil drawings of complex shapes with ambiguous animacy, which could be interpreted either as creatures or as minerals. The forms were inspired by the shape of the historic Vinča figures, products of a Neolithic culture from the Balkan region. These abstract drawings were created to form two categories, differing in their visual properties: one category consisted of curved shapes, in rounded forms, and the other category, angular shapes, in a vertical orientation (see Figure 1B). Each category contained six members. Given their abstract forms (reminiscent of Picasso), we term these stimuli Vinčasso illustrations.

Twelve auditory pseudowords were used as labels for the pictures. A female native speaker of Serbian read aloud the pseduowords, which had a C-V-C-V-C structure. Stimuli were recorded in a single session and filtered to remove hiss and hum using GoldWave. Stimuli were approximately equal in duration (M=790ms, SD=82.3ms). Half of the stimuli contained soft phonological structure (e.g. ‘volab’) and the other half, sharp phonological structure (e.g. ‘šičak’). Criteria of sharpness and roundness of phonemes were based on findings of several previous studies of Serbian, the language of test (Sučević et al. 2015).

Experimental design and procedure

Participants were asked to imagine they have just landed on an unexplored planet and they need to learn to differentiate between two species which live on the planet in order to survive. Participants were seated in front of the computer and were given headphones. Instructions were presented on screen.

The experiment consisted of a training and a test phase. In the training phase, participants were familiarized with the categorical structure of the presented objects. In the first half of the training phase, members of the two categories were presented one-by-one, with an auditory label: Each trial began with a fixation cross presented for 500 ms (±100ms), followed by the auditory label, then a single Vinčasso, approx 12cm in height. While the creature remained onscreen, participants were asked to guess which of the two categories it belonged to, by pushing one of two buttons ('C' and 'N' on a standard keyboard). When participants made their selection, feedback was displayed on the screen for 600ms ('Correct!' or 'Incorrect!') (Figure 1A). All twelve stimuli were presented once in a random order. In the second stage of training, labels were omitted.

After the training phase, participants were instructed to identify whether the two creatures presented side-by-side were the same ('identical') or different. In the Test block, a fixation cross was presented for 500ms (±100ms), followed by the presentation of two Vinčassos side-by-side. The Creatures remained on the screen until participants responded. The pairs depicted the same item (Identical Match), or items drawn from different categories (Category Mismatch)[1].

Training Conditions

Label Congruence was systematically manipulated between participants: Half of the participants heard labels which were congruent with the visual properties of the Vinčassos (soft phonology –

[1] A third condition was originally included, with two items drawn from the same category (Category Match). However despite the unambiguous wording of the question "are these items identical" participants were inconsistent in their interpretation of the question – some responded as though category matches were 'same' and some responding as though they were 'different'. Follow up tests revealed that it was not always possible to determine a participant's response strategy from their answers, so the condition is removed from analysis.

curvy shapes; sharp phonology – angular shapes), and half heard incongruent labels. Participants were randomly assigned to a Congruence condition. It is worth noting that the two categories are defined solely by their visual characteristics, making the labels an arbitrary, irrelevant feature of the training environment.

Label Type was manipulated between experiments: In Experiment 1, participants heard each Vinčasso named with a different label (Item Labels), making the auditory labels an irrelevant feature of the training environment, uncorrelated with any aspect of the task. In Experiment 2, participants heard only two labels, each of which labeled one of the categories (Category Labels), making the labels a correlated, but redundant feature of the training environment.

Since the categories were defined by their visual properties (rounded, angular), in both experiments, the labels were an irrelevant feature of the training environment. Here, we ask the question whether labels presented during a first encounter with a visual object alters subsequent visual processing of the object.

Data handling and analysis

Mean error rates were computed for individuals in each of the four training conditions, and each of the three types of test trial. Reaction times were transformed into inverse RT (iRT=1/RT), to approximate normal distribution for each participant. Based on visual inspection, extreme outliers (exceeding 100-4000ms) were excluded from further analysis. For correct trials each individual's mean inverse RT was computed. Following analysis, reaction times were back-transformed into milliseconds (RT=1/iRT) for visual presentation (Fig1C).

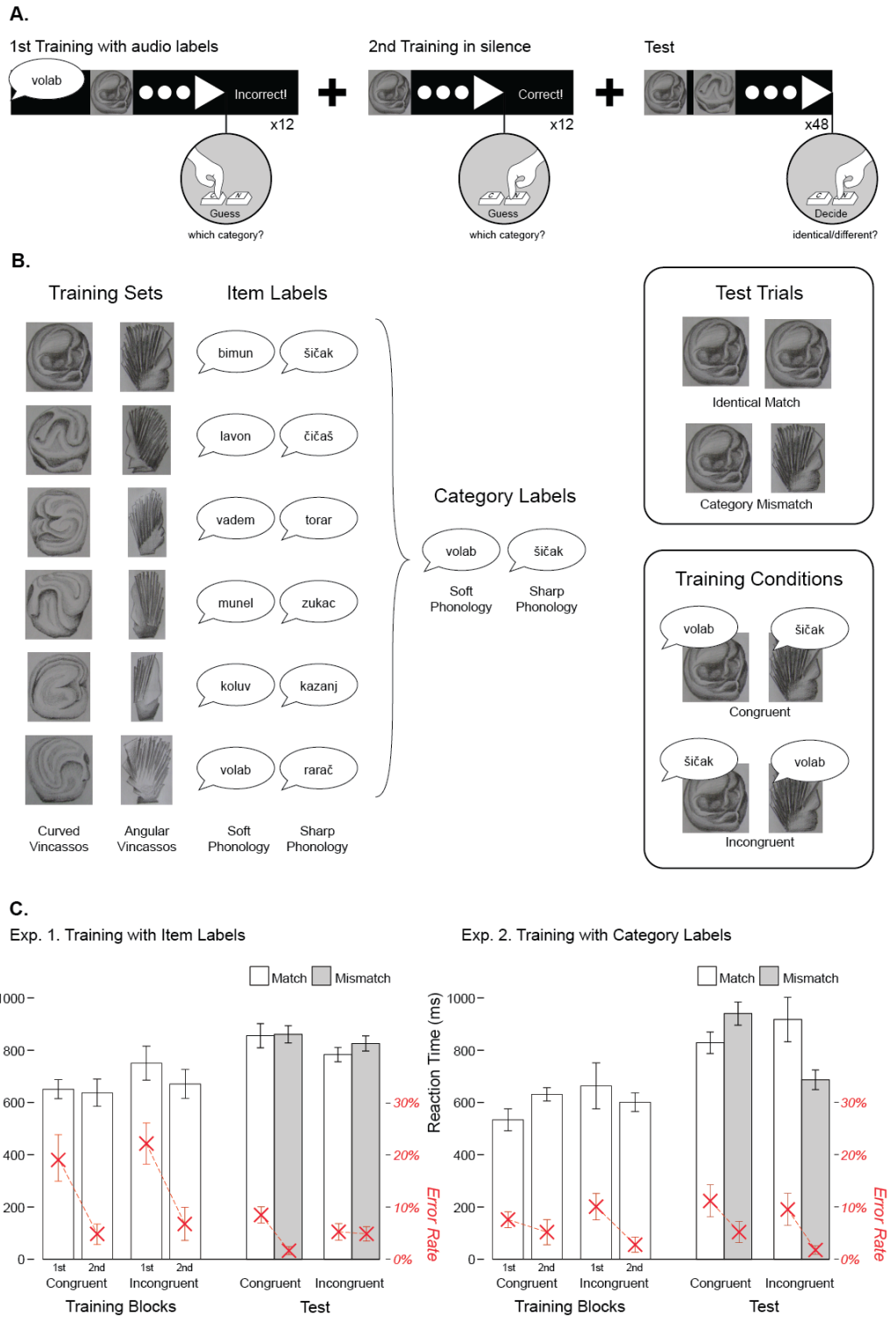

Fig 1. A. Trial structure. B. Stimuli and Experimental Conditions. C. Bars show reaction times for each experiment (L-hand Axis), with Error Rates overlaid (R-hand axis). RTs back-transformed into milliseconds. +/- 1 SE.

For analysis of the training phase, mixed ANOVAs investigated the influence of Training Condition (Congruent, Incongruent) on Error Rate and on Reaction Time across the two training Blocks (First, Second). For analysis of the test trials, mixed ANOVAs investigated the influence of Training Condition (Congruent, Incongruent) on Error Rate and Reaction Time across the three match types (Identity Match, Category Match, Mismatch).

Experiment 1: Item Labels

Each Vinčasso was presented with a different label during the first training block. Half of the participants heard congruent, and half, incongruent item labels. Labels were yoked to pictures for all participants in a given condition.

Results and Discussion

Training. Participants solved the categorization task, with a reduction in errors from the first to the second block (Error: $F(1,40)=31.55$, $p<.001$, ${}_p\eta^2=.44$). No further effects were observed for Error Rate or RT. As seen elsewhere(Kovic et al. 2010), in this training-by-guessing paradigm, sound symbolism is not observed to influence performance during training.

Test. Error Rates differed across the different Match conditions (Match Type: $F(1,40)=8.08$, $p=.007$, ${}_p\eta^2=.17$), with less errors for the Mismatch condition than for the Match condition. This effect was larger for participants who were trained with item labels which were congruent with the shape of the individual items, and was absent for participants in the incongruent condition (Match Type x Congruence: $F(1,40)=6.38$, $p=.016$, ${}_p\eta^2=.14$). This finding suggests that the correct detection of large differences between paired images was enhanced by the having previously encountered each item with labels which were congruent with the item's visual appearance, or inhibited by having encountered incongruent labels. Reaction times did not differ for participants in the different training conditions.

Rejecting a mismatch would typically be easier in a task of this kind, since low-level visual features (e.g., vertical edges, curves) can provide definitive information about a mismatch

drawn from different visual categories. Interestingly, for participants who heard incongruent labels during their training, there was no difference between match and mismatch trials. Effectively, they were better at correctly identifying matches.

Experiment 2

Each Vinčasso was presented with one of two auditory labels, each of which labeled a category of six Vinčasso creatures during the first training block. Half of the participants heard congruent, and half, incongruent item labels. Labels were yoked to categories for all participants in a given condition.

Training. As in Experiment 1, participants solved the categorization task, with a reduction in errors from the first to the second block (Training Phase: $F(1,38)=9.49$, $p=.004$, ${}_p\eta^2=.20$). However, unlike in Experiment 1, participants exposed to labels correlated with the category structure were, on the whole, *slower* to make their category judgments in the second training block, where category labels were not presented ($F(1,38)=7.70$, $p=.009$, ${}_p\eta^2=.17$). This effect was not predicted, but suggests that in the first block, participants may have been relying on the diagnostic properties of the audio label to make their category guesses, and subsequently found judgments harder in the silent second block when this label was absent. As elsewhere, no influence of sound symbolism was observed on error rates or reaction times.

Test. As in Experiment 1, participants made more errors accepting an identical pair than they did rejecting a mismatch (Match Type: $F(1,38)=14.00$, $p=.001$, ${}_p\eta^2=.27$).

Reaction Time was influenced by a combination of Match Type and Congruence (Match x Congruence: $F(1,38)=21.89$, $p<.001$, ${}_p\eta^2=.37$), such that participants trained with congruent labels were faster to accept matches than to reject mismatches, while participants trained with incongruent labels were faster to reject mismatches than to accept matches. This finding suggests that passive exposure to labels during training generates differences in object processing, which are in line with the idea that congruent labels facilitate recognition of salient feature similarities, while incongruent labels may highlight featural differences.

Discussion

The key-finding of the present research is that the sound symbolism in labels with different range of reference (category-label vs item-label) has different outcomes on object processing. In particular, passive exposure to category or item labels influences later abilities to detect similarities and differences between pairs of visual stimuli.

Participants in both experiments were clearly able to infer the category structure from the trials presented in the first training block, as their accuracy improved significantly in the second (silent) training block, where errors fell to below 10% for participants in all training conditions. In previous research (Kovic et al. 2010), sound-symbolism did not influence the trajectory of category learning in a learning-by-guessing categorization task, with task irrelevant category labels. In the present research, we replicated and extended this observation, with no difference in category learning for congruent versus incongruent labels, when trained with *either* item or category labels (Experiment 1 and 2, respectively).

Even though the labels presented during the first training block were irrelevant to the task presented in the subsequent test blocks, sound symbolism had a pervasive influence on performance in the silent, visual discrimination task: When trained on categories where each item had different label, participants were better at identifying differences in a test pair if they have been trained with congruent labels (as shown by their pattern of errors), but this difference was absent if trained on incongruent labels, where performance in both conditions was at ceiling. This suggests that individual item recognition was enhanced by exposure to an incongruent label. By contrast, when trained on items in labeled categories, participants were better at detecting a match when the labels were congruent, and better at detecting a mismatch when the labels were incongruent (as shown by their RTs). This pattern of results suggests that sound symbolism in category labels enhances object processing when congruent, and enhances object discrimination when incongruent. Thus, incongruent item labels improve some aspects of object processing (error rates) whereas the congruence of category labels has mixed effects on processing speed (RTs) depending on the task (match, mismatch), in this non-linguistic no-label object processing paradigm.

These finding are interesting for the following reasons. Firstly, these experiments suggest that even passive exposure to sound symbolic dependencies influences later object processing (suggesting effects of sound symbolism can be subtle, but pervasive); and secondly, these results add interesting perspectives to modeling work on advantages and disadvantages of iconicity versus systematicity at different levels of labeling.

Previous experimental and modelling research on massed word learning by Monaghan et al. (2011), has shown that both human learners and neural networks will learn to map word-forms to meaning classes faster if the mappings are systematically linked to the meanings. However, learning to individuate specific form-meaning mappings is more effective if the mappings are arbitrary. Hence, systematicity is more effective at grouping together forms with a similar function, and arbitrariness is better at distinguishing individual word meanings. This finding is in line with, Gasser (2004) demonstrated that it is possible to encode efficiently a relatively small number of sound-symbolism words. However, as the vocabulary increases, confusability between similar sounding items also increases, as the phonological space becomes crowded, therefore necessitating the emergence of more-arbitrary linguistic structures. Thus, when systematicity results in a crowded phonological space, it can lead to inefficiencies in learning item labels, but may well remain efficient for category labels. Further modeling and experimental work suggested that sound symbolism is most useful for the categories of the objects which are learnt early, when the lexicon is still small (Monaghan et al. 2014). This modeling perspective sits well with findings that sound symbolism can facilitate early word learning (Imai et al. 2008), and may act as a 'Bootstrap' for the acquisition of language (Imai & Kita 2014).

Complementing these theoretical perspectives, here we demonstrate that when sound symbolism provides a kind of systematicity to the mapping between labels and their referents, it has different outcomes for labels with different ranges of reference: Systematic sound symbolism improves detection of visual similarities for category labels, while iconicity enhances object discrimination for both item labels (less errors), and category labels (faster responses). More importantly, we show that the influence of labels goes beyond processing of the link between the a visual object and its learned label, but also influences visual processing of the object some minutes after passive non-task-relevant exposure.

By contrast, until now the majority of previous studies have focused on learnability, guessability or recall of the mapping between a label and its referent. For example, Kovic (2010) demonstrated sound symbolic effects in a test phase where participants heard an auditory label, then saw a matching or mismatching picture; Monghan and colleague's (2011) participants heard an auditory label and guessed from an array of 12 pictures; and Imai, Kita, Nagumo and Okada (2008) tested participants on extension of action description to novel agents in a two-alternative forced choice task. To the best of our knowledge, this is the first study of its kind to show that sound symbolism influences object processing outside of the pairing between a label and its referents.

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