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A round Bouba is easier to remember than a curved Kiki:

Sound-symbolism can support associative memory

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Abstract

Past research has shown that prior knowledge can support our episodic memory for recently encountered associations. According to the model proposed by Cox and Criss (2018) and Cox and Shiffrin (2017), any features shared by associated items should facilitate encoding and retrieval. We implemented a strict test of this prediction by taking advantage of sound-symbolism associations; here, the latter refer to relationships between phonemes and object characteristics—relationships that participants readily find natural—even if they have never encountered the items before. For instance, the non-word 'maluma' is much more readily seen to refer to a random shape with rounded contours than to a shape that has sharp angles. In our study, 70 participants completed paired-associate memory tests after studying lists of three pairs, each composed of a random shape and a non-word. As predicted, there was better associative memory performance for sound-shape pairs that could rely on sound-symbolism links.

Keywords: Sound-symbolism, episodic memory, associative memory

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A round Bouba is easier to remember than a curved Kiki:

Sound-symbolism can support associative memory

One of the defining features of episodic memory is that its content involves associating multiple elements, often including the who, what and where of an event. As such, the content of episodic memory involves both items (people, places, objects, feelings) and the associations between those items (e.g., Cox & Criss, 2017, 2018; Kahana, Howard, & Polyn, 2008; Murdock, 1982; Tulving, 1972). Associations matter; our capacity to explicitly relate objects and their meaning and to relate context and items (events / people) is at the heart of learning and memory (e.g., Anderson & Bower, 1973; Zacks & Tversky, 2001). Moreover, one of the signatures of normal cognitive aging is a loss in the capacity to create new associations between items—a phenomenon known as the age-related associative deficit (Naveh-Benjamin, 2000). Although most agree on the importance of associative memory, our understanding of the nature of associations and how they relate to item information is still very limited (Cox & Criss, 2017, 2018; Cox & Shiffrin, 2017). It follows that a better understanding of associative memory will support the development of memory theory and contribute to our understanding of important issues such as normal and abnormal cognitive aging.

In the laboratory, episodic memory for associations or associative memory, is often assessed by presenting pairs of stimuli. At test, pairs are presented for recognition or one pair member is presented, and participants attempt to produce or select the second pair member (cued recall). It has been established for some time that semantically related and frequently co-occurring items are more easily recalled than unrelated pairs (e.g., Dosher, 1984). However, Jones, Estes, and Marsh (2008) and Badham, Estes, and Maylor (2012) showed that novel word pairs can be recalled at the same level as semantically related pairs if they share an integrative relation. In an integrative relation, the first word of the pair specifies or classifies the second

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word of the pair (e.g., monkey-foot or horse-doctor). Badham et al. (2012) also showed that

integrative relations very significantly reduced the age-related deficit in associative memory.

Moreover, there is evidence that integrative relations facilitate processing in an obligatory

fashion, without strategic control, contrary to what has often been assumed for semantic relations

(see Badham et al., 2012; Estes & Jones 2009). The findings of Jones et al. (2008) and Badham et

al. (2012) suggest that prior knowledge can support associative memory in a variety of indirect,

not-so-explicit ways.

This view is echoed within recent models of item and associative memory. Cox and

Shiffrin (2017; Cox & Criss, 2017, 2018) proposed models of associative memory in which any

features shared by pair members facilitate encoding and recall of the pair. They suggest that,

when presented with a new pair of stimuli, associative features can only be formed once

participants accumulate enough information on the individual items presented. In other words,

associative features between the items of a pair would be derived from the individual features of

the items and would serve as a form of compound cue. As is stated by Cox and Criss (2018) "Our

dynamic account of associative encoding says that shared item features of any kind make it

possible to encode more associative information in memory, leading to better recognition of

intact pairs and better rejection of rearranged pairs" (p. 253). While this quote applies to

recognition, the authors argued that similar mechanisms are involved in other types of tests,

including cued recall (Cox, Hemmer, Aue, & Criss, 2018).

Here, we examined the impact of an unusual type of prior knowledge on associative

memory, namely sound-symbolism. Studies of sound-symbolism have shown that some

phonemes are inherently associated with specific features (Köhler, 1929; Ramachandran &

Hubbard, 2001). For example, some phonemes such as /u/ as in *who* and /o/ as in *hope* are

associated to roundness while other phonemes such as /k/ and /t/ are associated to sharpness

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(Maurer, Pathman, & Mondloch, 2006; Nielsen & Rendall, 2011). Empirically, these sound-symbolism relationships are highly reliable; if participants are presented with an angular shape as well as a more rounded shape and asked which is a 'kiki' or a 'bouba', over 95% associate the shape with sharper edges with the non-word 'kiki' and the rounder shape with the non-word 'bouba' (Ramachandran & Hubbard, 2001).

In the work reported here, our goal was twofold. First, we wanted to verify if sound-symbolism could support associative memory. Second, we wanted to implement what can be thought of as a strict test of the view proposed by Cox and collaborators that any form of shared features should support item and associative memory (Cox & Criss, 2017, 2018; Cox & Shiffrin, 2017). In our experiment, a non-verbal item (random shape) and a verbal item (non-word) were combined to form an unfamiliar to-be-remembered pair; note that both the items and their associations are new. Moreover, neither the items nor their relationship can be supported by semantic knowledge of the type involved in semantic relatedness or integrative relations. We compared memory for associations relying on known sound-symbolism pairings with memory for associations that did not conform to these sound-symbolism links.

To the best of our knowledge, there has been a single attempt to investigate the impact of sound-symbolism relationships on associative memory. In their study, Preziosi and Coane (2017) asked participants to study the definition of non-words that were either sound symbolically congruent or incongruent with the non-word. Results revealed a beneficial effect of sound-symbolism. However, the definitions were generated by another group of participants. This raises the possibility that in addition to congruency between sound qualities of the non-words and their definition, some additional associations were present. In addition, since the normative group spontaneously generated these definitions, participants in the memory experiment may have produced the correct answer by guessing the definition. Preziosi and Coane addressed this issue

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in a control experiment in which non-words and their definition were not participant-generated

and the effect did not reach significance. Therefore, it remains to be seen if associative memory

can benefit from sound-symbolism.

Method

Participants

Seventy participants (M_{age} = 26.53, SD = 3.80, 42 female, 28 male) were recruited from

the online platform ProlificAC using the following inclusion criteria : (a) Native English speaker;

(b) currently living in Canada, the United States or the United Kingdom; (c) Vision normal or

corrected to normal; (d) no language disorder; (e) no cognitive impairment of any kind; (f)

approval rating of at least 90% on prior submissions; and (g) age between 18 and 32. All

participants were offered £1.50 for their participation. The complete procedure including consent,

instructions and debriefing lasted approximately 10 minutes.

Materials

Non-word selection. Non-words were selected from Westbury, Holis, Sidhu, and

Pexman's (2017) database. Westbury et al. began with 21,220 non-morphologically inflected

English words, which were input into the LINGUA software in order to create 629,797 non-

words using a Markov chaining process to connect sets of three characters. All trigrams created

this way also appeared in real words and were proportionately represented according to their

probability of occurring in real words. This process led to the production of non-words beginning

like real words, marked for one level of stress and being syllabified. Westbury et al. then hand

selected 12,556 non-words of 3 to 8 letters judged to have an unambiguous pronunciation and a

plausible ending. Using text-to-speech software, they created audio files for all selected non-

words and removed problematic files until 8000 remained. They then asked participants to make

yes/no judgments on category membership for 20 categories. Of interest here, the stimuli were

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judged on how well they fit in either the 'sharp' (i.e., spiky) or 'round' categories; it was hence

possible to compute the probability of assigning each non-word to the sharp and round categories.

For the current study, we used the following criteria for selecting non-words from

Westbury's et al. (2017) database. First, the probability of being characterized as round was

subtracted from the probability of being selected as sharp. With this metric, words with the

highest positive scores were the sharpest, words with the highest negative scores were the

roundest, and words with the scores closest to zero were neutral. Second, in order to avoid over

representing some initial letters, a maximum of five non-words starting with the same letter were

allowed in a category (sharp, round, and neutral). Each category was first populated with the 5

most representative non-words starting with all 26 letters of the alphabet, except for the letter X

since only 3 non-words in the database start with the letter X; this generated a total of 128 non-

words per category. If more than five non-words started with the same letter and had the same

difference score, five of them were randomly selected from the tied items. In addition, when two

non-words in a category were too similar to each other, one of the non-words was randomly

deleted and replaced with the next most representative non-word. Two non-words were judged

too similar if they (1) were orthographic neighbors (shared all letters at the same positions but

one, i.e., moom and mool) or (2) if they were identical except one had an extra letter (i.e., mool

and mooll or camulo and campulo). Thirdly, all non-words with a difference score smaller than

.50 were removed from the sharp list, all non-words with a difference score larger than -.50 were

removed from the round list and all non-words with an absolute difference larger than .05 were

removed from the neutral list. At this stage, there were 72, 121 and 88 non-words in the sharp,

neutral and round categories respectively. Fourth, to further reduce the number of non-words in a

list, the least representative non-words in each category were removed; however, in order to keep

the number of non-words starting with different letters similar, the number of non-words starting

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with each letter was calculated and only non-words starting with the most common letter were

removed. Consequently, if five non-words started with the letters A and C and only three started

with the letter O, non-words starting with the letters A and C were removed before removing a

non-word starting with the letter O. This procedure was applied until only 66 non-words

remained in each category (total=198; see Figure 1 for examples).

   Shape stimuli. Shape stimuli were taken from Sidhu and Pexman (2017); there were 28

sharp, 28 round and 28 ambiguous shapes (total= 84; see Figure 1 for examples). Ambiguous

shapes served as the neutral stimuli as they share both round and sharp characteristics. These

shapes were created by drawing outlines, in black on a white background, with round edges for

the round shapes, sharp edges for the sharp shapes and a combination of round and sharp edges

for the ambiguous shapes. Anti-aliasing was used on all images to avoid jagged stair-like contour

lines, without losing jagged edges for the sharp and neutral images. Shapes in all three categories

were matched in terms of area, height and width. We standardized the image size to 300x300

pixels.

Procedure

   The experiment was developed using the PsyToolkit (Stoet, 2010, 2017) and run online.

Participants completed a paired-associate learning task comprising 12 trials. Each participant

completed 6 congruent and 6 incongruent trials. Presentation order of the 12 trials was

randomized independently for each participant. As shown in Figure 1, on each trial, three pairs of

stimuli comprising a non-word and a shape were sequentially presented. With each trial

comprising 3 pairs, each trial generated 3 observations for a total of 18 observations per

participant per condition (6 trials/condition x 3 pairs). In the congruent condition, said three pairs

included a sharp, round, and neutral pair, with each shape paired with an appropriate non-word.

That is, the round shape was always paired with a round non-word, the sharp shape with a sharp

non-word and the neutral shape with a neutral non-word. In the incongruent condition, a given

shape can be associated with two types of non-word to produce an incongruent pair. For instance,

a round shape can be associated with a sharp or neutral nonword. To balance the design, over the

six incongruent trials, shapes were paired three times with one incongruent non-word type and

three times with the other type. Hence, for three trials, the round shape was paired with a sharp

non-word and on three trials, it was paired with a neutral non-word, etc.

For each trial and each participant, an appropriate group of three shapes and three non-

words were randomly selected without replacement, with the condition constraining how pairs

were constructed (congruently or not). This implies that each participant only saw a subset of the

possible shapes and non-words; each participant was presented with 36 shapes in total from the

possible pool of 84 and 36 non-words from the overall pool of 198. This ensured that any

observed effects were not due to stimuli-set effects.

Participants were instructed that, on each of the 12 trials, they would see three pairs

composed of one shape and one non-word. They were further informed that their task was to

memorize the non-word that was presented with each shape for a memory task in which the

shapes would appear one at a time in a random order along with the three presented non-words.

They were warned that their task would be to click on the appropriate non-word. As shown in

Figure 1, each trial began with the presentation of a fixation cross at the center of the screen for

500 ms, followed by the sequential presentation of the three pairs of shape/non-word stimuli.

Pairs were presented at a rate of 3 seconds per pair with an inter-stimulus interval of 500 ms. The

shape was always presented on the left side of the screen while the non-word was always on the

right side of the screen, both centered within their respective side. Recall began 500 ms after the

last pair of stimuli was presented. At recall, all three non-words were simultaneously presented in

a vertical list format and in a random order on the right side of the screen. Non-words presented

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at recall were the same three non-words that appeared during the encoding phase. Each shape was

sequentially presented on the left side of the screen. The presentation order at recall was pseudo-

random with the constraint that the recall order could not be identical to the presentation order

and that the last presented shape could not be the first one to be recalled. Participants had to

select the appropriate non-word by clicking on it. Once an answer was selected, the next shape

was presented following a 100 ms delay. No feedback was provided about the accuracy of the

response.

Results

Mean proportion of correct responses were computed separately for each condition.

Results revealed significantly better performance in the congruent ($M = .78$, $SD = .16$) than in the

incongruent condition ($M = .68$, $SD = .22$), $t(69) = 3.86$, $p < .001$, Cohen's $d = 0.461$.

We further investigated the contribution of sound-symbolism to associative memory by

testing an alternative interpretation. According to this alternative interpretation, the benefit

observed for the congruent pairs is not due to memory, but to a form of guessing whereby if

participants cannot remember a response, they tend to select the item that satisfies the sound-

symbolism relationship. In order to examine this possibility, we analyzed the errors in the

incongruent condition as this is the only condition where selecting a congruent shape can produce

an error. In this condition, a shape was always studied with one of the two incongruent non-word

types. For instance, a round shape could either be paired with a neutral or a sharp non-word, but

never with a round non-word. Consequently, two kinds of errors can be produced at the point of

test; recall that each shape is presented along with the sharp, round, and neutral non-word studied

in the trial. Two erroneous choices are hence possible; participants could select the congruent

non-word (the round one in our example) or the incorrect incongruent non-word. If the beneficial

effect of sound-symbolism observed in the congruent condition is not due to memory processes,

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but to a form of guessing, errors in the incongruent condition should show a similar bias. In other

words, when an error is made—presumably this is more likely when memory fails—the

congruent non-word should be selected more frequently than the incongruent non-word. Given

the presence of two alternatives, a probability of .50 of selecting the congruent response would

indicate no bias, a probability of 1 would indicate a perfect bias toward selecting the congruent

response and a probability of 0 would indicate a perfect bias toward selecting the other

incongruent response.

In total, in the incongruent condition, there were 406 errors representing 32.22% of

responses. The mean probability of selecting the congruent alternative was .502 (SD = .173).

After collapsing data across participants, the one-sample *t*-test revealed that this probability was

not significantly greater than the expected chance level of .50, $t(59) = 0.09$, $p = .93$, Cohen's d =

0.012. Given the theoretical importance of this null effect and the impossibility of arguing for the

null effect with null hypothesis testing, we further analyzed the data using a Bayesian one-sample

t-test analogue by means of the BayesFactor package (Morey & Rouder, 2018) in the R statistical

software (Version 3.6.1; R Core Team, 2019). We used the default priors provided in the

BayesFactor package. Results revealed a Bayes factor of 7.05 indicating positive evidence in

favor of the null hypothesis according to Raftery's (1995) labeling system.

Discussion

In this paper, we offer the first demonstration of the impact of sound-symbolism on episodic

memory for associations. Based on the work of Cox and Criss (2017, 2018) and Cox and Shiffrin

(2017), we expected that novel item pairs that conformed to known sound-symbolism parings

would lead to better memory for associations when compared to pairs that did not.

Results confirmed this expectation; pairs of non-words and abstract shapes that were

congruent with known sound-symbolism associations were better recalled than incongruent pairs

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of the same stimuli. This finding is important because the relations between the items were novel;

moreover, contrary to other types of relations, the benefit provided by sound-symbolism is not

likely to depend on explicit processing of meaning or shared features (Sidhu & Pexman, 2018).

Consider the case of the integrative word pair advantage (Badham et al., 2012; Jones et al., 2008).

Integrative word pairs can only facilitate associative memory if the meaning of each item is

accessed and the semantics of the words allow meaningful integration. Even if the pair and the

relations were never encountered before, the integration still relies on meaning and prior

knowledge of integration rules (e.g., metal-flower is a 'compositional' relation; it implies that the

flower is made of metal). The work presented herein extends these findings by showing memory

facilitation for pairs that have no prior relations and are also entirely novel items (i.e., random

shapes and non-words). Hence, our findings suggest that learning novel associations between

unfamiliar items can benefit from forms of prior knowledge that do not rely on semantic

integration or other forms of relatively elaborate semantic processing.

What is the nature of the knowledge embodied in sound-symbolic links? Although there is

a wealth of research on the impact of sound-symbolism, much less is known about the

mechanisms that give rise to these associations between the acoustic and articulatory properties

of phonemes and other stimuli or properties. Sidhu and Pexman (2018) provided a review of the

current thinking regarding potential causal mechanisms which include: (1) a co-occurrence view

whereby phoneme features and related stimuli features co-occur in the world, (2) the proposal

that phonemes and associated stimuli share some properties at the perceptual, conceptual,

affective or linguistic level, (3) a hypothesis attributing the associations to structural properties of

the brain, evolution, or language patterns. It seems possible that sound-symbolism and its impact

on memory might be attributable to a special form of co-occurrence / associative learning. The

latter would lead to obligatory, pre-awareness, but albeit weak links (see Heyman, Maerten,

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Vankrunkelsven, Voorspoels, & Moors, 2019) between phonemes and certain properties of

objects which—like other forms of co-occurrence-based associations—can support encoding and

retrieval of new associations. However, this remains a speculative account; further research is

needed to elucidate the nature of the sound-symbolism links.

Overall our findings fit well with the proposals of Cox and Criss (2017, 2018) and Cox

and Shiffrin (2017), as they stipulated that any information shared by both items of a pair should

facilitate the encoding and retrieval of associative links. In this case, the links embedded within

sound-symbolism associations led to better recall performance in a cued-recall task where both

the items and their associations were novel. Although results fit well with the model of

associative memory put forward by Cox and colleagues, it can be argued that, because there were

no interfering tasks between encoding and retrieval, the paired-associate memory test used here

also called upon short-term memory. This possibility would fit nicely with Cowan's model

(2019) suggesting that short-term memory is formed from a subset of the elements in long-term

memory that are in a temporarily heightened state of activation. Under this view, properties of

associative memory should impact performance in a short-term memory task. Alternatively, it

can be argued that short-term memory is distinct from associative memory with a separate copy

of the information and different operating principles (e.g., Norris, 2017). In this case, if it is

assumed that short-term memory is unable to capitalize on sound-symbolism associations, we

would have underestimated the size of the sound-symbolism effect. This issue could be addressed

in further studies by using a delayed task.

Conclusion

We found that pairs of novel stimuli congruent with sound-symbolism principles were

better recalled than pairs of novel stimuli incongruent with the same principles. The major

finding of this study was to show the facilitative role of subtle associations between very different

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types of stimuli—i.e., the acoustic and articulatory properties of phonemes and the visual

properties of random shapes. These associations are not considered to be the result of semantic

processing, nor are they reliant on meaning as is the case for integrative relations or semantic

relatedness – although they might be the results of a form of implicit learning based on co-

occurrence in the environment. Overall, our results extend the influence of sound-symbolism to

the domain of episodic memory and are congruent with the expectations derived from the work of

Cox and Criss (2018) and Cox and Shiffrin (2017) on associative memory.

The data and materials are available at

*(*https://osf.io/84sfu/?view_only=f8bb27530644455fbb088e337167c956) *and the experiment was*

not preregistered.

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Congruent trial

+

500ms — fultus

3000ms — ackic

500ms — dobulum

3000ms — ackic dobulum fultus

500ms — ackic dobulum fultus

3000ms — ackic dobulum fultus

100ms — ackic dobulum fultus

100ms

Study items

Test items (maximum of 10,000ms per item)

Incongruent trial

+

500ms — urvia

3000ms — ploon

500ms — skic

3000ms — skic urvia ploon

500ms — skic urvia ploon

3000ms — skic urvia ploon

100ms — skic urvia ploon

100ms

Study items

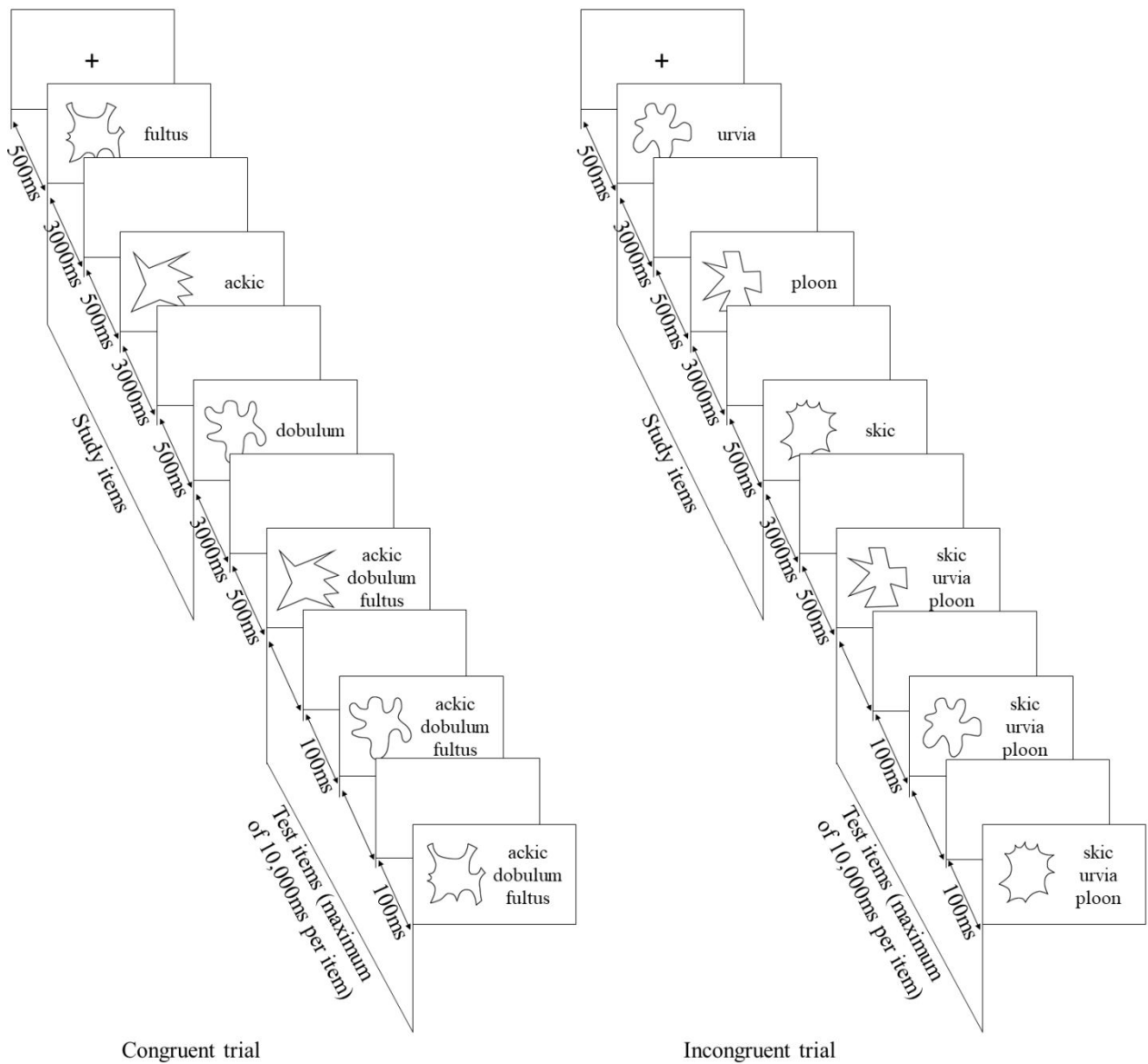Test items (maximum of 10,000ms per item)

Figure 1. Illustration of two typical trials starting with a fixation cross, followed by item

presentation and recall. A congruent trial is presented on the left side and an incongruent trial is

presented on the right side.