A Curved Honulo improves your Short-Term and Long-Term Memory

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Open practice Statement

The stimuli and the data are available on the Open Science Framework project page (https://osf.io/hxvaw/).

Public significance statement

To remember the events of our lives, our brain needs to successfully link multiple event features together in a reasonably stable ensemble. As previously shown by William Hockley, the development of these links can benefit from prior knowledge. Here, we showed that the correspondence between phonemes and visual features can support learning of new associations.

Abstract

During his distinguished career, Bill Hockley contributed to memory research in many ways, with work characterized by rigorous and innovative experimental designs. One of the areas he has explored is that of memory for associative information. We echo this interest here and attempt to emulate his careful experimental attitude. We report four experiments which examined how previously established links can support the development of new episodic associations. More specifically, we tested the idea that sound-symbolism links can support learning of new associations. Sound-symbolism links are relationships between phonemes and object characteristics that participants find natural − even if they have never encountered the items before. For instance, the nonword "honulo" is more readily seen to refer to a shape with curved contours than to a shape that has sharp angles. In Experiment 1, 70 participants studied three pairs and their memory for the associations between the members of each pair was tested in a paired-recognition task. Results demonstrate that sound-symbolism associations support the learning of new associations. Experiment 2 confirmed that the effect is replicated in a between-participants design. In Experiment 3, we replicated the findings with a 30-second filled interval between presentation and test, and in Experiment 4, we extended the delay to 2 minutes, establishing that the pattern is also found with a paradigm more typical of episodic memory. The results are discussed in terms of the importance of associative memory, while referring to some of the ideas Bill Hockley championed in his own work.

Keywords: Sound-symbolism, episodic memory, associative memory

Having a Curved Honulo improves your Short-Term and Long-Term Memory

To remember the events of our lives, the content of episodic memory, our brain needs to successfully link multiple event features together in a reasonably stable ensemble. Episodic memories typically include the who, what and where of an event; hence, the content of episodic memory includes actual items (people, places, objects, feelings) as well as the associations between them (e.g., Cox & Criss, 2018; Hockley, et al., 2016; Kahana, et al., 2008). These associations are central to a properly functioning episodic system: linking objects and their meaning as well as context and items (events / people) allows us to develop coherent representations of events that have unique configurations. The associations and their idiosyncrasies are central to the distinctiveness of said configuration, more often than the items themselves (e.g., Anderson & Bower, 1973).

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 limited (Cox & Criss, 2018, 2020; Cox & Shiffrin, 2017). It follows that a better understanding of associative memory will support the development of memory theories. In the laboratory, associative memory is often explored by presenting pairs of stimuli to participants and testing their recognition of correct or reconfigured pairs or by asking them to recall or identify the second item of a pair when presented with the first pair member (e.g. cued recall). In this area, we know that related and frequently co-occurring items are more easily recognized than unrelated pairs (e.g., Dosher, 1984).

William Hockley and his collaborators significantly contributed to this area (Ahmad & Hockley, 2014; Ahmad & Hockley, 2017; Ahmad, et al., 2015; Hockley, et al., 2016; Hockley & Consoli, 1999; Hockley & Cristi, 1996). In one example, Hockley and Cristi (1996) examined the forgetting rates of both item and associative information and asked to what extent recollection and familiarity played a role in recognizing both types of information. Hockley and collaborators also contributed through their work on the impact of compound words on associative recognition—a compound word contains words that form a new meaning when considered together, like shop keeper. For example, Ahmad et al. (2015) showed that young and older adults better discriminated word pairs when they formed compound words. This work was often framed within the dual-process model of associative recognition, with results suggesting that compound words support performance through enhanced familiarity (e.g. Ahmad & Hockley, 2014).

In other work, Hockley, et al. (2016) asked if associative information is encoded incidentally. Although associative information can be encoded intentionally, the results of Hockley et al. established that associative information was also encoded incidentally. They further suggested that this incidental encoding of associations was supported by pre-experimental associations, such as provided by compound words. As we will see below, the work presented herein pursues this theme by asking if a type of opaque similarity (sound-symbolism links) can also support associative memory.

In related work, Jones et al. (2008) and Badham et al. (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 word of the pair (e.g., monkey-foot or horse-doctor). Badham et al. (2012) showed that integrative relations significantly reduced the age-related deficit in associative memory. Also, there is evidence that integrative relations facilitate processing in an obligatory way, 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, 2018, 2020) proposed models of associative memory in which any features shared by pair members facilitate encoding and recall of the pair. They suggest that any similarity between the pair items is thought to lead to a reduction in the resources necessary to encode said items, leaving more resources to encode the relational or associative information. 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 argue that similar mechanisms are involved in other types of tests, including cued recall (Cox, et al., 2018).

Sonier et al. (2020) examined the impact of an unusual type of prior knowledge on associative memory, namely sound-symbolism. Studies of sound-symbolism have suggested that some phonemes correspond to specific visual features (Köhler, 1929). For example, 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 (Maurer et al., 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 ‘takete’ or a ‘baluba’, the large majority associate the shape with sharper edges with the non-word ‘takete’ and the rounder shape with the non-word ‘baluba’. This finding has been replicated across languages and cultures (Cwiek et al., 2021); its interpretation usually points to crossmodal correspondences or similarities – whereby the effect is rooted in similarities between visual properties and the temporal or motor execution features of the phonemes involved (e.g., Cwiek et al., 2021).

In the work of Sonier et al. (2020) a non-verbal item (abstract shape) and a verbal item (non-word) were combined to form an unfamiliar to-be-remembered pair, where both the items and their associations were new. The authors compared memory for associations relying on known sound-symbolism pairings with memory for associations that did not (see Figure 1). They asked if associative memory was supported when, for example, a non-word mainly composed of 'round' phonemes was paired with a shape that had rounded contours. Their results showed better associative memory performance for sound-shape pairs that could rely on sound-symbolism links. These findings were significant as they offered the first demonstration of the impact of sound-symbolism on episodic memory for associations. Moreover, this first set of results supported a prediction derived from the proposals of Cox and Criss (2020) who suggested that similarity should support the encoding of episodic associations – their model led to our prediction that sound-symbolism links should support episodic associative learning.

However, close examination of the work of Sonier et al. (2020) led us to identify two issues that need to be addressed to establish the robustness and generality of the reported findings. The first relates to the variability of the links between non-words and shapes. By definition, in the congruent condition, a non-word could only be paired with its corresponding shape. For instance, a sharp non-word could only be paired with a sharp shape. However, in the incongruent condition, a non-word could be paired with two types of shapes. For instance, a sharp non-word could be paired with a round shape or a neutral shape. Sonier et al. used this strategy. As a result, the advantage for the congruent sound-symbolism pairs might be due to the sound-symbolism links or to this reduced variability of the pairings between non-words and shapes. Therefore, the associative memory benefit from sound-symbolism needs to be confirmed. Experiment 1 with a within design and Experiment 2 with a between design reported herein address this question by eliminating the confound. This was achieved by always pairing a non-word category to the same shape category for a given participant. For instance, in the incongruent condition, Participant 1 would always see a round non-word with a neutral shape and Participant 2 would always see a round non-word with a sharp shape.

The second issue with the findings of Sonier et al. (2020) is more general – the delay between study and test in their experiment was minimal, i.e. half a second. Hence, it is not clear that the pattern they reported would also be found with a delay typical of episodic memory tasks. The third and fourth experiments we report asked if the Sonier's et al. results generalize to a classic episodic memory task.

Experiment 1

The aim of Experiment 1 was straightforward; we wanted to replicate the work of Sonier et al. (2020) as closely as possible while eliminating any differences between the non-word/shape pairs when it comes to the variability of the relationship between the sound-symbolism link and the features ('round' or 'sharp') of the abstract shapes called upon.

Method

Sample size. For all experiments, our sample size was based on a priori power estimates. We used the effect size of Sonier et al. (2020) to guide our power analyses as our experiments were modelled after their. For Experiments 1, 3, and 4, we conducted an a priori bilateral paired-sample *t*-test power analysis with an alpha of .05, a power of .95, and the effect size of Sonier et al. (Cohen's $d = 0.461$) with G*Power (Faul et al., 2009). This analysis suggested a sample size of 64 was needed. We decided to slightly overpower our design and selected 70 participants to match the sample size of Sonier et al.

Participants. Seventy volunteers from the Prolific platform took part in this study; they received £1.50 for their participation. To be eligible, participants had to be between 18 and 30 years old, be from the United States, have English as their first language, normal or corrected-to-normal vision, a Prolific approval rate of at least 90%, not have any reading or writing related disorders, cognitive impairments, or dementia. None of the participants took part in the study by Sonier et al. (2020). The participants' age ranged from 18 to 30 ($M = 23.66$; $SD = 3.31$); 58 self-identified as women, 11 as men, and 1 prefer not to specify their gender. All our experiments were approved by the research ethics committee of Université de Moncton.

Materials. Materials here were identical to those of Sonier et al. (2020). More specifically, the non-words from the Westbury et al. (2017) database used by Sonier et al. (2020) were also used here. In total, we used 66 non-words for each of three following categories: round non-words (e.g., ambous), neutral non-words (e.g., gruptal), and sharp non-words (e.g., keppick). Likewise, we used the shapes from Sidhu and Pexman (2017) used by Sonier et al. In total, 28 sharp shapes, 28 round shapes and 28 ambiguous shapes (neutral shape) were called upon. Details about the selection of the words and images can be found in Sonier et al.

Design. These materials were used to create two conditions, known here as 'congruent' and 'incongruent'. For the congruent condition, each pair was created so that the sound-symbolism of the non-word phonemes were congruent with the features of the associated shape. Hence, a non-word with mainly 'round' phonemes was paired with a shape with rounded contours. Likewise, a non-word with 'sharp' phonemes was presented along with a shape that had angular contours. Finally, 'neutral' non-words, with an approximately even mix of 'round' and 'sharp' sounds were associated with shapes that had both sharp and rounded contours (see Figure 1 for examples). For the incongruent condition, this correspondence within the paired items was always broken. So, a 'sharp' non-word was associated with either a rounded shape or with a shape that had a mix of sharp and round contours. Similarly, a 'round' non-word was either associated with a shape that had 'sharp' contours or a mix of sharp and round. Finally, neutral non-words would be studied along with either 'sharp' or 'round' shapes.

A repeated measure design with condition (congruent vs. incongruent) as the only factor was implemented. Participants completed 12 paired-associate learning trials composed of 6 congruent trials and 6 incongruent trials. As shown in Figure 1, on each trial, a series of 3 pairs composed of a shape and a non-word were presented. The three pairs presented within each trial were all from the same condition – i.e. all congruent or all incongruent. The order of the 12 trials was randomized for each participant. In addition, the non-words and the shapes were randomly sampled from their respective pool for each participant. Therefore, only a subset of stimuli was used for each participant, ensuring that observed effects were not due to a specific set of stimuli.

Unlike in Sonier et al. (2020), in the incongruent condition, for a given participant, the non-word category (‘sharp’, ‘round’, ‘neutral’) was associated to the same category of shape throughout the experiment. So, for half of the participants, round non-words were always paired with sharp shapes, neutral non-words were paired with round shapes and sharp non-words were paired with neutral shapes. For the other half of participants, round non-words were paired with neutral shapes, neutral non-words were paired with sharp shapes and sharp non-words were paired with round shapes. For congruent pairs, the shape category always matched the non-word category (i.e., round-round, neutral-neutral, shape-sharp).

Procedure. All experiments were programmed with PsyToolkit (Stoet, 2010, 2017). The stimuli were displayed in lowercase letters in white 40-point Times New Roman on a black background. The procedure for this experiment was also based on Sonier et al. (2020). All participants were tested in one online experimental session lasting about 10 minutes. They were informed that on each trial three pairs, composed of one shape and one non-word, would be sequentially presented. The instructions explained that their task was to memorize which non-word was presented with which shape for a later paired-association memory test. When ready to begin, participants pressed the space bar, initiating the first trial. As shown in Figure 1, each trial began with a fixation cross appearing at the center of the screen (500 ms on, 0 ms off). Immediately after, the to-be-remembered pairs (shape on the left side of the screen and non-word on the right) were presented sequentially (3000 ms on, 500 ms off). Five hundred ms after the last pair, the paired-associate test began. All three non-words reappeared simultaneously in a vertical list and in a random order on the right side of the screen, while one of the studied shapes was shown in the center of the left half of the screen. Participants had to select the non-word corresponding to the shape by clicking on it. Once an answer was given, the next shape appeared following a 100 ms delay. This procedure was repeated until all three shapes were tested. The presentation order for the paired-associate test was pseudo-random with the constraint that the test order had to be different from the presentation order and that the last presented shape could not be tested first.

Data Analysis. Below, both Frequentist and Bayesian statistics are reported. For Frequentist analyses we report effect size, *t* values, and *F* ratios. For Bayesian statistics we report BF_{10} corresponding to the Bayes factor in favor of the alternative hypothesis and BF_{01} ($BF_{01} = 1/BF_{10}$) corresponding to the Bayes factor in favor of the null hypothesis. Our interpretation of the Bayesian statistics was guided by the labelling system of Kass and Raftery (1995). All Frequentist and Bayesian analyses were computed with R (R Core Team, 2021). For Frequentist statistics, the “lsr” (Navarro, 2015) and “ez” R package (Lawrence, 2016) were used. For Bayesian statistics, the “BayesFactor” R package and default parameters were called upon (Morey & Rouder, 2018).

Results and Discussion

The proportion of correct responses as a function of condition (congruent vs. incongruent) is shown in Figure 2. Performance was better in the congruent than in the incongruent condition, $t(69) = 6.78$, Cohen’s $d = 0.81$, $BF_{10} > 10{,}000$. The results of Experiment 1 clearly replicated the findings of Sonier et al (2020), while ensuring that each shape category, in the incongruent trials, was associated with only one non-word category. As was the case in the original study, we observed a large (15%) memory benefit for congruent trials relative to incongruent trials.

Experiment 2

Many of the memory phenomena that rely on item features (e.g. frequency, imageability, generation, enactment, etc.) vary or depend on the design that is called upon (e.g., Watkins, LeCompte, & Kim, 2000). More specifically, multiple experimental effects are robust in within-participant design, but are much reduced or eliminated in between-participicans design. In Experiment 2, we studied the same conditions as in Experiment 1 but used a between-participants design. We also increase the number of trials per participant to achieve more reliable estimates.

Method

Sample size. We conducted an a priori bilateral independent-sample *t*-test power analysis with an alpha of .05, a power of .95, and the effect size of Sonier et al. (2020) (Cohen's $d = 0.461$) with G*Power (Faul et al., 2009). The results revealed that we would need a total of 124 participants in each group (congruent, incongruent) to reach the desired power.

Participants. Two hundred and forty different volunteers from the Prolific platform took part in this study and were paid £1.50 for their participation. The eligibility criteria were the same as those used in Experiment 1. None of the participants took part in Experiment 1 or Sonier's et al. (2020) study. The participants' mean age was 23.13 ($SD = 3.36$; ranges from 18 to 30). Two hundred and six participants self-identified as women, 37 as men, and 5 prefer not to specify their gender.

Materials, design, and procedure. The materials, design and procedure were identical to those of Experiment 1 except for the following changes. In this experiment, a between-participants design was implemented with condition (congruent, incongruent) as the between factor. Hence, participants completed either 12 congruent or 12 incongruent trials.

Results and Discussion

The proportion of correct responses was analyzed as a function of condition (congruent vs. incongruent) via an independent Bayesian *t*-test for the Bayesian approach and via a Welch's independent samples *t*-test for the Frequentist approach.

Overall, as in Experiment 1, participants in the congruent group (*M* = .85, *SD* = .13) outperformed those in the incongruent group (*M* = .77, *SD* = .15) *t*(243.47) = 4.16, Cohen's *d* = 0.528, BF_{10} = 406.55 (see Figure 2). The findings of Experiment 2 confirmed that the sound-symbolism advantage does not depend on whether the relevant conditions are tested within or between-subjects. This helps to determine that the phenomenon is not an artefact of the specific conditions called upon. We have shown that the effect appears whether the pairings vary somewhat across congruent and incongruent conditions or not.

Experiment 3

So far, the sound-symbolism effect has been tested in short-term memory paradigms – i.e. there is only 500 ms between the last studied pair and the start of the test. The aim of Experiment 3 was to determine if the sound-symbolism advantage would be found in conditions that are more typical of episodic memory experiments. It is well-known that some effects observed in short-term memory tasks do not replicate in long-term memory tasks. For instance, McCabe (2008) found that immediate memory performance was superiority in the simple span task than in the complex span task. However, participants were also tested on a delayed recall test, and the reverse pattern was observed with a better recall of items processed in the complex than the simple span task.

Accordingly, we replicated Experiment 1, but this time with a 30-second filled interval between the end of the presentation and the recall phase. The 30-second retention interval was chosen because, as powerfully exhibited by H.M., the duration of information in short-term memory does not appear to exceed the 15-30 second range (see, e.g., Prisko, 1963). During the retention interval, participants performed a parity judgment task, well-known to block working memory processing (e.g., Cyr et al., 2021; Jonker et al., 2014).

Method

Participants. Seventy different volunteers from the Prolific platform took part in this study and were paid £1.50. The same eligibility criteria from Experiments 1 and 2 were used. The participants' mean age was 22.30 (*SD* = 3.54; ranges from 18 to 30). Fifty-nine participants self-identified as women, 10 as men, and 1 preferred not to specify their gender.

Materials, Design, and Procedure

We used the materials, design, and procedure from Experiment 1, with the addition of a filler task. After the presentation of the last pair, a parity judgment task was included before the memory test: 500 ms after the last pair, a random digit (0-9) appeared at the center of the screen. Participants were instructed to press the 'Z' key if the digit was an odd number and the 'M' key if it was an even number. Once the response was given, another digit appeared. This task lasted 30 seconds and participants were instructed to make as many judgments as they could. The paired-association memory test, as in Experiments 1 and 2, immediately followed.

Results and Discussion

Performance on the parity judgment task was first examined to ensure that participants were adequately engaged in the task. Overall, the proportion of correct parity judgments was high and very similar for the congruent (*M* = .94, *SD* = .08) and the incongruent conditions (*M* = .95, *SD* = .08), $t(69) = -1.27$, Cohen's $d = 0.15$, $BF_{01} = 3.53$. The number of parity judgments was virtually identical for the congruent (*M* = 39.89, *SD* = 8.64) and the incongruent conditions (*M* = 39.99, *SD* = 9.04), $t(69) = -0.29$, Cohen's $d = 0.03$, $BF_{01} = 7.32$ and the frequency suggests a reasonably high response rate, considering display timings, at more than 1 response per second.

Figure 2 shows the proportion of correct responses as function of condition (congruent vs.

incongruent). Memory in the congruent condition was better than in the incongruent condition, $t(69) = 2.62$, Cohen's $d = 0.31$, $BF_{10} = 3.07$.

Overall, despite the addition of the parity judgment task, there was a beneficial effect of sound-symbolism, although the magnitude was smaller. The results of Experiment 3 are important as they contribute to establishing that the sound-symbolism advantage is also observable in conditions that are typical of episodic memory research.

Experiment 4

Results of Experiment 3 nicely extend those observed in the first two experiments. However, it could be argued that a 30-second interval is not optimal for testing the involvement of episodic memory. Admittedly, the timing of short-term memory has been vigorously debated and there is no consensus yet (Cowan, 2017; Voyer et al., 2021). To alleviate this possible concern, following Cyr's et al. strategy (2021), we increased the time interval between the end of the presentation and the recall phase from 30 seconds to 2 minutes.

Method

Participants. Seventy different volunteers from the Prolific platform took part in this study and were paid £3.75. The same eligibility criteria from previous experiments were used. The participants' mean age was 24.79 ($SD = 3.46$; ranges from 18 to 30). Forty-four participants self-identified as women, 21 as men, and 5 preferred not to specify their gender. None of the participant took part to the previous experiments.

Materials, Design, and Procedure

The material, the design, and the procedure were identical to Experiment 3, except for the filler task which was increased from 30 seconds to 2 minutes.

Results and Discussion

Like in Experiment 3, we first examined performance in the parity judgment task. The proportion of correct parity judgments was high and slightly superior in the congruent condition (*M* = .943, *SD* = .04) than in the incongruent condition (*M* = .936, *SD* = .05), *t*(69) = 2.24, Cohen's *d* = 0.27, BF_{10} =1.37. However, the number of parity judgments was similar between the congruent (*M* = 160.76, *SD* = 34.29) and the incongruent conditions (*M* = 162.13, *SD* = 34.65), *t*(69) = -0.59, Cohen's *d* = 0.07, BF_{01} = 6.45.

The proportion of correct responses is illustrated as function of condition (congruent vs. incongruent) in Figure 2. In line with our previous results, memory performance in the congruent condition was superior than in the incongruent condition, *t*(69) = 4.17, Cohen's *d* = 0.50, BF_{10} = 232.89. Despite the increased from 30 seconds to 2 minutes between the end of the presentation and the recall phase, there was again a beneficial effect of sound-symbolism.

Cross-Experiments Sound-Symbolism Analysis

A cross-experiment analysis was conducted to examine the contribution of sound-symbolism across our short- and long-term memory tasks. For each experiment using a repeated-measures design (Experiment 1, 3, & 4) we computed the magnitude of the sound-symbolism effect by subtracting memory performance in the incongruent condition from the congruent condition. A one-way ANOVA was then calculated and revealed only anecdotal evidence in favour of a variation of the sound-symbolism between experiments, *F*(2, 207) = 3.95, η_p^2 = 0.04, BF_{10} = 1.58. Given the importance of this possible main effect and the minor discrepancy between the frequentist and the Bayesian approach, we systematically compared the means. These *t*-tests revealed that the sound-symbolism effect was larger in Experiment 1 (*M* = .15, *SD* = .19) relative to Experiment 3 (*M* = .06, *SD* = .20), Cohen's *d* = 0.45, BF_{10} = 4.13. However, there was no credible difference between the sound-symbolism effect in Experiment 1 and Experiment 4 (*M* = .09, *SD* = .18), Cohen's *d* = 0.35, BF_{10} = 1.24, nor between Experiment 3 and Experiment 4, Cohen's *d* = 0.13, BF_{01} = 4.29.

General Discussion

We have reported four experiments that serve to establish the robustness, size, and generality of the sound-symbolism memory advantage. More specifically, Experiment 1 showed that the effect did not depend on the details of recent association statistics. We replicated the findings reported by Sonier et al. (2020), after controlling for the variability in the pairings that were studied for congruent and incongruent associations. In Experiment 2, we replicated these findings with a between participant design, as many encoding effects appear to rely on contrast effects that are part of within participant manipulations (e.g. Saint-Aubin et al., 2021). In Experiments 1 and 2, the timescale of recall was more typical of what is found within short-term / working memory research. In order to test the reliability of the findings for episodic memory, Experiment 3 and 4 called upon 30-second and 2-minute filled delays between the studied pairs and the memory test, a classic episodic memory design. The sound-symbolism advantage was again observed establishing it is present across these time scales or memory systems. Furthermore, the cross-experiments analysis suggests that the size of the sound-symbolism effect is stable across the studied delays.

Taken together, our findings establish a new knowledge-based memory effect: Phonemes that correspond to certain features – in this instance ‘round’ and ‘spiky’ sounds—lead to better associative memory when they are linked to objects which have properties that are congruent with these sound-symbolism dimensions. These findings echo the work of Hockley and his collaborators on the compound word effect while insisting on a form of prior knowledge that is not as explicit – sound-symbolism similarity. Although we did not test for this, it seems likely that participants are not aware of the sound-symbolism correspondences that are included in the materials. Future research could better establish that this is the case, but assuming it is, our findings extend the work of Hockley et al. (2016). The latter suggested that associative information was encoded incidentally; here we suggest that incidental similarities can also support associative memory.

Our findings also generally support the models put forward by Cox and Shiffrin (2017) and Cox and Criss (2020) who suggest that similarity should enhance memory for associative information. In as much as one can characterize sound-symbolism as a form of similarity, then the prediction would be that pairs supported by sound-symbolism would lead to correlated processing at encoding, with the latter freeing up resources for the encoding of associative information. What is more, this process could be supported by long-term learning. Recently, Sidhu et al. (2021) suggested that certain phonemes are systematically associated more frequently with object properties such as ‘roundness’ and ‘sharpness’. The latter learning could be seen as increasing the perceived similarity between pairs of non-words and objects that conform to prior co-occurrence.

In his work on associative memory and on the compound word effect, William Hockley often contributed to discussions surrounding the dual-process view of recognition and associative recognition, where both familiarity and recollection processes are often thought to contribute (see, e.g., Ahmad et al., 2015; Ahmad & Hockley, 2014, 2017; Hockley & Consoli, 1999). The balance/importance of each is considered to depend on the task called upon and the factors manipulated (e.g. Ahmad & Hockley, 2014). In the experiments we report, aims, tasks and designs precluded a systematic exploration of these issues. However, future research could establish what impact sound-symbolism might have on what are considered classic measures of recollection-based and familiarity-based recognition decisions, from the perspective of dual-process theory. Cox and Shiffrin (2017) suggested an alternative to dual-process views in which associative recognition, instead of depending on recollection, depend on associative features that appear after a delay [relative to item-based features]. Again, further research could test more precise predictions derived from that model relating to the sound-symbolism effect, providing a richer database to refine theories of associative memory.

Conclusion

In this paper, we have examined the impact of sound-symbolism correspondences on associative memory, calling upon a form of force-choice recognition. We used novel items and novel associations between item pairs; however, these pairs were either congruent or not with known sound-symbolism correspondences. The findings of Sonier et al. (2020) and the findings reported here convincingly showed that associative recognition of novel pairs can be supported by sound-symbolism. Moreover, this effect was shown to hold in paradigms that are typical of both short-term/working memory and episodic memory studies. In all his research, Bill Hockley exemplified attention to careful experimental design and meticulous attention to experimental controls and potential confounds. We would like to think that our revisiting of the original effect reported by Sonier et al. as well as the extension of the sound-symbolism effect to episodic memory we report, emulate Dr. Hockley's careful designs and sound methods. Moreover, we hope that these findings will contribute to the field of research on item and associative memory to which Bill Hockley also significantly contributed.

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Figure 1

Illustration of the shapes and nonwords used for the experiment on the left panel and illustration of an incongruent trial on the right panel.

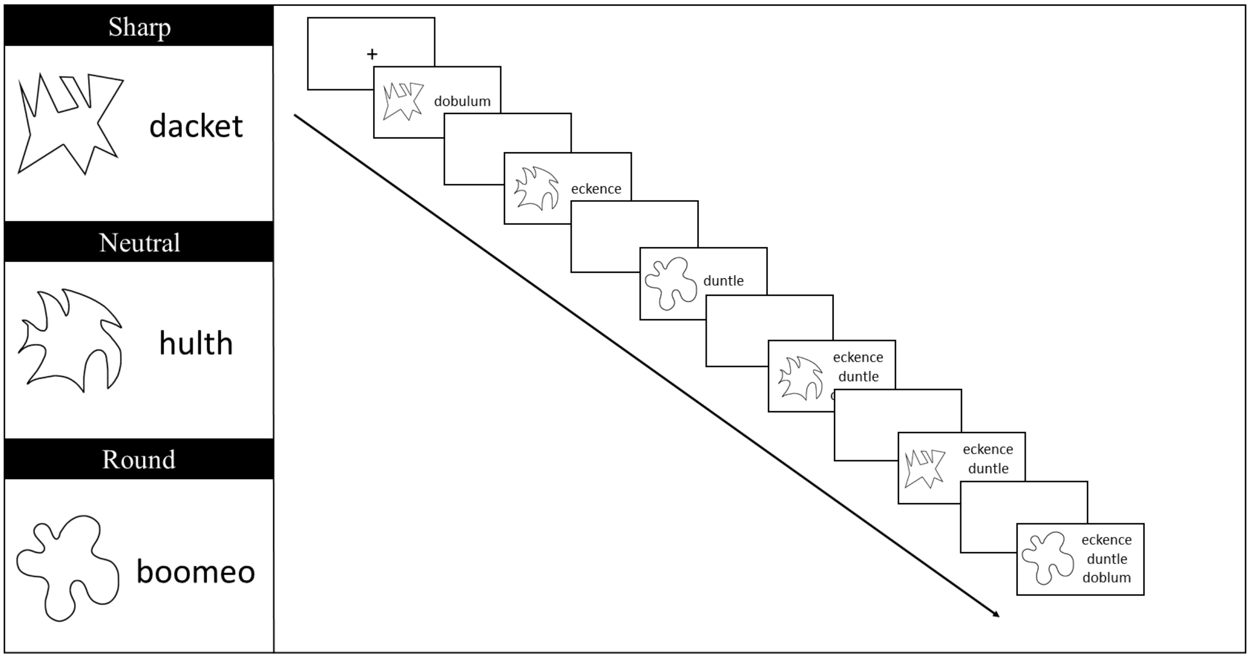
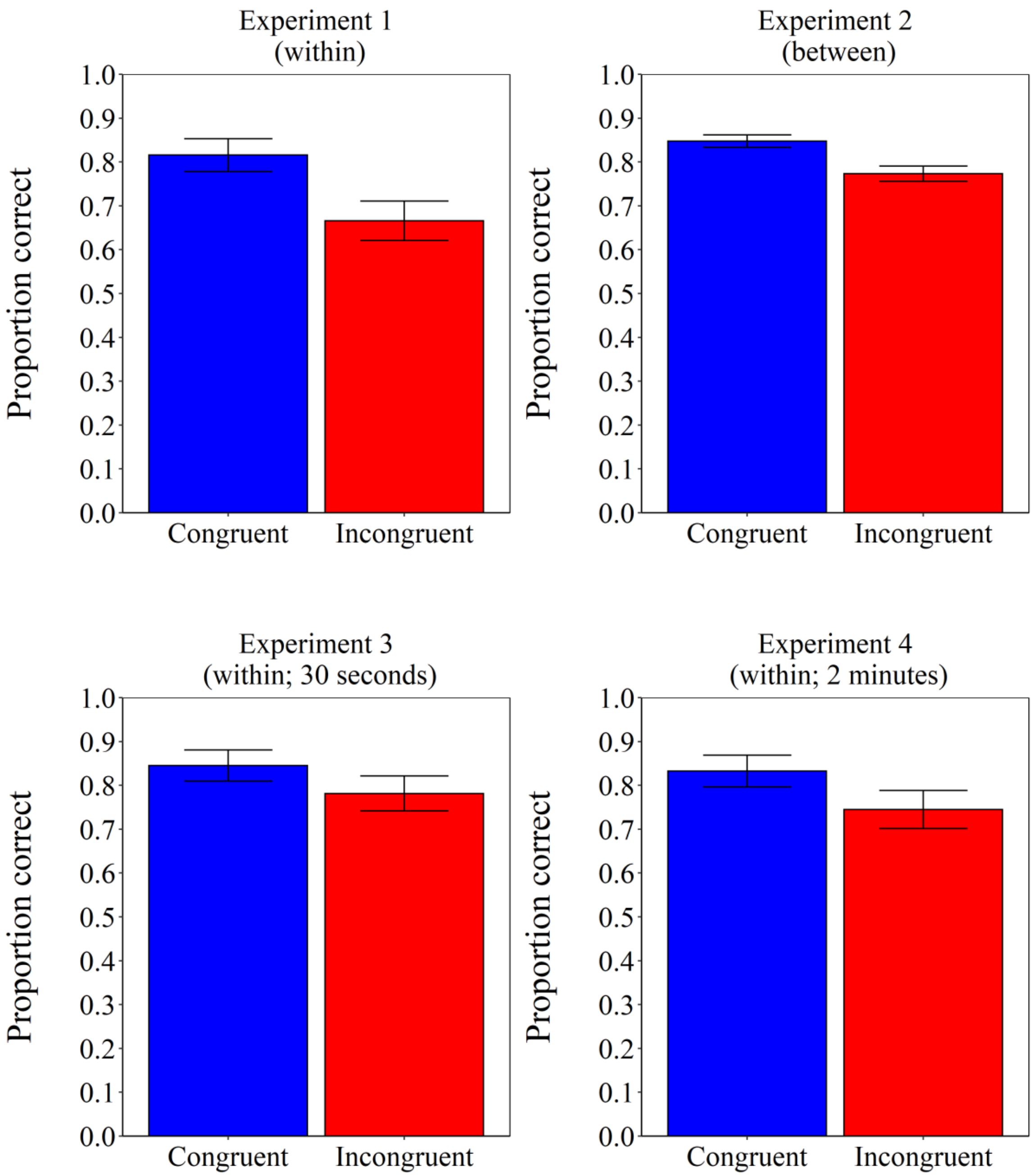


Figure 2

Proportion of correct responses as function of experiments (Experiment 1, Experiment 2, Experiment 3, Experiment 4) and conditions (congruent vs. incongruent).



Note. Error bars are 95% confidence intervals computed with the Morey's (2008) method.