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Authors
Brunel, Lionel
Riou, Benoit
Vallet, Guillaume
et al.

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The Sensory Nature of Knowledge: Generalization *vs.* Specification Mechanisms

Brunel Lionel (lionel.brunel@univ-lyon2.fr), Vallet Guillaume (guillaume.vallet@univ-lyon2.fr), Riou Benoit (benoit.riou@univ-lyon2.fr) & Versace Rémy (remy.versace@univ-lyon2.fr)

Université Lumière Lyon 2. Laboratoire d'Etude des Mécanismes Cognitifs (EMC)
EA 3082. 5 avenue Pierre Mendès France, F 69676, Bron cedex.

Abstract

The aim of the present study was to show the perceptual nature of conceptual knowledge and the dialectic between conceptual and episodic knowledge. We used an original paradigm adapted from Brunel, Labeye, Lesourd, Versace study (*in press*) . This paradigm is divided into three phases. The first one consists in learning a variable association between a geometrical shape and a white noise. The second phase consists in a short-term priming paradigm where a prime shape (either associated or not with a sound in the first phase) preceded a pure tone. The participants have to categorize this sound as low-pitched or high-pitched sound. At least, the third phase consists in a recognition phase about the learning phase. The results have provided evidence supporting the assumption that memory mechanisms are not dissociated from perceptual mechanisms. Moreover, through the manipulation of the shape/sound association in the learning phase, we have demonstrated that generalization mechanism allowed a stimulus to benefit from the feature belonging to its category, whereas specification mechanism allowed a stimulus to keep its specificity compared to the category.

Keywords: Generalization, specification, memory trace, single-memory theory

Introduction

Memory is one of the most important cognitive functions. Over the last decade, the cognitive psychology tried to examine, isolate some processes and mechanisms relevant for this function. Despite dissensions in the literature, authors acknowledge two sets of "memory capacities": the generalization and the specification capacity.

According to Tulving (1985), these capacities depend on the existence of two independent memory systems: the semantic and episodic systems. The semantic memory is involved in the processing of general amodal knowledge and the episodic memory is involved in the processing of specific modal knowledge (our memories). Whereas Tulving argued that these two kinds of memory are dissociated and differ in the abstractness of the information they retain, other authors are more cautious (*e.g* Barsalou, 2008; Witthlesea, 1987).

For example, Barsalou (*e.g.*, 1999; 2005) has taken a particular interest in the perceptual nature of concepts and has developed the idea of "concept simulators". According to Barsalou, in order to categorize a hammer's picture as a tool, the neural systems for vision, action, audition, touch, etc., re-enact the experience of a hammer. This re-enactment is thought to involve the activation of sensori-motors areas, but also of associative areas that register the configurations of sensory features at both the intramodal and intermodal levels. Any given simulator can produce an unlimited number of simulations which will be corresponding to the multimodal representations of a concept's different instantiations. The exemplar that is actually generated depends on a number of different factors (context, subject's state, goals, etc.).

Moreover, Whittlesea (1987) explained that dual-memory accounts, which suggest dissociations between episodic and abstract information, can also be interpreted as a single-memory account (for a review see Versace, Labeye, Badard, Rose, *in press*). In this approach, abstraction and specification are no longer dissociated.

According to Versace et al. (*in press*), the memory that encodes the perceptual components of our experiences is therefore should involve the systems which are associated with the perceptual mechanisms rather than take the form of specific and differentiated memory systems. Thus, all forms of knowledge emerge from the activation, integration, and synchronization of these multiple systems. In a single-memory system, episodic and abstract knowledge could emerge from activation and integration of the same memory traces.

Therefore, the general goal of this research is to show that episodic and conceptual knowledge could emerge from activation and integration of the same memory traces. In our view, a stimulus should acquired the same meaning (should be generalized) as a set of other stimuli, if all its features are also presents in the majority most of the other stimuli. This stimulus is then considered as entering the same category as the other stimuli and can then acquire the properties shared by most of the majority of these stimuli of this category. The generalization mechanism should be much more difficult if this stimulus has a specific property (a property which is not possessed by that the other stimuli of the category don't have). In this case, this stimulus should be discriminated from other stimuli and then it shouldn't acquire their properties of the other stimuli. However, the specification in memory of a stimulus from a set of other stimuli should also require a minimum of homogeneity from the other stimuli. If the other stimuli are very dissimilar from each other, then the discrimination of the isolated stimulus should be strongly reduced.

To test these assumptions we used a paradigm divided into three phases. In the first phase (learning phase), the participants have to discriminate simple geometrical shapes (a circle and a square). Then, in the second phase (priming phase), they were tested in a short-term priming paradigm in which a shape (either associated or not with a white noise in the first phase) preceded a pure tone that they had to categorize as low-pitched or high-pitched sounds (with a 500 ms SOA). At least, in the third and last phase (recognition phase), they first had to find the shape which was not presented with sound (isolated sound shape) between shapes presented with noise during the learning phase (non-isolated sound shape). And then, they had to find the shape which was presented with sound (isolated silent shape) between shapes presented without noise (non-isolated silent shape) during the learning phase.

In this experiment, the circle and the square were displayed in four different levels of gray. For one, e.g. a square, 3 sub-types of this shapes (3 squares of different grey), named called "non -isolated shapes", were systematically presented simultaneously with a white noise, and the last shape ("isolated shape") was systematically presented alone (without sound). The reverse was true for the other shapes (the circle in our example): 3 of these circles (non -isolated shapes) were systematically presented alone (without sound) and the last circle (isolated shape) was systematically presented simultaneously with white noise. These associations were counterbalanced for half of the participants. Our hypothesis was that the isolated shape should be generalized to the shape category in the first case (the isolated square in our example), since all its features (a grey square) were shared by the other squares. On the contrary, in the second case, the isolated shape (the isolated circle) should remain distinctive from the other stimuli of the same shape, since it has a specific feature (associated with a white noise), and because all the others circles have a great homogeneity. These hypotheses were assessed in the second phase, where participants were tested in a short-term priming paradigm as described above. Brunel et al. (*in press)* demonstrated that the presentation of a prime shape that was associated with a sound in a learning phase reactivates the auditory component (see also Meyer et al., 2007) and facilitated the processing of a target sound with a 500 ms SOA. In the present experiment, the same sound stimuli and the same SOA were used. Therefore, we hypothesized that the prime non-isolated sound shape (presented with sound into the learning phase, in our example the squares) would facilitate processing of the target sound in comparison to the prime non-isolated silent shape (presented without sound into the learning phase, in our example the circles). Moreover, the prime isolated shape presented without sound in the learning phase (in our example a square) would also facilitate the processing of targets sounds like non-isolated sound shape. In this case, an exemplar acquires the properties shared by most of the stimuli of the category. On the contrary, the prime isolated shape presented with sound in the learning phase (in our example a circle) would facilitate the processing of the targets sounds unlike non-isolated silent shape. In this case, an exemplar has a specific property (a property that the other stimuli of the category don't have).

To provide more evidence to our hypotheses, participants were also tested in a third phase in two successive recognition tasks. If the specification mechanism was involved into the learning phase, participants should be able to recognize the isolated shape which was associated to a sound during the learning phase among non-isolated silent shapes. On the contrary, if generalization mechanism was involved into the learning phase, participants should be unable to recognize the isolated shape which was presented without sound during the learning phase.

Experiment

Participants

Thirty-two right-handed voluntary participants were recruited for the first experiment. All of them were students at the University Lumière Lyon 2, France, and had normal or corrected-to-normal vision.

Stimuli & Material

Very simple stimuli were used to permit the precise control of the visual and auditory stimuli components. The visual stimulus was a geometric shape, either a 7cm side square or 3.66cm radius circle. The auditory stimulus was a white noise, used in the learning phase, and two pure tones: a high-pitched one of 312Hz and another low-pitched of 256Hz. All the auditory stimuli were presented in monophony and lasted 500ms. All squares and circles could be displayed in four different levels of gray.

The experiment was conducted on a Macintosh computer (eMac G4). Psyscope software X B41 LDEC8 (Cohen, MacWhinney, Flatt, & Provost, 1993) was used to create and manage the experiment. In addition, a chin rest was used to maintain a 60cm distance between the subjects and the monitor.

Procedure & Design

After filling in a written consent form, each participant was tested individually during a session of approximately 10 minutes. The experiment consisted in three phases adapted from the study by Brunel, Labeye, Lesourd & Versace (*in press*). The first phase (learning phase) was based on the hypothesis that repeating a sound-shape-colour association, which was not explicitly formulated by the experimenter, should lead to the integration of these three different components in memory (see the procedure in Figure 1a). Moreover, we have manipulated the association frequency between sound, shapes and levels of gray. For example, three (non-isolated) squares were presented with a sound whereas one (isolated) square wasn't. One (isolated) circle was presented with a sound whereas the three (non-isolated) other circles weren't (the gray used for the isolated shape presented without sound is systemically different from the gray used for the isolated shape presented with sound. The colour of the isolated shapes was counterbalanced). Consequently, each trial consisted in presenting a shape (a square or a circle) for 500ms and one of these shapes was simultaneously presented with the white noise. The participants were told that their task was to judge, as quickly and accurately as possible, whether the shape was a square or a circle. They indicated their response by pressing the appropriate key on the keyboard. All visual stimuli were presented in the center of the screen, and the intertrial interval was 1,500ms. For half of the participants, the squares were generally presented with the white noise and the circles were generally presented without sound, while the opposite arrangement was used for the other half of the participants. Each shape was presented 40 times (10 times for each of the 4 gray scale levels) in a random order. Half of the participants used their right index finger for the square and their right middle finger for the circle, with response fingers being reversed for the other half of the participants.

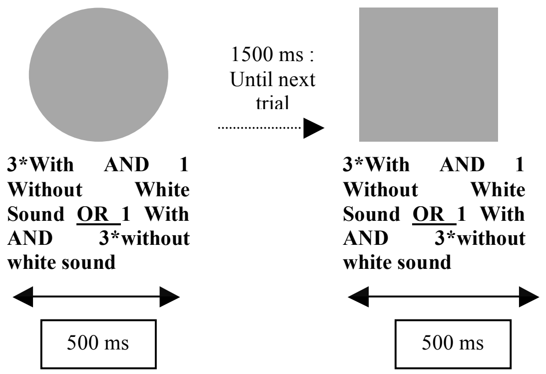

Figure 1a: Organization of the trials in first phase.

The second phase consisted in a short-term priming paradigm (see the procedure in Figure 1b). The prime was one the two shapes presented during the learning phase (a square or a circle). For all participants the prime was presented for 500ms. The prime was immediately followed by a target which was either the high-pitched or the low-pitched sound. The participants had to judge as quickly and accurately as possible whether the target sound was low-pitched or high-pitched by pressing the appropriate key on the keyboard. It is important to mention here that all the participants were instructed to keep their eyes open during the whole phase. As the target appeared immediately when the prime disappeared, the SOA between the prime and the target was also 500ms. All visual stimuli were presented in the center of the screen, and the intertrial interval was 1,500ms. Each participant saw a total of 80 trials, i.e. 40 with each target sound, and half of them (20) were presented with a prime shape that had been generally associated with the white noise during the learning phase and the other half with a prime shape that had generally not been presented with this noise. The order of the different experimental conditions was randomized

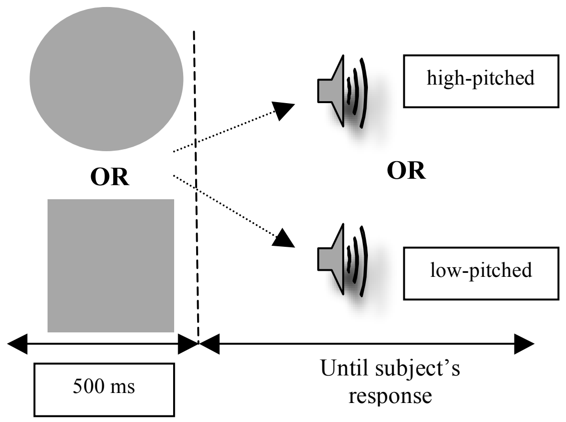

Figure 1b: Organization of the trials in the second phase.

The third phase consisted in a recognition task (see the procedure in Figure 1c). Participants had to perform two successive recognitions. It is important to highlight that all the participants were informed that they would had to perform this task but they weren't informed about the nature of the questions. First, the participants had to find the shape which was not presented with sound (isolated sound shape) between shapes presented with noise during the learning phase (non-isolated sound shape). And then, they had to find the shape which was presented with sound (isolated silent shape) between the shapes presented without noise (non-isolated silent shape) during the learning phase. They indicated their response by pressing the appropriate key on the keyboard. The order of the questions was counterbalanced.

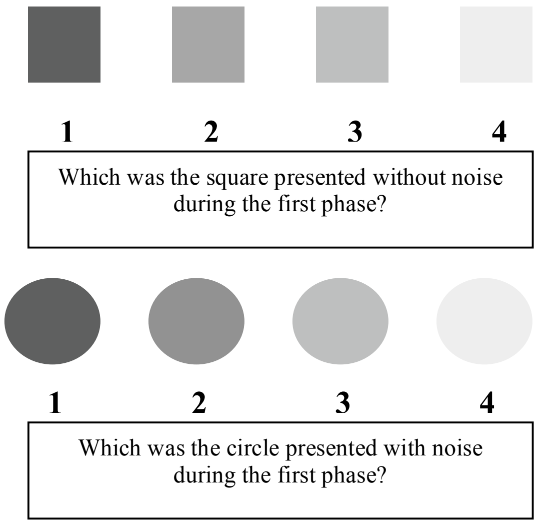

Figure 1c: Organization of the trials in third phase.

Results

Learning phase

The mean correct response latencies and the mean percentages of correct responses were calculated across subjects for each experimental condition. Latencies below 250 ms and above 1,250 ms were removed (this same cut-off was used throughout the entire experiment and never led to exclusion of more than 3% of the data). Separate analyses of variance were performed on latencies and percentages of correct responses, with subjects as random variables, sonority of the shape (shape generally presented with a sound or generally not) as a within-subject factor, and isolation (isolated *vs.* non-isolated shape manipulated through the frequency of the association during the learning phase) as a within-subject factor.

The analyses performed on the correct responses (F (1,31) = 6.03; p<.05) and on latencies (F (1,31) = 22.77; p<.01) revealed a significant interaction between shape sonority and isolation. These results are consistent with the idea that subjects performed the shape discrimination task accurately (overall level of correct response is 96.75%) and that they are influenced by the non-systematic association between sound and shape (see Table 1). Isolated shapes are processed faster when they are presented with sound between shape associated without sound and isolated shapes are processed slower and less accurately when they are presented between shapes associated with sound.

Table 1. Mean Response Times (RTs; in milliseconds) and mean percentages of correct responses in each experimental condition (Standard errors are in parentheses)

Shape Sonority	Isolation: Non-isolated RT(ms)	Non-isolated CR(%)	Isolated RT(ms)	Isolated CR(%)
Silent	533 (19)	97,4(0.7)	484 (15)	98.1(0.8)
Sound	527 (21)	97,1(0,6)	570 (22)	94.4(1.3)

Priming Phase

Separate analyses of variance were performed on latencies and percentages of correct responses, with subjects as random variables, prime type (prime generally associated or generally not associated with a sound in the learning phase), and isolation (isolated vs. non-isolated shape manipulated through the frequency of the association during the learning phase) as a within-subject factor.

The analyses performed on the correct responses revealed neither a significant main effect nor any interaction. This result could be explained by ceiling effects since the overall level of correct responses was 95.53%. As far as for the latencies were concerned and, as expected, our analyses revealed a significant interaction between prime type and isolation, $F(1,31) = 4.21$; p<.05.

As showed in Figure 2, priming effects didn't only depend on the prime type. Planned comparisons showed that for non-isolated shapes, the responses were significantly faster when the prime consisted in the shape which had been associated with the white noise during the encoding phase (sound prime) than when the prime consisted in the shape that had not been associated with the white noise (silent prime), $F(1,31) = 6.12$; p<.01 (for similar results see Experiment 1 of Brunel *et al* study, *in press*). On the contrary, for isolated shapes, the responses were not significantly different (F<1).

However, for isolated shapes, responses were significantly faster than for non-isolated silent prime ($F_{isolated.silent.prime}(1,31) = 10.92$; p<.01 and $F_{isolated.sound.prime}(1,31) = 8.30$; p<.01) but responses were not significantly different than for non-isolated sound prime ($F_{isolated.silent.prime}<1$ and $F_{isolated.sound.prime}<1$).

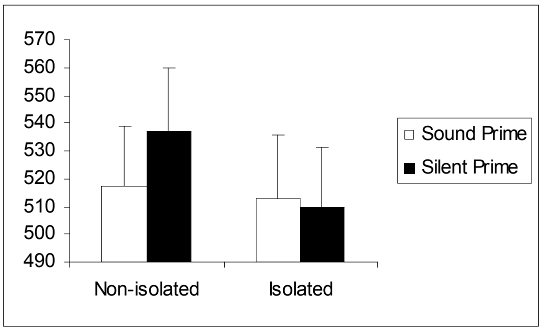

Figure 2: Mean RT's, as a function of Isolation and for each prime type. Error Bars represent standard error.

Recognition Phase

We calculated a percentage of correct recognition for each kind of question. Then, we tested (Student *t* test) if these scores were significantly different from chance (25% - one on four-).

When participant had to find the isolated shape which was not presented with sound (isolated sound shape) between shapes which were presented with noise during the learning phase (non-isolated sound shape), the percentage of correct recognition was 21,79% and didn't significantly differ from chance (t=-0,42; p=.33).

When participants had to find the isolated shape which was presented with sound (isolated silent shape) between shapes presented without noise (non-isolated silent shape) during the learning phase, the percentage of correct recognition was 50% and did significantly differ from chance (t=2,78; p<.01)

Discussion

One of theoretical aims of the present study was to show that memory mechanisms are not dissociated from perceptual mechanisms and involve shared neuronal systems. Our study clearly shows that the activation of an auditory memory component (a component that is not really present) is able to influence the sensory processing of a sound presented later. In the priming phase, non-isolated sound prime shapes facilitated the processing of the target.

More specifically, the aim of this research was to assess the generalization and discrimination mechanisms in a same and unique paradigm. Our results have showed that, in the learning phase, isolated shapes were differently processed than non -isolated shapes and also differently recognized in the third phase. The most interesting finding of this experiment is that the isolated sound shape (like non-isolated sound shape) can facilitate the sensory processing of a sound presented later (priming effect). Nevertheless, the isolated sound shape wasn't presented with sound during the learning phase and wasn't later recognized. How did the isolated sound shape have benefited from a feature that was never presented with? We propose that this is a generalization mechanism which brings an exemplar to benefit from one relevant feature of a category (*e.g.* prototype conception in exemplar models, Nofosky, 1986).

On the contrary, the isolated silent shape (associated with sound during the learning phase) was able to facilitate the processing of the target sound while non-isolated silent shapes were presented without sound during the learning phase. Moreover, the isolated silent shape was accurately recognized in the third phase. How did the isolated silent shape keep its specificity? We propose that specified knowledge in memory depends on the specificity the features of the stimulus (number of dimensions which differs from the other stimuli; *e.g.* trace distinctiveness conception, Brunel, Oker & Versace, 2008) and, probably the most important, on the accuracy of the memory integration mechanism (see Source Monitoring Framework, Johnson, 1997).

In conclusion, we need to conduct further research in order to examine the automaticity of the generalization mechanism and the links between generalization and specification mechanisms.

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