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Performing prototype distortion tasks requires no contribution from the explicit memory systems: Evidence from amnesic MCI patients in a new experimental paradigm

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ABSTRACT

Evidence shows that amnesic patients are able to categorize new exemplars drawn from the same prototype as in previously encountered items. It is still unclear, however, whether this ability is due to a spared implicit learning system or residual explicit memory and/or working memory resources. In this study, we used a new paradigm devised expressly to rule out any possible contribution of episodic and working memory in performing a prototype distortion task.

We enrolled patients with amnesic MCI and Normal Controls. Our paradigm consisted of a study phase and a test phase; two-thirds of the participants performed the study phase and all participants performed the test phase. In the study phase, participants had to judge how pleasant morphed faces, drawn from a single prototype, seemed to them. Half of the participants were shown faces drawn from the A-prototype and half from the B-prototype. A- and B-faces were opposite in a morphing space with a neutral human face at the center. In the test phase, participants had to judge the regularity of faces they had never seen before. Three different types of faces were shown in the test phase, that is, A-, B-, or neutral-faces. We expected that implicit learning of the category boundaries would lead to a category-specific increase in perceived regularity. The results confirmed our predictions. In fact, trained subjects (compared with subjects who did not undergo the study phase) assigned higher regularity scores to new faces drawn from the same prototype as the faces seen during training, and they gave lower regularity scores to new faces drawn from the opposite prototype. This effect was super imposable across subjects' groups.

1. Introduction

In the 1990s, Knowlton and Squire (1993) added categorization to the list of what amnesic patients are still able to learn and the question about which memory system underlies category learning is still being debated today. At variance with recognition memory tasks, in which subjects have to recognize *previously studied* items among unseen distracters, in category learning tasks during the test phase subjects have to endorse *previously unseen* items as belonging to the same category as the items encountered during the study phase. To perform a recognition task well, *individual items* must be stored in long-term memory; by contrast, to perform a categorization task well, *category boundaries* must be learned but no memory for particular items is needed. Although in their seminal work Knowlton and Squire (1993) argued that the dissociation between impaired recognition and spared categorization in amnesic patients strongly supports the hypothesis of a dedicated memory for categorization, the question still remains as to whether category learning and recognition memory rely on different memory systems. Indeed, two decades of intense research have made it clear that the issue of which cognitive processes underlie category learning cannot be resolved without further qualifying the particular category learning task. In an extensive review of the categorization literature on how *perceptual categories* are learned, Ashby and Maddox (2005) identified three main types of category learning tasks characterized by variable reliance on different memory systems. According to their model, to solve rule-based category learning tasks, in which category membership can be decided by applying a simple *verbalizable* rule (e.g., square objects belong to category A and round

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objects belong to category B), subjects have to rely on their episodic and working memory systems. By contrast, in information integration tasks the categorization rule is not easy to verbalize and items belonging to the same category are not necessarily perceptually similar because category boundaries can take different forms (e.g. linear or quadratic) according to an arbitrarily selected mathematical rule, which defines category members on multiple dimensions (e.g. length and orientation of lines); to solve this kind of tasks subjects are supposed to rely on the procedural memory system. Finally, in prototype distortion tasks (similar to information integration tasks) no verbalizable categorization rule can be discovered, but exemplars belonging to the same category are perceptually similar because they are created by distortion of a single prototype. There are essentially two types of prototype learning tasks: A/not A and A/B. In A/not A, subjects encounter random distortions of a single prototype (i.e. members of the A category) in the study phase, whereas in the test phase they are requested to endorse category members and to reject items that do not cluster around any alternative prototype (i.e. not A items). In the second case, exemplars drawn from two prototypes (A and B) are shown during the study phase; in the test phase, new A and B members have to be labeled according to the prototype they are drawn from. In the rest of this introduction, we will focus on concurrent hypotheses regarding the cognitive processing that underlies prototype distortion tasks and we will describe a new prototype learning paradigm we devised to address some pending issues.

At variance with rule-based and information–integration learning, the theoretical framework developed by Ashby, Alfonso-Reese, Turken, and Waldron (1998); Ashby and Maddox (2005, 2010); Casale and Ashby (2008) is less clear cut regarding the cognitive systems that subserve prototype distortion learning. According to these authors, the visual cortex should play a key role in this kind of learning, but some other memory systems should cooperate in solving the task, at least in the A/B paradigm. Later in this section, we will return to the possible cognitive differences related to the two kinds of prototype learning tasks. First, we will review the main neuropsychological evidence that supports or counters the independence of prototype learning from both explicit and procedural learning systems.

The most used A/not A paradigm is the dot pattern task devised by Posner and Keele (1968). In the study phase, subjects are shown patterns of 7 to 9 dots, which are created by displacing each dot around its original position in a (not shown) prototype pattern. In the test phase, subjects have to endorse new distortions of the original prototype and reject random dot patterns. To provide neuropsychological evidence that this kind of learning does not rely on the explicit memory system, Knowlton and Squire (1993) administered the dot pattern task to 10 patients suffering from medial temporal lobe or diencephalic amnesia. In keeping with the hypothesis of separable learning systems, all patients showed normal dot pattern categorization learning despite severely impaired recognition memory for studied items.

In order to provide neuropsychological support for the independence of prototype distortion learning from the procedural memory system, Reber and Squire (1999) administered the dot pattern task to patients suffering from Parkinson's disease. This neurological population is well suited for this aim because patients are known to be impaired in procedural learning tasks because of their basal ganglia dysfunction (Jackson, Jackson, Harrison, Henderson, & Kennard, 1995). Also in this case, results were in keeping with the hypothesis of separable memory systems, that is, the patient with Parkinson's disease showed normal dot pattern categorization learning.

Finally, Reed, Squire, Patalano, Smith, and Jonides (1999) replicated the basic neuropsychological findings about spared prototype learning in amnesic patients using cartoon animals that varied on a range of discrete features (e.g., striped body vs. spotted body) instead of dot patterns. The finding of the same pattern of spared categorization vs. impaired recognition memory when using completely different visual material was interpreted as further supporting the hypothesis of a dedicated system in human memory for learning perceptual categories.

The main criticisms of the hypothesis of a separable (implicit non-procedural) system for prototype learning have focused on the role of explicit memory in the performance of prototype learning tasks. In this view, the possible contribution of either working memory or episodic memory has been hypothesized. Palmeri and Flanery (1999) have probably provided the most compelling evidence of the contribution of working memory in the performance of prototype distortion tasks. These authors administered an A/not A dot pattern categorization task to a group of healthy subjects who had no prior exposure to instances of category members. Instead of the study phase, participants performed an irrelevant computerized verbal task. Then, they were asked to perform the classification task. They were told that this was possible because during the previous task patterns of dots had been flashed subliminally, thus providing them with exposure to category members they were unaware of. The subjects' accuracy in endorsing category exemplars was comparable to that exhibited by the amnesic patients in Knowlton and Squire's (1993) original work. The conclusion of Plameri and Flanery (1999, p. 529) was the following: "The categorization task used by Squire and Knowlton allows participants to discover which clusters of patterns are likely to be members simply because many members are similar to one another and all nonmembers are dissimilar from one another. Successfully performing the categorization task may require only the use of working memory, which is known to be spared in amnesia". The demonstration of a possible role for working memory in solving the dot pattern task raises serious doubts about the ability of this paradigm to make a strong case in favor of a nondeclarative system for category learning. On the other hand, as Palmery and Flanery (1999) acknowledge, demonstrating that new exemplars can be categorized without memories for exemplars encountered in a previous study phase is equally problematic for single system accounts, which claim that categorization in prototype learning tasks (as well as recognition of old patterns) relies on having such memories stored in a unique explicit memory system. In the past decade, evidence has accumulated that working memory has a role in prototype learning tasks (see Tunney & Fernie, 2012 for a review and for new experimental evidence). By contrast, compelling evidence of prototype learning in the absence of any contribution of the working memory system is still lacking. Recently, Bozoki, Grossman, and Smith (2006) attempted to demonstrate implicit prototype learning in amnesic patients over and above a possible contribution of working memory. In that study, patients with Alzheimer's disease and matched normal controls were requested to perform a prototype learning task with cartoon animals that were defined on a list of ten binary features (e.g. spotted vs. striped body, snout vs. trunk). As in Palmeri and Flanery's (1999) study, half of the subjects (in both groups) received training and half did not but were told that they had seen category exemplars subliminally during a previous computerized task. Bozoki et al. (2006) established two stringent criteria for implicit learning: (i) performance on test trials had to be significantly higher in the training compared with the no-training condition, and (ii) subjects had to show above-chance performance on the first 10 test trials, that is, "before there has been sufficient chance for working-memory-based learning to occur on test trials" (p. 817). Results only partially supported the implicit learning hypothesis; in fact, only Alzheimer's disease