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Research report

Changes in pattern completion – A key mechanism to explain age-related recognition memory deficits?

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ABSTRACT

Accurate memory retrieval from partial or degraded input requires the reactivation of memory traces, a hippocampal mechanism termed pattern completion. Age-related changes in hippocampal integrity have been hypothesized to shift the balance of memory processes in favor of the retrieval of already stored information (pattern completion), to the detriment of encoding new events (pattern separation). Using a novel behavioral paradigm, we investigated the impact of cognitive aging (1) on recognition performance across different levels of stimulus completeness, and (2) on potential response biases. Participants were required to identify previously learned scenes among new ones. Additionally, all stimuli were presented in gradually masked versions to alter stimulus completeness. Both young and older adults performed increasingly poorly as the scenes became less complete, and this decline in performance was more pronounced in elderly participants indicative of a pattern completion deficit. Intriguingly, when novel scenes were shown, only the older adults showed an increased tendency to identify these as familiar scenes. In line with theoretical models, we argue that this reflects an age-related bias towards pattern completion.

1. Introduction

All too often we find ourselves faced with the problem of recognizing something familiar even though its appearance may have changed; for example, finding our way across a park with all the trees having lost their leaves, or recognizing a person wearing a different haircut. Pattern completion is essential for the successful retrieval of memories from such degraded or partial cues. This process has been defined as a hippocampal computation during which the original memory trace is restored (completed) via reactivation (Marr, 1971; McClelland, McNaughton, & O'Reilly, 1995). However, behavioral evidence for such computations in episodic memory processing in humans is rare. One line of evidence comes from

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studies using continuous object recognition tasks to assess pattern separation – a concurrent process which differentiates new input from stored representations (for review, see Yassa & Stark, 2011). Typically, stimuli used in these paradigms are similar lures, and participants' ability to correctly reject them as similar and not identify them as old is interpreted as behavioral pattern separation (Stark, Yassa, Lacy, & Stark, 2013). The identification of pattern completion processes is usually a by-product of this assessment; that is, the failure to correctly reject a lure as similar and judging it as old (false alarms) is interpreted as behavioral pattern completion (Ally, Hussey, Ko, & Molitor, 2013). However, as of yet, it is unclear how exactly pattern separation and completion contribute to behavior, and whether they are distinct processes that work concurrently or in competition, or whether they represent two ends of a unified process (for review, see Hunsaker & Kesner, 2013).

Because the structural integrity of the hippocampus is particularly sensitive to the aging process, it has been suggested that the aged brain should show a bias toward pattern completion (Wilson, Gallagher, Eichenbaum, & Tanila, 2006). Behavior concomitant with these age-related changes in hippocampal processing has been assessed with a similar focus on pattern separation, only indirectly showing a shift towards pattern completion (Toner, Pirogovsky, Kirwan, & Gilbert, 2009; Yassa, Mattfeld, Stark, & Stark, 2011). However, a more recent study has raised objections to these conceptualizations by showing that both measures (lure correct rejections and false alarms) likely entail both pattern separation and completion, suggesting that more process-pure behavioral measurements need to be developed (Molitor, Ko, Hussey, & Ally, 2014). In that study, eye-tracking data revealed that performance differences were driven by differential encoding rather than retrieval, hence lure correct rejections and false alarms should rather be interpreted as successful and unsuccessful pattern separation during encoding as opposed to pattern completion biases during retrieval.

In the present study, we devised a behavioral paradigm more suitable to assess pattern completion, and to test the hypothesis that older adults would show a bias towards this process. We developed a recognition task that required participants to learn simple line-drawn scenes and later identify them amongst new scenes. During recognition, we manipulated stimulus completeness by gradually reducing scene information similar to Gollin figures (Gollin, 1960). The resulting partial input was intended to trigger the pattern completion process, a manipulation suggested by Hunsaker and Kesner (2013). With this paradigm, we could (1) assess the recognition ability across different levels of stimulus completeness, and (2) calculate a response bias score by comparing the performance for learned versus new stimuli, while simultaneously characterizing age effects.

2. Materials and methods

2.1. Subjects

All participants were recruited by the German Center for Neurodegenerative Diseases (DZNE), Magdeburg. After screening for mild cognitive impairment using the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), we excluded 4 older participants, because they scored lower than 23 (Luis, Keegan, & Mullan, 2009). Thirty young (20–35 years old; 15 males) and 30 older adults (62–78 years old; 15 males) were included in the study. Informed consent was obtained in writing before the experiment, and the study received approval from the Ethics Committee of the University of Magdeburg. All participants received monetary compensation of 6.50 €/h.

2.2. Materials

The experimental stimuli comprised 15 black and white line-drawn images (Hollingworth & Henderson, 1998) depicting simple indoor scenes (e.g., kitchen, bar, library, etc.). Stimulus completeness was manipulated for 10 of the 15 line-drawn images by masking them with a grid (5 × 6) of white circles. Four different completeness levels (35%, 21%, 12%, and 5%; percentages reflect the amount of the image visible through the mask) were created by gradually increasing the circle by a factor of 1.2 after each iteration (the size of this manipulation was determined by careful piloting of the paradigm). The original stimulus (100%), therefore, became progressively more occluded by the mask and appeared less complete (see Fig. 1, bottom panel). All stimuli were presented on a 15″ computer screen.

2.3. Procedure

Prior to the test phase of the experiment (the results of which are outlined in this paper), participants learned 5 different scene exemplars. Each exemplar was presented for 2 sec in the center of the screen, on a gray background; a verbal label of the image (e.g., 'dining room') preceded each scene for 1 sec. All items were presented 3 times in a random order throughout the learning phase. To ensure that participants remembered the 5 scene exemplars, these items were presented again, intermixed with 5 new scene foils. Each stimulus was presented for 2 sec, after which participants were required to indicate whether they had seen it before; if so, they had to select the corresponding description from among 3 semantically similar options (e.g., 'kitchen', 'canteen', 'cafeteria'). Participants were allowed to proceed with the experiment only after correctly identifying each learned scene on 3 consecutive trials.

In the test phase of the experiment (see Fig. 1), the 5 original scene exemplars were again presented intermixed with 5 novel scene items; all stimuli were presented unmasked (100%) and in the 4 incomplete versions (35%, 21%, 12%, and 5%), resulting in 50 test items. Each item was shown 4 times in a random order with a duration of 2 sec. On each trial, participants had to indicate which of the 5 learned scenes was presented or whether it was a new scene (i.e., 'bar', 'library', 'dining room', 'bedroom', 'kitchen', 'none of these'). Responses were self-paced. Performance was scored as correct only when participants identified the one appropriate response (i.e., the exact stimulus name for learned stimuli, and 'none of these' for new stimuli), resulting in a chance level of 1/6 for each trial. Additionally, participants had to rate their