# Increased Daily Activity Associated With Improved Episodic Memory Processes in Young Adults

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## Introduction

In both animals and humans, exercise improves episodic memory processes that rely on the hippocampus, a brain structure critical for learning and memory (Voss et al., 2013). The benefits of exercise on hippocampal memory may be mediated in part by increased adult-born neurons (adult neurogenesis) in the dentate gyrus of the hippocampus. Indeed, animal studies have demonstrated concomitant exercise-induced increases in adult neurogenesis and in performance on hippocampal behavioral tasks (Voss et al., 2013; 2019). Pattern separation, or the ability to distinguish between similar events in memory, is one area where adult hippocampal neurogenesis has been hypothesized to play a significant role—especially under conditions of high memory interference. Few studies, however, have attempted to examine this hypothesis in humans. In an initial study (Wong-Goodrich et al., 2017), we found that individuals who self-reported higher levels of weekly strenuous exercise performed significantly better on a spatial pattern separation task analogous to tasks dependent on adult hippocampal neurogenesis in rodents. Building on our previous findings, the current study implemented wearable physical activity-tracking technology to more comprehensively assess the cognitive benefits of daily physical activity on hippocampal function, including spatial pattern separation and verbal episodic memory. As a first step, we performed correlational analyses to examine the association between amount of daily physical activity, performance on a spatial pattern separation task, and performance on a verbal episodic memory task using recollection or familiarity retrieval strategies.

## Method

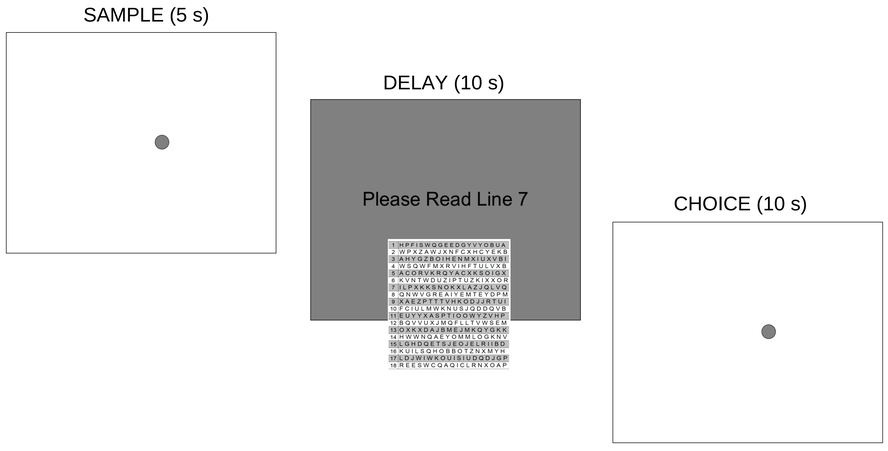
### Participants and General Procedures

A sample of 36 young adults (50% females; $M_{age}$ = 19.00, $SD_{age}$ = 1.64) participated in the current study to fulfill their General Psychology course requirements. Participants were asked to wear a Fitbit Flex 2 wristband device (Fitbit Inc., San Francisco, USA) for 4 consecutive weeks to track their daily number of steps taken and distance travelled (miles) during periods of regular activity and during any exercise-based activities performed at will. At the end of the 4 weeks, participants completed a free word recall task and a spatial pattern separation task.

### Verbal Episodic Memory Task

- Visual presentation of 28 words on a 24-inch computer, using PowerPoint (one word per slide every 2 seconds)
- Delayed oral recall (~36 minutes)
- **Participants made remember-know judgements about how each word was remembered. Remember judgements indicate recollection (episodic) retrieval strategies known to engage the hippocampus, while Know judgements indicate familiarity (semantic) retrieval strategies that do not engage the hippocampus (Eldridge et al., 2000).**
- Total number of words recalled using a recollection or familiarity strategy were recorded for analyses.

## Method (cont'd)




### Spatial Pattern Separation Task

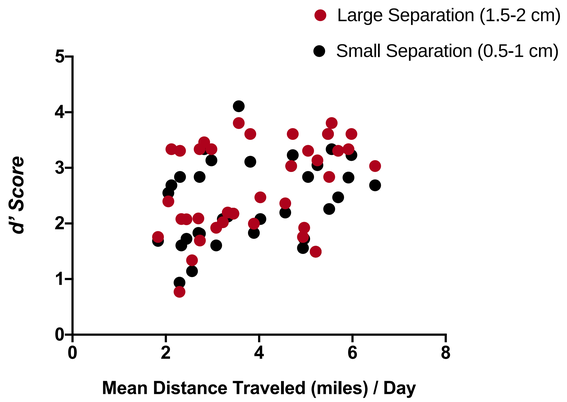
This delay match-to-sample task was adapted from Williams et al. (2018) and kindly provided by Dr. Paul Gilbert and colleagues. Participants completed the task through PowerPoint on a computer with a 24-inch monitor surrounded by a 15-cm black border around the screen. Participants were given 72 trials where they judged whether the spatial location of a grey circle appearing on a computer screen during the choice phase was either in the same or different location as the original grey circle that appeared in the sample phase. The spatial location of the circle appearing in the choice phase was either 0, 0.5, 1, 1.5, or 2 cm to the left or right of the original location shown in the sample phase.

### Data Analyses

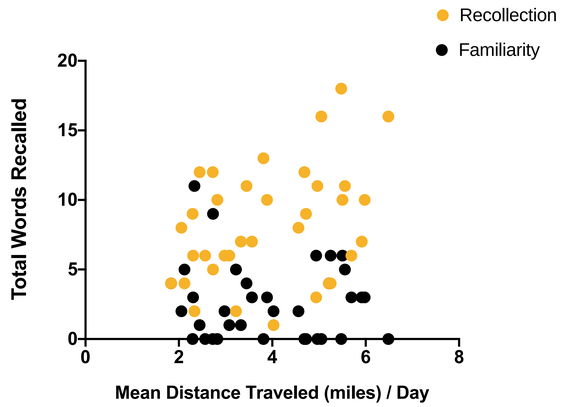
Compared to LARGE separations (1.5 or 2 cm), SMALL separations (0.5 or 1 cm) between the sample and choice phase spatial locations placed greater demands on pattern separation due to the increased potential for memory interference. To control for response biases, task performance was analyzed using standard signal detection theory procedures (Stanislaw & Todorov, 1999), which yielded a separate discrimination sensitivity measure (*d'*) for small (high interference) and large (low interference) trials. Higher *d'* scores indicate higher levels of spatial pattern separation performance.

## Results

**Greater mean distance traveled (miles) per day was significantly associated with greater spatial pattern separation performance for both small and large separation conditions, as well as with higher numbers of words recalled using a recollection (episodic), but not familiarity (semantic) retrieval strategy.**

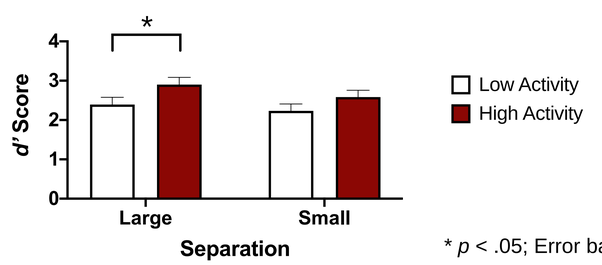



* Large Separation: $r(34) = .40$, $p = .017$
* Small Separation: $r(34) = .34$, $p = .042$

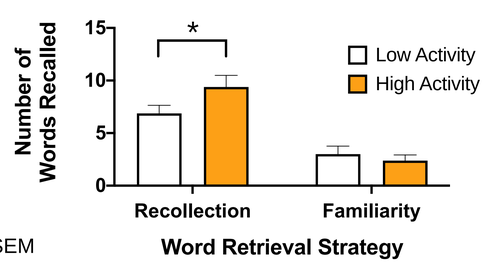



* Recollection: $r(34) = .36$, $p = .035$
Familiarity: $r(34) = .-.08$, $p$ = ns

**Performing a median split on distance traveled per day (Mdn = 3.68, range = 1.84-6.49, *M* = 3.90, *SD* = 1.37) to create a low and high activity group revealed that compared to the low activity group, the high activity group had significantly higher spatial pattern separation performance, $F(1, 34) = 2.94$, $p < .05$, and remembered significantly more words using a recollection, but not familiarity, retrieval strategy.**




* $p < .05$; Error bars = SEM




## Discussion & Conclusion

To our knowledge, no study to date has used these methods to comprehensively track and examine the influence of regular physical activity on hippocampal pattern separation or on retrieval strategies used during free word recall. Consistent with our first study examining self-reported exercise effects on spatial pattern separation (Wong-Goodrich et al., 2017), the current findings suggest that in young adults, higher levels of average daily activity over 4 weeks are associated with improved spatial pattern separation performance. The current findings are also consistent with previous animal studies demonstrating exercise-induced enhancements in both pattern separation and adult hippocampal neurogenesis, as well as with previous human studies demonstrating improvements in pattern separation of objects following physical exercise (Dery et al., 2015; Voss et al., 2013; 2019). Interestingly, our findings suggest that the association between physical activity and free word recall may be specific to hippocampal function, as we did not detect associations between physical activity and memory for familiar words for which retrieval strategies do not appear to engage the hippocampus (Eldridge et al., 2000). These findings may speak to potential cognitive and neural mechanisms of exercise-induced memory improvements and may suggest that daily physical activity may be a useful measure for evaluating the benefits of physical activity on some specific memory processes.

### References


- Dery, N., Pilgrim, M., Gibala, M., Gillen, J., Wojtowicz, J.M., MacQueen, G., & Becker, S. (2015). Adult hippocampal neurogenesis reduces memory interference in humans: Opposing effects of aerobic exercise and depression. *Frontiers in Neuroscience, 7*(68), 1-15. doi: 10.3389/fnins.2013.00066
- Eldridge, LL, Knowlton, BJ, Furmanski, CS, Bookheimer, SY, & Engel, SA. (2000). Remembering episodes: A selective role for the hippocampus during retrieval. Nature Neuroscience, 3, 1149–52. doi: 10.1038/80671
- Stanislaw, H. & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods, Instruments, & Computers, 31*, 137-139.
- Voss, M.W., Vivar, C., Kramer, A.F., & van Praag, H. (2013). Bridging animal and human models of exercise-induced brain plasticity. *Trends in Cognitive Sciences, 17*, 525-540. doi: 10.1016/tics.2013.08.001
- Voss, M.W., Soto, C., Yoo, S., Sodoma, M., Vicar, C., & van Praag, H. (2019). Exercise and hippocampal memory systems. *Trends in Cognitive Sciences, 23*(4), 318-333. doi: 10.1016/j.tics.2019.01.006
- Williams, M.E., Graves, L.V., DeJesus, S.Y., Holden, H.M., DeFord, N.E., & Gilbert, P.E. (2019). Spatial memory ability during middle age may depend on level of spatial similarity. *Learning and Memory, 26*, 20-23. doi: 10.1101/lm.048280.118
- Wong-Goodrich, S.J.E., Iaccarino, M., & Armetta, C. (March, 2017). The influence of self-reported exercise activity on episodic memory processes. Poster presented at the annual meeting of the Association for Psychological Sciences, Boston, MA.