Episodic memory is used to access features of past experience for flexible choice

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Abstract

Our choices often require us to prioritize some features of our experiences over others. One way to solve this problem is by focusing on relevant information while discarding that which is irrelevant. Yet learning which features to prioritize requires extensive experience. Moreover, features that are irrelevant now may become relevant in the future. These issues can be addressed by instead sampling individual richly encoded experiences from episodic memory. Here we hypothesize that episodic memory is used to guide decisions based on multiple features of past events. We test this hypothesis using two experiments in which people made choices about the value of features that were present across multiple past experiences. We find evidence suggesting that participants used episodes to flexibly access features of past events during decision making. Overall, these results suggest that episodic memory promotes adaptive choice when knowledge of multiple features is necessary.

Keywords: decision making; episodic memory; reinforcement learning

Introduction

In many daily tasks only a few features of our rich sensory experience are relevant for the decisions we make, necessitating that some features be prioritized over others. For example, deciding where to go for lunch may generally depend more on a restaurant's quality of food rather than whether a particular colleague has joined you there in the past. One way to solve this problem is by encoding only features that are relevant for a choice. Yet this approach is only possible if it is clear which features are relevant and which are not. For example, if in the future your colleague proposes to have lunch at the restaurant you once visited together but all you remember is the quality of the food, you will likely be dining alone. How do we make flexible decisions based on many features of past events?

One way is to try and maintain the "raw data" of experienced events (Gershman & Daw, 2017; Lengyel & Dayan, 2008). Humans have developed a dedicated memory system to aid in this purpose: episodic memory. Episodic memory has two primary properties that, together, distinguish it from other forms of memory: i) the ability to store individual events experienced in one-shot and ii) the ability to store the many spatial and temporal details of these events (Tulving, 1972). These properties may grant us the ability to make flexible decisions about stimuli with multiple feature dimensions, such as those that are commonly encountered outside of the laboratory. Rather than focusing only on some currently prioritized features when encoding an event, an agent using episodic memory can instead encode the full event with all features, deferring feature selection to a later time, such as when a choice is required. This idea is based on previous suggestions that an attentional filter may be applied to multidimensional stimuli at choice time rather than at the time of encoding (Dayan, Kakade, & Montague, 2000; Gershman & Daw, 2017). The flexibility afforded by this approach may be one reason for our ability to remember so many details, but this idea has yet to be tested.

Here we ask whether episodic memory is indeed used to guide decisions based on multiple features of past events. We test this hypothesis using two novel behavioral experiments in which participants were required to make choices about features that were present in multiple past experiences. We find evidence suggesting that people tend to reference episodes during these types of choices, and that episodes are particularly useful when it is unclear what to prioritize during learning.

Experiment One

We asked participants across two independent samples (Main N = 67 and Replication N = 47) to complete a four-part experiment over the course of a single online session (**Figure 1A**). Completing all four parts (a "round") took approximately five minutes, and participants completed five rounds in total.

Participants first completed an encoding task in which individual items were presented alongside an associated value for 6 seconds (which we refer to as an "episode"). Immediately after viewing each episode, participants completed an attention check consisting of the item shown alongside its value or another randomly selected value. Each episode was viewed once for a total of six trials per round. Items (**Figure 1B**) were selected to vary across two features: color and category. Following encoding, participants completed a 90 second 2-back working memory task which served as a distractor.

Next, participants made up to six decisions based on the features of each item. Each decision consisted of an offer in which a single feature (e.g. "animal") was displayed, and participants were asked to either take or leave this offer. Participants were informed that the value of each offer consisted of the sum of each episode that was described by the offer (e.g. the the value of the "animal" offer would be the sum of all animals seen during encoding), and that they should take positive

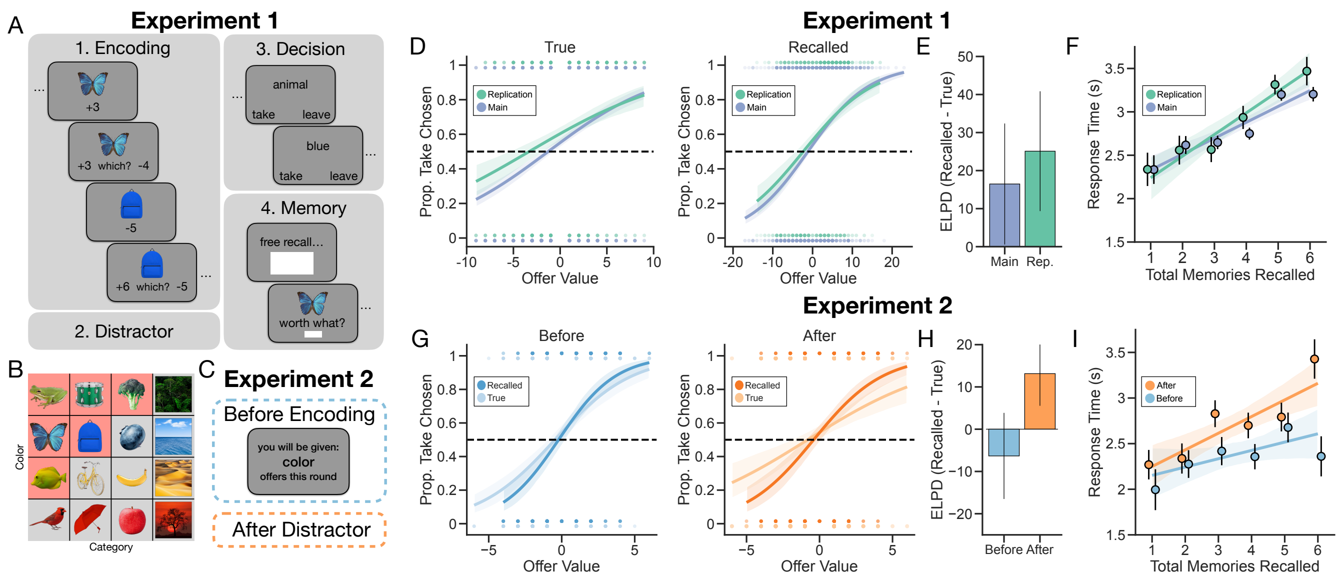

Figure 1: **A)** The four phases completed by participants in each round of the experiment. **B)** The full set of images shown to participants. Six images were sampled to be shown in each round (example in red). **C)** The manipulation added in experiment two. **D)** The proportion of take choices that were made as a function of summed true offer value (left) and recalled offer value (right). Mixed effects logistic regression models predicting choice from value were fit using Bayesian inference. **E)** Model fit was assessed using 10-fold cross-validation. The expected log pointwise predictive density (ELPD) was then computed. Higher ELPD values indicate a higher likelihood of accurately predicting new data. Here the difference in ELPD is shown alongside standard error. **F)** Decision response times as a function of the total number of memories recalled during the free recall phase. **G,H,I)** The same as panels D, E, and F but separated by whether choice information was provided before encoding or after the distractor in experiment two. Unless otherwise noted, all bands and error bars represent 95% confidence intervals.

offers and leave negative offers. Participants had 7.5 seconds to make each decision. Following the decision phase, we assessed participants' memory by asking them to freely recall the items they saw in each round, and then to provide their memory for the value of each item.

There are at least two strategies that can be used to make good decisions in this task. The first relies on tracking a running sum for each feature and does not require that traces of each episode be maintained after encoding. In contrast, the second relies on using the memory of each episode to compute an offer's value on-the-fly during decision making. This strategy offers the advantage of being more flexible, as each episode can be used and re-used according to the demands of the present decision. Critically, it also makes two predictions. First, the values of individual episodes should impact choice. Second, recalling an episode should take time, leading choices that reference more episodes to take longer.

Participants learned to make effective decisions in the task and were sensitive to the true summed value of each offer (Main: β_{value} = 0.17, 95% CI = [0.13, 0.21]; Replication: β_{value} = 0.14, 95% CI = [0.08, 0.20]; **Figure 1D**). In line with the first prediction, participants' choices were better explained by the summed value of their recalled memories (Main: $ELPD_{true}$ = -875.12, $ELPD_{recalled}$ = -850.02; Replication: $ELPD_{true}$ = -871.18, $ELPD_{recalled}$ = -854.71; **Figure 1E**). In line with the second prediction, participants also took longer to make choices on rounds in which they recalled more items (Main: $\beta_{nMemories}$ = 0.05, 95% CI = [0.02, 0.09]; Replication: $\beta_{nMemories}$ = 0.08, 95% CI = [0.03, 0.13]; **Figure 1F**).

Experiment Two

We next sought to determine whether episodic memory is used preferentially when it is unclear which features should be prioritized during encoding. To do so, we had participants (N = 50) complete a modified version of experiment one. In this experiment, participants were told either before encoding (4 rounds) or after the distractor task (4 rounds) that they would be given offers of only one feature type (either color or category) during the decision phase. We predicted that episodes would be used more during choices made in rounds in which it was unclear at encoding which features would be needed.

In line with this prediction, we found that participant's choices were better explained by the summed value of recalled memories relative to the true value of each offer when offer information was provided after the distractor ($ELPD_{true}$ = -254.34, $ELPD_{recalled}$ = -241.2) but not before encoding ($ELPD_{true}$ = -239.73, $ELPD_{recalled}$ = -246.06; **Figure 1G-H**). Further, we found that the total number of recalled memories was more predictive of response times when information was provided after the distractor, but not before encoding ($\beta_{nMemories \times condition}$ = 0.05, 95% CI = [0.00002, 0.11]).

Taken together, these experiments support the hypothesis that people use episodic memory to make decisions that require knowledge of multiple features of past events.

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