

Brief Communication

Agency alters memory organization during free recall

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This study examined how agentic decisions in the absence of explicit rewards influence memory organization. Participants studied lists of items to assign as gifts to two characters—either choosing freely (Choice group) or following instructions (Fixed group). During free recall, participants in the Choice group showed reduced temporal clustering and instead organized their memories around the choices they made. Specifically, they were more likely to recall together items that were assigned to the same character. These findings suggest that agency shifts memory organization away from temporal proximity and toward meaningful associations, highlighting how agency can shape the organization of memory.

[Supplemental material is available for this article.]

People value the ability to exert agency and actively make choices, which not only enhances the value of outcomes but also shapes their experiences (Martin 2004; Leotti et al. 2010; Haggard and Chambon 2012; Izuma and Murayama 2013; Haggard 2017; Code 2020). More recent research demonstrates that making choices can also influence what is remembered (Gureckis and Markant 2012; Markant et al. 2014; Murty et al. 2015, 2019; DuBrow et al. 2019; Rotem-Turchnski et al. 2019; Hon and Yeo 2021). However, these studies primarily focused on item-level memory, leaving open questions about how agency might shape the sequence or clustering of remembered events. Prior work from our laboratory (Ruiz et al. 2023) found that participants with agency exhibited stronger associative links in memory between decision cues, choices, and outcomes using alternative forced choice paradigms. By forcing explicit sequence judgments, this paradigm precluded analysis of how agency shapes memory across multiple contextual dimensions. Thus, the role of choice in shaping the implicit organization of memory remains unclear. Demonstrating such an effect would suggest that choice not only enhances memory for individual events or associations, but also serves as a core organizing principle for memory.

In the current study, we used a free recall paradigm, which allows people to retrieve studied information without explicit cues about recall order, providing a unique window into the structure of natural memory (Rait and Hutchinson 2024). Leading theoretical accounts propose that recall order is guided by the similarity of encoding contexts, with items encoded in similar contexts more likely to be recalled successively (Howard and Kahana 2002; Sederberg et al. 2008; Polyn et al. 2009a). Because temporally adjacent items are often experienced in similar contexts, these shared contextual features (i.e., temporal context) serve as cues during retrieval. This makes it more likely that people recall items in the original study order, a pattern known as temporal clustering (Kahana 1996; Sederberg et al. 2010). While agency has been shown to enhance memory for temporal order during exploration (Houser et al. 2022), it remains unclear whether this translates to free recall. In fact, prior research from our laboratory found no differences in temporal clustering based on motivational context, suggesting that alternative organizational strategies may take pre-

cedence over temporal order in certain situations (Horwath et al. 2023, 2024).

Context shifts (e.g., changes in location, task demands, or goal states) have been shown to disrupt temporal context (Polyn et al. 2009a; DuBrow et al. 2017; Pu et al. 2022; Lohnas et al. 2023). In these situations, people tend to organize memories around the new context, grouping together items from the same task (Polyn et al. 2009b). Prior research has shown that motivational factors, such as reward value, shape memory organization by promoting the grouping of information based on higher-order categories (Horwath et al. 2023). However, it is less clear whether this same effect holds in the context of agency, which engages similar neural circuitry but is not explicitly associated with reward incentives (Murty et al. 2015). When people are given the ability to make choices, they may prioritize organizing their memories based on the relationships established through those choices, even if those choices are not consequential, rather than on temporal proximity. Thus, we hypothesize that participants with agency over their choices will group items in memory based on the choices they actively made during encoding.

In this study, we examined how giving people agency during decision-making affects the later organization of memories in a between-groups design. To test this, the experiment consisted of 10 lists, with each list consisting of three sequential phases: encoding, distractor, and recall. During encoding, participants were asked to create meaningful gift baskets for two characters by sorting items represented by words for each character. On each trial, participants in the Choice group ($n=34$; see *Supplemental Methods* for details) had 4000 msec to decide which character would receive the item. To help track responses, five empty circles appeared next to each character, filling in as items were assigned. As feedback, the selected character's name and corresponding circle turned blue (Fig. 1, top). Critically, the characters offered no inherent cues about how the items should be grouped, so item organization was entirely participant-generated. Participants were asked to assign items evenly, giving five to each character across 10 trials. All stimuli remained on the screen for the full 4000 msec to ensure

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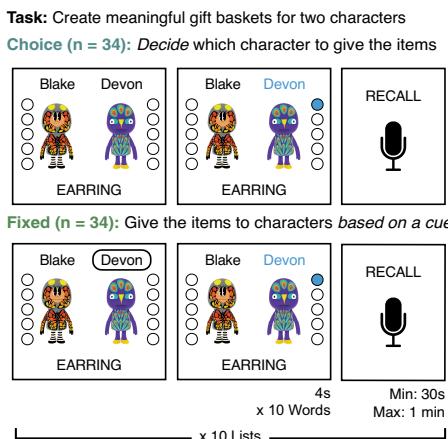


Figure 1. Experimental design. On each trial, participants assigned an item (word) to one of two characters in order to create meaningful gift baskets for each character ("z" for the character on the left and "m" for the character on the right). In the Choice group, participants decided the recipient within 4000 msec, and received feedback to track the number of items sorted for each character to ensure even division. Critically, participants received no instructions about how to assign items, and the characters themselves offered no inherent cues about how the items should be grouped. In the Fixed group, a rectangle around the character's name indicated the assigned recipient, based on the choices of a yoked participant from the Choice group. Each list contained 10 items and featured different character pairs. After each list, participants verbally recalled as many items as possible for a maximum of 1 min.

equal encoding time. In contrast, participants in the Fixed group ($n = 34$) were guided by a visual cue (a rectangle around the character's name) indicating the designated recipient (Fig. 1, bottom). This cue was based on previous choices made by a yoked participant in the Choice group. Each list featured different pairs of characters. After a 10 sec math distractor task (see *Supplemental Methods* for details; Howard and Kahana 1999), participants were given a maximum of 1 min to verbally recall as many words as possible from the list, without any explicit instructions about recall order.

We first examined the order in which participants in the Choice group assigned items to the two characters at encoding. For each participant, we calculated the proportion of consecutive responses where the selected character differed from the previous one (e.g., a switch from Blake to Devon). Because participants were required to assign exactly five items to each character, the expected switch rate under random responding is 55.60%. A one-sample *t*-test revealed that participants switched characters during encoding significantly more often than this expected value ($M = 67.19\% \pm 10.61\%$, s.d.), $t(33) = 6.37$, $P < 0.001$, $d = 1.09$, indicating a systematic bias toward switching characters.

Next, to characterize how agency influenced overall recall performance, we compared the number of items recalled from the immediately preceding list between the Choice and Fixed groups. Across both groups, the mean recall was $48.68\% \pm 11.43\%$. We then ran a mixed-effects logistic regression model predicting word recall (yes/no) by group (Choice vs. Fixed), also including a fixed effect of list number and random effects of word and yoked pair subject identity. The analysis showed that group did not significantly predict recall performance ($\beta = -0.03$, $P = 0.55$, 95% CI $[-0.13, 0.07]$; marginal $R^2 = 0.002$; conditional $R^2 = 0.051$), suggesting that the likelihood of recalling a word is not influenced by whether participants have agency over their choices.

Next and of central interest, we investigated whether making a choice, rather than having it made for you, influenced memory.

organization. We first investigated this through temporal clustering, the tendency to successively recall items (recall transition) encoded in nearby positions on the study list. We calculated a temporal clustering score (see [Supplemental Methods](#) for details) for each participant in each group for each list (Polyn et al. 2009a). A score of 1 indicates high temporal clustering, meaning that participants recalled items in the exact order (or reverse order) they were studied, reflecting transitions to nearby list positions. A score of 0.5 indicates chance-level temporal clustering, meaning that transitions were just as likely to be to a nearby or remote item. While temporal clustering was above that expected by chance in both groups (clustering scores >0.5 ; Choice: $t(33)=6.28$, $P<0.001$, $d=1.08$; Fixed: $t(33)=8.69$, $P<0.001$, $d=1.49$, one-sample t -tests), group significantly predicted temporal clustering scores ($\beta=0.04$, $P=0.012$, 95% CI [0.01, 0.07]; marginal $R^2=0.026$; conditional $R^2=0.041$; linear mixed-effects regression model; Fig. 2), such that temporal clustering was significantly lower in the Choice compared to Fixed group (see [Supplemental Methods](#) and [Supplemental Table S1](#) for full model details). This suggests that participants with agency relied less on temporal structure when organizing their recall.

To further explore how participants organized their memories, we tested whether making choices during encoding could serve as a context that later organizes memory. Specifically, we examined whether participants were more likely to successively recall items that had been given to the same character. For each participant, we calculated the real transition probabilities for within-character (stay; e.g., Devon to Devon) and between-character (switch; e.g., Devon to Blake) transitions by dividing the number of each type of transition by the total number of transitions that started with that character. We then computed dynamic, subject-specific chance probabilities for each recall transition, based on the proportion of remaining recalled items from each character. The final score reflects the difference between real and chance probabilities, providing a corrected measure of whether recall was structured by encoding character beyond what would be expected by chance (see [Supplemental Methods](#) and Horwath et al. 2023 for details). We found that group significantly predicted stay transition probabilities ($\beta = -0.05$, $P = 0.024$, 95% CI $[-0.10, -0.007]$; marginal $R^2 = 0.018$; conditional $R^2 = 0.060$; linear mixed-effects regression model; Fig. 3A), with participants in the Choice group making more stay transitions than those in the Fixed group (see [Supplemental Methods](#) and [Supplemental Table S2](#) for full model details). This suggests that when a participant in the Choice group recalled a word, they were more likely to recall their next word as one that had been assigned to the same character. In contrast, group was not a significant predictor of switch transition probabilities ($\beta = -0.003$, $P = 0.924$, 95% CI $[-0.07, 0.07]$; marginal

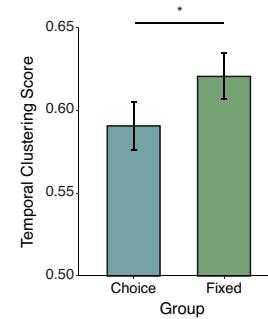
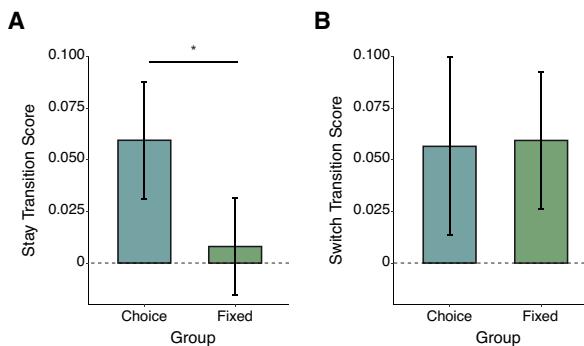


Figure 2. Temporal clustering by group. Participants in the Fixed group had significantly higher temporal clustering scores than participants in the Choice group. (*) $P < 0.05$. Error bars indicate \pm SEM.



$R^2=0.004$; conditional $R^2=0.089$; Fig. 3B), meaning that the groups did not differ in how often they transitioned between characters during recall.

Lastly, we examined whether the pattern of encoding choices was related to subsequent recall. Because this was a yoked design, the Choice and Fixed groups made identical sequences of choices, allowing us to test whether actively making choices influenced how the amount and pattern of switching during the study sequence related to later memory. We first measured the total number of switch choices per list, or how often participants changed item assignments, and found no significant relationship with differences between Choice and Fixed groups in recall performance ($\beta=0.0008$, $P=0.908$; 95% CI $[-0.01, 0.02]$; marginal $R^2=0.000$; conditional $R^2=0.257$), temporal clustering ($\beta=-0.013$, $P=0.167$; 95% CI $[-0.03, 0.01]$; marginal $R^2=0.006$; conditional $R^2=0.104$), or stay transitions ($\beta=0.01$, $P=0.486$; 95% CI $[-0.02, 0.04]$; marginal $R^2=0.002$; conditional $R^2=0.138$). We also measured the distribution of switches by measuring the longest streak of consecutive switches. Again, no significant relationships were observed between switch choices and the difference between groups in recall performance ($\beta=-0.001$, $P=0.847$, 95% CI $[-0.01, 0.01]$; marginal $R^2=0.000$; conditional $R^2=0.258$) or temporal clustering ($\beta=-0.0004$, $P=0.960$, 95% CI $[-0.02, 0.01]$; marginal $R^2=0.000$; conditional $R^2=0.100$), but there was a marginal trend for stay transitions ($\beta=0.02$, $P=0.083$, 95% CI $[-0.003, 0.04]$; marginal $R^2=0.010$; conditional $R^2=0.149$), suggesting that lists with longer consecutive runs of switching were associated with a modest increase in how the Choice group organized items by character relative to the Fixed group.

The present study shows that recall structure was shaped by whether an individual had agency over how items were assigned at encoding. Participants who had no agency over their choices relied more on temporal information to organize recall, where they were more likely to retrieve items in the order they were studied. In contrast, those who actively made choices were less dependent on temporal structure and instead organized their recall around their choices. This suggests that making choices during encoding creates a meaningful context that later guides memory organization.

While previous research demonstrated that agency enhances memory for chosen items (Ruiz et al. 2023) and even extends to

memory for choice-irrelevant content (Murty et al. 2015, 2019; DuBrow et al. 2019), our findings contrast with this work, as we found no overall memory benefit based on whether participants had agency over their choices. However, this aligns with recent work showing no differences in free recall memory between participants with and without agency using “choose-your-own-adventure” narratives (Li et al. 2024). In fact, one study from our laboratory even found that participants who actively explored an environment recalled less than those who explored passively (Houser et al. 2022). One possible explanation for these discrepancies is that the benefits of agency on memory may depend on the nature of the task. In free recall, agency may just shape how information is structured in memory without enhancing overall memory performance, though future work using both recognition and free recall measures is needed.

Of central interest to the present study was the influence of agency on memory organization. While people typically recall information in a similar temporal order to which it was learned (Kahana 1996; Sederberg et al. 2010), changes in encoding context have been shown to influence the degree of temporal clustering (DuBrow and Davachi 2013, 2016; Rait et al. 2024). Although previous research manipulating motivational context did not find differences in temporal clustering across conditions (Horwath et al. 2023, 2024; Li et al. 2024), we found that participants who made choices during encoding exhibited less temporal clustering compared to those who had no control over their choices. These results suggest that allowing people to have agency over their choices altered how they later organized their memories by reducing reliance on temporal information, leading to a different organizational structure.

Instead, people with agency structured their memories around relationships they formed through their choices. This parallels research from our laboratory on reward motivation, where reward creates higher-order categories for organizing memories (Horwath et al. 2023). Although agency is not tied to explicit reward incentives, it engages similar neural circuitry as reward (Murty et al. 2015) and appears to shape memory organization in a comparable way. Notably, Horwath et al. (2023) found that clustering patterns remained stable after a 24 h delay, suggesting that this organizational structure is largely determined at encoding and maintained over time. One possible mechanism is that actively making choices strengthens the perceived relevance of item-character associations (Hon and Yeo 2021; Li et al. 2024), creating a richer “character context” for organizing memory. The stronger clustering in the Choice group suggests that agency primarily strengthens or elaborates this existing context rather than creating it de novo. By reinforcing this context, choice provided an organizing principle for memory, potentially by enhancing meaningful associations that guide recall.

The present results show that participants with agency were more likely to organize their memories around their own choices, despite being more likely to switch between characters during encoding. This suggests that these choice-driven associations provided structure for recall that could supersede the temporal order of items. In this way, choice acted as a strong organizing force, analogous to having distinct categories within a list. Previous research showed that the presence of multiple categories within a single list can reduce temporal organization by drawing recall toward shared category features (Puff 1974; Polyn et al. 2011; Hong et al. 2024). In fact, previous work showed that participants “jumped over” temporally closer items to recall items from the same category together (Chan et al. 2017). Importantly, both groups had identical character assignments and number of switches, and in both groups, higher memory accuracy was associated with greater organization around decision context (see Supplemental Table S2 for model details). Yet, despite these shared features, participants in the Choice

group exhibited stronger character clustering than those in the Fixed group. These findings provide novel evidence that it was not simply the shifts in character assignment driving the effect, but rather the subjective experience of making choices that shaped how participants structured their recall.

The current work adds to a growing body of literature on how context switching influences memory. While much of previous work focused on externally driven context shifts to investigate how context shapes memory (Godden and Baddeley 1975; DuBrow and Davachi 2013, 2014, 2016; Pettijohn et al. 2016; Pettijohn and Radvansky 2018), the role of internally generated shifts has received less attention (Wang et al. 2023). In some cases, internal context shifts occur in response to an external cue (Polyn et al. 2009b; Horwath et al. 2023), which subsequently influence how memories are organized. In other cases, changes in context could be completely self-generated and independent of external instruction. Prior research suggests that both externally and internally driven shifts in goal states can create event boundaries that impair temporal order memory across the boundary (Wang and Egner 2022). However, the present findings demonstrate a critical distinction: When context shifts are tied to a participant's own choices, not those forced by an experiment, they shape memory organization differently than externally imposed shifts. Future work could incorporate models of why people shift actions to further investigate how self-generated context shifts shape memory (Radvansky et al. 2015, 2016).

In conclusion, our findings demonstrate that while agency did not enhance overall memory performance, it restructured how participants organized their memories. Compared to participants with no control over their choices, those with agency showed reduced temporal clustering and instead were more likely to organize their memories around the relationships they constructed through their choices. This pattern highlights a shift in memory organization strategies, where agency may encourage clustering by meaningful associations rather than by temporal proximity. However, future work should explore whether this shift in organization reflects a tradeoff between different clustering strategies. Overall, these results contribute to a growing literature examining how motivational context shapes memory structure.

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