

THE EFFECTS OF DEVIANCY AND ITEM DIFFICULTY
ON LEARNING TEMPORAL ORDER IN ACTION

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Abstract

Performing actions in a specific order is an essential part of many daily activities. Working memory is known to support memory for temporal order in digit and spatial sequences, but less is known about the ability to learn temporal order in regard to action sequences, which are an essential part of many daily activities. Research with children has shown that memory for order is sensitive to deviant input and is the least prioritized in a hierarchy of processing steps when learning action sequences, following object identification and sub-action identification. Similar research had not been conducted with adult participants until now. The present study investigated the effects of deviant order on temporal memory for actions with adult participants, with varied ease of object categorization used to assess whether adults' memory for ordered sequences is supported by the processing hierarchy. Results showed that the ease of object categorization had a significant effect on memory for target actions, as participants recalled more actions in the easy condition. Additionally, the presence of a deviant order had a significant effect on memory for order in the difficult-to-categorize object condition, but the effect was not significant in the easy-to-categorize object condition. This suggests that the presence of a deviant order hinders adults' ability to learn order sequences, but does so to a lesser extent when the actions in the order sequence are performed with easily categorized objects. These results support the theorized processing hierarchy, with the presence of a deviant order having a larger effect on memory for novel action sequences when the objects are difficult to categorize. These results have implications for theories of working memory and learning in real world contexts.

The Effects of Deviancy and Item Difficulty on Learning Temporal Order in Action

The ability to learn order is important to many aspects of our everyday lives. As children we learn how to count and how to say the alphabet, which are critical for conveying meaning. With the words “parental”, “prenatal”, and “paternal”, the same letters are arranged differently to express a different meaning. In addition, the order in which words are organized is imperative in communicating. As an example, saying “Steve hit Jenn” means something notably different than “Jenn hit Steve”. Similarly, digits are often presented to us in a meaningful order, such as phone numbers, prices, or addresses. These are just a few examples of the important role that order plays in human communication.

In some instances, the order of actions is necessary for functionality. When you’re getting dressed in the morning, the order in which you put on different items matters – putting your socks over your shoes would not be functional. Learning order has social applications as well, such knowing what order to do things in when you go to a coffee shop or restaurant (Schank & Abelson, 1977), learning the order of dance choreography, or learning a team hand shake. In order to be functioning members of society, it is crucial that we are able to learn and remember order in a variety of contexts.

Working memory, a cognitive process that enables individuals to eventually store things in long-term memory, allows individuals to recall order (Baddeley & Hitch, 1974). Both the visuospatial sketchpad and phonological loop – two of the slave systems controlled by the central executive – have the ability to represent the temporal order of events. However, research has found that there is a dissociation in the representations of order in these separate memory stores, as memory for order is more robust in the phonological loop than in the visuospatial sketchpad. That is, memory for order is stronger

for verbal sequences, such as digits, than spatial sequences, or locations (Gmeindl, Walsh, & Courtney, 2011). This might indicate that the processing of order within these separate memory stores is different.

Moreover, the retrieval of spatial and temporal information are shown to rely on different cortical areas. A study by Ekstrom and Bookheimer (2007) used fMRI to determine which cortical regions were active as participants were asked to recall different types of information. In a virtual navigation task, participants drove around a city as a taxi driver, picking people up and dropping them off in different places. Afterwards, they were asked to identify which landmarks they had seen (object memory), whether they saw a specific person in a specific place (spatial memory), and the order in which they saw different people (temporal memory). Participants displayed better memory in the object recognition task than in the spatial and temporal memory tasks. Additionally, recall of order and of spatial information were found to activate separate neural regions. This tells us that learning and recalling temporal order does not occur as a result of learning spatial information – there are different underlying processes.

Many of the sequences that we view or come into contact with in our everyday lives have variable characteristics – things that change from instance to instance. An important factor to look at when studying the ability to learn and recall temporal order is how we handle information that is unexpected, or different from what has been encountered previously. Farrar and Goodman (1992) conducted a study with 4- and 7-year-olds, where children participated in either 1 or 3 standard (unchanging) visits, followed by a deviant visit, during which they completed similar activities as in the standard visit but with distinct changes. In each standard visit, four activities with separate names, props, and

locations were completed. In the following deviant visit, there were three types of changes: two of the activities switched spots in the sequence of activities, one had the same name and location but different props, and one was removed and replaced with a completely new activity. There were also two control groups, who participated in either one standard visit, or one deviant visit, to test the baseline ability of children to recall details of the two visit types without repeated experience.

Farrar and Goodman (1992) looked at the children's ability to recall details of both the standard visit and the deviant visit. Both children who had encountered only the standard event one time, and those in the group that had three experiences with the standard event before the deviant event, had better recall than those who viewed both the standard and the deviant events one time. This suggests that when a deviant is present, more experience with the standard event is needed in order to be able to distinguish which details occurred during which event. Recall for details of the standard event was fairly high when viewed one time without then viewing a deviant – but when a deviant was viewed after only one experience with the standard event, it decreased recall for details of both events.

Though Farrar and Goodman's (1992) study provides evidence that the presence of deviant information disrupts the ability to recall details from both standard and deviant events, we are not able to know from these results what types of deviation causes this disruption. The deviation event in this study included three changes from the standard event – one activity used different objects, one was replaced with a novel activity, and two were presented in a different order than in the standard visits. As all three types of deviation were present at the same time, we are unable to determine if the effect is a result

of one type of deviation alone, or a combination of the three.

To further understand which types of deviation play a role in disrupting recall ability in children, it is necessary to look at each type individually. Connolly, Gordon, Woiwod, and Price, (2016) recently investigated children's ability to recall details of a repeated event when there is just one type of deviant present. Participants viewed magic shows on four different days, with the same general script but details differing on each day. On the fourth day, the actor wore a large bowtie and named the magic show. After the fourth magic show, participants in the deviation group witnessed a deviation from the general event, where something occurred that had not happened in the other four instances. Results showed that when a deviant is presented, children have increased recall across all instances. Connolly et al. (2016) suggest that the presence of deviant details in a repeated event elicits rehearsal of all previously seen variable details, and therefore helps consolidate memory for what happened in the standard event. The introduction of different items or actions may highlight the commonalities in previous instances.

While the results of Connolly et al. (2016) indicate that deviation details could aid in recall, other research has found that another type of deviant could hinder memory. Loucks and Price (2018) recently investigated the effect that a subtler type of deviation, deviancy in order, had on recall of temporal order. Children ages 4- to 8-years-old viewed two different action sequences, each across four instances, and were then asked to perform the action sequences with new items that had not previously been seen. One instance in one of the sequences was deviant: the four steps in the action sequence were the same, but two of the actions switched places in the order (e.g., if the standard sequence of actions were A, B, C, D, then the deviant sequence would be A, D, C, B). The deviant occurred either in the

second or the fourth instance. Their results showed that children had poorer recall for order when they viewed a deviant instance, even though the majority of the sequences they viewed were standard order. Loucks and Price (2018) concluded that deviant order does affect children's memory, and that deviancy in order seems to have a different effect than deviation details. While the presence of deviant details appeared to facilitate recall for the standard event as well as the deviation (Connolly et al., 2016), the presentation of a deviant order hinders recall for the standard temporal order.

In the same study, Loucks and Price (2018) also tested a hypothesis that memory for order is the least prioritized in a hierarchy of processing steps. They hypothesized that when viewing an action sequence, one must be able to identify what objects they are seeing, before they can identify what actions someone does with those things, in order to then determine what order those actions are done in. In their study they investigated whether the ease of object identification affects the learning of action sequences that involve those objects. Their results showed that sequences with easy-to-categorize items (animals and fruit) led to better recall of the temporal sequence, while recall of sequences with difficult-to-categorize items (green items and items smaller than the green items) was poorer. These results support the theorized processing hierarchy, where temporal order is the least prioritized, following item identification and sub-action identification.

Furthermore, Loucks and Price (2018) observed an interaction between ease of item identification and the presence of a deviant order, where the effect of the deviant was larger in the conditions with difficult items than in the conditions with easy items.

Relatively little is known about how people learn new action sequences in regard to the working memory model. It is well-known that the working memory model supports

memory for order in relation to digit and spatial sequences (Baddeley, 2003), but there is a lack of research focusing on order for real actions that are similar to what people might encounter in their everyday lives. It is still unclear how order is learned for live sequential actions. Though Loucks and Price (2018) found that encoding of temporal information is only possible if attention is not already dedicated to processing objects or sub-actions that are involved in the sequence, this was the first time that this processing hierarchy had been investigated. Moreover, there has thus far only been evidence for the existence of the processing hierarchy in children, and there are many noted differences between children's and adults' memory (Gathercole, Pickering, Ambridge, & Wearing, 2004). Loucks and Price (2018) also determined that children's memory for order is impacted by the presence of a deviant order, but it was previously unclear whether this association exists for adults as well.

The current research addressed the effect that the presentation of deviance in order has on adults' ability to recall temporal order, and investigated the applicability of the theorized processing hierarchy to adults' learning of action sequences. As children have more difficulty recalling an action sequence when the objects involved are more difficult to categorize, this study analyzed the effect that using objects of varying identification ease has on adults' ability to learn an action sequence. We hypothesized that the use of easy-to-categorize objects would facilitate recall of the action sequence, showing support for the theorized processing hierarchy. We also hypothesized that the presence of a deviant order would hinder recall of the action sequence, and that the effect would be greater for sequences that involve items that are more difficult to categorize.

A third research question arose from research by Brainerd and Reyna (2002)

regarding false memory. They reported that when meaningful relationships between encountered items can be easily formed, older children and adults are more likely to falsely identify having encountered a new item if it fits within the formed relationship, because the viewed target items were identified by their category, or gist information, rather than the identity of that item. When meaningful relationships cannot be formed among target items, false identification does not occur, as the target items are remembered as that specific object, or verbatim, rather than in relation to other items. The current study also investigated whether objects that are explicit category members are more difficult to distinguish from other objects within that same category, in comparison to objects that are not readily categorized. We hypothesized that recognition for the items in the difficult-item condition would be better than recognition of items in the easy-item condition, as a result of identifying easy items as category members rather than distinct objects.

Method

Participants

The study included a sample of $N = 128$ participants. A power analysis with $\alpha = 0.05$ and power = .80 indicated that a medium effect size ($f = .25$) could be detected by an $N = 128$. Participants were psychology undergraduate students who were recruited through the University of Regina Department of Psychology Participant Pool, and were compensated with partial course credit. This research has been approved by the University of Regina Research Ethics Board.

Stimuli

Stimuli for this study included 10 different sets of objects used in action sequences – 4 sets for the easy-item condition, 4 for the difficult-item condition, and 2 sets used for the

generalization trial in the test phase. In the easy-item condition, each set contained two variable items which were easily identified as being members of a category (toy vehicles and fruits), while the two variable items in the difficult-item condition were more difficult to identify as category members (metal items and small items – small items being smaller than the metal items). The variable items in each set were paired with a coloured wooden stick and a coloured wooden block, which varied only in shape and colour.

Action sequences were video recorded for each of the 8 sets used in the exposure phase. These action sequences were presented by an actor on a white foam board, and these videos were approximately 20 s in length. An example of an easy-item and difficult-item set can be seen in Figure 1.

The standard action sequences were executed as follows: A) stamp block with fruit/small item; B) tap vehicle/metal item three times with stick; C) touch bottom of fruit/small item to bottom of vehicle/metal item over the center of the board; D) trace circle around block with stick. The action sequence for each item set was also filmed in a deviant order that was presented to participants in the deviant condition. The four sub-actions in the sequence were identical but were performed in a different order: instead of A-B-C-D, they were ordered A-D-C-B. After completion of both the standard and deviant

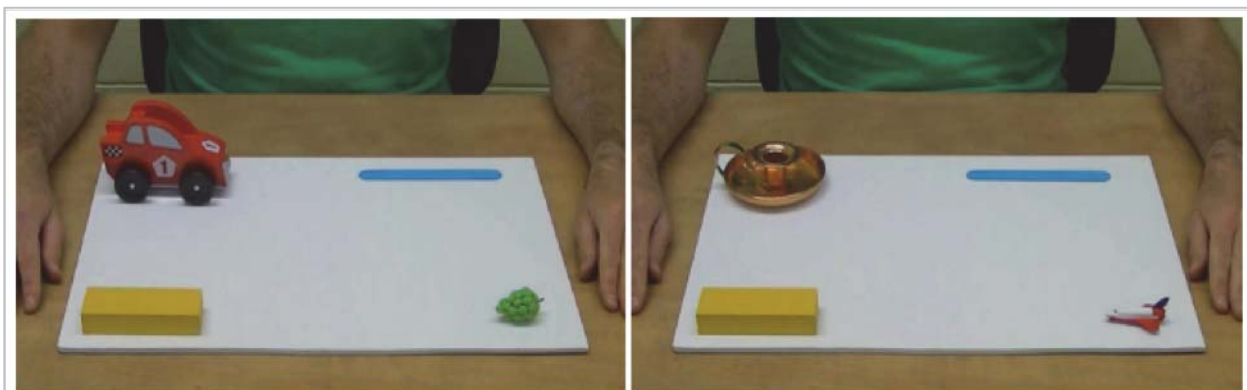


Figure 1: An example easy-item (left) and difficult-item set (right).

action sequence, each item was back in its starting position, so no spatial transformation occurred within each video. Across the four action videos in both the easy- and difficult-item conditions, the position of items on the board were rotated 90 degrees with each new set of items, to prevent participants from recalling the order based on the locations of items. A full list of items used in the action sets can be found in Table 1.

In addition to the variable items that were used for the action sequences, each variable item had a perceptually similar distractor. Photos of the items used in the action sequences and the distractor were used in the object recognition task. An example of target items and their distractor items can be seen in Figure 2. Other stimuli included four nature videos, each one minute in length, that were shown in-between each of the four action sequence videos. There were also word search puzzles and an animal-memory task used as distractors.

Design

Participants visited the lab on one occasion for approximately 45 minutes. We used a 2 (easy vs. difficult items) x 2 (standard vs. deviant sequence) between-subjects design.

	Variable Item 1	Variable Item 2
Sequence	Toy Vehicles	Toy Fruit
Easy	Car	Grapes
	Bus	Strawberry
	Jet ski	Pomegranate
	Airplane	Lemon
	Gen: Tractor	Gen: Watermelon
Difficult	Metal Things	Small Things
	Candle holder	Toy space shuttle
	Nail	Match
	Decorative pear	Marble
	Number '6' (address)	Toy broom
Gen: Gravy boat	Gen: Plastic container	

Table 1: Action sequence set items.

An additional between-subjects counterbalancing variable was sequence presentation order (which action sequence was presented first).

Procedure

After providing informed consent, participants were randomly assigned to the easy-item or difficult-item condition. Four action sequence videos were presented on a laptop computer using E-Prime 3.0 software (Psychology Software Tools, Pittsburgh, PA), with the four nature videos being presented after each action sequence video. E-Prime was also programmed to assign half the participants to the standard condition, and half to the condition with a deviant order presented. In the deviant condition, the action sequence with a deviant order was presented in the second position in the presentation of the four action sequence videos.



Figure 2: Variable items and their perceptually similar pair for the object recognition task.

After viewing the action sequence and nature videos, participants engaged in two distractor tasks, used to create a 30-minute gap between exposure and test. The first distractor was an image memory task, which took approximately 12 minutes. Following this, they were directed to complete as many word searches (provided on paper) as they were able to in 18 minutes.

In the test phase, participants were seated at a new table and presented with a generalization set on a white foam board (either easy-item or difficult-item) and asked to perform the sequence that they had seen in the videos. If participants noted that they saw two different sequences and asked which one to perform, the researcher responded, “the one you saw in the videos”, without acknowledging that there may have been two different sequences presented. Following the sequence recall task, participants completed the object recognition task. Participants were provided with eight images at a time – four variable items that were used in the action sequences, and those items’ perceptually similar pairs – and asked to identify which four objects they had seen in the videos. This was done for each set of variable items in their condition (vehicles then fruit or metal items then small items). The sequence recall and object recognition tasks were both video-recorded. After the object recognition task, participants were asked to recall what animals they had seen in the nature videos that were presented intermittently with the action sequences. This task was meant to provide a general measure of attention to the videos and serve as a general memory check.

Scoring

Scoring of the sequence recall task and the object recognition task was done using the recorded video of the tasks. The score for the animal video recall task was recorded

immediately in session. Participants each have four scores: a sub-action score, a partial order score, an object recognition score, and an animal recall score.

The sub-action score reflects how many of the four sub-actions in the action sequence a participant performed in the sequence recall task. One point was awarded for each correctly-recalled sub-action, without regard for the order the actions were performed in. Minor deviations in sub-actions, such as tapping the vehicle/metal item with the stick more or less than three times, were coded as partially correct and scored as 0.5, but major deviations like using incorrect items for sub-actions were scored as 0. The sub-action scores range from 0 to 4.

The partial order score indicates participants' memory for the temporal order of the sub-actions in the action sequence. This score ranges from 0 to 3. Participants were given a 0 if no two sub-actions were performed in the correct order, a 1 if a pair of two actions was recalled in the correct order, a 2 if three actions were recalled in the correct order (A-B-C or B-C-D), or if two pairs were recalled consecutively (C-D-A-B), and a 3 if they recalled all four sub-actions in the correct order (A-B-C-D).

The object recognition score reflects how many of the target items were correctly identified. Participants could receive a score of 0 to 4 for each variable item set – one point for each item that was correctly selected, given that they did not also select the distractor item. If participants selected both a target item and its distractor, they received a 0 (of a possible 1) for that item.

The animal recall score indicates how many of the animals shown in the nature videos were correctly recalled by participants, with scores ranging from 0 to 4. If participants were able to describe the animal or another aspect of the video but could not

recall the name of the animal, this was coded as correct.

Results

Object Recognition

A 2 (condition: easy vs. difficult) \times 2 (deviancy: deviant vs. standard) factorial ANOVA revealed no significant main effect of condition, $F(1, 124) = .232, p = .631$, or of deviancy, $F(1, 124) = 1.822, p = .18$. The interaction was also not significant, $F(1, 124) = .009, p = .923$. This was contrary to our hypothesis that easy-to-categorize items would be more difficult to recognize as distinct items, as items were recognized equally among all of the conditions.

Sub-Action Scores

Figure 3A displays sub-action scores by condition and deviancy. A 2 (condition) \times 2 (deviancy) factorial ANOVA revealed a significant main effect of condition, $F(1, 124) = 7.346, p = .008, \eta_p^2 = .056$, with more actions remembered in the easy condition than the difficult condition. There was not an effect for deviancy, $F(1, 124) = .027, p = .87$, and there was also not a statistically significant interaction between condition and deviancy, $F(1, 124) = .061, p = .806$.

Partial Order Scores

Figure 3B displays partial order scores by condition and deviancy. A 2 (condition) \times 2 (deviancy) factorial ANOVA revealed that there was a significant main effect of condition, $F(1, 124) = 12.948, p < .001, \eta_p^2 = .095$, with memory for order being better in the easy condition, as well as a significant main effect of deviancy, $F(1, 124) = 9.586, p < .002, \eta_p^2 = .072$, with better memory for order in the standard condition. However, there was not a statistically significant interaction between condition and deviancy, $F(1, 124) = 1.183, p =$

.279.

Due to previous research (Loucks & Price, 2018) that suggested that deviancy would have a greater effect in the easy condition, we hypothesized that this relationship would be present in the current research as well. Based on this hypothesis, this was further investigated using independent samples t-tests. In the easy condition, there was not a significant difference in the partial order scores for the deviancy ($M = 1.188, SD = 1.12$) and no deviancy ($M = 1.563, SD = 1.216$) conditions; $t(62) = 1.283, p = .204$. In the difficult condition, there was a significant difference in the partial order scores for the deviancy ($M = .313, SD = .471$) and no deviancy ($M = 1.094, SD = 1.228$) conditions; $t(62) = 3.361, p = .001$. This supports the hypothesis that the presence of a deviant order hinders recall of action sequences, and does so to a greater extent when sequences involve objects that are difficult to categorize.

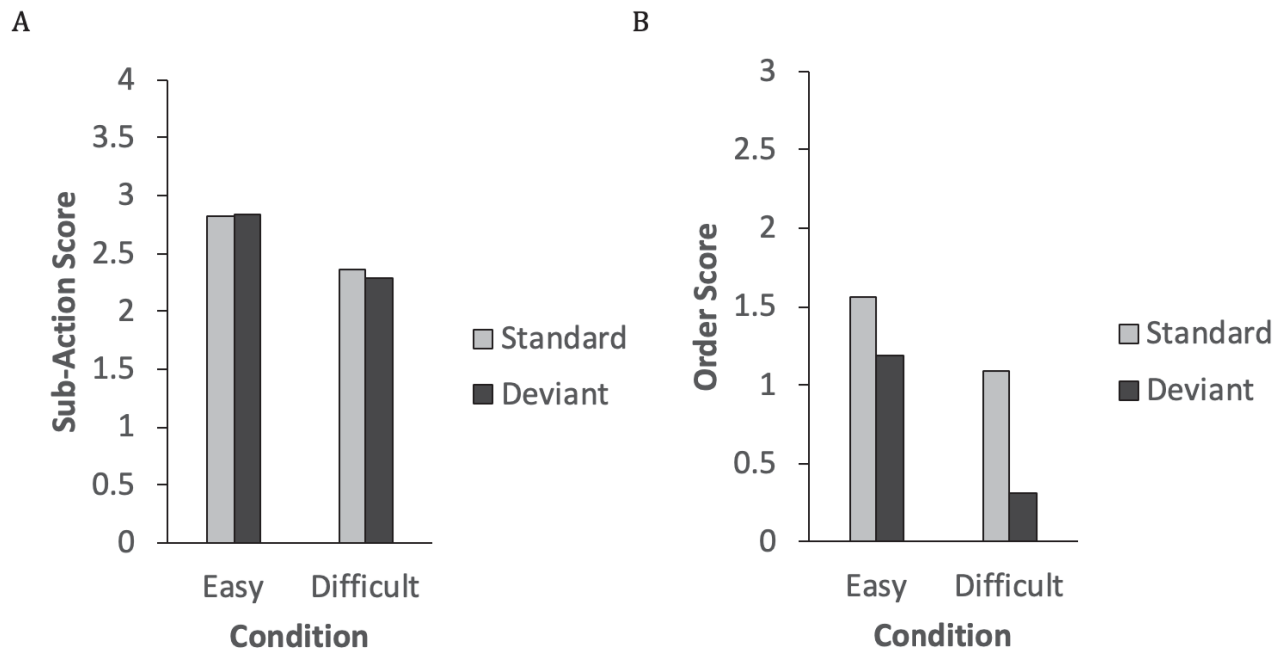


Figure 3: Sub-action scores (A) and order scores (B) by condition and deviancy.

Discussion

In order for individuals to become functioning members of society, there are many behavioural sequences that they must acquire. A critical element of learning behavioural sequences is the ability to learn the temporal order of events in action sequences. This component was recently investigated in children (Loucks & Price, 2018). It was concluded that learning temporal information is hindered by the presence of a deviant and seems to follow a theorized processing hierarchy. However, the literature on working memory for real actions is sparse, and this type of learning had been previously uninvestigated in adult participants.

The current research provides evidence for the presence of the theorized processing hierarchy in adults that Loucks and Price (2018) found to exist in children's learning of action sequences. Individuals must first identify what objects they are seeing, before they can identify what actions are being performed with those things, in order to then determine what order those actions are done in. The results of the present study indicate that the ease of object categorization affects the learning of action sequences that involve those objects. When sequences are performed with easy-to-categorize items, recall of the action sequence is facilitated, while difficult-to-categorize items hinder recall. These results support the presence of the theorized processing hierarchy in adults' learning of action sequences, where order is the least prioritized following object identification and sub-action identification.

The current research also determined that the presence of a deviant order when viewing action sequences hinders later recall of the action sequence in adults, similar to what Loucks and Price (2018) concluded in children. However, Loucks and Price (2018)

observed an interaction between ease of item categorization and the presence of a deviant order, where the effect of the deviant was larger in the conditions with difficult items than in the conditions with easy items. This suggested that the easy-to-categorize items provided a protective effect against the presence of a deviant. This interaction was not found in the present study, which tells us that the easy condition was not fully protected from the effect that the deviant had on memory for order.

Based on the results of previous research (Loucks & Price, 2018), we hypothesized that this interaction would be present in the current research as well. Due to this hypothesis, independent samples t-tests were used to further investigate the effects of deviant order on memory. These tests revealed that the effect of the presence of a deviant order was significant in the difficult condition but did not have a significant effect on memory for order in the easy condition, suggesting that the easy condition was partially protected from the presence of a deviant sequence.

Across the four action videos presented to participants in both the easy- and difficult-categorization conditions, the position of items on the board rotated 90 degrees with each new set of items to prevent participants from recalling the order based on the locations of items. One possible explanation for the lack of an interaction is that the easy condition was too difficult as a result of the rotation of the boards.

Regarding object recognition, participants across the conditions did not significantly differ on the number of objects they were able to recognize. This was contrary to our prediction that items in the difficult-categorization condition would be better remembered than those in the easy-categorization condition. Brainerd and Reyna (2002) reported that retrieval of gist information will be favored over verbatim information when there are

various exemplars of a category presented (such as various fruits) with no repeating exemplar. Additionally, gist retrieval is more prone to false memory than verbatim retrieval is. We predicted that because the easy-to-categorize items could be meaningfully grouped together, and there were no repeating items, that participants in this category would rely on gist information and recall these items as category members rather than as the specific item. Moreover, we predicted that the difficult-to-categorize items would be encoded and retrieved verbatim, as the categories of “metal things” and “small things” would not be readily formed. We hypothesized that verbatim memory for items in the difficult condition would surpass memory for items in the easy condition, with false identification of unencountered items being higher in the easy condition. However, our hypothesis was not supported, as participants in the easy and difficult conditions did not significantly differ on the number of objects they recognized.

One possible reason that our hypothesis was not supported could be that the easy condition items were members of too broad a category, so they were encoded and retrieved as the specific item rather than as category members. Perhaps our variable items, while easily identifiable as vehicles or fruits, were not similar enough to one another to facilitate categorization, and were identified as “car, airplane, jet-ski, bus” rather than as “vehicles”. If these variable items were encoded and retrieved verbatim, as items likely were in the difficult condition, we would expect to see similar memory among both conditions, as observed in the present study. Further research in this area might investigate the use of narrower categories, such as “types of cars” or “types of boats”.

The present study provides a variety of possibilities for future research. Among these, one would be to explore ways to improve our ability to learn temporal action

sequences. Additionally, further investigation into the effect of deviant order on learning could attempt to reproduce the protective effect of the easy condition that was present in the Loucks and Price (2018) study. One way to do this would be to eliminate the rotation of the action sequence boards, and tailor the difficulty levels of the action sequence to adults in another way. Perhaps the sequence could include more actions, or slightly more complex actions. Alternatively, the board rotation could remain in order to discourage learning based on spatial positions, but the categories of items could be narrower in the easy condition to further facilitate categorization.

The ability to acquire temporal sequences in action is an essential component of social functioning that we know very little about, particularly in adults. The current study contributes to knowledge regarding how we learn the order of real actions similar to what people may encounter in their everyday lives, and the results indicate that adults' learning of action sequences is sensitive to the presence of deviant order. Further, action sequence learning in adults' seems to follow a processing hierarchy where memory for order comes last after object recognition and sub-action recognition. Literature regarding how people learn order in real action sequences similar to what they may experience in their daily lives is sparse, but the present study has contributed to the research in this area, and provided some insight into adults' learning of temporal action sequences.

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