Order effects in choice are selectively modulated by cognitive load

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Abstract

The order in which options are presented influences choice in ways that parallel primacy and recency effects in memory, but the depth of this connection remains underexplored. I present sequences of art to experimental participants who select their favorite pieces, and find evidence that cognitive load can selectively weaken choice primacy or recency depending on its timing, analogous to established findings in memory research. The data suggests that primacy is reduced by an externally-imposed distractor task in between each option or by natural fatigue, while recency is reduced by an extra delay containing a distractor after the last option is presented. Thus, order effects in choice may be predictably modulated by the targeted disruption of processing.

Keywords: order effects; memory; decision making; primacy; recency; cognitive load

Introduction

Choices frequently must be made from options that appear in a sequence, such as when consumers decide between presented products, employers evaluate prospective job candidates, and judges appraise athletic or musical performances. I experimentally study how preferences are systematically biased by serial position, and how such biases may be alleviated based on principles of memory.

It has been empirically documented across several settings that a contenders chances of being selected are related to their serial position, that is, where they appear in the sequence of contenders. The very latest and the very earliest to appear are more likely to win compared to intermediate contenders. This is striking because if ordering is random, as is often explicitly the case in an attempt to be fair, then rank should be unrelated to serial position. These order effects have been found in the Queen Elisabeth music competition (Flôres Jr & Ginsburgh, 1996; Glejser & Heyndels, 2001), the Eurovision Song Contest (de Bruin, 2005, 2006), the American Idol television franchise (Page & Page, 2010), and across synchronized swimming (Wilson, 1977), figure skating (de Bruin, 2005, 2006), gymnastics (Rotthoff, 2015), and sales pitching (Wagner & Klein, 2007), with significant consequences for competitors careers (Ginsburgh & Van Ours, 2003). Moreover, these effects seem to apply to preferences over goods where attributes are objectively fixed and order is experimentally randomized (Payne, Schkade, Desvousges, & Aultman, 2000; Mantonakis, Rodero, Lesschaeve, & Hastie, 2009; Li & Epley, 2009).

Primacy and recency effects are hypothesized to occur for different reasons. The earliest items may be favored in memory because people can mentally rehearse them more than later items, while the latest items may be favored because they remain fresh in peoples memories (or because the context facilitating retrieval remains similar). Intermediate items would not benefit from either of these forces, leading their mental impact to fade, and consequently suffering worse evaluations. Support for these claims in memory comes from many approaches, including the *continuous distractor* paradigm in which a distracting task between item presentations specifically reduces primacy effects, and the *delayed recall* paradigm in which an extra interval between the final item and the test specifically reduces recency effects (Bjork & Whitten, 1974; Glenberg et al., 1980; Glenberg, Bradley, Kraus, & Renzaglia, 1983; Watkins, Neath, & Sechler, 1989; Neath, 1993; Howard & Kahana, 1999; Kahana, 2012). If these hypotheses apply to choice as well, the implications can be counterintuitive; order-related bias in judgment might be reduced by *disrupting* cognitive processing.

Studying connections between distortions in memory and in judgment is important for two reasons. First, this knowledge furthers our theoretical understanding of how two fundamental cognitive processes—recall and valuation—may be related, a topic of long-standing interest in psychology (Hastie & Park, 1986; Kahneman, Fredrickson, Schreiber, & Redelmeier, 1993; Murty, FeldmanHall, Hunter, Phelps, & Davachi, 2016; Zhao, Richie, & Bhatia, 2021) with growing impact in neuroscience (Wimmer & Shohamy, 2012; Shohamy & Daw, 2015; Bornstein & Norman, 2017; Bhui, 2018) and economics (Mullainathan, 2002; Gennaioli & Shleifer, 2010; Bordalo, Gennaioli, & Shleifer, 2020). Second, it helps us better predict when decision making will be systematically biased, and enables us to develop new classes of interventions to arrive at better choices and fairer outcomes.

Limited work to date has focused on links between memory and judgment in this context. Mantonakis and colleagues (Mantonakis et al., 2009) observed that the last wines tasted in a sequence were preferred more only in longer sequences, when memory would be under a greater load. Li and Epley (Li & Epley, 2009) showed that increasing the delay between presentation and evaluation of a desirable individual painting led to lower evaluations. However, even the existence

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of primacy and recency effects in judgment varies substantially across studies including these two. Such inconsistencies could be reconciled based on subtle situational differences thought to influence memory strength. For example, despite having broadly similar paradigms, Mantonakis and colleagues (Mantonakis et al., 2009) reported both primacy and recency effects, while Li and Epley (Li & Epley, 2009) observed only recency effects. This may have been caused by procedural differences, as participants in the former study merely waited for a period of time in between stimulus presentations while participants in the latter study engaged in filler tasks.

I test whether appropriately timed cognitive load inhibits choice-based primacy and recency effects similar to past findings in memory research. In two experiments, I show participants sequences of digital art, after which they report their favorite, and take a recognition memory test. Experiment 1 follows a continuous distractor paradigm in which a distracting task sometimes occurs in the intervals between each art piece's presentation. There is suggestive evidence that the choice primacy effect is diminished as anticipated in distractor trials and in the later part of the experiment. Experiment 2 follows a delayed response paradigm in which the selection of one's most preferred art piece occurs either immediately after the last item is presented or following a long delay filled with a distracting task. The choice recency effect appears to be diminished as anticipated in the delayed response trials with no apparent reduction in primacy. Order effects in judgment thus seem to be modulated by the targeted disruption of processing.

Experiment 1

Participants

Participants were 69 students recruited through the Caltech Social Science Experimental Laboratory. They were paid a $10 show-up fee plus bonuses for performance as described below. This experiment was approved by the Caltech IRB.

Experimental Procedure

The setup is depicted in Figure 1. This experiment was implemented using Psychtoolbox in MATLAB. In each of 36 trials, participants were shown a sequence of 5 abstract digital art images, each displayed for 5 seconds and shown in only a single trial. The images were complex novel visual stimuli which had to be evaluated holistically, so the exact nature and evoked feeling of each image could not be perfectly remembered. After each sequence, participants were asked to indicate which image they liked the most, on a screen with none of the images shown. They did this by hitting the number key corresponding to its serial position. They could also hit "0" to represent indifference between all 5. This indifference option provided a convenient default to ensure choices of 1 through 5 were intentional, and enabled measurement of impaired evaluation due to cognitive load.

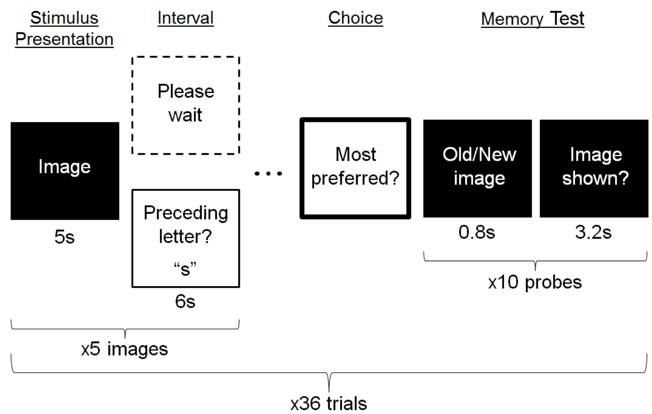

Figure 1: Schematic of Experiment 1. On half of the trials, a timed delay of 6 seconds occurred between each image presentation. On the other half of the trials, a distractor task taking roughly 6 seconds occurred between each image presentation.

The treatment consisted of a continuous distractor. Between every image, participants faced either timed delays (exactly 6s) or three distractor task subtrials (with average total time 5.6s). Half of the trials (randomly dispersed) exclusively involved delays and the other half exclusively involved distractors. During the delays, the words "Please wait" appeared on the screen, and participants were told that they may think about the images they had seen. In the distractor task, participants were shown a random letter on the screen and responded by hitting the key of the alphabetically preceding letter (e.g., if "r" was shown, they should hit "q"), and had to respond within 3 seconds, earning $0.01 for a correct answer to induce engagement. Average accuracy over all distractor trials was 82%.

A recognition memory test followed image selection. Participants were shown 10 images in random order, each on screen for 0.8 seconds. Five of these were versions of the images just displayed in the preceding sequence, while the rest were not shown at all in the experiment. The images were Gaussian blurred to help avoid ceiling accuracy. After each image, participants had to indicate whether they had seen it before, and if they had, in which position it was displayed. They hit the key "0" if they believed the image was new, or a key from "1" to "5" to note its position if they believed they had encountered it previously. They had to respond within 4 seconds and earned $0.04 for a correct answer to incentivize effort. In the condition with no distractor, hit rate was 63% and false alarm rate was 8%. In the continuous distractor condition, hit rate was 49% and false alarm rate was 8%.

Results

Two participants are excluded in the following analyses, one who selected the indifference option in every trial and the other who wrote notes on paper as a memory aid. I assess the

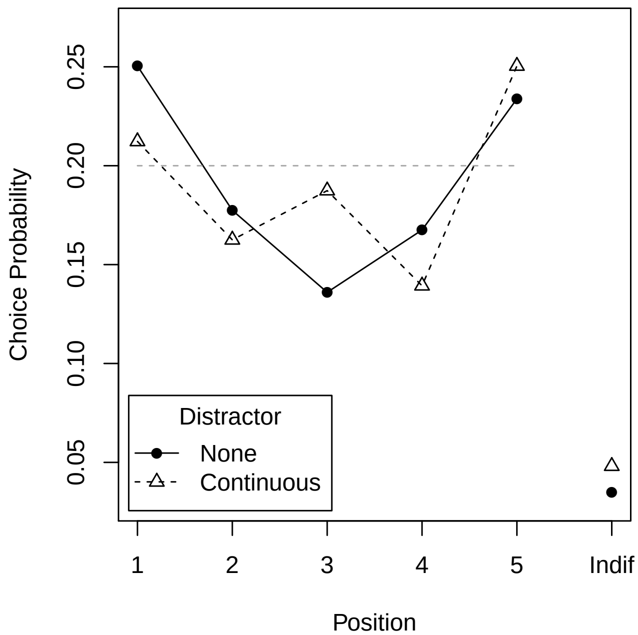

Figure 2: Choice probability as a function of condition in first half of Experiment 1. Dashed gray line indicates uniform random choice probability.

consequences of two kinds of cognitive load on the primacy effect: one imposed by the distractor task, and the other resulting from fatigue based on the experiment's length and difficulty (720 decisions over 60–75 mins). Both should reduce the ability or willingness of participants to engage in rehearsal that would disproportionately benefit early options. In line with previous memory research, many participants explicitly stated that they rehearsed the images in order of appearance. Several also noted that the distractor task did indeed impair their ability to rehearse images, and some informally admitted that they became tired or bored in the later part of the experiment.

The aggregate distributions of stated preferences and memory accuracy in the first half of the trials are shown in Figures 2 and 3 split by condition. Both primacy and recency effects in choice are present at baseline, recapitulating earlier findings (Mantonakis et al., 2009) while also avoiding a possible confound of novelty bias (favoring early items due to novelty in stimulus type) since participants are shown many sequences. As the presence of the indifference option hinders application of standard discrete choice models, I analyze the data using separate Bayesian logistic regressions (reported in Table 1). These regressions predict the probability of choosing the image in a given position based on experimental treatment (no distractor or continuous distractor in the trial), the trial timing (first or second half of the experiment), and their interaction. It allows a different baseline effect for each person to help account for individual variation. Bayesian analyses allow a more nuanced look at uncertainty and the information contained in the data (Wasserstein, Schirm, & Lazar, 2019). All presented regressions use the default weakly informative Cauchy prior recommended by Gelman and colleagues (Gelman, Jakulin, Pittau, & Su, 2008) with center 0 and scale 2.5.

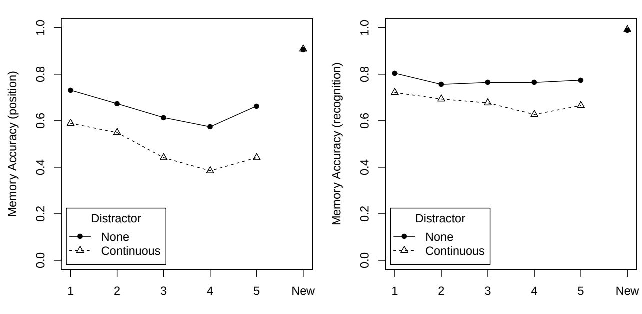

Figure 3: Memory accuracy as a function of condition in first half of Experiment 1. Accuracy defined as correct identification of image serial position (left) or merely whether image was seen before (right).

Figure 2 reveals a reduction in the primacy effect, as choice of the first option drops from 25% to 21%. The regression indicates the treatment had a negative effect on primacy (i.e., a negative regression coefficient) with posterior probability 95%. Primacy also dropped in the second half of the experiment from 25% to 18% with no distractor, having a negative effect with posterior probability >99.9%. However, likely because participants eventually get accustomed to the distractor—which is a known issue in the memory literature (Koppenaal & Glanzer, 1990)—the treatment effect weakens as the experiment progresses, as revealed by a interaction term which is positive with posterior probability 99%.

The data also lets us gauge a potential cost of cognitive load, which is to reduce people's overall ability to evaluate options. This side effect can be measured by the frequency of choosing the indifference option. From the baseline of 3%, the distractor task raises this to 5%, a positive effect with posterior probability 86% according to a similar regression as above (not reported). Hence, at least as perceived by individuals themselves, the distractor task appeared to perhaps modestly reduce their ability to discriminate between options.

Figure 3 indicates that the distractor generally impaired memory for the images, according to either a stricter measure based on correct identification of serial position or a weaker measure based on correct recognition of whether the image was new or old. However, the distractor's effect on memory did not mirror its effect on choice, as there was no specific reduction in accuracy for the first item. Thus, this result is not consistent with the simplest mechanism in which serial position effects in memory are affected identically to those in choice. This might have occurred because stimulus encoding and evaluation had to happen at the same time. It is known that the relationship between memory and judgment depends crucially on the format of the task (Hastie & Park, 1986), and

Exp. 1	Choice = 1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	*Indif*
Coefficient	Post. mean ($p < 0$)					
Treatment	−0.038 (0.95)	−0.015 (0.77)	0.051 (0.01)	−0.028 (0.92)	0.017 (0.25)	0.013 (0.14)
Late Trial	−0.066 (1.00)	−0.030 (0.93)	0.012 (0.28)	−0.007 (0.63)	0.048 (0.03)	0.043 (0.00)
Treat. × Late	0.076 (0.01)	−0.010 (0.63)	−0.071 (0.99)	0.007 (0.41)	−0.002 (0.52)	0.000 (0.50)

Table 1: Posterior estimates from Bayesian logistic regressions of choice probabilities on cognitive load, with individual-level intercepts, for Experiment 1. The Treatment variable indicates the continuous distractor condition. Posterior mean refers to the mean estimated coefficient value, and $p < 0$ refers to the posterior probability the coefficient is negative.

Exp. 2	Choice = 1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	*Indif*
Coefficient	Post. mean ($p < 0$)					
Treatment	0.021 (0.10)	0.001 (0.48)	0.009 (0.29)	−0.013 (0.78)	−0.037 (0.98)	0.019 (0.03)
Late Trial	−0.014 (0.81)	−0.021 (0.89)	−0.012 (0.76)	−0.012 (0.76)	0.031 (0.05)	0.028 (0.00)
Treat. × Late	−0.020 (0.81)	0.027 (0.13)	−0.014 (0.72)	−0.003 (0.55)	0.001 (0.48)	0.009 (0.26)

Table 2: Posterior estimates from Bayesian logistic regressions of choice probabilities on cognitive load, with individual-level intercepts, for Experiment 2. The Treatment variable indicates the delayed response condition. Posterior mean refers to the mean estimated coefficient value, and $p < 0$ refers to the posterior probability the coefficient is negative.

	Experiment 1	Experiment 2
	Item Chosen	
Coefficient	Posterior mean (s.e.)	
Correct Memory	0.692 (0.052)	0.656 (0.041)
Subjects	67	112

Table 3: Posterior estimates from Bayesian logistic regressions of choice on item memory, with individual-level intercepts. Correct item memory was positively related to the item being chosen in Experiments 1 and 2 with posterior probabilities >99.9%.

thus more complex mechanisms would be expected that reflect the dynamics of both.

Items that were chosen did tend to be remembered better, with a hit rate of 68% for the images selected as most favorite compared to 53% for the rest. A regression predicting whether each item was chosen based on whether it was correctly remembered is reported in Table 3. It indicates a positive correlational relationship with posterior probability >99.9%. Such a result is consistent with many different possible mechanisms, which I do not attempt to disentangle here.

Experiment 2

Participants

Participants were 113 students and non-students (age range 18-67) recruited through the Harvard Decision Science Laboratory and paid a $10 show-up fee in addition to bonuses for performance as described below, to incentivize effort. This experiment was approved by the Harvard IRB.

Experimental Procedure

The structure of the second experiment (depicted in Figure 4) was similar to the first, though participants only waited after each image except the last one. The key difference is that after the last image was presented, participants selected their favorite either immediately or after 5 distractor subtrials (with average total time 10.2s). Beyond this, they earned $0.03 for each correct response on the distractor task and $0.05 for each correct response on the memory test. Average accuracy on the distractor task was 65%. In the condition with no distractor, hit rate was 48% and false alarm rate was 16%. In the delayed response condition, hit rate was 46% and false alarm rate was 16%.

Results

One participant is excluded in the following analyses due to computer malfunction. As before, Figure 5 shows the aggregate distribution of stated preferences and recognition accuracy in the first half of trials. The baseline distribution diverges from Experiment 1, likely due to differences in the subject pool and the design. This experiment included many older, non-student participants, in contrast to the university students selected for academic qualities in the previous experiment. As indicated earlier, primacy effects depend on the ability and willingness to rehearse earlier items, traits which we might expect to be stronger in that subject pool; and indeed, performance was higher in Experiment 1 on both the memory test and the distractor task. This difference is exacerbated by the central design element, the lack of delay between the last image presentation and the choice, which makes the

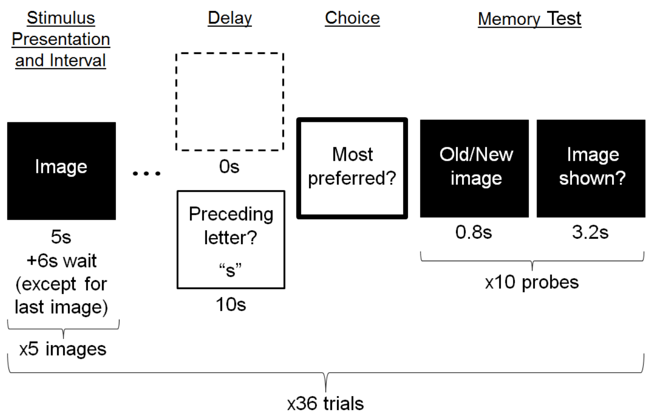

Figure 4: Schematic of Experiment 2. On half of the trials, the selection of the most preferred item occurred immediately after the final image presentation. On the other half of the trials, a distractor-filled delay taking approximately 10s delayed the selection.

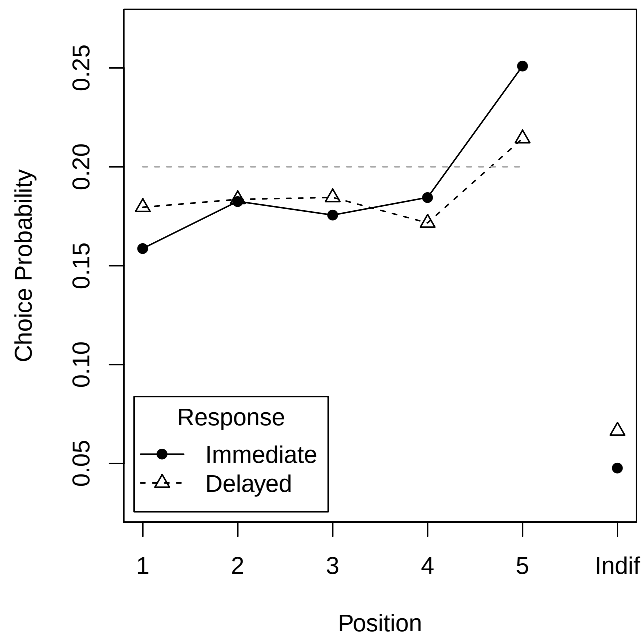

Figure 5: Choice probability as a function of condition in first half of Experiment 2. Dashed gray line indicates uniform random choice probability.

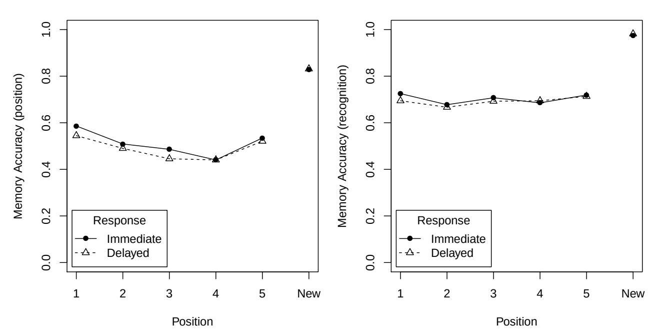

Figure 6: Memory accuracy as a function of condition in first half of Experiment 2. Accuracy defined as correct identification of image serial position (left) or merely whether image was seen before (right).

recency effect stand out at the expense of other positions, especially the earliest.

I assess the effect on choice recency of cognitive load induced by the distractor-filled delay, using similar regressions as above, reported in Table 2. In line with the prediction, the overall choice frequency for the last position is 25% at baseline compared to 21% in distractor trials, and the regression indicates the treatment had a negative effect with posterior probability 98%. The treatment increased the probability of indifference from 5% to 7%, a positive effect with posterior probability 97%, indicating impaired evaluation.

As before, the distractor's effect on choice was not paralleled in memory, where it had negligible effect in this case. Thus, the data is again inconsistent with the simplest possible link between memory and choice. Items that were chosen did once again tend to be better remembered. Recognition hit rate was 59% for items selected as the most preferred, compared to 45% for the rest. The second regression in Table 3 indicates a positive relationship between correct recognition and choice propensity with posterior probability >99.9%.

Discussion

When choosing from options presented in a sequence, people prefer the earliest and latest items, similar to serial position effects in memory. If memory and choice share a connection, then factors influencing the former may also affect the latter. I experimentally tested whether order effects in choice can be modulated by cognitive load in a targeted fashion, similar to established results in memory. Participants indicated preferences over pieces of art presented sequentially. The results suggested that cognitive load that impeded excess rehearsal of early options, imposed by an inter-stimulus distractor task or by natural fatigue, selectively reduced primacy effects. Cognitive load that reduced the excess mental freshness of later options, imposed by a post-sequence distractor task, selectively reduced recency effects. Thus, interventions or contextual factors that impair the ability or willingness of decision makers to attend to options might alter order effects in a targeted fashion.

A limitation of the current work is that the results do not speak directly to the exact relationship between memory and choice. A positive correlation between an individual's propensity to choose an item and the strength of their memory for the item could be consistent with multiple possible mechanisms. For example, availability models posit that greater availability of items in memory can cause them to loom larger in judgment (Tversky & Kahneman, 1973), while models of biased encoding or retrieval propose that judgment can cause items to become privileged in the process of memory construction or recall (Snyder & Uranowitz, 1978). However, the effects of the distractors on memory here do not seem to directly mirror their effects on choice. A more complex theory is accordingly needed. Although it is important to understand the exact processes that give rise to memory-judgment, the analyses presented here are unable to distinguish between various theories (Hastie & Park, 1986). Further decomposition of the mechanisms involved in choice-based order effects awaits continued theoretical and empirical study.

It also remains an open question as to how far the results generalize across different decision making formats. For example, participants here knew that they would face an image recognition test after making their choice. This knowledge could enter into the strategic control of memory encoding (Benjamin, 2007; Murphy & Castel, 2021). In addition, stimulus modality may also play a role in serial position effects (Conrad & Hull, 1968). Furthermore, choices were made by indicating the serial position of the preferred option. This creates a link not only to the memory of the experience itself, but also to the tag or temporal context (Howard, 2017). Many design choices are possible regarding the elicitation procedure and there is no universally applicable setting. Further studies varying the format would thus provide valuable insight into the many possible interactions between memory and choice.

Recent work has demonstrated that computational modeling can capture serial position effects in preferential decision making (Aka & Bhatia, 2021; Evans, Holmes, Dasari, & Trueblood, 2021). Models like these could be used to more precisely measure the experimental treatment effects we observe here, and to decompose the cognitive mechanisms involved. They could also help predict the impact of such interventions across a range of environments with different numbers of options or varying amounts of rehearsal time.

If the findings described in this paper extend to longer timescales and more complex stimuli, they may hold implications for assessing the protocols used by employers to select the best candidates. Minor procedural elements that typically go unnoticed could substantially alter outcomes. Consider, for instance, that there are commonly breaks for deliberation between sequential interviews. These pauses may facilitate rehearsal and enhance primacy effects, analogous to the interstimulus intervals of Experiment 1. Thus, despite enabling more information processing, such breaks might actually increase bias due to an imbalance in the information which is available at different points in time.

Decision theoretic models generally assume choices are made from elements in a mathematical set, in which item order is by definition irrelevant. This simplification is theoretically useful, but it is clear that order often matters in practice. The broad notion that preferences may be tied to memory is uncontroversial, but plenty remains to be discovered about the interplay between these elements. Memory is among the earliest pillars of experimental psychology (Ebbinghaus, 1885), and exhibits many unusual and counterintuitive properties. Research in decision making has much to learn from over a century of accumulated knowledge regarding memory.

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