Which task will we choose first? Precrastination and cognitive load in task ordering

Lisa R. Fournier¹ · Emily Coder¹ · Clark Kogan² · Nisha Raghunath¹ · Ezana Taddese¹ · David A. Rosenbaum³

Published online: 30 November 2018
© The Psychonomic Society, Inc. 2018

Abstract

Precrastination, as opposed to procrastination, is the tendency to embark on tasks as soon as possible, even at the expense of extra physical effort. We examined the generality of this recently discovered phenomenon by extending the methods used to study it, mainly to test the hypothesis that precrastination is motivated by cognitive load reduction. Our participants picked up two objects and brought them back together. Participants in Experiment 1 demonstrated precrastination by picking up the near object first, carrying it back to the farther object, and then returning with both. Also, participants given an additional cognitive task (memory load) had a higher probability of precrastinating than those not given the added cognitive task. The objects in Experiment 1 were buckets with balls that had a very low chance of spillage; carrying them required low demands on attention. The near-object-first preference was eliminated in Experiment 2, where the near and far objects were cups with water that had a high chance of spillage; carrying them required higher demands on attention. Had precrastination occurred in this case, it would have greatly increased cognitive effort. The results establish the generality of precrastination and suggest that it is sensitive to cognitive load. Our results complement others showing that people tend to structure their behavior to minimize cognitive effort. The main new discovery is that people expend more physical effort to do so. We discuss the applied implications of our findings, as well as the possibility that precrastination may be a default, automatic behavior.

Keywords Precrastination · Task ordering · Decision making · Cognitive load · Dual task

Introduction

People often make suboptimal decisions, even when the alternatives have ostensibly equal utility (e.g., Christenfeld, 1995). Suboptimal choices may take the form of outcomes that contradict probability theory or rational choice theory (Tversky & Kahneman, 1974). In addition, suboptimal choices may take the form of outcomes that violate physical energy reduction (Fournier et al., 2018; Jax & Rosenbaum, 2007; Rosenbaum, Gong, & Potts, 2014; van der Wel, Fleckenstein, Jax, & Rosenbaum, 2007). The present article is about the latter kind of suboptimal choice. Our aim was not to identify suboptimal

behaviors *per se*, as in observing that people often pick up heavy boxes by bending their backs rather than their knees. Rather, our focus was on behavioral choices that are biomechanically suboptimal resulting from the nature of decision-making itself.¹

We were interested in whether choices that appear to lead to costs in terms of *physical* energy may lead to benefits in conserving *cognitive* energy (cf. Ballard, Hayhoe, & Pelz, 1995; Ballard, Hayhoe, Pook, & Rao, 1997; Droll & Hayhoe, 2007). The phenomenon of primary interest was one that was discovered when participants were asked to walk down an alley and pick up either a bucket on the left or a bucket on the right (whichever seemed easier), and carry the chosen bucket to a platform at the end of the alley. The researchers who used this task (Rosenbaum et al., 2014) expected participants to choose

✉ Lisa R. Fournier
lfournier@wsu.edu

¹ Department of Psychology, Washington State University, Pullman, WA 99164-4820, USA

² Center for Interdisciplinary Statistical Education and Research, Washington State University, Pullman, WA, USA

³ Department of Psychology, University of California Riverside, Riverside, CA, USA

¹ Another example of biomechanically suboptimal performance based on decision-making is the *hand-path priming* effect (Jax & Rosenbaum, 2007; van der Wel et al., 2007). This is the tendency to make needlessly curved hand movements after obstacles have been removed. The unnecessarily large curvature of the hand paths is not due to failure to notice removal of the obstacle. Instead, it reflects cognitive inertia, a tendency to adhere to an existing plan as long as the resulting movement is not too physically costly. The hand-path priming effect suggests that there is a cost to computation that may dominate the cost of biomechanics.

the far bucket because doing so would reduce the carrying distance compared to choosing the near bucket. Surprisingly, most participants chose the bucket near the starting line even when both buckets weighed as much as 7 lbs. This was true even though there was no uncertainty about the buckets' weights because participants lifted the buckets in advance. Nine experiments conducted with over 250 participants confirmed the near bucket preference.

Rosenbaum et al. (2014) introduced the term *precrastination* to describe this surprising preference. They introduced the term to draw a contrast with *procrastination*, the tendency to put off tasks for as long as possible. Rosenbaum et al. (2014) defined precrastination as the tendency to hasten subgoal completion, even at the expense of extra physical effort. Critically for the main focus of the experiments described here, Rosenbaum et al. (2014) speculated, after ruling out several other hypotheses, that precrastination stemmed from the desire to off-load prospective or working memory. The idea was that picking up a bucket was on participants' mental "to-do" list. Picking up the near bucket would reduce the working memory load, even though picking up a bucket probably imposed a trivial load on prospective memory. Ironically, picking up the near bucket would reduce working memory load but at the expense of increasing physical load.

Choosing between a near and a far bucket is not a task that most people do often. The reason Rosenbaum et al. (2014) used the bucket choice task was to follow up on earlier research concerning biomechanical factors in physical action planning (Rosenbaum, Chapman, Weigelt, & Weiss, 2012). The bucket-choice task became interesting because of the surprising near-bucket preference that emerged in the 2014 experiments. The phenomenon of precrastination was intriguing because it appears to reflect tendencies in general behavior. For example, precrastination seems to be manifested in other contexts like answering emails too soon, paying bills much earlier than they are due, carrying too many groceries in too few trips, and so on. Because of the general application of precrastination, it was picked up by the media (e.g., Richtel, 2014) and even led to the suggestion that people who precrastinate sacrifice creativity because they don't leave enough time for incubation (Grant, 2016). In addition, results from an operant procedure with pigeons were taken to illustrate precrastination (Wasserman & Brzykcy, 2015). Considering that pigeons and people diverged in the evolutionary tree about 300 million years ago, the tendency to precrastinate may have existed at least that long ago (Lewandowsky, 2014).

Fournier et al. (2018) explored precrastination with a bucket-choice procedure that was set up to challenge a key component of the definition of precrastination given by Rosenbaum et al. (2014), who had suggested that precrastination is the tendency to hasten the *completion* of

subgoals, even at the expense of extra effort. Fournier et al. (2018) tested the alternative hypothesis, that precrastination is the tendency to hasten the *start* of subgoals, even at the expense of extra effort. Their idea was that because starting and completing subgoals often occur at different times, completing subgoals quickly may not be what really matters. Through a variety of manipulations investigating choices of task order (some of which were used in the experiments reported here), Fournier et al. (2018) showed that precrastination actually stems from the tendency to *start* on the path to subgoal completion. This outcome suggests that the urgency implied by the concept of precrastination was even greater than Rosenbaum et al. (2014) realized.²

Although Fournier et al. (2018) resolved this question about precrastination (at least as tested in the bucket choice context), they were not able to resolve (and did not try to resolve) another question: Is precrastination driven by a tendency to off-load working memory? Rosenbaum et al. (2014) speculated that it may, and they were attracted to the memory offload hypothesis because prospective memory demands (having to remember to do things in the future) are taxing (Einstein, McDaniel, Williford, Pagan, & Dismukes, 2003; Einstein & McDaniel, 2005; Haxby, Petit, Ungerleider, & Courtney, 2000) and are avoided if possible (Zeigarnik, 1927). If cognitively offloading the subgoal eases the load on prospective or working memory, then it would be more cognitively efficient to offload the subgoal earlier in the task than later. However, the hypothesis was not directly tested by Rosenbaum et al. (2014), nor has it been tested in any published study to our knowledge.

Fournier et al. (2018) were also attracted to the memory-offload hypothesis and noted that an object close at hand can automatically signal its affordance for grasping. They reasoned that if an object automatically signals its grasping affordance, then immediately grasping the object would mean that the prospective memory requirement to take hold of the object is immediately discarded. They buttressed their suggestion by pointing out that perception of objects can automatically activate responses associated with the objects'

² While preparing this article, the authors happened upon an article in the 9 July 2018 issue of the New York Times entitled "Why Your Brain Tricks You Into Doing Less Important Tasks" by Tim Herrera, editor of the Smarter Living section of the Times (https://www.nytimes.com/2018/07/09/smarter-living/eisenhower-box-productivity-tips.html?rref=collection%2Fbyline%2Ftimherrera&action=click&contentCollection=undefined®ion=stream&module=stream_unit&version=latest&contentPlacement=1&pgtype=collection). The article described the "mere urgency effect" reported in a journal not typically read by the authors of the present report (Zhu, Yang, & Hsee, 2018). In the mere urgency effect "people are more likely to perform unimportant tasks (i.e., tasks with objectively lower payoffs) over important tasks (i.e., tasks with objectively better payoffs), when the unimportant tasks are characterized merely by spurious urgency." Zhu, Yang, & Hsee, 2018 reported four experiments (none involving physical exertion) that confirmed this tendency.

affordances (Castiello, 1996; Humphreys & Riddoch, 2001; Jax & Buxbaum, 2010; Tucker & Ellis, 1998), and that action preparation can facilitate object selection (e.g., Botvinick, Buxbaum, Bylsma, & Jax, 2009a; Craighero, Fadiga, Umiltà, & Rizzolati, 1996; Pavese & Buxbaum, 2002).

The idea that precrastination may serve to conserve cognitive energy, which can be accomplished by memory-offloading, is consistent with other research showing that people tend to avoid choices that require higher cognitive demands (e.g., Droll & Hayoe, 2007; Dunn, Lutes, & Risko, 2016; Kool, McGuire, Rosen, & Botvinick, 2010). Relatedly, Botvinick and Rosen (2009) found elevated skin conductance responses prior to selecting a high-demand alternative when a low-demand alternative was also present. Furthermore, Botvinick, Huffstetler, and McGuire (2009b) demonstrated that choosing a low-cognitive-demand alternative can be associated with greater activation of the nucleus accumbens, suggesting that choosing the low-demand alternative may be more rewarding. Droll and Hayhoe (2007) showed that people often offload cognitive control demands in perceptual motor tasks by continually sampling information in the perceptual environment rather than relying on internal representations (see also Ballard et al., 1995, 1997). Taken together, these studies support the view that people generally tend to structure their behavior to minimize cognitive effort.

The foregoing observations set the stage for the two experiments reported here. These new experiments had several innovations. One concerned the nature of the bucket-carrying task. Whereas Rosenbaum et al. (2014) had their participants pick up and carry *one* of two buckets, participants in the present experiments picked up *both* buckets in the workspace. Second, whereas Fournier et al. (2018) had participants pick up and return two buckets *one at a time*, in the present experiments participants walked out into the workspace and picked up *both* buckets at once, either picking up the near bucket and then the far bucket, or vice versa (Fig. 1). The question was whether participants would pick up the near bucket first. If they did, that would be a clear indication that they precrastinated, for picking up the near bucket first would mean that they chose to carry that bucket further than necessary. A near-bucket-first preference in this context would, in our view, comprise the most dramatic evidence yet of precrastination.

The third innovation of the present experiments concerned auxiliary features of the tasks to be performed. In both experiments described here, half the participants memorized digit lists in addition to performing the physical action task. By having some participants memorize (and then recall) digit lists, we could test the hypothesis that precrastination is related to memory off-loading. If that hypothesis is correct, the incidence of precrastination – the probability of picking up the near bucket first – would be higher among participants with a memory load than among participants without a memory load.

That is, if offloading the subgoal eases the load on prospective or working memory, then it would be more cognitively efficient to offload the subgoal earlier rather than later in the transport task, particularly if working memory is busy with another task. This should only be true, however, when the means to execute the task requires minimal demands on attention. This brings us to the fourth innovation of our study.

The fourth innovation concerned the nature of the physical task and the attention it required. In the first experiment, the objects to be carried were buckets with golf balls (Fig. 2, top row). We varied the number of golf balls in the near bucket versus the far bucket. With more golf balls per bucket, the greater the weight, so we could ask whether our participants would be less likely to choose the near bucket if it were heavier than the far bucket. The chance of spilling balls was very low even when a bucket had many golf balls, because even in that case, the top of the balls fell well below the rim of the bucket. In the second experiment, however, the objects to be carried were cups that were either full or half full with water (Fig. 2, bottom row). The cups that were full were on the verge of spilling, and participants were admonished not to spill any water. We reasoned that carrying full cups would require more attention than carrying half-full cups, so the incidence of precrastination would be lower if participants took cognitive demands into account. In other words, if precrastination is sensitive to reducing cognitive effort, selecting the near cup first when it was full of water should be greatly reduced to avoid taking on extra attentional demands associated with carrying this cup over a longer distance. Also, those participants given a memory load should be more likely to avoid taking on extra attentional demands than those not given a memory load. We were led to favor these hypotheses not just based on intuition, but also based on the results reviewed above showing that participants are biased to make decisions that conserve cognitive energy. We discuss this research further in the *General discussion*.

Experiment 1

Our participants picked up two buckets at different distances along a corridor in front of them and carried both buckets back to a table behind their start location (Fig. 1). We varied the distances of the buckets from the participants' start position. Our primary question was whether participants would first pick up the near bucket. If so, that choice would entail more physical effort than picking up the far bucket first because it would increase the distance any bucket had to be carried.

Besides varying the distances of the buckets, we also varied the number of balls in the near and far buckets, as mentioned above (Fig. 2, top row). The rationale was to assess participants' sensitivity to the load-bearing demands of the task. We expected that the greater the number of balls in the near bucket

Fig. 1 Example of the sequence of events in a trial of Experiment 1. First, the participant performed the alphabet-arithmetic task (panel a). After completing that, the participant stood facing the table at the start location (panel b) and was either given the digit-span task to perform during the transport task (memory load group) or was not (no memory load group). Next (panel c) the participant turned around and took a moment to locate the buckets. After this (panel d), the participant walked down the corridor,

picked up the two buckets (in the order of his or her choice) and carried the buckets together in one trip back to the table behind the start position (panel e). After placing both buckets on the table (panel e again), the participant attempted to recall the five digits s/he was given before the transport task if s/he was in the memory-load group. For participants in the no-memory-load group, the trial terminated once both buckets were put on the table. The individual here agreed to have his face shown

Fig. 2 Transport task objects in Experiment 1 (top row) and Experiment 2 (bottom row). The Experiment 1 objects were plastic handle-less buckets with (a) 10 and 40 golf balls at the near and far bucket locations (ratio = 0.25), (b) 25 and 25 golf balls at the near and far bucket locations (ratio = 1.0), or (c) 40 and 10 golf balls at the near and far bucket locations (ratio = 4.0). The Experiment 2 objects were plastic cups half full (50% volume)

or completely full (100% volume) with water with (d) 50% and 100% water volumes at the near and far cup locations (ratio = 0.5), (e) 100% and 100% water volumes at the near and far cup locations (ratio = 1.0), or (f) 100% and 50% water volumes at the near and far cup locations (ratio = 2.0)

relative to the far bucket, the lower the probability that participants would pick up the near bucket first.

We were also interested in whether the near-bucket-first preference, if it existed, would interact with memory load. As mentioned above, we varied the load on working memory. Half the participants memorized a digit list that they were to recall after returning with the two buckets. The other half of the participants had no such memory test; they were not presented with digits to be memorized, and they did not have to recall anything upon returning with the buckets. We assumed that if precrastination reflects a tendency to reduce the load on working memory, participants with a memory load would be more likely to precrastinate than would participants with no memory load.

Method

Participants

One hundred and three undergraduates from Washington State University participated for optional extra credit in their psychology courses. The study was approved by the Washington State University Institutional Review Board. Informed consent was given by all participants. An *a priori* power analysis estimated that we needed 19–59 participants in each of our two groups (memory load and no memory load) to have 80% power to detect significant differences in estimated proportions of precrastination of .7 for our no-memory-load and .9–1.0 for our memory-load group using binomial count data assuming normality of the estimated proportions with an alpha cutoff value of .05. The estimated proportion of precrastination for the no-memory-load group (.7) was approximated from the Rosenbaum et al. (2014) study, which based on a sample size of 27 participants, and the proportion estimation for the memory-load group (.9–1.0), was taken as our best guess, as there were no other previous experiments (published or from our lab) to use as a guide. Our participant cutoff was set to 48 usable participants for each group for counterbalancing purposes, although we had collected data from one extra participant per group in attempting to satisfy our counterbalancing criteria, which led to a total of 49 participants per group.³

Apparatus and materials

Participants were tested in a room (30 ft × 10 ft) that contained the following materials: Two wooden stools (2 ft tall; diameter approximately 1 ft); two transparent, plastic buckets (7 in. tall; diameter 6.5 in.) containing orange golf balls; a wooden table

(2.4 ft tall; length 2.5 ft and width 4 ft); black masking tape placed on the floor (12 in. × 2 in.); and a booklet (2.75 in. × 8.5 in.) containing 12 pages of an alphabet arithmetic task. The masking tape indicated the participant's start location for each trial. The table functioned as the target platform (i.e., end goal of where to transport both buckets) and also contained the alphabet arithmetic task. The table was located behind the participant's start location (1 ft from the masking tape). In front of the participant's start location, the two stools were aligned in a vertical array down the corridor of the room. Each stool contained a bucket of golf balls. A bucket could contain ten golf balls (bucket and ball weight totaled 1.29 lbs), 25 golf balls (bucket and ball weight totaled 2.81 lbs), or 40 golf balls (bucket and ball weight totaled 4.32 lbs).

Procedure

We tested participants individually. Participants performed an alphabet-arithmetic task (just a filler task) followed by a task in which they transported two buckets, located on stools in front of them, to the table behind their start location in one trip (the transport task). Half the participants were also asked to remember five random digits in order (digit-span task) during the transport task trial. The three tasks (alphabet arithmetic, digit span, and transport) are described separately below.

Prior to each transport task trial, participants completed one page (12 problems) of the alphabet-arithmetic task (e.g., Zbrodoff, 1999) from a booklet. This activity just served as a distraction task while the experimenter set up the next trial. The arithmetic performance was not analyzed. However, the task is described here so others can replicate what we did. The alphabet-arithmetic problems consisted of a letter (A through Y) from the English alphabet followed by an addition sign (+), a number (1 through 5), an equal sign (=), and then a question mark. The solution to these problems required starting from the given letter location and moving ahead in the alphabet based on the given number, and reporting the letter at that location. Examples of alphabet arithmetic problems used were: A + 3 = ? and E + 2 = ? The correct solutions were D and G, respectively. Prior to the start of the study, participants completed practice problems and were instructed to perform this task at a comfortable pace. After doing so, participants said “done,” and remained facing the table (with the stools and buckets behind them – out of view). A total of 144 unique alphabet-arithmetic problems were generated randomly, and a subset of 12 problems were assigned to a single page in the 12-page booklet. The page order of problems was randomized across participants.

After completing the alphabet-arithmetic task, half the participants were given five digits to hold in memory during the transport task. The experimenter read the five digits (ranging from 1 through 9) aloud while participants faced the table, so they faced away from the stools and buckets. Immediately afterwards, participants turned around and viewed the stools

³ The actual power of detecting the proposed difference between our memory-load and no-memory-load groups in our Experiment 1, conducted after collecting and analyzing our sample of 98 usable participants (49 in the memory-load and 49 in the no-memory-load groups), was 72.5% for binomial count data and assuming normality of proportions.

and buckets and performed the transport task. After participants completed the transport task by placing both buckets on the table, the experimenter asked them to vocally recall the five digits in order. The experimenter then wrote down the recalled digits (in order) reported by the participants, and later recorded responses as correct or incorrect on each trial. A new set of five digits was presented in each of the 12 trials. The digit orders were randomly generated prior to the study, and no numbers repeated within any five-digit sequence.

After the memorization or immediately after the alphabet arithmetic for those participants without a memory load, we told the participants to turn around, look at the workspace, then walk and pick up the two buckets of golf balls resting on the stools, and return the two buckets together in one trip to the table behind their start position. We did not provide any other instructions to participants, particularly in terms of which path to take to retrieve the buckets, which hand to use, how to grip or hold the buckets, or, especially, in what order to pick up the buckets. The specific bucket transport instructions given to each participant is provided in the [Appendix](#). If the participant asked the experimenter about the order in which the buckets should be retrieved, the experimenter replied that it was his/her choice.

In each trial, participants had 2–3 s to view the section of the room containing the buckets before the experimenter announced, “You may begin.” The two buckets rested on stools along the midline of the corridor, extending in depth from the participants’ start position.

The experimenter recorded which bucket the participants picked up first (1=near bucket, 0=far bucket). After participants retrieved and placed both buckets on the table, the participants who were given the digit-span task recalled the digits. The next trial commenced with participants performing the alphabet-arithmetic task while the experimenter set up the buckets for the upcoming transport task.

The study used a mixed factorial design with three variables. We manipulated memory load between participants. As already indicated, half the participants engaged in a five-digit memory span task (memory load) while transporting the buckets, whereas the other half of the participants did not (no memory load). We also manipulated two factors within participants. One was far bucket distances. The near and far buckets were located at 6 ft and 12 ft, 6 ft and 16 ft, 12 ft and 18 ft, and 12 ft and 22 ft from the participant’s start location, creating four different far bucket distances of 12 ft, 16 ft, 18 ft, and 22 ft. The other within-subject factor was the ratio of golf balls in the near and far buckets. These numbers and associated ratios were 10 and 40 (.25), 25 and 25 (1.0), and 40 and 10 (4.0). [Figure 2](#) (top row) shows the three ball ratios. The buckets were made of transparent plastic so that the orange golf balls in them could be seen from outside.

Participants completed 12 trials of the transport task (consisting of the three different ball ratios at each of the four

far bucket distances). The order of trials was counterbalanced across participants. The ball ratios were presented equally often across all four of the far bucket distances, with the trial presentation order counterbalanced across participants.

After finishing the experiment, participants completed a strategy survey specific to the task. They also completed three personality questionnaires: The Big Five Personality Test (Modified; Goldberg, 1993); the Barrat Impulsiveness Scale (Patton, Stanford, & Barratt, 1995); the Hewitt-Flett-Perfectionism Scale (Hewitt & Flett, 1990); and a cognitive effort questionnaire (Need for Cognition Scale; Cacioppo, Petty, & Kao, 1984). The questionnaire data collected here were part of a larger study (in progress) examining personality and cognitive factors contributing to precrastination. Those data will be reported elsewhere, and hence the results will not be discussed in this article. The study, including completion of the survey and questionnaires, took about 45 min.

Results

Data for five participants were excluded. One participant’s data were excluded because of an experimenter error. Data from the other four participants were excluded because the participants did not follow instructions. They returned only one bucket at a time on at least one trial. Data from 98 participants were analyzed (49 in the memory-load and 49 in the no-memory-load conditions).

Digit-span performance

The average digit recall accuracy for each of the far bucket distances and ball ratios is presented in [Table 1](#). The accuracy was high, $M = 84.5\%$, and was not significantly correlated with probability of starting with the near bucket, $r(47) = -.153$, $p = .30$. Accordingly, digit-span accuracy will not be discussed further.

Bucket transport performance

[Figure 3](#) shows how often participants in the memory-load and no-memory-load groups precrastinated at different rates: 100% of the time, 90–99% of the time, and so on. The values shown in [Fig. 3](#) were averaged over the 12 trials and were collapsed over the ball ratios and far-bucket distances. As seen in [Fig. 3](#), the vast majority of participants in both the no-memory-load group (36 of the 49 participants) and the memory-load group (40 of the 49 participants) started with the near bucket 100% of the time. A handful of participants never or rarely precrastinated, but the distribution of frequencies below the 100% value did not exhibit a systematic pattern.

[Figure 4](#) shows the mean relative frequencies of precrastinating (starting with the near bucket first) for the

Table 1 Percent correct recall accuracy in the digit span task for Experiment 1 (based on ball ratios and far bucket distances) and Experiment 2 (based on water ratios and far cup distances)

Experiment 1				
	Ball ratios (near:far)			
	10:40 (0.25)	25:25 (1.0)	40:10 (4.0)	
Far bucket distances				Mean
12'	79.6	89.8	89.8	86.4
16'	75.5	79.6	81.6	78.9
18'	89.8	87.8	81.6	86.4
22'	93.9	83.7	81.6	86.4
Mean	84.7	85.2	83.7	84.5
Experiment 2				
	Water ratios (near:far)			
	50%:100% (0.5)	100%:100% (1.0)	100%:50% (2.0)	
Far cup distances				Mean
12'	93.8	81.3	96.9	90.6
16'	90.6	81.3	90.6	87.5
18'	90.6	87.5	84.4	87.5
22'	87.5	81.3	90.6	86.5
Mean	90.6	82.8	90.6	88.0

*Note: Values rounded to nearest decimal point

memory-load participants and no-memory-load participants given the three ball ratios and four far-bucket distances. As

Fig. 3 Number of participants by frequencies (0–100%) who picked up the near bucket first (across the 12 trials) shown separately for the memory-load ($n=49$, black bars) and no-memory-load ($n=49$, white bars) groups in the bucket transport task. Data from Experiment 1

seen in Fig. 4, there was a tendency for participants in the two memory-load groups to precrastinate across all ball ratios and far bucket distances.

To analyze these data, we conducted a mixed effects, logistic regression designed to relate the probability of picking up the near bucket first to the variables of memory load (load, no load), ball ratios (0.25, 1.0, and 4.0), and distances to the far bucket (12 ft, 16 ft, 18 ft, and 22 ft), with participant included as a random effect. The regression was performed using the R language for statistical computing (R development core team, 2017) and the lme4 package (Bates et al., 2015). Memory load, ball ratios (ratio), and distances to the far bucket (distance) were fixed effects, and ratio and distance were considered numeric variables. Computational limitations precluded running a full factorial model, so the model was reduced to include only two-way interactions for the fixed effects. Backward stepwise selection was conducted using Akaike's Information Criterion (AIC), and p -values for model terms are reported using a likelihood ratio test (LRT) with a parametric bootstrap to construct the reference distribution. Stepwise selection resulted in the sequential removal of memory load $\times$ ratio [$\chi^2_{(1)}=0.003$, $p=.96$], distance $\times$ ratio [$\chi^2_{(1)}=0.78$, $p=.43$], and ratio [$\chi^2_{(1)}=0.25$, $p=.65$]. The AIC selected model included memory load $\times$ distance [$\chi^2_{(1)}=5.06$, $p=.029$] as well as participant [$\chi^2_{(1)}=528.38$, $p<.00001$]. The parametric bootstrap was also used to construct confidence intervals on the effect of distance for the no-memory-load and memory-load groups. The model was used to estimate average probabilities of picking up the near bucket first for each combination of memory load and distance. A non-parametric bootstrap of

Fig. 4 Mean ($\pm$ SE) relative frequencies with which participants picked up the near bucket first for the three near-far ball ratios of 0.25 (10 balls in the near and 40 balls in far bucket), 1.0 (25 balls in both the near and far buckets), and 4.0 (40 balls in the near and 10 balls in the far bucket) at the

four far-bucket distances for participants in the memory-load (black bars) and the no-memory-load (white bars) groups. The dashed line represents a mean relative frequency of 50%. Data from Experiment 1

participants was used to construct 95% percentile-based confidence intervals on the mean probabilities of picking the near bucket first. Figure 5 shows the mean probabilities of picking up the near bucket first for memory loads and distances estimated by the model, as well as the average relative frequencies.

The probability of picking up the near bucket first was significantly above chance for participants in the no-memory-load group and in the memory-load group across all far bucket distances, consistent with precastination; all 95% bootstrap confidence intervals failed to include 0.50, as seen in Fig. 5. Furthermore, the near-bucket-first preference declined as distance to the far bucket increased for participants in the no-memory-load group [model slope parameter = -0.22, 95% CI:

(-0.44, -0.035)], whereas the near-bucket-first preference showed no evidence of decline in the memory-load group [model slope parameter = 0.031, 95% CI: (-0.15, 0.21)]. This suggests that for participants who were *not* engaged in the memory-load task, and hence had relatively low cognitive load, precastination declined slightly as the physical load associated with walking distance to the far bucket increased. However, participants who were engaged in the memory load task, and hence had relatively high cognitive load, opted to continue to pick up the near bucket first even as the physical demands of the task (walking distance to the far bucket) increased. Therefore, participants experiencing higher levels of cognitive load (the memory-load group) were willing to carry the bucket filled with golf balls a longer distance than those experiencing lower levels of cognitive load (the no-memory-load group).

Fig. 5 Mean relative frequencies (RF) and predicted probabilities (P) of picking up the near bucket first for participants in the no-memory-load and memory-load groups across the far bucket distances in the bucket transport task. Predicted probabilities with 95% confidence intervals were based on the logistic mixed effects model fit to all participants. Data from Experiment 1

Discussion

The results of Experiment 1 showed that precastination generalizes to the ordering of tasks (or task subgoals). Participants preferred to first pick up the bucket that was closer to the start location and carry it with them as they walked along to get the second, farther, bucket before returning. This result replicates and extends the original finding of Rosenbaum et al. (2014), who demonstrated precastination in a task involving picking up one bucket and carrying it to the end of an alley. It also replicates and extends the findings of Fournier et al. (2018), who demonstrated precastination in a task involving picking up one bucket, bringing it back to the participants' start location, and then returning to the bucket area, picking up a second bucket, and bringing it back to the participants' start location. In the present experiment, precastination took the form of picking up a near bucket followed by a far bucket and bringing both buckets back to the participants' start location in a single trip. On the vast majority of trials in the present experiment,

participants chose the near bucket first rather than the far bucket first. Critically, the participants' reluctance to pick up the far bucket first was not due to any (obvious) visual or biomechanical factor. It was not the case, for example, that the farther bucket was hard to see when the first bucket stood in front of it, nor was it the case that the near bucket posed a mechanical obstacle on the way to the far bucket. The materials and setup were designed to minimize these possibilities.

The present results also showed more directly than any previous study has that precrastination is sensitive to cognitive load. Here, participants *with* a memory load showed a high probability of selecting the near-bucket-first across all far bucket distances and across all ball ratios, but this was not the case for participants *without* a memory load. For the latter group, the probability of selecting the near-bucket-first declined as the far bucket distance increased (although ball ratio had no effect on the choices).

The decline in the near-bucket preference for the no-memory-load participants compared to the memory-load participants suggests that there was a tradeoff between cognitive effort and physical effort. When participants had a memory load, they were more likely to act on the near-bucket grasp affordance. By contrast, when there was not a memory load, participants were less likely to act on the near-bucket grasp affordance and were better able to differentiate their bucket choices according to the distance of the far bucket. (The numbers of balls in the near vs. far buckets were, apparently, not sufficiently different to make much of a difference for either group.)

Thus, with *more* cognitive resources to spare, our participants made choices that *reduced* physical effort. But with *less* cognitive resources to spare, our participants made choices that *increased* physical effort. This outcome, of course, is consistent with precrastination, and it demonstrates that precrastination occurred even at the *expense* of extra physical effort, consistent with the definition of precrastination.

Consistent with the conclusions that precrastination is sensitive to reducing cognitive effort, post-experiment subjective reports by our participants indicated that the near-bucket-first preference in this task did not require much cognitive effort, or if it did, it typically required less cognitive effort. Participants not given a memory load reported that they made the near-bucket-first choice for the following reasons: (1) it was closer, first, or they saw it first ($n=11$); (2) it was on their way, they had to pass it anyway, or did not want to pass it ($n=11$); (3) it was logical, efficient, or easier ($n=8$); (4) it felt natural ($n=3$); or (5) they indicated that they did not think about it or could not offer a reason ($n=6$). The remaining participants who did *not* show a near-bucket-first preference said they made their choices to reduce work or carry both buckets less of a distance ($n=4$) or they made choices based on bucket weight but offered no reason as to why, or they said they did not think about it ($n=5$). One participant said that he tried all combinations of weights and found choosing the near bucket first was easier.

Experiment 2

In Experiment 1, we did not obtain an effect of the number of balls in the near versus far bucket. Our participants started with the near bucket equally often, regardless of whether the ratio of near-bucket balls to far-bucket balls was 40:10 (0.25), 25:25 (1.0), or 10:40 (2.0). It is conceivable that our participants were oblivious to the different physical demands associated with these variations, but regardless of whether that was the case, it does not follow that participants from the population we sampled would always ignore or be indifferent to physical or perceptual-motor demands of starting with a near or far object. In cases where the physical demands of carrying out the task would require more attention (e.g., carrying items while walking on uneven ground or carrying full, open buckets of paint), participants would probably realize that starting with the near object would ultimately require more attention than starting with the far object. The reason is that extra attention would be needed for the out and back walk and not just the back (return) walk.

If precrastination is prompted by the tendency to reduce cognitive effort, it should be reduced or eliminated in tasks where this behavior would create an increase in cognitive effort. We pursued this possibility in the second experiment by replacing the buckets with cups and by replacing the golf balls with water. We asked participants in Experiment 2 to carry cups that were either full with water or half full with water without spilling any water from either cup. Participants in Experiment 2 picked up the two cups at different distances along the corridor in front of them and carried both cups back in one trip to a table behind their start location. The distances of the cups from the participants' start location varied, as in Experiment 1, and as before, half the participants performed the digit-span task (memory load) and half did not (no memory load). The new manipulation was the transportation of objects containing water that could spill, and hence transporting these objects should require more attention to carry out the task than was the case in Experiment 1. We reasoned that if people prefer to make choices that minimize the amount of attention to the tasks they perform (and hence minimize cognitive effort), they would stop showing the near-object-first preference when the near cup was full and the far cup was half full. We further examined whether the memory-load group would have a greater tendency to avoid selecting the near cup first compared to the no-memory-load group to further minimize cognitive effort associated with more demands on attention.

Method

Participants

Seventy undergraduates from Washington State University participated for optional extra credit in their psychology courses. The study was approved by the Washington State

University Institutional Review Board, and informed consent was given by all participants. An *a priori* power analysis estimated that we needed 21–40 participants in each of our two groups (memory load and no memory load) to have 80% power for detecting significant differences in estimated proportions of precrastination of .6–.7 for our no-memory-load group and .3 for our memory-load group for binomial count data assuming normality of the estimated proportions with an alpha cutoff value of .05. The estimated proportion of precrastination for the no-memory-load group (.6–.7) was based on the assumption that precrastination would be reduced or eliminated in this experiment compared to Experiment 1, and the estimated proportion for the memory-load group (.3) was our best guess based on the assumption that precrastination would more likely be avoided to reduce overall memory load—the value chosen was our best guess, as there were no other previous experiments (published or from our lab) to use as a guide. Our participant cutoff was set to 32 usable participants, partly for counterbalancing purposes, and an *a priori* estimation of availability of participants and staff to complete the study within the semester.⁴

Apparatus, materials, and procedure

The apparatus, materials, and procedures were the same as in Experiment 1 except that participants transported two cups of water (instead of two buckets of golf balls). The cups were 16-oz plastic cups (*Solo* Dart Ultra Clear flush-fill PET) and were either half full with water (weighing approximately 235.7 g) or full with water (2 mm below the top edge of the cup, weighing approximately 509.4 g). An orange ping pong ball (weighing 2.5 g) floated in the water of each cup so participants could see the relative height of the water in each cup from a distance. In addition, the cups were made of transparent plastic so the water levels inside the cups (half full = 50% or full = 100%, along with the floating ping pong balls, could be clearly seen. The ratio of water levels in the near and far cups varied across trials, within participants. The volume level of water in the near and far cups and associated ratios were: 50% full and 100% full (ratio = 0.5), 100% full and 100% full (ratio = 1.0), and 100% full and 50% full (ratio = 2.0). Figure 2 (bottom row) shows the three water ratios.

Results

Data for six participants were excluded because the participants did not follow the instructions. One repeatedly spilled

water during the transport, and five returned one cup at a time to the table on one or more trials. A total of 64 participants' data were analyzed (32 in the memory-load and 32 in the no-memory-load groups).

Digit-span performance

The average digit recall accuracy for each of the far cup distances and water ratios is presented in Table 1. The accuracy was high, $M = 88\%$, and was not significantly correlated with the probability of picking up the near cup first, $r(30) = -.038$, $p > .83$. Accordingly, digit-span accuracy will not be discussed further.

Water cup transport

Figure 6 shows how often participants in the memory-load and no-memory-load groups precrastinated at different rates: 100% of the time, 90–99% of the time, and so on. The values shown in Fig. 6 were averaged over the 12 trials and were collapsed over the far-cup distances and water ratios. Whereas the histograms were essentially unimodal in Experiment 1 with the peak at 100%, the histograms in this experiment were strikingly bimodal, with many participants choosing the near cup first less than 10% of the time. In contrast to Experiment 1, the number of participants in the no-memory-load group (12 of the 32 participants) and memory-load group (six of the 32 participants) who selected the near cup first (precrastinated) on 100% of the trials was similar to

Fig. 6 Number of participants by frequencies (0–100%) who picked up the near cup first (across the 12 trials) shown separately for the memory-load (black bars, $n=32$) and no-memory-load (white bars, $n=32$) groups in the cup transport task. Data from Experiment 2

⁴ The actual power of detecting the proposed difference between our memoryload and nomemoryload groups in our Experiment 2, conducted after collecting and analyzing our sample of 64 usable participants (32 in the memory-load and 32 in the no-memory-load groups), was 71% for binomial count data and assuming normality of proportions.

the number of participants who selected the far cup first on 90–100% of the trials (i.e., 0–9% near-cup-first selections). Participants in the no-memory-load group (14 of the 32 participants) and memory-load group (ten of the 32 participants) selected the far cup first approximately 90–100% of the time (at least 11 out of 12 total trials). Thus, unlike in Experiment 1, there was no clear preference to precrastinate.

Figure 7 shows the mean relative frequencies of precrastinating for the memory-load participants and for the no-memory-load participants given the three water ratios and four far-cup distances. This figure shows that the strong preference to start with the near object first found in Experiment 1 was also eliminated across the different water ratios and far cup distances in this experiment.

To analyze the data, we conducted a mixed effects, logistic regression to relate the probability of picking up the near cup first to the variables of memory load (load, no load), near-to-far cup water ratio (ratio; 0.5, 1.0, and 2.0), and far cup distance (distance; 12 ft, 16 ft, 18 ft, and 22 ft) with participant included as a random effect. The regression was performed using the R language for statistical computing (R development core team, 2017) and the lme4 package (Bates et al., 2015). Memory load, ratio, and distance were fixed effects, and ratio and distance were considered numeric variables. Computational limitations precluded running a full factorial model, so the model was reduced to include only two-way interactions for the fixed effects. Backward stepwise selection was conducted using the AIC, and p -values for model terms are reported using a likelihood ratio test (LRT) with a parametric bootstrap to construct the reference distribution. The stepwise selection resulted in the sequential removal of ratio $\times$ distance [$\chi^2_{(1)}=0.01$, $p=.93$], memory load $\times$ distance [$\chi^2_{(1)}=0.79$, $p=.38$], distance [$\chi^2_{(1)}=0.005$, $p=.94$], and memory load $\times$ ratio [$\chi^2_{(1)}=0.94$, $p=.34$]. The AIC selected model was an additive model that contained both ratio [$\chi^2_{(1)}=28.13$, $p<.001$] and memory load [$\chi^2_{(1)}=3.17$, $p=.12$] as well as

participant [$\chi^2_{(1)}=504.94$, $p<.00001$]. The model was used to estimate average probabilities of picking up the near cup first for each combination of memory load and ratio. A non-parametric bootstrap of participants was used to construct 95% confidence intervals on the mean probabilities of picking up the near cup first. Figure 8 shows the average probability of picking up the near cup first for memory load and ratio estimated by the model, as well as the average relative frequency.

The probability of picking up the near cup first was not significantly above chance for participants in the no-memory-load or memory-load groups, and this was true regardless of water ratios (all 95% bootstrap confidence intervals included values below 0.50). The significant main effect of ratio indicated that as the near-to-far cup water ratio increased, the tendency to first pick up the *far* cup (vs. the near cup) increased. The model also predicted that the estimated probability of picking up the near cup first was greater in the memory-load [$\hat{p}_{\text{memory load}} = 0.55$; 95% CI:(0.39, 0.69)] than in the no-memory-load group [$\hat{p}_{\text{nomemory load}} = 0.36$; 95% CI:(0.24, 0.50)], although the difference in estimated probability was not statistically significant [$\hat{p}_{\text{memory load}-\text{nomemory load}} = 0.19$; 95% CI:(-0.028, 0.38)] relative to a traditional cutoff of .05. These findings show that increasing the attentional demands required to carry out the transport task reduces the probability of precrastination. It also suggests that loading working memory, by engaging in a secondary task, does not necessarily increase the probability of making choices that would conserve cognitive effort in the transport task.

Discussion

In Experiment 2, we increased the perceptual-motor challenge of carrying the two objects. Instead of carrying two buckets with golf balls that had little chance of spillage (as in

Fig. 7 Mean (± 1 SE) relative frequencies with which participants picked up the near cup first for the three near-far water ratios of 0.5 (near cup 50% full and far cup 100% full), 1.0 (near cup and far cup 100% full) and 2.0 (near cup 100% full and far cup 50% full) at the four far cup distances

for participants in the memory-load (black bars) and the no-memory-load (white bars) groups. The dashed line represents a relative frequency of 50%. Data from Experiment 2

Fig. 8 Mean relative frequencies (RF) and predicted probabilities (P) of picking up the near cup first for participants in the no-memory-load and memory-load groups by the ratio of water levels in the near and far cups: 0.5 = near cup 50% full and far cup 100% full; 1.0 = near cup and far cup 100% full; 2.0 = near cup 100% full and far cup 50% full. Predicted probabilities with 95% confidence intervals were based on the logistic mixed effects model fit to all participants. Data from Experiment 2

Experiment 1), we asked participants to carry two cups with water, one or both of which had a high chance of spillage, especially if one or both cups was nearly full. If participants in the water cup transport task were indifferent to the perceptual-motor challenges before them, they should have chosen the near object first as often as participants in the bucket transport task. They did not do so. Participants in the water cup transport task largely abandoned the near-object-first preference, tempering that preference, we believe, because they would have to pay a great deal of extra attention to the task if they started with the near cup. The elimination of the near-object-first preference in the cup transport task accords with the hypothesis that participants would base their action choices at least partly on how much attention, and hence how much cognitive effort, their action choices would entail.

Our participants' sensitivity to the cognitive demands of the task was further suggested by the performance trends based on memory load selected by the logistic regression model. The trend found for the factor of memory load suggests that participants in the memory-load group were somewhat more likely than subjects in the no memory-load group to pick up the near cup first (see Figs. 6, 7, and 8). This trend accords with the hypothesis that with cognitive resources directed elsewhere, participants would be more likely to respond to the affordance for grasping the near object. Of course, because the participants in Experiment 2 were less likely to choose the near object first than were participants in Experiment 1, we think our participants were able, in general, to adjust their overall criterion for starting with the near or far object.

Ironically, however, participants in the memory-load group, who were more in need of cognitive relief than those in the no-memory-load group, may have been less likely to afford themselves that relief by starting with the far object rather than the near object.

It could be argued that participants made choices to avoid making a mess (due to spilling) as opposed to reducing cognitive effort. It would be difficult to isolate these two possibilities because cognitive effort in the cup transport task is linked to carrying the cups so as not to spill. However, we would expect that if participants' choices were driven simply by the desire to avoid making a mess, they would have consistently avoided choosing the near cup first in order to minimize cup carrying time and hence probability of spillage. This was not the case. Also, the near-to-far cup water ratio influenced choices of cup order— with the tendency to pick up the far cup increasing when the near cup was full and the far cup was half full (near-to-far cup water ratio was 2) as opposed to when both near and far cups were full (near-to-far cup water ratio was 1), which is consistent with the “conservation of cognitive effort” hypothesis but not with the “avoiding a mess” hypothesis. Further, the trend showing an increase in the near-cup-first preference for participants given a memory load compared to participants who were not suggests that sharing attention with a secondary memory load task influenced choice of cup order— consistent with the cognitive effort hypothesis. Finally, post-experiment, subjective reports by our participants were generally consistent with the interpretation that choices of cup order were influenced by cognitive effort reduction. For participants without a memory load: 14 reported that their choices were related to efficiency, effort or focus of attention; seven reported they made their choices to reduce the possibility of spilling water; six reported their choices were based on which cup they saw first, encountered first, or was closest to them; and three gave no explanation for their choices. Thus, only seven of the 32 participants without a memory load reported that their choices were made to specifically avoid spilling.

General discussion

The present study showed that precrastination, the tendency to start a task or subgoal as soon as possible even at the expense of extra physical effort, is sensitive to cognitive effort. It also showed that choices of serial order in object transport tasks are biased toward conserving cognitive effort even at the cost of physical effort. Participants picked up two objects located at different distances along a corridor in front of them and carried both objects in one trip back to a table behind the starting position. The objects that were transported were either buckets with golf balls requiring low attention demands (Experiment 1) or cups with water requiring higher attention demands

(Experiment 2). When little attention was needed to execute the transport task (Experiment 1), precrastination occurred. Also, participants in Experiment 1 who were given an additional cognitive task (memory load) had a higher probability of precrastinating when the far object was at a greater distance than did participants not given the added cognitive task. This outcome suggests that there was a tradeoff between cognitive and physical effort such that increased physical effort was favored when more cognitive effort was required. Moreover, when the transport task was more attention demanding (Experiment 2), precrastination was essentially eliminated. Had precrastination occurred in this case, it would have greatly increased cognitive effort. Therefore, the results of the second experiment, taken together with the findings of the first, suggest that physical behavior is structured to reduce cognitive effort.

Our findings are consistent with previous research showing that people are biased to make choices that minimize cognitive load (e.g., Allport, 1954; Baroody & Ginsburg, 1986; Camerer & Hogarth, 1999; Droll & Hayhoe, 2007; Dunn et al., 2016; Kool et al., 2010; Rosch, 1999). Our results are also consistent with the view that choosing less cognitively demanding alternatives can be more rewarding (e.g., Botvinick & Rosen, 2009; Botvinick et al., 2009). In addition, our results accord with research on the psychological refractory period showing that people prefer to perform the easier of two tasks first (Ruiz Fernández, Leonhard, Rolke, & Ulrich, 2011; Ruiz Fernández, Leonhard, Lachmair, Rolke, & Ulrich, 2013). Furthermore, the tradeoff we observed between cognitive effort and physical effort in our bucket transport task is consistent with other evidence showing that one may favor increasing physical effort when cognitive effort becomes too taxing, and vice versa (Ballard et al., 1995, 1997; Droll & Hayhoe, 2007; Einstein & McDaniel, 2005). For example, Droll and Hayhoe (2007) showed in a brick-sorting task that fewer eye movements were made to the target brick prior to sorting when the number of features relevant for sorting (working memory demands) were low and predictable than when they were higher and less predictable. This outcome suggests that participants relied more on physical effort (frequent eye movements) when working memory demands were high than when working memory demands were low. In addition, Ballard et al. (1995) showed in a block-copying task that back-and-forth gaze shifts between the model and workspace were more frequent for short gaze distances (requiring eye movements) than for long gaze distances (requiring both eye and head movements). This outcome suggested that participants relied more on working memory and less on gaze shifting when gaze distances were long (more physically effortful) than when gaze distances were short (less physically effortful).

Our findings align with an emerging theme in cognitive psychology/neuroscience that reliance on response tendencies that minimize cognitive effort increases availability of cognitive

resources for other activities (Ballard, et al., 1995, 1997; Droll & Hayhoe, 2007; Kool et al., 2010; McDaniel, Einstein, Stout, & Morgan, 2003), and can leave one better prepared for future cognitive demands (e.g., Haxby et al., 2000). However, our results also suggest that relying on (or defaulting to) response tendencies may *not* always be adaptively linked to task demands, particularly in a dual-task situation. For example, in the water cup transport task, one would expect a higher probability of *avoiding* near-cup-first selections for those performing a memory load task (vs. those who were not) because these participants were already experiencing a cognitive load and hence would be more averse to taking on more of a cognitive load by selecting the near cup first – particularly when it was full of water. However, as our data showed, there was a trend suggesting that participants in the memory-load group had a higher probability of selecting the near cup first than those in the no-memory-load group. This trend, along with the finding that the near-bucket-preference was more robust for the memory-load versus no-memory-load group in the bucket transport task, suggests that when attention is shared with another task (e.g., memory load) leaving less attention resources available for the transport task, precrastination may be the default behavior. That is, sharing attention (cognitive resources) with a secondary task (digit span) may increase the default tendency in the object transport task to start the task as soon as possible because fewer attention resources are available to overcome (inhibit) this default behavior.

By this way of thinking, precrastination may be the default, automatic, tendency in many choice situations, as suggested by Fournier et al. (2018) and Wasserman (2018). Our new results suggest that this more automatic tendency can be overcome if enough cognitive resources are available to inhibit this tendency. However, sharing attention with another task may leave insufficient resources to consistently inhibit such an automatic tendency even though the failure to do so can lead to a cognitive cost. This, in turn, may leave one less prepared for future demands.

The latter remarks, which point to the paradoxical effects of having too much cognitive load and thereby being unable to reduce cognitive load, raise applied concerns. Most obviously, people may run the risk of physical injury if they overexert themselves or rush needlessly, particularly when they have much on their minds. Distraction is a notorious cause of accidents, of course, but our research suggests that when people are distracted, they may precrastinate more than they would otherwise, which might cause them to run the risk of *more* accidents. Thus, our research suggests a mediating variable between distraction and accidents, which might not have been obvious before.

Among the groups for whom such a mediating relationship might be especially worrying are the elderly. If physical abilities decline along with the ability to cognitively gauge what is physically and cognitively possible, the decisions that are made may be unfortunate – leading to injury or even death.

Still other applications extend to other domains. Based on the research presented here, one might wonder whether drivers enter exit lanes too soon, whether people stand longer than needed to board planes, whether people multitask more than they otherwise would because they feel hurried, whether people eat too quickly for reasons related to precrastination, and finally and quite surprisingly, whether people interrupt others to reduce their own mental workload rather than for lack of respect or the exercise of power. Raising a raft of questions like these suggests that the time to learn more about precrastination is nigh.

Author Note This research was supported in part by a Washington State University, Psychology Undergraduate Research Grant awarded to Emily Coder, a Washington State University Advance Grant to Lisa R. Fournier, and a University of California, Riverside, Committee on Research grant awarded to David A. Rosenbaum. We also received statistical support from the Center for Interdisciplinary Statistical Education and Research (CISER) at Washington State University. This research was presented at the 58th Annual Meeting of the Psychonomic Society in Vancouver, British Columbia, Canada in 2017. We thank Washington State University undergraduate McKenna Keng for project management and data collection for Experiment 1 and Washington State University undergraduates Bryan Haflich, Tiffany Gray, Franklin Ramirez, Kristi Reiker, Aria Petrucci, and Olivia Snow for helping with pilot testing and data collection. Finally, we thank Deborah Sullivan for insights that led to the water cup carrying task.

Appendix

Instructions for transporting buckets task (Experiment 1)

“After you finish the alpha arithmetic task, I will ask you to ‘turn around’. When I do, please note the two buckets on the two different stools”.

- a. “Your next task will be to pick up the two buckets and return them to the table.” (experimenter points to table). “The buckets contain golf balls.”
- b. “You may begin this task when I say, ‘you may begin’.”
- c. “After you place the two buckets on the table, I will remove them and setup the next trial, and you can begin the next page of alpha arithmetic problems.”
- d. “Again, after you finish the arithmetic problems, let the experimenter know by saying ‘done’.”

“This process will repeat 12 times. Each time you will complete 1 page of alpha arithmetic problems and one bucket transport task.”

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

- Allport, G. W. (1954). *The nature of prejudice*. New York: Addison Wesley.
- Ballard, D. H., Hayhoe, M. M., & Pelz, J. B. (1995). Memory representations in natural tasks. *Journal of Cognitive Neuroscience*, 7(1), 66–80. <https://doi.org/10.1162/jocn.1995.7.1.66>.
- Ballard, D. H., Hayhoe, M. M., Pook, P. K., & Rao, R. P. (1997). Deictic codes for the embodiment of cognition. *Behavioral and Brain Sciences*, 20(04), 723–742.
- Baroody, A. J., & Ginsburg, H. P. (1986). The relationship between initial meaningful and mechanical knowledge of arithmetic. In J. Hiebert (Ed.), *Conceptual and procedural knowledge: The case of mathematics* (pp. 75–112). Hillsdale, NJ: Erlbaum.
- Bates, D., Achler, M., Bolker, B., Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67(1), 1–48. <https://doi.org/10.18637/jss.v067.i01>
- Botvinick, M. M., Buxbaum, L. J., Bylsma, L. M., & Jax, S. A. (2009a). Toward an integrated account of object and action selection: A computational analysis and empirical findings from reaching-to-grasp and tool-use. *Neuropsychologia*, 47(3), 671–683. <https://doi.org/10.1016/j.neuropsychologia.2008.11.024>
- Botvinick, M. M., Huffstetler, S., & McGuire, J. T. (2009b). Effort discounting in human nucleus accumbens. *Cognitive, Affective, & Behavioral Neuroscience*, 9(1), 16–27. <https://doi.org/10.3758/CABN.9.1.16>
- Botvinick, M. M., & Rosen, Z. B. (2009). Anticipation of cognitive demand during decision-making. *Psychological Research*, 73(6), 835–842. <https://doi.org/10.1007/s00426-008-0197-8>.
- Cacioppo, J. T., Petty, R. E., & Kao, C. F. (1984). The efficient assessment of need for cognition. *Journal of Personality Assessment*, 48, 306–307. https://doi.org/10.1207/s15327752jpa4803_13
- Camerer, C. F. & Hogarth, R. M. (1999). The effects of financial incentives in experiments: A review and capital-labor-production framework. *Journal of Risk and Uncertainty*, 19, 7–42.
- Castiello, U. (1996). Grasping a fruit: Selection for action. *Journal of Experimental Psychology: Human Perception and Performance*, 22(3), 582–603. <https://doi.org/10.1037/0096-1523.22.3.582>.
- Christenfeld, N. (1995). Choices from identical situations. *Psychological Science*, 6(1), 550–55. <https://doi.org/10.1111/j.1467-9280.1995.tb00304.x>.
- Craigheo, L., Fadiga, L., Umiltà, C. A., & Rizzolatti, G. (1996). Evidence for visuomotor priming effect. *Neuroreport*, 8(1), 347–349.
- Droll, J. A. & Hayhoe, M. M. (2007). Trade-offs between gaze and working memory. *Journal of Experimental Psychology: Human Perception and Performance*, 33(6), 1352–1365. <https://doi.org/10.1037/0096-1523.33.6.1352>.
- Dunn, T. L., Lutes, D. J., & Risko, E. F. (2016). Metacognitive evaluation in the avoidance of demand. *Journal of Experimental Psychology: Human Perception and Performance*, 42, 1372–1388. <https://doi.org/10.1037/xhp0000236>
- Einstein, G. O., & McDaniel, M. A. (2005). Prospective memory: Multiple retrieval processes. *Current Directions in Psychological Science*, 14(6), 286–290. <https://doi.org/10.1111/j.0963-7214.2005.00382.x>.
- Einstein, G. O., McDaniel, M. A., Williford, C. L., Pagan, J. L., & Dismukes, R. K. (2003). Forgetting of intentions in demanding

- situations is rapid. *Journal of Experimental Psychology: Applied*, 9(3), 147–162. <https://doi.org/10.1037/1076-898X.9.3.147>.
- Fournier, L. R., Stubblefield, A. M., Dyre, B. P., & Rosenbaum, D. A. (2018). Starting or finishing sooner? Sequencing preferences in object transfer tasks. *Psychological Research*, <https://doi.org/10.1007/s00426-018-1022-7>
- Goldberg, L. R. (1993). The structure of phenotypic personality traits. *American Psychologist*, 48(1), 26–34.
- Grant, A. (2016). Why I Taught Myself to Procrastinate. *New York Times Sunday Review*. <http://www.nytimes.com/2016/01/17/opinion/sunday/why-i-taught-myself-to-procrastinate.html?emc=eta1&r=0>
- Haxby, J. V., Petit, L., Ungerleider, L. G., & Courtney, S. M. (2000). Distinguishing the functional roles of multiple regions in distributed neural systems for visual working memory. *Neuroimage*, 11(2), 145–156.
- Hewitt, P.L., & Flett, G.L. (1990). Perfectionism and depression: A multidimensional analysis. *Journal of Social Behavior and Personality*, 5, 423–438.
- Humphreys, G. W., & Riddoch, M. J. (2001). Detection by action: Neuropsychological evidence for action-defined templates in search. *Nature Neuroscience*, 4(1), 84–88. <https://doi.org/10.1038/82940>.
- Jax, S. A., & Buxbaum, L. J. (2010). Response interference between functional and structural actions linked to the same familiar object. *Cognition*, 115(2), 350–355. <https://doi.org/10.1016/j.cognition.2010.01.004>.
- Jax, S. A., & Rosenbaum D. A. (2007). Hand path priming in manual obstacle avoidance: Evidence that the dorsal stream does not only control visually guided actions in real time. *Journal of Experimental Psychology: Human Perception and Performance*, 33(2), 425–441. <https://doi.org/10.1037/0096-1523.33.2.425>.
- Kool, W., McGuire, J.T., Rosen, Z.B., & Botvinick, M.M. (2010). Decision making and the avoidance of cognitive demand. *Journal of Experimental Psychology: General*, 139(4), 665–682. <https://doi.org/10.1037/a0020198>.
- Lewandowsky, S. (2014). 300 million years of pre-crastination. <http://www.psychonomic.org/featured-content-detail/300-million-years-of-precrastination>
- McDaniel, M.A., Einstein, G.O., Stout, A.C., & Morgan, Z. (2003). Aging and maintaining intentions over delays: Do it or lose it. *Psychology and Aging*, 18(4), 823–835. <https://doi.org/10.1037/0882-7974.18.4.823>
- Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt impulsiveness scale. *Journal of Clinical Psychology*, 51(6), 768–774. [https://doi.org/10.1002/1097-4679\(199511\)51:6<768::AID-JCLP2270510607>3.0.CO;2-1](https://doi.org/10.1002/1097-4679(199511)51:6<768::AID-JCLP2270510607>3.0.CO;2-1).
- Pavese, A., & Buxbaum, L. J. (2002). Action matters: The role of action plans and object affordances in selection for action. *Visual Cognition*, 9(4–5), 559–590. <https://doi.org/10.1080/13506280143000584>.
- R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>
- Richtel, M. (2014). Sometimes, early birds are too early. *New York Times*, page BU3. <http://www.nytimes.com/2014/07/20/business/sometimes-early-birds-are-too-early.html?src=twr&r=1>.
- Rosch, E. (1999). Principles of categorization. In E. Margolis & S. Laurence (Eds.), *Concepts: Core readings* (pp. 189–206). Cambridge, MA: MIT Press.
- Rosenbaum, D. A., Chapman, K. M., Weigelt, M., & Weiss, D. J. (2012). Cognition, action, and object manipulation. *Psychonomic Bulletin & Review*, 138, 924–946. <https://doi.org/10.1037/a0027839>
- Rosenbaum, D. A., Gong, L., & Potts, C. A. (2014). Pre-crastination: Hastening sub-goal completion at the expense of extra physical effort. *Psychological Science*, 25(7), 1487–1496. <https://doi.org/10.1177/0956797614532657>.
- Ruiz Fernández, S., Leonhard, T., Lachmair, M., Rolke, B., & Ulrich, R. (2013). Processing order in dual-tasks when the duration of motor responses varies [Special issue: Cognitive science]. *Universitas Psychologica*, 12(5), 1439–1452. <https://doi.org/10.11144/Javeriana.UPSY12-5.podt>
- Ruiz Fernández, S., Leonhard, T., Rolke, B., & Ulrich, R. (2011). Processing two tasks with varying task order: Central stage duration influences central processing order. *Acta Psychologica*, 137(1), 10–17. <https://doi.org/10.1016/j.actpsy.2011.01.016>
- Tucker, M., & Ellis, R. (1998). On the relations between seen objects and components of potential actions. *Journal of Experimental Psychology: Human Perception and Performance*, 24(3), 830–846. <https://doi.org/10.1037/0096-1523.24.3.830>.
- Tversky, A. & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, 185, 1124–1131.
- van der Wel, R. P. Fleckenstein, R., Jax, S., & Rosenbaum, D. A. (2007). Hand path priming in manual obstacle avoidance: Evidence for abstract spatio-temporal forms in human motor control. *Journal of Experimental Psychology: Human Perception and Performance*, 33, 1117–1126.
- Wasserman, E.A. (2018). Precrastination: The fierce urgency of now. *Learning & Behavior*. <https://doi.org/10.3758/s13420-018-0358-6>.
- Wasserman, E. A., & Brzykcy, S. J. (2015). Pre-crastination in the pigeon. *Psychonomic Bulletin & Review*, 22(4), 1130–1134. <https://doi.org/10.3758/s13423-014-0758-3>.
- Zbrodoff, N. J. (1999). Effects of counting in alphabet arithmetic: Opportunistic stopping and priming of intermediate steps. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 25(2), 299–317.
- Zeigarnik B. (1927). Das Behalten erledigter und unerledigter Handlungen. *Psychologische Forschung*, 9, 1–85.
- Zhu, M., Yang, Y., Hsee, C. K., Johar, G., & Lee, L. (2018). The Mere Urgency Effect. *Journal of Consumer Research*. <https://doi.org/10.1093/jcr/ucy008>.