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Is Precrastination Related to Updating and Inhibition Aspects of Executive Function?

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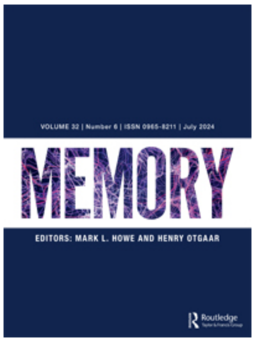

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Is precrastination related to updating and inhibition aspects of executive function?

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ABSTRACT
Precrastination is the act of completing a task as soon as possible even at the expense of extra effort. Past research has suggested that individuals precrastinate due to a desire to reduce their cognitive load, also known as the cognitive load-reduction (CLEAR) hypothesis [VonderHaar, R. L., McBride, D. M., & Rosenbaum, D. A. (2019). Task order choices in cognitive and perceptual-motor tasks: The cognitive-load-reduction (CLEAR) hypothesis. *Attention, Perception, & Psychophysics, 81*(7), 2517–2525. https://doi.org/10.3758/s13414-019-01754-z]. This idea stems from the notion that it is taxing to hold intentions in working memory and completing a task as soon as possible releases cognitive resources for other tasks. Based on this hypothesis, we predicted that aspects of executive function may play a role in precrastination. We tested this prediction using a box-moving task developed in a previous study to measure precrastination. We also incorporated tasks measuring updating and inhibition aspects of executive function: the Stroop interference (both experiments) and Simon tasks (Experiment 2) to measure inhibition and the 2-Back memory task (Experiment 1) to measure updating. We found that the majority of participants precrastinated significantly throughout the box-moving task trials, consistent with results from past studies. However, no relation was found between the executive function tasks and rates of precrastination. These results may be due to the automaticity of precrastination when cognitive resources are limited.

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Task choices; precrastination; executive function; inhibition; cognitive offloading

Do you find that you often put off a task until the last minute? Or do you immediately complete a task as soon as possible after you identify it needs to be done? If you resonate with the former, as most people do, you most likely recognise this as procrastination. However, if you resonate with the latter, you might just consider yourself "ahead of the game". This behaviour is called *precrastination*.

Precrastination is the act of completing a task as soon as possible, even at the expense of extra effort (see Rosenbaum et al., 2019, for a review of research investigating this behaviour). The term was coined by Rosenbaum et al. (2014) after observing this phenomenon in a study investigating coordination of walking and reaching tasks. In their study, Rosenbaum et al. asked college students to walk down an alley, pick up one of two buckets, and place the bucket on a platform at the end of the alley. The students had two choices: carry the bucket positioned close to them or carry the bucket that was positioned farther from them and closer to the platform. To the researchers' surprise, participants chose the bucket closer to them on a large majority of trials and carried it a farther distance, rather than pick up the bucket closest to the table and save themselves some extra effort. When asked to explain their reasoning for this decision, participants reported that they chose the closer bucket to complete the task as soon as possible. Based on their findings, Rosenbaum et al. speculated that one possible reason for this behaviour is that participants wanted to rid themselves of the "cognitive burden" of picking up a bucket. While the act of picking up a bucket may not seem like a taxing task, remembering to complete future intentions (i.e., prospective memory) reduces cognitive resources that may be needed for other tasks (e.g., Smith, 2003).

This idea was further tested in a set of studies by Fournier et al. (2019a, 2019b). In both studies, participants were asked to pick up two objects down an alley (buckets, cups of water) and carry the objects back to a table. In all trials, participants had a choice to pick up a nearer object or a

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farther object first. In most of the tasks used in their studies, participants picked up the nearer object before the farther object, carrying the nearer object farther in most trials. Performing a working memory span task while completing the object movement task increased the tendency to pick up the nearer object first in the carrying task. However, when participants were asked to carry cups of water without spilling, the tendency to pick up the nearer cup was reduced when the cup was full (versus half-full) of water. From these results, Fournier et al. (2019b) suggested that precrastination may be an automatic behaviour that can be inhibited when precrastinating will increase attentional effort for the task, such as when carrying a cup full of water.

The occurrence of precrastination has now been well established in the literature on decision-making, but *why* we precrastinate is still being investigated. Previous studies have suggested a number of mechanisms that may potentially drive our desire to precrastinate, yet these proposals remain speculative. One attractive theory is that individuals may be driven to precrastinate by the desire to reduce cognitive effort. This idea stems from the notion that it is taxing to hold intentions over a delay, known as prospective memory (e.g., Einstein & McDaniel, 2005). The burdensome nature of maintaining intentions over a delay may lead individuals to reduce this cognitive load by ridding themselves of the intention as soon as possible, even at additional costs, such as carrying a weighted bucket farther than needed. VonderHaar et al. (2019) labelled this description of precrastination the cognitive-load-reduction (CLEAR) hypothesis. The CLEAR hypothesis suggests that individuals will "clear their minds" to the extent they can, at least among simple task choices. According to the CLEAR hypothesis, tasks that require more cognitive effort to remember to do will be done sooner than tasks that are less cognitively demanding in the case of short, simple tasks, as this early completion will optimise the use of mental resources. In other words, precrastination can optimise the use of working memory and executive function in the face of multiple tasks to complete.

There are a number of popular perspectives on working memory and executive function (e.g., Baddeley et al., 2019; Diamond, 2013; Engle & Kane, 2004; Nairne & Neath, 2013). The approach we followed in the current study is Diamond's (2013) multi-component description of executive function. She described executive function with three core processes: inhibition, working memory, and cognitive flexibility. All three elements may be involved in simple task order decisions of the sort examined in the current study. Inhibition is likely involved, as there are situations when precrastination is suboptimal and is best avoided. For example, in Fournier et al.'s (2019b) study, participants were less likely to pick up the full cup of water that had to be carried farther, saving it for the return trip. Working memory can be taxed by holding multiple intentions in mind, leading to precrastination. This was shown in Fournier et al.'s (2019a, 2019b) studies where precrastination increased if participants also completed a concurrent short-term memory recall task. Participants precrastinated the carrying task to free up resources needed for the working memory task. Fournier et al.'s results (2019b) showing a change in behaviour when precrastination would further tax attentional resources, additionally shows cognitive flexibility.

Although working memory tasks have been shown to be related to prospective memory needed to maintain an intention over time (e.g., Marsh & Hicks, 1998; Smith et al., 2011), working memory and other elements of executive function have yet to be fully investigated with regard to task order choices. In one of few such studies, Raghunath et al. (2020) examined whether precrastination behaviour is influenced by individual differences in working memory capacity, which is related to one's ability to manage higher cognitive loads successfully (Diamond, 2013). If working memory capacity does in fact have an influence on precrastination through attentional control, individual differences might be related to this behaviour. The researchers reasoned that individuals with lower attentional control might lack the resources to either inhibit the automatic impulse to pick up the first object or evaluate the optimal order in which to perform the tasks. In their study, Raghunath et al. (2020) asked participants to complete a transport task similar to that of Fournier et al.'s (2019b) Experiment 2, where the task involved carrying cups of water that needed to be carried without spilling. On each trial, the two cups varied in water levels, which manipulated attentional demand of the carrying task. The researchers measured the frequency with which participants chose the closer cup first. Their results showed that the tendency to select the farther cup first increased when the closer cup had higher water levels (full) rather than lower water levels; in other words, the tendency to avoid precrastination increased when the task required high attentional demand, replicating Fournier et al.'s results that participants' first-cup choices tend to conserve cognitive effort. However, they also found that those with higher working memory capacities had a stronger tendency to avoid precrastination when the attentional demand of carrying the closer cup was relatively high, a result consistent with the suggestion that individual differences in working memory capacity represent differences in attentional control of currently relevant task information (Engle & Kane, 2004). Working memory capacity was not linked to task order choices when the attentional demand of the task was low. Thus, working memory ability could not directly explain why some people always precrastinate in cases where it is suboptimal to do so, which was one of their main research questions. Raghunath et al. suggested that precrastination may be an automatic response when little attention is required to carry out a task that can be inhibited by individuals with higher working memory capacity in situations where precrastination increases cognitive load.

VonderHaar et al. (2019) also tested this hypothesis in their study using cognitive tasks that simulated the carrying tasks used by Rosenbaum et al. (2014) and Fournier et al. (2019a, 2019b). Participants were asked to sort boxes, moving them to specific locations on a computer screen. They were also asked to generate items from a given category at some point of their choosing in the box moving task. The only constraint was that it could not be while moving a box. Thus, participants chose when to complete the generation task during the trial. VonderHaar et al. found that the main results of their study were consistent with the predictions of the CLEAR hypothesis – participants generated the items before moving any boxes on a large majority of trials, completing the generation task as early as possible. However, one result in their study was not consistent with the predictions. It was expected that individuals would be more inclined to perform the cognitive task earlier as the task difficulty increased. This prediction was not supported by their results, as participants tended to generate items later in the box moving task when they were asked to generate more items (10 or 15 items versus 5 items). Therefore, VonderHaar et al. suggested further research on the effects of relative task difficulty on precrastination to better understand this result.

In addition to VonderHaar et al.'s (2019) results, the CLEAR hypothesis has been supported by studies utilising perceptual-motor tasks. For example, Patterson and Kahan (2019) gave individuals a choice of when to complete a cognitively demanding task. They examined whether precrastination rates are affected by a concurrent memory load, further testing the CLEAR hypothesis. They asked participants to complete two tasks: a transportation task and a working memory task. The transportation task involved retrieving two buckets placed along a corridor and walking them back to a table positioned at the starting location all in one trip, similar to the tasks in the Fournier et al. (2019a, 2019b) studies. On each trial, the near bucket was placed on one side of the path, and the far bucket was placed on the other side of the path. The working memory task consisted of remembering randomly generated numbers that participants needed to recall when they picked up the bucket marked with a red sticker. Participants were further informed that the order in which they picked up the buckets were independent of the memory task and that they could pick up the buckets in whatever order they wanted. Following the CLEAR hypothesis, the researchers predicted that precrastination would decrease when the bucket task was placed in opposition to the memory task (the farther bucket was paired with recalling the digits) and would increase when consistent with the memory task (the nearer bucket was paired with recall). The results showed that when participants could unload the list of digits early (i.e., the bucket with the red sticker was placed nearer to them), rates of precrastination increased and they picked up the nearer bucket before the farther bucket. However, when participants could not unload the list of digits until picking up the farther bucket, rates of precrastination decreased and they picked up the farther bucket first. As predicted by the CLEAR hypothesis, the results of Patterson and Kahan's study provided evidence that when precrastination was consistent with reducing cognitive effort, the rates of precrastination increased. A similar study by Ma and Zhang (2023) further supported the CLEAR hypothesis, showing higher rates of precrastination in East Asian participants when the transportation task was paired with a cognitive load compared to the task without a cognitive load and generalising the effect to another population.

Rosenbaum et al. (2022) provided additional evidence supporting a cognitive description of precrastination. In their study, participants were asked to make two responses in a cognitive task. They hypothesised that if the responses were based on participants wanting to complete the task accurately as soon as they could, they would decide on their response first and then make two responses quickly, with the first response taking longer than the second response. However, if participants were completing a task early simply to act (i.e., have something to do), then they would make the first response quickly and then think about the accuracy for the second response, causing the second response to take longer than the first response. Their results in three experiments clearly supported the hypothesis that participants were getting the task done as quickly as they could rather than simply responding quickly to act – in all experiments, the first response took significantly longer than the second response. Thus, Rosenbaum et al. concluded that participants are completing tasks early to get them done and "clear their mental to-do list" rather than to simply act and "have something to do".

In summary, the CLEAR hypothesis has received support as an explanation of precrastination, but as yet, we do not know which cognitive processes are involved in this behaviour. If precrastination behaviours are strategic in reducing cognitive load needed to remember a task in the future amid the completion of other tasks, then aspects of executive function are likely involved. Choosing to strategically complete one task immediately and before other tasks requires one to hold multiple tasks in mind at once (working memory), inhibit one task in favour of another, and (in some cases) switch tasks at an appropriate time. The box-moving/category generation procedure employed by VonderHaar et al. (2019) may capture these executive function processes in the decision of when to complete the category generation task within box moving, a choice that can be any one of 11 different locations in the task. Thus, the current study used the box-moving/category generation procedure to measure precrastination and examine its relation to executive function.

The majority of studies to date have examined precrastination in perceptual-motor carrying tasks, such as in the Raghunath et al. (2020) study. Thus, we aimed to further examine the CLEAR hypothesis in additional tests of the relation between precrastination of a cognitive task (category generation) and executive function. Where a relation with working memory was only found for their high-attention load-carrying task in Raghunath et al.'s study, a cognitive task may provide a stronger test of this relation. Furthermore, among Diamond's (2013) three main aspects of executive function, inhibitory control intuitively seems the most involved in choosing to complete the category generation task early in the box-moving procedure. To precrastinate the category generation task, participants must inhibit starting (or continuing) the box-moving task that is in front of them on the screen and instead complete a mentally generated task initiated internally. Thus, in the current study, we focused on working memory and inhibitory control aspects of executive function and their relations to precrastination of a cognitive task.

In two experiments, we used the precrastination task developed by VonderHaar et al. (2019) where participants were asked to complete a category item generation task (a cognitive task) during a computerised box-moving task, generating the items at a time of their choosing in the trial. They were also asked to complete two additional tasks to examine executive function, a Stroop interference task (both experiments) and a Simon interference task (Experiment 2) to measure inhibitory control, and an N-back memory task (Experiment 1) to measure working memory updating. We predicted that participants would complete the category item generation task early in (or before) the box-moving task trials, consistent with past studies (McBride et al., 2023; VonderHaar et al., 2019) and as predicted by the CLEAR hypothesis. As suggested by the studies reviewed above, individuals should be more inclined to complete a cognitive task earlier when doing so reduces their cognitive burden. However, our main research question was whether the trial position chosen for the item generation task would be related to inhibition and/or updating aspects of executive function.

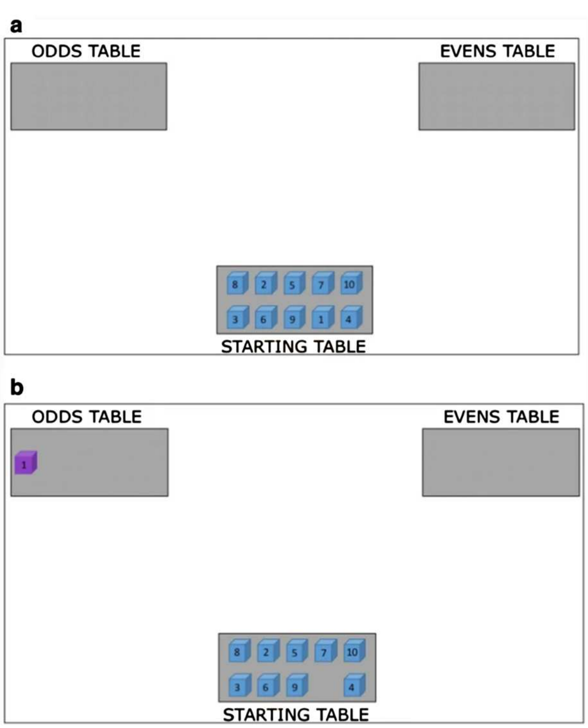

Figure 1. Screenshots of the Box-Moving Task **(a)** Starting screen for the task; (**b)** Screen configuration after the first box is moved to the correct table at the top.

Experiment 1

In Experiment 1, two tasks measuring executive functions were included: a Stroop interference task (Stroop, 1935) to measure inhibitory control and a 2-Back working memory updating task. Participants completed these tasks and the VonderHaar et al. (2019) box moving task as a measure of precrastination of a cognitive task (category item generation). Item generation difficulty was also manipulated by the number of items participants were asked to generate on different trials in the box moving task in an attempt to further replicate VonderHaar et al.'s results. We then tested the relation between precrastination rates and the performance measures from the Stroop and 2-Back task.

We chose an N-Back task[1] to measure working memory rather than the span task used by Raghunath et al. (2020). Span tasks measure one's working memory capacity, whereas N-Back tasks measure updating aspects of working memory, which may better capture the dynamic features of working memory needed for the task order decisions related to precrastination. Thus, the N-back task may reveal a relation with precrastination that a span task does not. Furthermore, the Stroop task was chosen as a classic inhibitory control task to examine the relation between response inhibition in this task with task order choices in the box-moving/category generation procedure.

Method

Participants

Participants consisted of 87 undergraduate students from Illinois State University. Students took part in this study in exchange for course credit, for which they voluntarily signed up on the university's psychology research participation sign-up system. Data from two participants were not used due to experimenter error ($n = 1$) and failure to follow instructions ($n = 1$). As a result, data from 85 participants were included in the final analyses. A power analysis using G*Power (Erdfelder et al., 1996) indicated power above .80 for this sample size to detect a medium-sized correlation ($\rho = .30$). This correlation size is comparable to those found in past studies that have examined the relation between precrastination behaviours and individual difference measures (e.g., Adachi & Adachi, 2024; Ma & Zhang, 2023).

Materials & procedure

SuperLab 6 software was used to run this experiment. This programme was used to administer the tasks, as well as record participant's data. The three tasks in this experiment included a computerised box-moving task, the Stroop task, and the 2-Back task. To counterbalance the order of the three tasks across participants, we followed a Latin square design to ensure that a similar number of participants received each task order.

Box-Moving Task. The computerised box-moving task consisted of 10 numbered boxes positioned in a random sequence in a labelled section at the bottom of the computer screen; this was labelled as the "starting table" (see Figure 1, panel a). Two sections representing tables were positioned at the top of the computer screen, an "odds table" in the left corner and an "evens table" in the right corner (see Figure 1). On each of the 6 box-moving task trials, the numbered boxes on the "starting table" were shown in different locations. Participants were also asked to generate either 5, 10, or 15 items from the following categories: kitchen items, four-footed animals, body parts, sports, clothing items, and fruits categories. Each category was given once across the 6 trials.

The instructions for the box-moving task were read aloud to the participants. They were told that 10 blue boxes would be shown on the starting table at the bottom of the screen and that the boxes would be numbered 1 through 10 but were not presented in order. Their task was to move the boxes in ascending numerical order to the two tables at the top of the screen according to whether the number on the box was even or odd. Participants were told to click on the corresponding box in numerical order, and that once they selected the correct box it would turn purple. Once the box turned purple, they were to move the box to the corresponding ending table by using the mouse to click on that table, and the box then appeared on the selected table (see Figure 1, panel b). Participants were asked to complete this task as quickly and accurately as possible.

Before the item generation task was introduced, participants completed a practice trial of box moving on its own. After completing the practice trial, they were told that in the forthcoming trials they were to generate lists of 5, 10, or 15 items belonging to different categories given at the start of each trial. Participants were told that they could say their list out loud to the experimenter whenever they choose to do so, but it would have to be while they were not moving any boxes. As examples, they were told they could state the category items before moving any of the boxes, in between any of the boxes, or after moving all 10 of the boxes. However, they were told they had to state all items in their list before continuing with next box. On each trial, participants were provided with the category and how many items were to be generated for that category at the start of the trial. Participants' generated items were recorded by the experimenter. Six trials of the box-moving task were performed, two trials per number of items condition. The assignment of categories to the number of items conditions was counterbalanced across participants.

Stroop Task. For the Stroop task, colour names appeared in the middle of the computer screen one at a time in one of four different font colours: red, green, blue, or yellow. On some trials, the word appeared in a different ink colour than the word itself (e.g., the word "green" shown in red font); on the other trials, the word was shown in a consistent colour (e.g., the word "green" shown in green font). Thus, the colour words red, green, blue, and yellow appeared in a random sequence on the screen in one of these four colours. Four coloured stickers corresponding to these colours were placed on letters Q, W, O, and P on the computer keyboard for participants to select the appropriate answer. Two sets of 8 practice trials were presented. Experimental trials were presented after the two practice sets and included 43 items (23 compatible and 20 incompatible).

Instructions for the Stroop task were read aloud to each participant. Participants were told that they would see the colour words red, green, blue, and yellow in different font colours, and their task was to indicate the font colour of the word. They were instructed to press one of the four associated colour dots on the keyboard to respond. Participants were reminded to ignore the meaning of the colour word, and instead focus on the font colour. They were also asked to complete the trials as quickly and accurately as possible.

After going through the instructions, participants started with the first set of practice trials. For the first practice set, the words were shown for 5 s each. On the second practice set, presentation time was shortened to 2 s each to allow for practice at the speed at which experimental trials were presented. Experimental trials were then shown for 2 s each. A fixation cross appeared for 500 ms before each word. On all trials, feedback was provided. The message "Correct" appeared for trials on which a correct response was provided within the presentation time, and the message "Wrong" appeared for trials with incorrect responses or when no response was received during the presentation time.

2-Back Task. For the 2-Back task, a sequence of letters (A, D, J, K, L, M, N, or S) appeared in the middle of the computer screen, one at a time. Participants were tasked with deciding if they saw that same letter two trials (i.e., two letters) ago. They were then provided with a visual example of how the task would work. If the letter was shown two trials before, participants were instructed to press the letter "M" on the keyboard and if it was not shown two trials before to press the letter "N" on the keyboard. There were 20 practice trials provided followed by 38 experimental trials (18 match, 18 mismatch, and 2 starting trials). Participants were informed that the first block contained practice trials, and that they could press any key to respond to the first two letters in the sequence.

Each letter appeared for 3500 ms. A fixation cross appeared for 500 ms before each letter. On all trials, feedback was provided as in the Stroop task.

Results

Mean trial position for each number of items condition was determined in the box-moving task based on the box number before which participants chose to state their list on each trial (with a value of 11 given when they stated their category items after moving all 10 boxes). Interference scores were calculated for the Stroop task for each participant by subtracting the mean RT for compatible trials from the mean RT for incompatible trials. In addition, only trials with correct responses were included in the analyses. Accuracy for the 2-Back task was calculated for each participant as well. Mean scores for each task are presented in Tables 1 and 2. As the regression analyses were not significant, Bayes analyses, with a $BF_{01} > 3.0$ indicating moderate evidence for the null hypothesis, are included with these statistical tests (Stefan et al., 2019).

Overall, across all trials, 54.12% of participants completed the item generation task before moving any of the boxes on every trial. Only 14.11% of participants generated items after moving all the boxes on all trials. The remaining participants either consistently generated their items after boxes 1–9 or were inconsistent in when they chose to generate their items. See Figure 2 for a frequency distribution of chosen trial position across all trials in the experiment (all levels of generation difficulty conditions are shown together).

To evaluate levels of precrastination, we conducted a one-sample *t* test for each level of task difficulty to compare means with an expected value of 6, which would indicate neither precrastination nor procrastination of the category item generation task (i.e., the midpoint trial number in the box moving task). We found that all three levels of number of items (5, 10, and 15) showed precrastination with means significantly below the expected value of 6. The one-sample *t* tests indicated that precrastination was significant for the 5-item level of difficulty, $t(84) = -5.55$, $p < .001$, $d = .60$; 10-item level of difficulty, $t(84) = -6.73$, $p < .001$, $d = .73$; and 15-item level of difficulty, $t(84) = -6.44$, $p < .001$, $d = .70$ (see Table 1 for means by condition). These results demonstrate that participants precrastinated in all conditions of the generation task throughout the trials. This finding supports the CLEAR hypothesis.

Accuracy in item generation based on number of items to be generated was examined in a within-subjects ANOVA for the 5-, 10-, and 15-item conditions. There was no difference found in the percentage of accurate responses across the item conditions, $F(1.70, 140.23) = 0.66$, $p = .49$, $\eta_p^2 = .01$, with high accuracy in all three conditions: 5 items (M = 99.41%, $SE = .06$), 10 items (M = 98.41%, $SE = .08$), and 15 items (M = 98.71%, $SE = .07$).[2] Thus, we can conclude that regardless of the number of items they were instructed to generate, participants performed the generation task highly accurately across conditions.

We next conducted a one-way ANOVA to examine the effect of task difficulty on rates of precrastination in the 5-item, 10-item, and 15-item conditions. The analysis of variance showed no significant difference across task difficulty conditions, $F(2,168) = 2.33$, $p = .10$, $\eta_p^2 = .03$. Therefore, these results indicate that number of items to generate did not affect when participants chose to generate them. This finding contrasts with the results reported by VonderHaar et al. (2019) that when fewer items needed to be generated, participants generated the items earlier in the box moving task.

The final analysis examined whether precrastination rates were related to either of the working memory task scores. These were the Stroop interference task to measure inhibition and the 2-back memory task to measure working memory updating. Multiple regressions were run, one for the overall average trial position collapsed across number of items conditions and then one for each number of items condition. Trial position chosen for the category generation task was the dependent variable, and the Stroop interference reaction times and 2-back task accuracy task scores were the predictors. Neither of the predictors was significant in any of the models. Table 3 reports the details of the regressions. Figures 3 and 4 show the lack of relations in scatterplots for each pair of measures. Bayes analyses were conducted for the linear regressions as well for BF_{01} indicating the factor greater than the prior odds that the null hypothesis is true. These are provided in Table 4 for all models and predictors. In all models, BF_{01} was greater than 3.0, indicating moderate support for the null hypothesis. Given these results, there is no evidence in this experiment that executive function, as measured by these tasks, plays a role in precrastination. A supplementary analysis was also conducted for the multiple regression with transformed precrastination data for all categories combined. At a reviewer's suggestion, we calculated precrastination scores as proportion of trials on which participants chose to generate category items before moving any boxes (a value of 1 in our original analysis) and as a proportion of trials on which they chose to generate category items after moving all 10 boxes (a value of 11 in our original analysis). This transformation did not change the results of the regression. The details of this analysis are provided in the supplementary section online.

Table 1. Mean and median scores for the trial position in the box moving task (1-11) chosen for the category generation task in Experiments 1 and 2.

	M	*Median*	*SE*
Experiment 1			
5 items	3.68	1.0	0.42
10 items	3.21	1.0	0.41
15 items	3.34	1.0	0.41
Experiment 2			
Easy	3.28	1.0	0.37
Hard	3.94	1.0	0.39

Table 2. Descriptive statistics for the executive function tasks in Experiments 1 and 2.

	M	*SE*	Min	Max	Kurtosis	Skew	Reliability
Experiment 1							
Stroop Interference RT	85.69	8.38	−118.00	265.00	.20	.39	.95
2-Back Accuracy	0.78	0.01	0.28	0.97	3.42	−1.31	.90
Experiment 2							
Stroop Interference RT	90.73	8.45	−142.00	346.00	0.66	0.79	.93
Simon Interference RT	40.24	4.87	−57.00	207.00	0.83	0.75	.94

Notes: RT values are in milliseconds. Reliability was calculated using the Spearman-Brown prophesy formula on split-half reliability measures. Split-half reliability was calculated for odd-even trials in each task.

Experiment 2

Experiment 2 was designed to replicate the results of Experiment 1 and to test a second inhibition task. We reasoned that if precrastination is an automatic behaviour that can be inhibited when it is not advantageous, as suggested by Raghunath et al. (2020), then inhibition abilities are the most likely components of executive function to predict precrastination behaviours in the modified box moving task used in Experiment 2. We modified the task by including simple math problems on the boxes that had to be solved to determine the correct box movement order. This small change has been shown to reduce precrastination of the category generation task in a past study (McBride et al., 2023), with participants noting they wanted to complete the task with math problems first. Thus, our objective was to reduce the appeal of precrastination by integrating math problems into the box-moving task, thereby increasing the difficulty of this task. If precrastination is an automatic behaviour, as suggested by past studies (Fournier et al., 2019a; Raghunath et al., 2020), then inhibition of the category generation task to focus first on the box-moving task would need to occur.

We also changed the category difficulty manipulation to further explore the effect of item generation task difficulty on precrastination rates. In Experiment 2, participants were asked to generate six items from the category presented in all trials of the box moving task. However, the categories themselves varied in item generation difficulty based on category norms (Van Overschelde et al., 2004). Thus, "easy" and "hard" categories were compared for the trial position chosen in the box moving task to further test the effect of generation task difficulty.

To focus on inhibitory control, we again tested the relation with Stroop task interference to determine if the results from Experiment 1 changed with the more difficult box-moving task. We also added a Simon interference task as a different measure of inhibition to ensure that the lack of relation seen in Experiment 1 was not due to the task chosen to measure this aspect of executive function. As working memory had already been tested (in Raghunath et al.'s study and the current Experiment 1), and there was no expectation that working memory involvement would change in the modified box-moving/category generation procedure, we chose to remove this measure from Experiment 2.

Method

Participants

Participants consisted of 113 undergraduate students from Illinois State University. A larger sample size was included in Experiment 2 to raise the power to detect smaller possible correlations, given the results found in Experiment 1. Students took part in this study in exchange for course credit, for which they voluntarily signed up on the university's psychology research participation system. Data from four participants were deleted due to experimenter error ($n = 2$) and failure to follow instructions ($n = 2$). As a result, data from 109 participants were included in the final analyses.

Materials & procedure

The box moving task and Stroop colour naming task were conducted in the same way as in Experiment 1, except for the inclusion of the math problems on the boxes and the category difficulty manipulation used in the box moving task. Participants were again instructed to move the boxes in ascending numerical order. However, in this experiment, the sequencing was determined by the solution of math problems (i.e., a box displaying the equation "3 - 2" would be moved first, as the answer is the value 1). Participants were also asked to generate six items from each of six categories, with three categories chosen from the Van Overschelde et al. (2004) norms from the top-ranked categories and bottom-ranked categories in terms of number of items generated for that category (see their Table 2). Thus, the Easy categories chosen were Colours, Body Parts, and Relatives, and the Hard categories chosen were Gardener's Tools, Types of Fuel, and Diseases.

Simon Task. The Simon task (Simon & Small, 1969) measures interference due to spatial incompatibility. In this task, participants viewed an arrow pointing in a horizontal direction (to the right or to the left). Participants were asked to press a labelled key on the keyboard that matched the direction of the arrow. However, arrows were presented on either the right or left side of the screen. Keys on the keyboard were to be pressed with the right or left hand on each side of the keyboard. Thus, the location on the screen was compatible with the correct arrow on the keyboard on half of the trials and incompatible with the correct arrow on the keyboard on

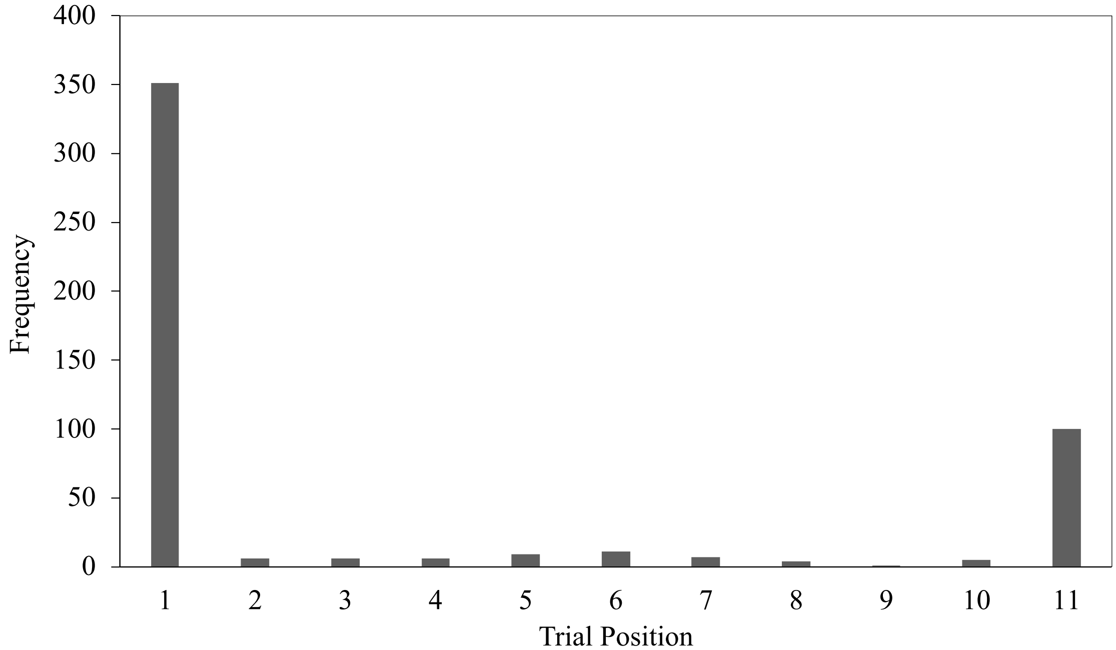

Figure 2. Frequency distribution of chosen trial positions across all trials in Experiment 1.

the other half of the trials. This task contained 12 practice trials and 100 experimental trials. Participants were asked to press the key that matched the direction of the arrow, the right key with their right hand if the arrow pointed to the right and the left key with their left hand if the arrow pointed to the left. They were asked to complete this task as quickly and accurately as possible. Interference was measured by the difference in the RT between the compatible and incompatible trials.

Table 3. Statistics for the multiple regressions run in Experiments 1 and 2 that included executive function measures as predictors and mean trial position in the box-moving task as the dependent variable.

	F	*df*	*p*	Std β	Unstd β	SE
Experiment 1 Models						
Overall Model	0.21	2.81	.81			
Stroop Interference			.60	.06	.003	.005
N-Back Accuracy			.64	.05	1.73	3.66
5 items Model	0.29	2.81	.75			
Stroop Interference			.48	.08	.004	.006
N-Back Accuracy			.70	.04	1.49	3.88
10 items Model	0.48	2.81	.62			
Stroop Interference			.39	.10	.005	.006
N-Back Accuracy			.53	.07	2.38	3.76
15 items Model	0.07	2.81	.93			
Stroop Interference			.95	-.01	.0004	.006
N-Back Accuracy			.73	.04	1.32	3.77
Experiment 2 Models						
Overall Model	0.22	2.106	.80			
Stroop Interference			.58	.06	.002	.004
Simon Interference			.67	-.04	-.003	.007
Easy Categories Model	0.11	2.106	.89			
Stroop Interference			.68	.04	.002	.004
Simon Interference			.77	-.03	-.002	.007
Difficult Categories Model	0.32	2.106	.73			
Stroop Interference			.50	.07	.003	.008
Simon Interference			.60	-.05	-.004	.008

Notes: Separate regression models are presented for the average of all category conditions and each category condition on its own. Std β = standardised beta for that predictor, Ustd β = unstandardised beta for that predictor, *SE* = standard error for that predictor.

Results

The box-moving and Stroop tasks were scored as in the first experiment. The Simon task was scored in a similar way to the Stroop task – mean RTs were calculated for compatible and incompatible trials by participant. Then, interference RT scores were determined based on the subtraction of mean RTs for compatible trials from the mean RTs for incompatible trials for each participant. Mean scores for each task appear in Tables 1 and 2. Regression model statistics are provided in Table 3 and Bayes factors for these models are shown in Table 4.

Across all trials, 53.21% of participants chose to generate items before moving any of the boxes on all six trials. Only 12.84% chose to generate items after moving all 10 boxes on all trials. The remaining participants either consistently chose a box between 1 and 9 after which to generate items or were inconsistent in when they generated items. See Figures 5 and 6 for frequency distributions of trial positions chosen for easy and hard categories, respectively.

As in Experiment 1, we examined the accuracy of generating items based on category difficulty. Accuracy of item generation was compared for easy and difficult categories in a paired samples *t*-test that analyzes each category of difficulty. As expected, there was a significant difference in the percentage of correct responses based on category difficulty, $t(108) = 5.17$, $p < .001$, $d = 0.50$, showing that the category difficulty manipulation was successful. The percentage accuracy of responses for difficult

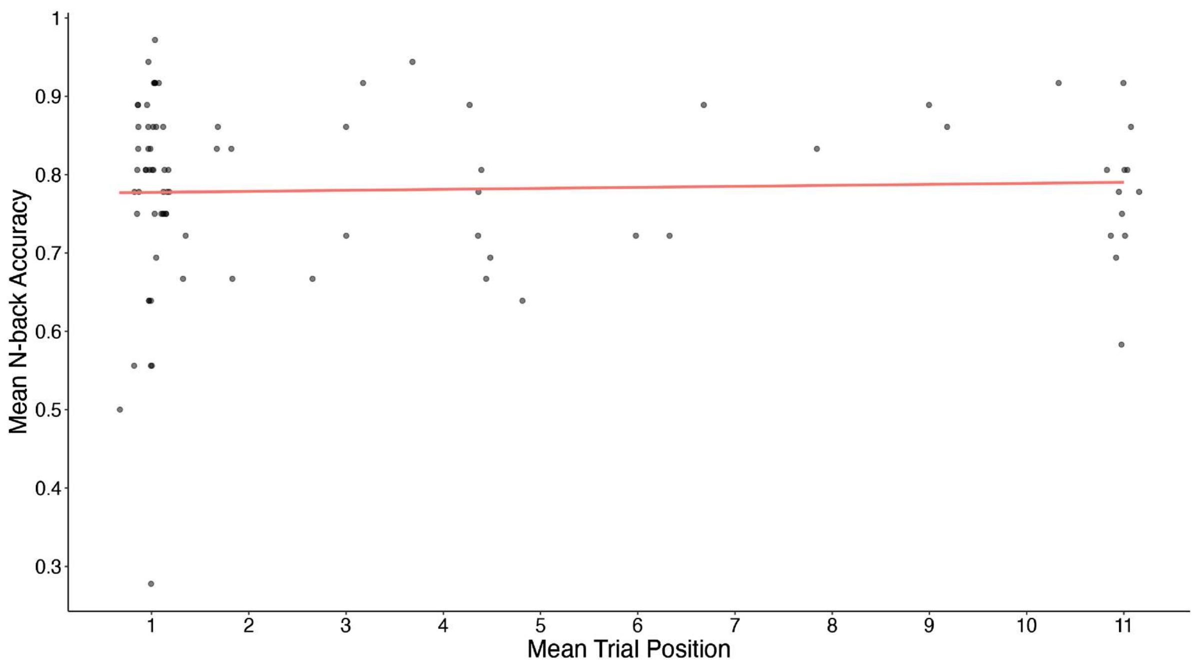

Figure 3. Scatterplot (with x-axis jitter) showing the lack of relation between mean trial position chosen for the category generation task within box-moving and mean n-back task accuracy in Experiment 1 with best-fit linear function (solid line).

categories ($M = 93.22$, $SE = 1.3$) was lower than for easy categories ($M = 99.95$, $SE = .05$). Despite this difference, generation accuracy was high overall.

For the box-moving task, mean trial position chosen for item generation was compared in a one-sample *t* test to the midpoint value of 6. Both Easy, $t(108) = 7.37$, $p < .001$, $d = .71$, and Hard, $t(108) = 5.36$, $p < .001$, $d = .52$, categories showed precrastination with mean values significantly lower than 6. See Table 1 for means for each category condition. The two types of categories were then compared in a related-samples *t* test, which showed significantly earlier trial position for the Easy than the Hard categories, $t(108) = 3.32$, $p = .001$, $d = .32$. Thus, the results in Experiment 1 showing no effect of number of items on trial position was not replicated in Experiment 2 using a different operational definition of task difficulty. The results in Experiment 2, however, are consistent with those reported by VonderHaar et al. (2019) showing earlier item generation for the 5 items condition than the 10 and 15 items condition. This result will be further discussed in the General Discussion.

Multiple regressions were then conducted as in Experiment 1 for the mean trial position overall (collapsed across the two category conditions), mean trial position for the Easy condition, and mean trial position for the Hard condition with the Stroop and Simon task interference scores as predictors. Consistent with Experiment 1, neither of the interference task scores predicted mean trial position for item generation in any of the analyses (see Table 3), indicating no relation between these inhibition tasks and task order choices in the box-moving task. Scatterplots of the relations with the two inhibition tasks are shown in Figures 7 and 8. Once again, Bayes analyses were conducted for the linear regressions for BF_{01} indicating the factor greater than the prior odds that the null hypothesis is true. These are provided in Table 4 for all models and predictors. In all models, BF_{01} was greater than 3.0, indicating moderate support for the null hypothesis. The same additional analysis as in Experiment 1 was also conducted for the multiple regressions with transformed precrastination data as a proportion of trials that were coded as 1s and 11s in the original analysis. Once again, the results of the regressions did not change. The details of this analysis are provided in the supplementary section online.

General discussion

Consistent with past studies (McBride et al., 2023; VonderHaar et al., 2019), the present study has shown that precrastination, the tendency to start a task as soon as possible, of a cognitive task is sensitive to the relative effort of the task compared with other tasks (i.e., box moving). However, in the current study our primary research question was how aspects of executive function are linked to precrastination. We explored this question in the context of the CLEAR hypothesis which predicts that tasks are completed earlier than necessary to reduce cognitive resources needed to remember the intention for the future (i.e., a prospective memory). We expected that if the CLEAR hypothesis is accurate, individuals who precrastinate to clear their mental "to-do lists" would also show more effective executive functioning. We focused on working memory updating and inhibitory

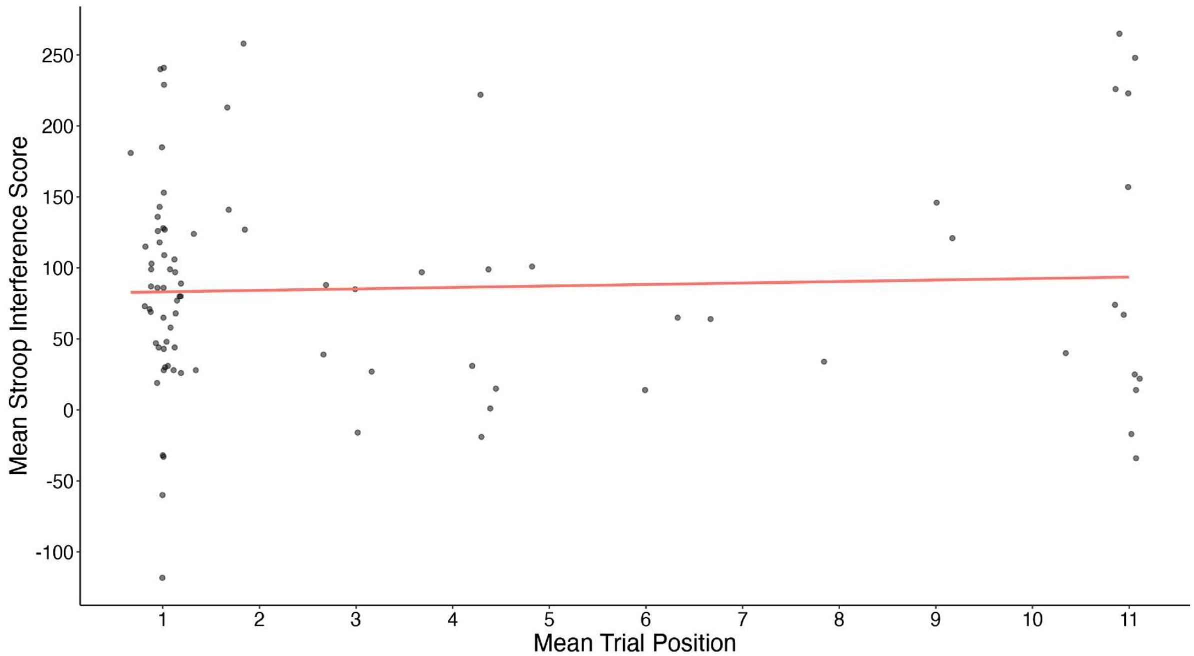

Figure 4. Scatterplot (with x-axis jitter) showing the lack of relation between mean trial position chosen for the category generation task within box-moving and mean Stroop task interference scores in Experiment 1 with best-fit linear function (solid line).

control as two key facets of executive function (Diamond, 2013) that seemed related to the task order choices made by participants in the current study. However, the current study provided no evidence supporting this prediction for working memory updating or inhibitory functions. What follows is a discussion of the results that were found and what can be concluded from these results.

Table 4. Bayes factors for all regression models, indicating the factor above the prior odds that the null hypothesis is true.

	BF_{01}
Experiment 1 Models	
All Categories	
Stroop Interference	4.05
N-Back Accuracy	4.14
Stroop Interference + N-Back Accuracy	11.07
5-Item Categories	
Stroop Interference	3.65
N-Back Accuracy	4.29
Stroop Interference + N-Back Accuracy	10.36
10-Item Categories	
Stroop Interference	3.45
N-Back Accuracy	4.00
Stroop Interference + N-Back Accuracy	8.83
15-Item Categories	
Stroop Interference	4.14
N-Back Accuracy	4.36
Stroop Interference + N-Back Accuracy	12.40
Experiment 2 Models	
All Categories	
Stroop Interference	4.50
N-Back Accuracy	4.92
Stroop Interference + N-Back Accuracy	14.97
Easy Categories	
Stroop Interference	4.63
N-Back Accuracy	4.81
Stroop Interference + N-Back Accuracy	14.85
Difficult Categories	
Stroop Interference	4.18
N-Back Accuracy	4.52
Stroop Interference + N-Back Accuracy	12.38

There are three key findings that address our predictions and main research question. The first is that there was a significant preference for completing the item generation task before or early in the box-moving task throughout all difficulty levels in both experiments. A majority of participants completed the generation task before moving any boxes on all trials of the task (see Figures 2, 5, and 6); this was true for all task difficulty levels of the item generation task, regardless of how task difficulty was manipulated (number of items in Experiment 1, ease of generation in Experiment 2). These results are consistent with our expectations, as well as consistent with the main prediction of the CLEAR hypothesis. The present results are also consistent with VonderHaar et al.'s (2019) findings where their participants showed similarly high rates of precrastination, and Experiment 2 of McBride et al.'s (2023) study. Furthermore, our results are consistent with studies using carrying tasks, such as Fournier et al.'s (2019a, 2019b) and Patterson and Kahan's (2019) studies, which provided evidence that a concurrent cognitive task significantly affected participants' preference for precrastination in a carrying task. These patterns of results show that when given the opportunity, participants will unload a future intention as early as possible if it will reduce their cognitive load.

The second result of note is that rates of precrastination were affected by the difficulty of the item generation task, but only in Experiment 2. Thus, the number of to-be-generated items did not influence participants' preferences for

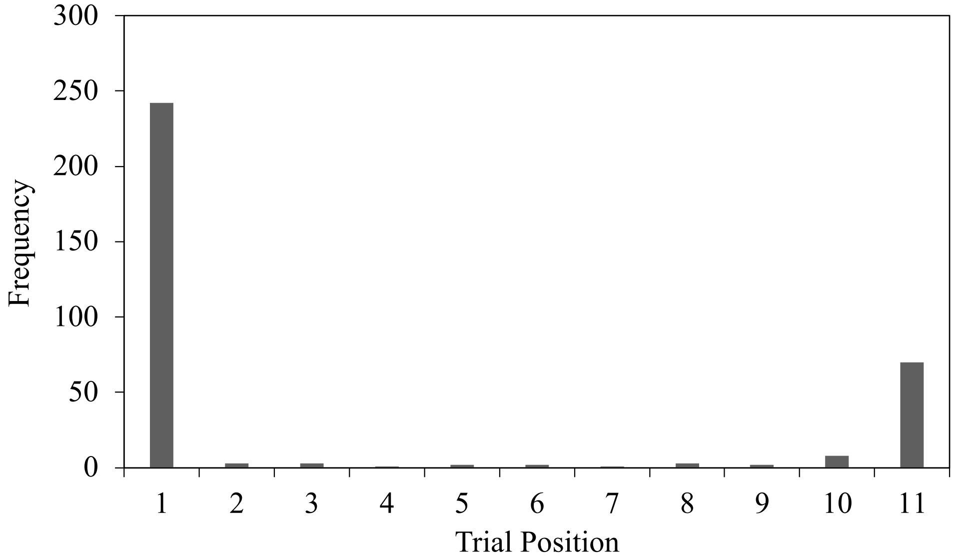

Figure 5. Frequency distribution of chosen trial positions across all trials for easy categories in Experiment 2.

early generation, but the difficulty of generating items from the category did affect those preferences. In contrast, VonderHaar et al. (2019) found that when asked to generate 5 items from the category, participants chose to complete this task earlier than when asked to generate 10 or 15 items. This result was supported by the earlier generation of easy than hard categories in the current Experiment 2, but not by the lack of difference between difficulty conditions in the current Experiment 1. These results can be compared to those from Fournier et al.'s (2019b) study, which showed that participants are less likely to precrastinate when it results in an increase in cognitive effort. When the objects participants carried were full of water that they were asked not to spill, precrastination declined due to the extra attentional effort of carrying the full cup farther relative to cups that were only half full. When this concept of extra attentional demand is applied to item generation in the box-moving task, the manipulation of number of items to generate and the ease of generation from the different categories vary the cognitive demand of the generation task. It is possible that when item generation is more difficult (generating more items or generating items from a hard category), participants want to consider the category for a bit longer before generating the items, thus reducing the cognitive effort needed when they do generate the items. In other words, precrastination of this task would reduce the time needed to complete the task successfully and is reduced when the task is more difficult. This behaviour is similar to Fournier et al.'s participants skipping the closer cup of full water to reduce the cognitive effort of carrying it both ways on their carrying trip. Looking at the task from this perspective, the difference between easy and hard categories would be expected. However, the expected difference was not found in Experiment 1 between the 5, 10, and 15 item conditions, and these results did not replicate those reported by VonderHaar et al. (2019) of earlier item generation for 5 items than for 10 and 15 items. One possible reason for the lack of effect in Experiment 1 may be reduced power to detect this effect in the current study. VonderHaar et al.'s study included 122 sets of data for the box-moving task, and only 85 sets of data were analysed in the current Experiment 1. Because our sample sizes in the current study were based on desired power for a medium-sized correlation between the measures, it is possible that this sample size was not large enough to detect the category difficulty difference found in VonderHaar et al.'s study. Furthermore, the manipulation of category difficulty in Experiment 2 likely increased the effect size with categories classified according to ease of generation, explaining why we detected the effect in this experiment but not in Experiment 1. Additional studies can possibly clarify the reason for the mixed results.

The current results regarding task difficulty have some precedents in the literature. Steel (2007) reported a positive relation between the aversiveness of tasks and how long people delay completing them. In addition, Habbert and Schroeder (2020) showed that in some types of cognitive tasks, the majority of participants chose to complete easy tasks before difficult ones and that this choice was related to an increase in reported self-efficacy. However, nearly a third of Habbert and Schroeder's participants preferred difficult tasks first, showing that there are individual differences in task preferences. We will return to the topic of individual differences in precrastination below.

Another result that did not replicate previous findings is the significant rates of precrastination found in Experiment 2 when math problems were added to the boxes in the box-moving task. McBride et al. (2023, Experiment 1) also included math problems on the boxes in this task, and this additional component of the task resulted in participants precrastinating less often. The current results

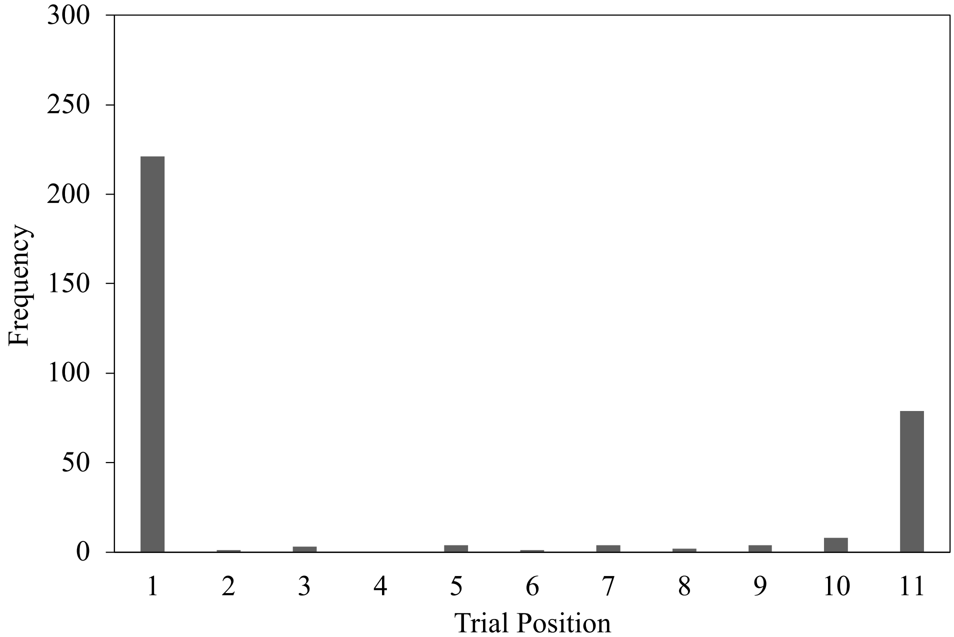

Figure 6. Frequency distribution of chosen trial positions across all trials for hard categories in Experiment 2.

contradict the expectation that increasing the relative task difficulty reduces precrastination, which was the purpose of adding the math problems in the current study. It is possible that the participants in the current experiments did not find the simple math problems on the boxes to increase the difficulty of box moving as much as the participants in McBride et al.'s experiment. Thus, the attempt to reduce precrastination in Experiment 2 relative to Experiment 1 failed, necessitating additional future tests of the relation between precrastination and inhibitory control when relative task difficulty increases.

The third key result is the lack of relation found between precrastination and executive function measures. Thus, the third conclusion from our results is that inhibition and updating aspects of executive function may not be linked to precrastination in the box-moving/category generation procedure, even when the box-moving portion is increased in difficulty. In neither experiment

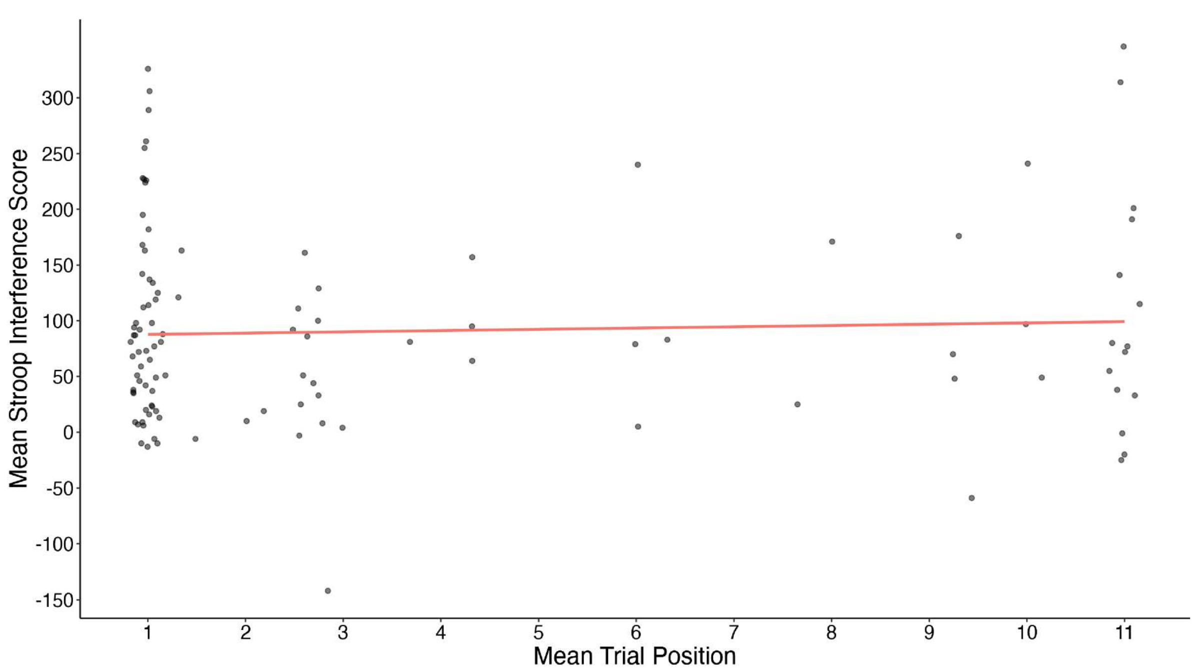

Figure 7. Scatterplot (with x-axis jitter) showing the lack of relation between mean trial position chosen for the category generation task within box-moving and mean Stroop task interference scores in Experiment 2 with best-fit linear function (solid line).

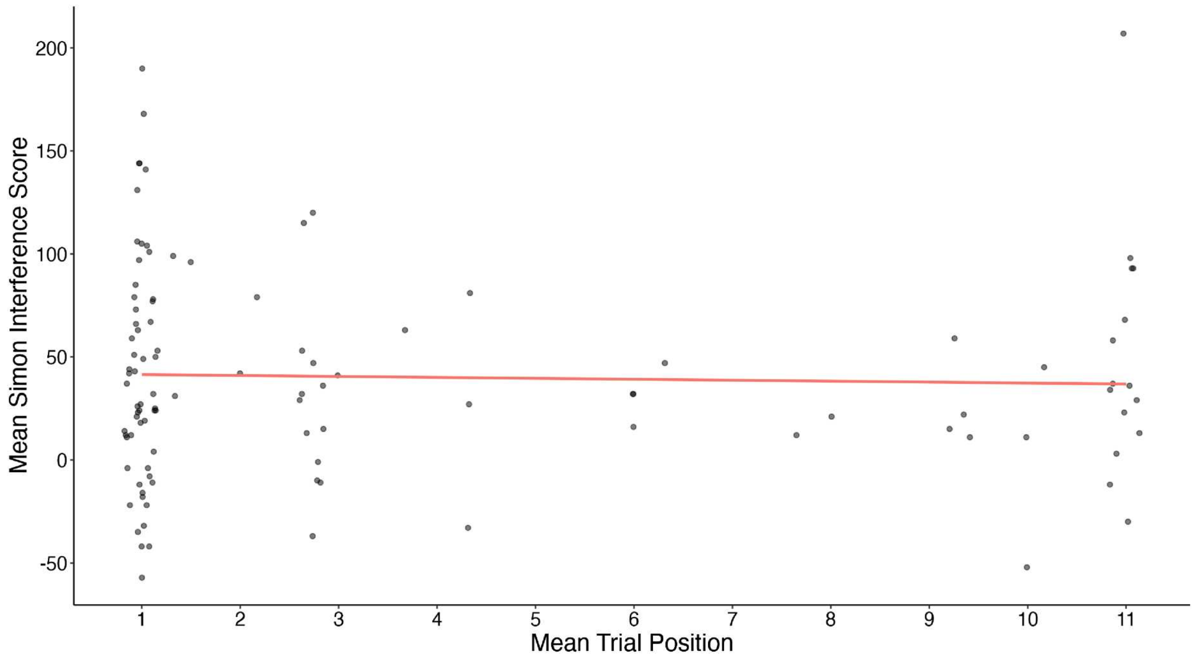

Figure 8. Scatterplot (with x-axis jitter) showing the lack of relation between mean trial position chosen for the category generation task within box-moving and mean Simon task interference scores in Experiment 2 with best-fit linear function (solid line).

were precrastination rates related to any of the executive function task scores. We expected that a cognitive task choice (i.e., when to complete the item generation task) might show a stronger link with working memory updating than a perceptual-motor task (i.e., carrying cups of water), yet we found no evidence of a relation with scores from the 2-Back working memory task. Raghunath et al. (2020) examined a similar relation between precrastination working memory span using Fournier et al.'s (2019b) cup-carrying task. They also found no direct relation between these measures, but they did find that participants with high span scores were more likely to reduce precrastination when the task was cognitively demanding (i.e., the near cup was full). This result provided some of the motivation for the main research question in the current study. The current results extend those of Raghunath et al.'s (2020) study, in which they found no evidence that precrastination overall is directly linked to differences in working memory. This lack of relation may be explained by the idea that precrastination is an automatic response. This idea was mentioned in Fournier et al.'s (2019b) study and supported by Raghunath et al.'s results showing that participants with high working memory abilities can intentionally reduce precrastination when it is suboptimal. However, neither of the inhibition tasks were found to be related to task order choices in the current experiments, despite the expectation that inhibitory control would be involved when precrastination is reduced due to an increase in difficulty of the box-moving task. This may be due to the lack of tendency to reduce precrastination in the current tasks as existed in the Raghunath et al. study. We attempted to create a task situation where precrastination has been shown to be reduced using the math problems on the boxes in the box-moving task but failed to replicate McBride et al.'s (2023) results of reduced precrastination under these conditions. Thus, this question requires further study, as inhibitory control seems to be a process needed to inhibit automatic precrastination tendencies when it is advantageous to do so.

Still, examining individual differences is important in understanding why precrastination occurs. As seen in the current study, VonderHaar et al. (2019) and McBride et al. (2023) also reported individual differences in task order preferences in the box-moving task, with most participants completing the item generation task at a consistent time in all trials and a minority completing the generation task inconsistently across trials. Relations between individual difference measures and precrastinative task choice preferences have been explored in a limited number of studies to date, but some links have been found with conscientiousness (Rosenbaum et al., 2019), future time focus and proactive personality (Ma & Zhang, 2023), and self-control (Adachi & Adachi, 2024). However, neither self-control nor impulsivity were found to relate to task order choices in the box-moving task in McBride et al.'s (2023) study.

The current results do show the robustness of precrastination behaviour in a cognitive task. Significant levels of precrastination of the category generation task were shown in both experiments, replicating results shown in past studies (McBride et al., 2023; VonderHaar et al., 2019). In fact, participants could choose to complete the category generation task at any one of 11 trial positions in the box-moving task used in the current study. Thus, if chosen by chance, the proportion for any of these positions being chosen would be .09. Yet, participants chose the first position (before moving any boxes) at a proportion of .69 across all trials in Experiment 1 and .70 over all trials in Experiment 2. These proportions are significantly above chance and remarkably consistent across experiments. These results also support the CLEAR hypothesis suggestion that a task that consumes cognitive resources and could be forgotten as other tasks are completed (i.e., a failure of prospective memory) is often completed earlier than necessary to reduce the cognitive load needed to maintain the intention. This description of precrastination relates to recent work on cognitive offloading by Gilbert and colleagues (see Gilbert et al., 2023, for a review). Gilbert (2015) showed that participants will offload a future intention when they have several pieces of information to remember for that intention, when they are interrupted in the task in which the intention will occur, and in conditions when accuracy is lower if offloading is not allowed. These results were found in a task where intentions only had to be held for several seconds, similar to the design of the category generation intention in the current study. Thus, precrastination in the face of simple task order decisions may be a form of cognitive offloading: if the intended task is done immediately, it has been "offloaded" and one need not expend cognitive effort to remember it for the future.

Despite the lack of evidence for a link with executive function, the present study has enhanced our understanding of the relation, or lack thereof, between precrastination and individual differences. Our findings are consistent with previous research showing that individuals are biased to make choices that minimise their cognitive load (e.g., Rosenbaum et al., 2014; Fournier et al., 2019b; Raghunath et al., 2020), a result that is consistent with the CLEAR hypothesis. However, we did not find any relation between executive functions of working memory updating or inhibitory control and precrastination in this cognitive task. Nevertheless, the present research contributes to a growing body of evidence suggesting that precrastination is a robust behaviour in both perceptual-motor and cognitive tasks. Additional work remains to be done before a full understanding of the individual differences related to this behaviour is reached.

Notes

1. Pilot testing for an unrelated study indicated that our participants found tasks beyond 2-Back too taxing, and they tended to disengage. Thus, the 2-Back task was chosen for Experiment 1.
2. The sphericity assumption was violated in this analysis; therefore, a Greenhouse-Geisser correction was applied to the statistics reported.

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