Scarcity impairs online detection and prospective memory

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Abstract

Operating under limited resources poses significant demands on the cognitive system. Here we demonstrate that people under time scarcity failed to detect time-saving cues as they occur in the environment (Experiment 1a). These time-saving cues, if noticed, would have saved time for the time-poor participants. Moreover, the visuospatial proximity of the time-saving cues to the focal task determined successful detection, suggesting that scarcity altered the spatial scope of attention (Experiment 1b & 1c). People under time scarcity were also more likely to forget previous instructions to execute future actions (Experiment 2). These instructions, if remembered and followed, would have saved time for the time-poor participants. Failures of online detection and prospective memory are problematic because they cause neglect and forgetting of beneficial information, perpetuating the condition of scarcity. The current study provides a new cognitive account for the counterproductive behaviors in the poor, and relevant implications for interventions.

Keywords: scarcity, attention, perception, memory, recall

Introduction

The condition of scarcity is widespread and manifests in many domains. For example, four billion people experience severe water scarcity during at least part of each year (Mekonnen & Hoekstra, 2016), and more than 10% of the world population live with less than US$1.90 per day (World Bank, 2016). A growing body of evidence has revealed how scarcity fundamentally shapes the way people perceive the environment and behave accordingly (Mani, Mullainathan, Shafir, & Zhao, 2013; Mullainathan & Shafir, 2013; Shah, Mullainathan, & Shafir, 2012; Shah, Shafir, & Mullainathan, 2015; Tomm & Zhao, 2016).

Since the cognitive system is limited in attentional and working memory capacity (Baddeley, 1992; Luck & Vogel, 1997; Miller, 1956; Pashler, Johnston, & Ruthruff, 2001; Rock & Gutman, 1981), scarcity induces a trade-off of attentional and cognitive resources dedicated on the focal task and other tasks that also require attention (Tomm & Zhao, 2016). This corroborates with past research showing that engagement with complex tasks can cause a failure to notice highly salient events (Simons & Chabris, 1999), even at the expense of personal safety (see Strayer, Drews, & Johnson, 2003).

In the current study, we investigate how time scarcity affects the online detection of information, and how time scarcity affects prospective memory performance. Our study is motivated by past work showing that people only start to increase their efforts to accomplish their goals when a deadline becomes salient (Gersick, 1988). Further, time pressure causes fewer attributes to be considered when choosing between alternatives (Wright, 1974). Given these findings, we propose that time scarcity may enhance attentional focus on the task at hand, while inducing neglect of other information in the environment, even if the information is beneficial. In two experiments, we examined the attentional and memory consequences of time scarcity.

Experiment 1a

The goal of the first experiment was to investigate how time scarcity affects the online detection of information in the environment. We hypothesize that time scarcity draws attention to the focal task, while inducing neglect of other useful information in the environment.

Participants

Undergraduate students ($N = 90$) were recruited from the Human Subject Pool at the Department of Psychology at the University of British Columbia (UBC), and participated in the experiment in exchange for course credit. All participants provided informed consent to participate. All experiments reported here were approved by the UBC Behavioral Research Ethics Board. We conducted a power analysis using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007), which showed that given an effect size of 0.6 (based on our prior work, Tomm & Zhao, 2016), a minimum of 90 participants would be required to have 80% power to detect the effect in our design.

Stimuli and Procedure

In the experiment, each participant was asked to solve a series of puzzles on the computer. The puzzles were a total of 50 trials of the Raven's Progressive Matrices (Raven, 2000). Each matrix appeared at the centre of a computer screen. The bottom right corner of the matrix was missing, and participants had to find the right piece that fits with the general pattern in the matrix. Each participant was asked to correctly solve the matrices to earn as many points as possible. In each trial, participants were shown one Raven's

matrix, with the numbered pieces appearing below. The response keys appeared in a vertical list on the left side of the screen. In the top-left corner of the screen, the question number and time remaining were displayed (see Figure 1). Participants were not told of the total number of trials until starting the first trial. To solve each matrix, participants pressed a number key corresponding to the correct piece.
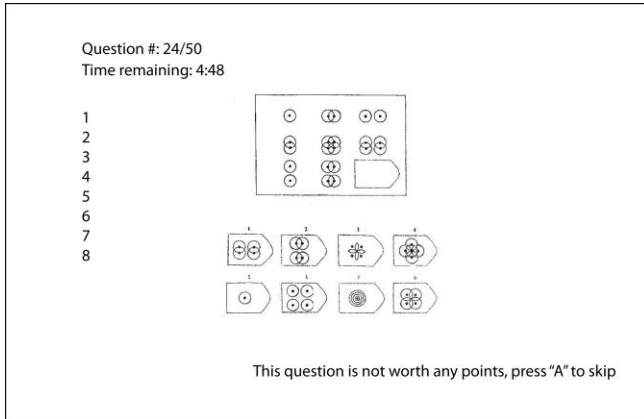

Figure 1. Trial screen for Experiment 1a.

To manipulate time scarcity, participants were randomly assigned with either a rich time budget (they had 40 minutes in total to solve the matrices; the time-rich condition, $N = 45$), or a poor time budget (they only had 10 minutes in total to solve the matrices; the time-poor condition, $N = 45$). Without explicit instruction or prompting, a time-saving cue appeared in the lower right part of the screen during the experiment. Specifically, on even-numbered trials starting from trial #24, the cue appeared on the screen stating: "This question is not worth any points. Press 'A' to skip." (see Figure 1) Thus, 14 of the 50 trials were allowed to be skipped without any loss of points. The cue appeared at the same as the matrix for those trials, and remained on the screen for 5000ms, and then disappeared. These trials presented an opportunity to skip the question in order to save time. Participants were not told anything about the cue. We wanted to see if they were able to detect this message during the experiment and skipped the even-numbered questions from trial #24.

Results and Discussion

Participants in the time-poor condition almost unanimously used their entire time budget (10 minutes) while participants in the time-rich condition used less than half of their time budget (16 minutes). Given this constraint, the time-poor participants spent less time on the task overall compared to time-rich participants [$t(88) = 6.51$, $p < .001$, $d = 1.37$] (Figure 2a). The time-poor participants completed fewer trials than the time-rich participants [$t(88) = 4.71$, $p < .001$, $d = .99$] (Figure 2b).

Notably, there was marginal difference in accuracy on the Raven's Progressive Matrices between the time-poor and the time-rich participants [$t(88) = 1.69$, $p = .09$, $d = .36$]

(Figure 2c). When accounting for the total amount of time spent on the task, the time-poor participants scored higher accuracy per minute than time-rich participants [$t(88) = 8.09$, $p < .001$, $d = 1.71$]. This result suggests that time scarcity can cause a greater focus on the task at hand, enhancing task performance within the time limit.
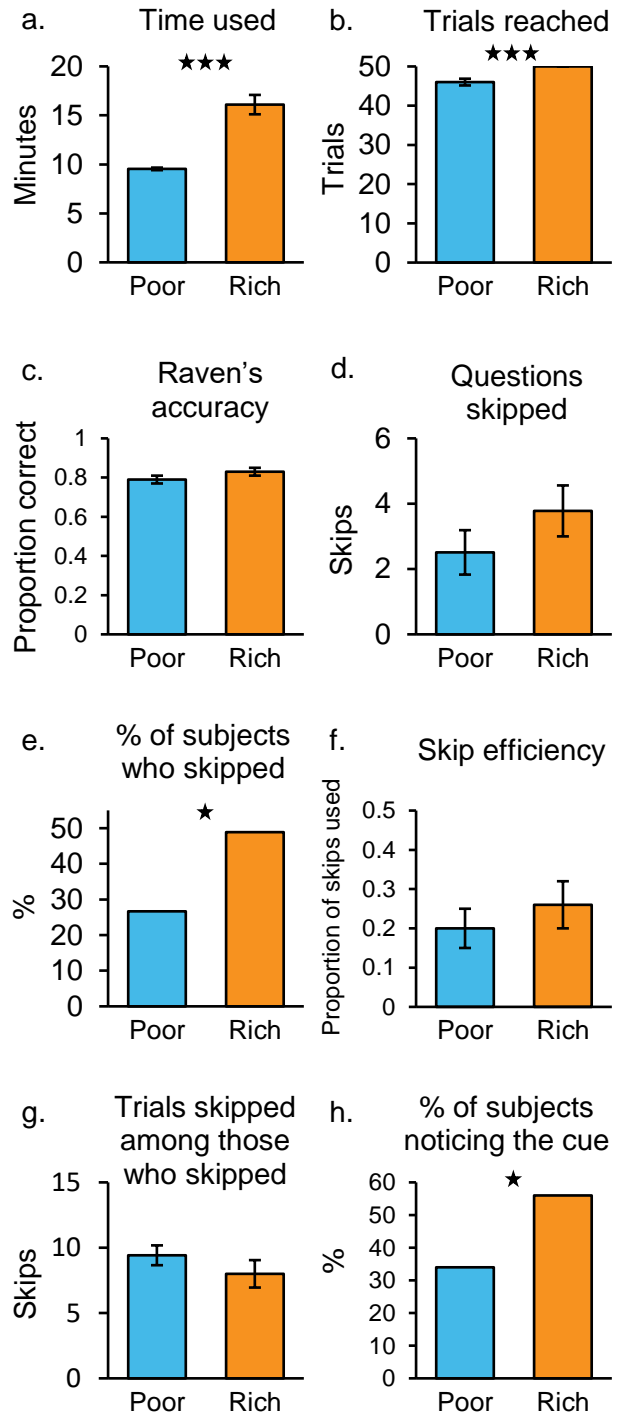

Figure 2. Results for Experiment 1a. Error bars represent ±1SEM. *p<.05, ***p<.001. Note: accuracy was computed for all trials excluding skipped trials.

Examining the number of questions skipped, we found that there was no significant difference in the average number of questions skipped between the time-poor and the time-rich participants [$t(88) = 1.23$, $p = .22$, $d = .26$] (Figure 2d). However, only 26.7% of the participants in the time-poor condition skipped at least once, and there were more time-rich participants (48.9%) who skipped at least once [$X^2(1,90) = 4.72$, $p = .03$] (Figure 2e). This result suggests that time scarcity caused a failure to use the time-saving cue appearing on the bottom of the screen.

To control for the total number of trials completed, we calculated skip efficiency as the number of questions skipped divided by the number of possible questions that could be skipped. There was no difference in skip efficiency between the time-poor and the time-rich participants [$t(88) = .91$, $p = .36$, $d = .19$] (Figure 2f).

Among those who skipped at least once, there was no difference in the number of questions skipped between the time-poor and the time-rich participants [$t(31) = .89$, $p = .38$, $d = .34$] (Figure 2g). This means that if the participant noticed the cue at least once, they were able to skip the same number of questions, regardless of scarcity.

To measure retrospective recall of the time-saving cues, we asked participants after completing the task during debriefing to report whether they saw any messages appearing on the screen during the task. We found that the time-poor participants were less likely to report seeing the cues than the time-rich participants [$X^2(1,84) = 3.81$, $p = .05$] (Figure 2h).

These results showed that fewer participants under time scarcity skipped the questions at least once, and reported seeing the cues, compared to time-rich participants. This suggests that time scarcity may narrow attention to the central task, while inducing a neglect of peripheral, even beneficial information in the environment. An alternative explanation is inattentional blindness, suggesting that the time-poor participants were less able to attend to salient but task-irrelevant information, than the time-rich participants. To tease these two accounts apart, we conducted the next experiment, probing whether scarcity alters the spatial scope of attention, or the ability to notice salient stimulus. Specifically, we manipulated the location of the time-saving cue, and examined the likelihood of skipping questions as a function of the spatial location of the cue under scarcity.

Experiment 1b

In this experiment, we reduced the spatial distance between the time-saving cue and the matrix (i.e., the focal task) by moving the cue closer to the center of the screen, and investigated how the spatial proximity of the time-saving cue to the focal task impacted its detection.

Participants, Stimuli, and Procedure

Participants ($N = 87$) were recruited from the Human Subject Pool at UBC, and participated in the experiment in exchange for course credit. The stimuli and the procedure were exactly the same as those in Experiment 1a, except one important change: the time-saving cue (i.e., the message to skip even-numbered questions after trial #24) now appeared directly underneath the Raven's Progressive Matrix after trial #24 for even-numbered questions (Figure 3).

If the neglect of the time-saving cue in Experiment 1a was due to the spatial narrowing of attention under scarcity, we would predict that the time-poor participants would be more likely to notice the cue, because it was not close to the central task. On the other hand, if the neglect of the time-saving cue was due to inattentional blindness, moving the cue closer to the central task would not affect performance.
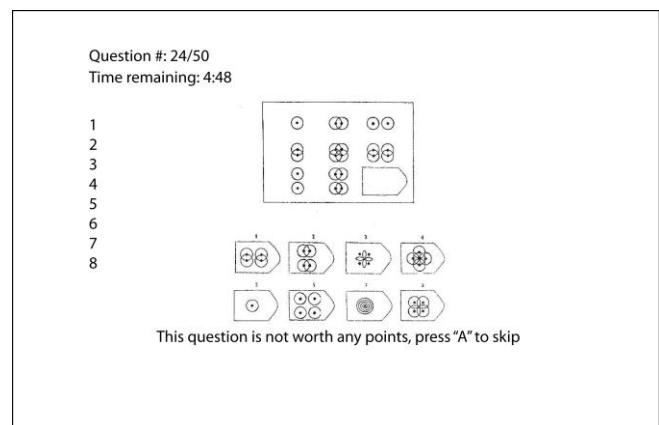

Figure 3. Trial screen for Experiment 1b, where the time-saving cue appeared right below the matrix.

Results and Discussion

Since in Experiment 1a, time scarcity influenced the number of participants who skipped at least once, we examined the same measure here again. We found that now there was no statistical difference in the percent of participants who skipped at least once [$X^2(1,90) = .71$, $p = .40$] (Figure 4a). Comparing Figure 4a to Figure 2e, the time-rich participants were not influenced by the change in the position of the cue, but the poor seemed to benefit from the closer proximity of the cue to the central task. This suggests that if the cue falls within the spatial scope of attention, the time-poor participants could still take advantage of the cue.
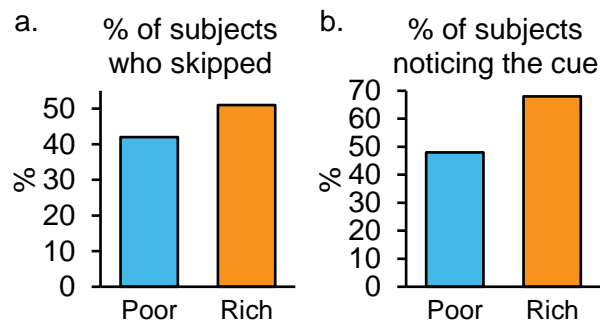

Figure 4. Results for Experiment 1b.

During debriefing, the time-poor participants were marginally less likely to report seeing any messages during the task compared to the time-rich participants [$X^2(1,88) = 3.78$, $p = .05$] (Figure 4b). Compared to the time-poor participants in Experiment 1a (34% reported noticing the cue), the closer proximity seemed to provide a large benefit to the time-poor participants in Experiment 1b (48% reported noticing the cue). These results support the account that scarcity narrows spatial attention to the focal task.

Experiment 1c

To further explore the boundary condition of the spatial narrowing effect of scarcity, in this experiment we moved the time-saving cue farther away from the focal task, and examined how likely participants were to notice the cue.

Participants, Stimuli, and Procedure

Participants ($N = 86$) were recruited from the Human Subject Pool at UBC, and participated in the experiment in exchange for course credit. The stimuli and the procedure were identical to those of Experiment 1a, but this time the time-saving cue appeared in the bottom right corner of the screen (Figure 5), which was even farther away from the focal task than in Experiment 1a.
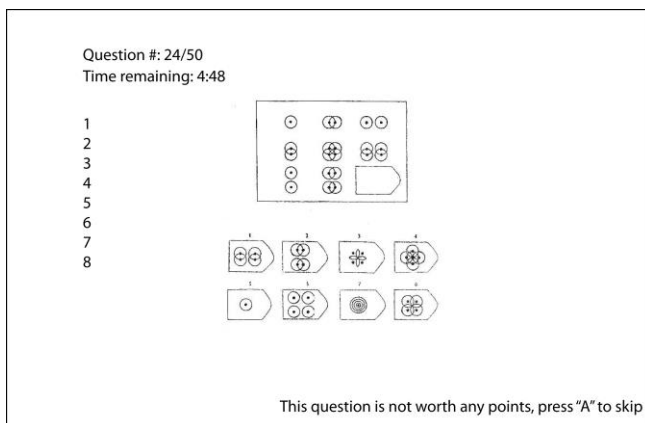
Figure 5. Trial screen for Experiment 1c, where the time-saving cue appeared far from the matrix, on the bottom right corner of the screen.

Results and Discussion

We found that participants in both conditions failed to take advantage of cue. There was no statistical difference in the percent of participants who skipped at least once [$X^2(1,90) = 1.54$, $p = .21$] (Figure 6a). During debriefing, there was no difference in the likelihood to report seeing any messages during the task between the participants in both conditions [$X^2(1,87) = 2.70$, $p = .10$] (Figure 6b). In fact, there was a floor effect in both the time-poor and the time-rich participants in skipping the questions or noticing the cue. This suggests that when the cue was spatially far away from the focal task, participants could not notice the cue, regardless of scarcity.
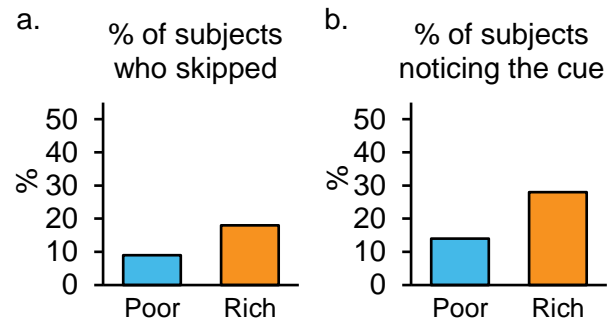
Figure 6. Results for Experiment 1c.

Experiment 2

Experiments 1a-c showed that time scarcity narrowed attention on the focal task, resulting in the neglect of a time-saving cue which appeared in the peripheral during the experiment. However, in daily life, we do not always have cues in the external environment as reminders for certain actions. Instead, we need to rely on internal cues from memory that need to be activated at the right time to direct actions. For example, in order to pick up groceries on the way home from work, we must remember to turn at the right intersection in order to go to the grocery store. This depends on prospective memory, which is the ability to remember to execute future actions based on previous instructions. Cues for prospective memory are internal, and must be present in mind in order to cue behavior at the right time (Graf, Uttl, & Dixon, 2002; Loftus, 1971). In this experiment, we examined how time scarcity affects prospective memory performance.

Participants

Participants ($N = 90$) were recruited from the Human Subject Pool at UBC and completed the study in exchange for course credit.

Stimuli and Procedure

Participants were asked to solve the same set of 50 Raven's Progressive Matrices used in Experiments 1a-c. As before, participants were randomly assigned either a small time budget (5 minutes; the time-poor condition), or a large time budget (20 minutes; the time-rich condition). A critical difference in this experiment was that the time-saving cue never appeared in the experiment. Rather, all participants were explicitly instructed at the start of the experiment the following: "Even-numbered questions from number twenty-four on are not worth any points. You can skip these questions without losing any points." This instruction was presented on paper to participants to read, and the experimenter also read through these instructions with each participant to maximize the comprehension of the instruction. As before, the question number and remaining time appeared in the top-left corner of the screen, and the keys available for the participants to press were listed on the

left side of the screen. Note that now the "A (skip)" key is listed among the available keys and was listed for every single question (Figure 7). There were no visual cues during the experiment to remind participants which questions they were allowed to skip. Thus, participants needed to remember to use the opportunity to skip when the applicable questions were reached.
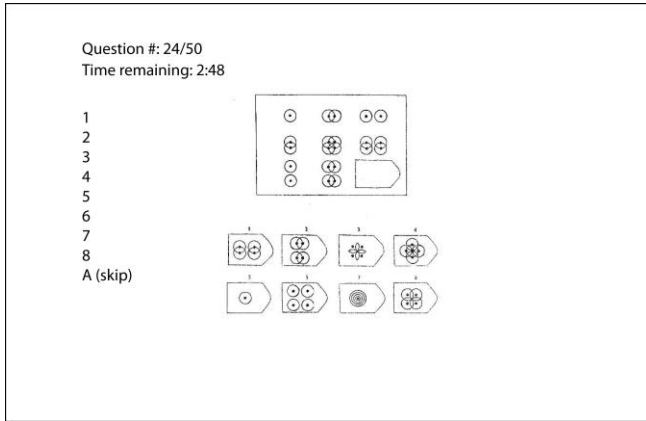

Figure 7. Trial screen for Experiment 2.

Results and Discussion

Participants in the time-poor condition almost unanimously exhausted their time budgets, while participants in the time-rich condition usually completed the experiment with some time to spare (Figure 8a). The time-poor participants spent less time solving the Raven's Matrices than the time-rich participants [$t(88) = 13.33$, $p < .001$, $d = 2.81$]. They also completed significantly fewer trials than the time-rich participants [$t(88) = 10.14$, $p < .001$, $d = 2.14$] (Figure 8b), and were significantly less accurate [$t(88) = 2.29$, $p = .02$, $d = .48$] (Figure 8c). When accounting for the total amount of time spent on the task, the time-poor participants scored higher accuracy per minute than time-rich participants [$t(88) = 9.53$, $p < .001$, $d = 2.01$], suggesting that time scarcity enhancing performance on the focal task.

The time-poor participants on average skipped fewer questions than the time-rich participants [$t(88) = 2.52$, $p = .01$, $d = .53$] (Figure 8d). However, this result is likely driven, at least in part, by the considerably smaller number of questions completed by the time-poor participants. Similarly, we found that fewer time-poor participants skipped at least once compared to the time-rich participants [$X^2(1,90) = 10.08$, $p < .01$] (Figure 8e), but this could be due to the smaller number of possible skips experienced by the time-poor participants. Thus, we examined the skip efficiency defined as the number of questions skipped divided by the number of possible questions that could be skipped experienced by the participant. We found that the time-poor participants were less likely to skip than time-rich participants (two time-poor participants were excluded from this analysis due to failing to reach trial number twenty-four) [$t(86) = 2.01$, $p = .05$, $d = .43$] (Figure 8f). This finding suggests that time scarcity impairs prospective

memory performance. We should note that among participants who skipped at least once, there was no difference in the number of questions skipped between the time-poor and the time-rich participants [$t(40) = .59$, $p = .56$, $d = .19$] (Figure 8g), or in skip efficiency [$t(40) = .76$, $p = .45$, $d = .26$] (Figure 8h).
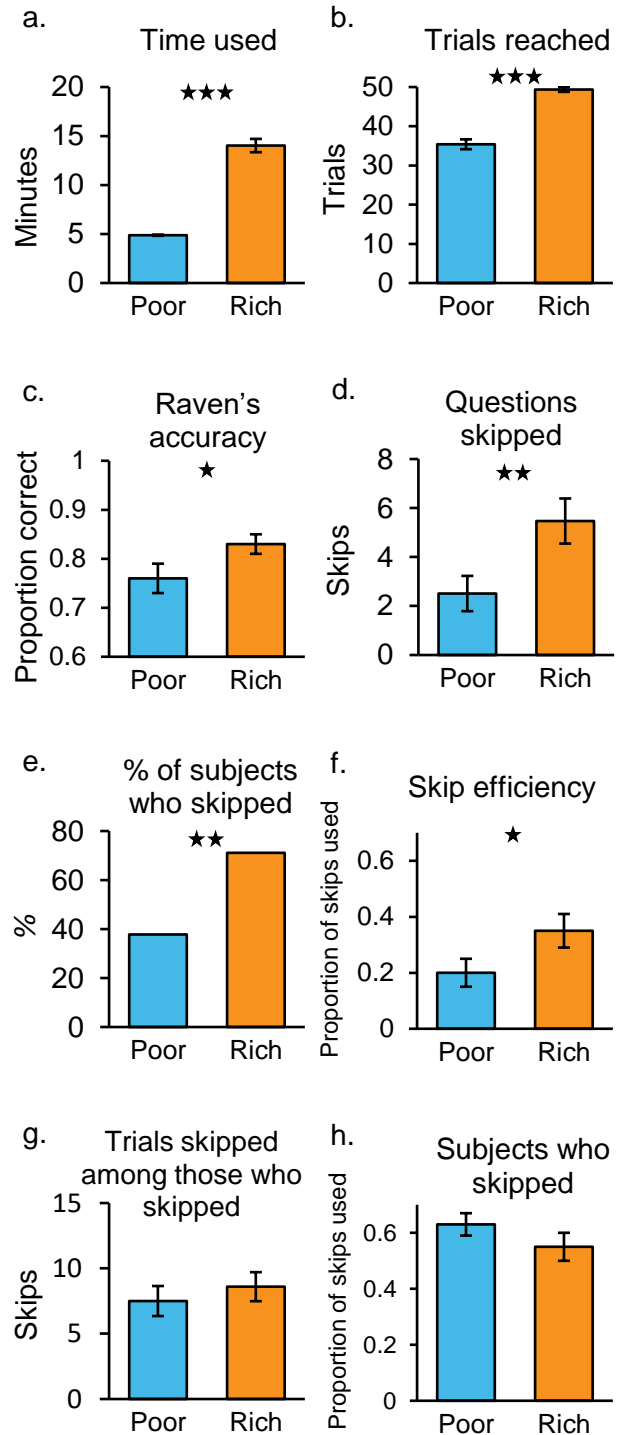

Figure 8. Results for Experiment 2. Error bars represent ±1SEM. *$p<.05$, **$p<.01$, ***$p<.001$.

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General Discussion

The goal of the present study was to examine how time scarcity impacts attention and prospective memory. We found that people under time scarcity were less likely to take advantage of a time-saving cue that appeared peripheral to the focal task (Experiment 1a), but nonetheless performed well on the focal task under the time constraint. This suggests that people under time scarcity are ironically less likely to notice opportunities to save time. This effect could be explained by a narrowing of spatial attention to the focal task (Experiments 1b & 1c). In the absence of an external cue, participants under time scarcity were less likely to remember to skip questions in the future (Experiment 2), suggesting that they failed to retrieve a cue from memory to execute actions at the right time.

These findings were particularly problematic for people under time scarcity because the attentional neglect of time-saving opportunities or the failure to remember to save time could be detrimental, perpetuating the condition of scarcity and creating a vicious cycle of scarcity. These cognitive impairments could explain a range of counter-productive behaviors observed in the low-income individuals, such as forgetting to follow instructions, or not signing up for public benefit programs. In addition, prospective memory errors can be seen by others as an indication of incompetence of the poor (Graf, 2012). The present findings instead attribute the memory failures not to the poor individuals themselves but to the condition of scarcity. The current study provides useful implications for designing policies and programs to mitigate the impact of scarcity, such as the use of reminders, automatic enrolment, or setting the right default, to reduce the attentional and memory burdens in the poor.

Acknowledgements

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