Exploring Self-Scheduling Strategies and Heuristics in Novice Schedulers

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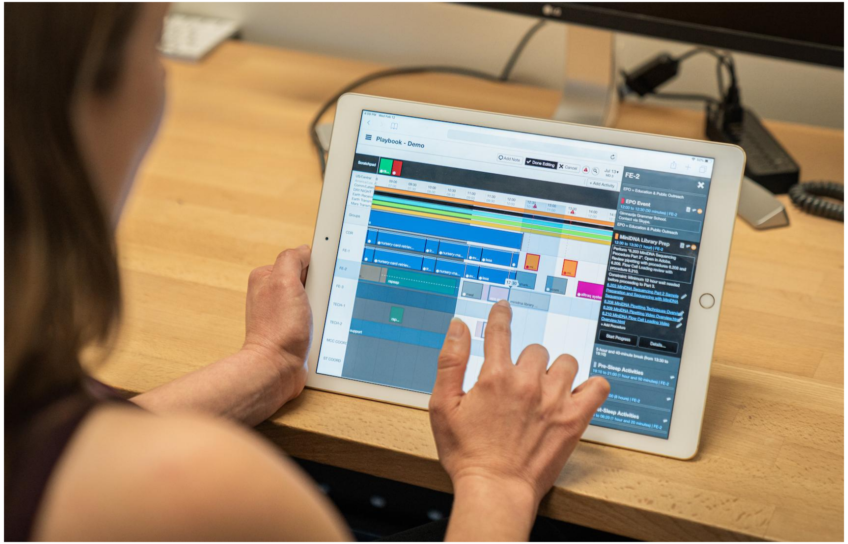
Introduction

Astronauts must operate more autonomously from ground stations during long duration exploration missions.

We envision self-scheduling as a critical part of autonomous crew capabilities.

Self-scheduling is the ability for crew to manipulate their timeline.

We conducted research to examine the role of strategies and heuristics in our self-scheduling enabling software, Playbook.



Self-Scheduling Enables Crew Autonomy

BENEFITS

Enables crew to contribute their insight how to best manage schedule.

Minimizes idle time waiting for Mission Control responses.

Mitigates effects of communication latency, intermittent communication, and limited bandwidth.

CHALLENGES

Different concept of operations that requires new protocols.

Do not want to overwhelm astronauts who are not expert mission planners.

Still need to ensure and retain constraint-abiding plans and schedules.

Marquez, Hillenius, Healy, & Silva-Martinez (2019)

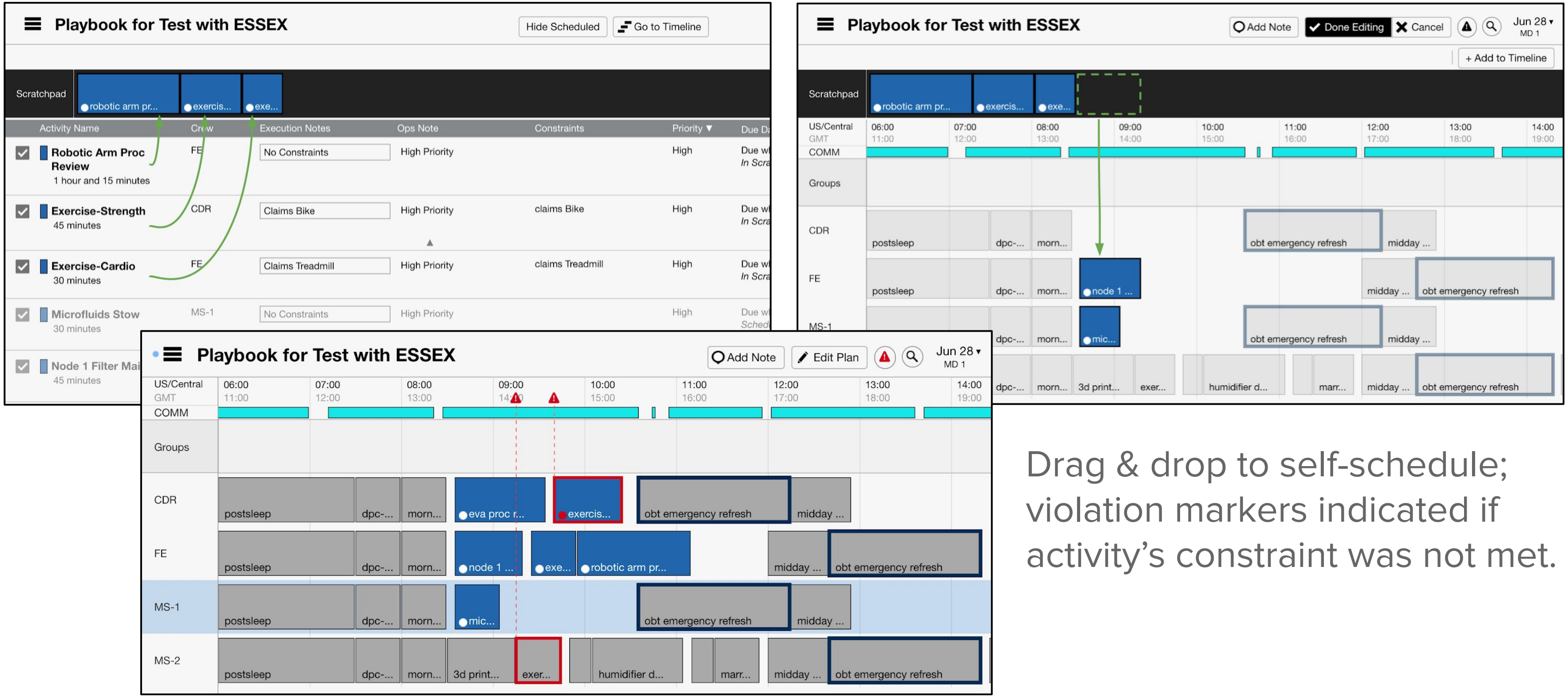
Method

We conducted two human-in-the-loop scheduling experiments investigating the impact of strategies and heuristics on scheduling performance.

- Usability study to determine the strategies that emerged from participants. This pilot study included novice and experienced planners solving self-scheduling exercises of a variety of difficulties.
- Formal experiment investigating the effects of different constraints on the difficulty of self-scheduling tasks. We instructed participants in this experiment to follow a specific strategy to attempt to reduce variability in human performance.

We then developed an automated approach to analyzing how participants' strategies changed as they completed the experiment and identified new heuristics that emerged.

Self-Scheduling Task



Drag & drop to self-schedule; violation markers indicated if activity's constraint was not met.

Usability Study

We recruited **nine** users for the study:

- **four** nursing students and **one** registered nurse (with 20 years of experience)
- **three** human factors graduate students
- **one** project manager (10 years of experience)

Nurses and nursing students were recruited as users because of their similarities to an astronaut population: both are highly trained experts that operate in dynamic, high-pressure, and high-risk environments. The project manager served as a marker for performance of those with planning and scheduling experience.

Once users signed a consent form, they were trained to conduct self-scheduling tasks with Playbook, completed the three scheduling tasks, and concluded the study with a short debrief.

Usability Study Results

Use of strategies for task completion

- Strategy preferences and usage varied widely from user to user.
- All participants attempted *Schedule Complex Activities First*: resolve the most complex and constrained activity first.
- Many participants had difficulty recognizing when a strategy was no longer effective.
- Most participants eventually abandoned these strategies, but sometimes created extra work for themselves before doing so.

Our paper describes additional strategies that we uncovered. We leveraged these results to instruct participants in formal experiment, reducing the number of ad-hoc strategies developed.

Formal Experiment

- Conducted a study with 31 participants conducting self-scheduling task.
- Leveraged Playbook's unobtrusive logging capabilities to generate lists of all the actions that participants took.
- Investigated which heuristics became prominent in the scheduling tasks.
  - We developed an automated approach to detect heuristics that participants followed based on the order that they completed actions.

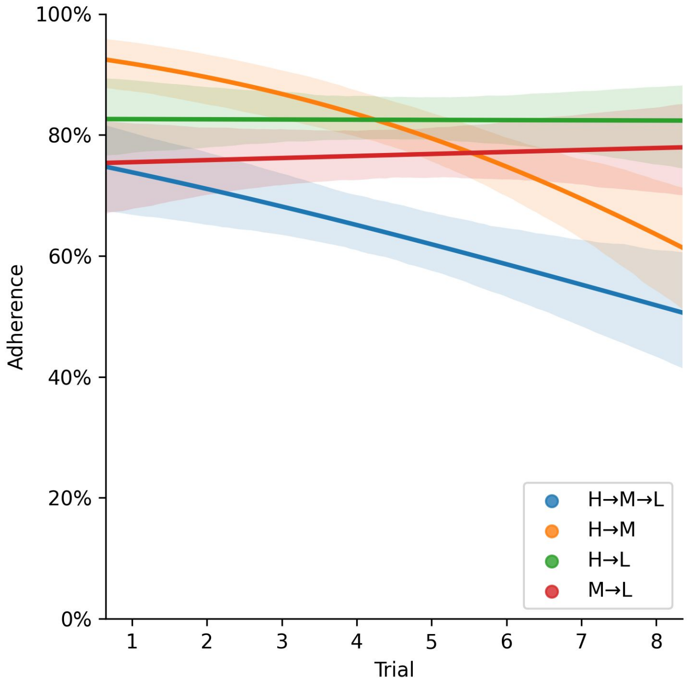
- This allowed us to define strategies and heuristics as a list of actions. The strategy that we instructed participants to use was defined as moving:

1. High (H) priority activities. . .
   1.1. . . . from the task list to the scratchpad.
   1.2. . . . from the scratchpad to the timeline.
2. Medium (M) priority activities. . .
   2.1. . . . from the task list to the scratchpad.
   2.2. . . . from the scratchpad to the timeline.
3. Low (L) priority activities. . .
   3.1. . . . from the task list to the scratchpad.
   3.2. . . . from the scratchpad to the timeline.

Participants followed the prescribed strategy

When investigating different strategies that participants took, we separated our analysis between the scheduling and rescheduling groups. We first investigated the scheduling group to evaluate if participants were following the prescribed strategy of scheduling in order of priority (H→M→L).

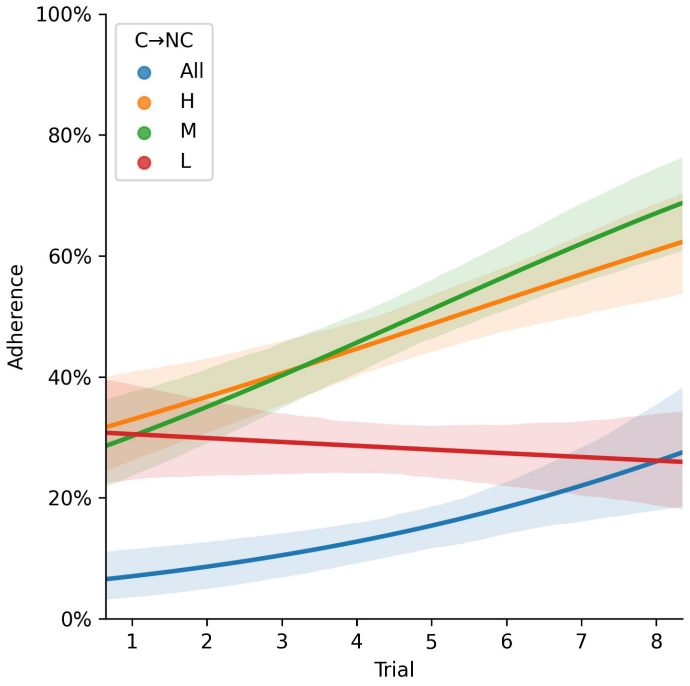
Initial adherence to this strategy was very high, near 75%, but dropped to approximately 50% as participants completed the experimental trials. We then investigated the different heuristics which make up this strategy, H→M, H→L, and M→L. The results showed that H→L and M→L were both followed at a high rate throughout the experiment, while H→M quickly dropped from ~90% to ~60%.



Participants learned new strategies

Though we instructed participants on how to schedule in terms of priority, we did not prescribe any strategy towards scheduling activities with constraints before those with no constraints (C→NC).

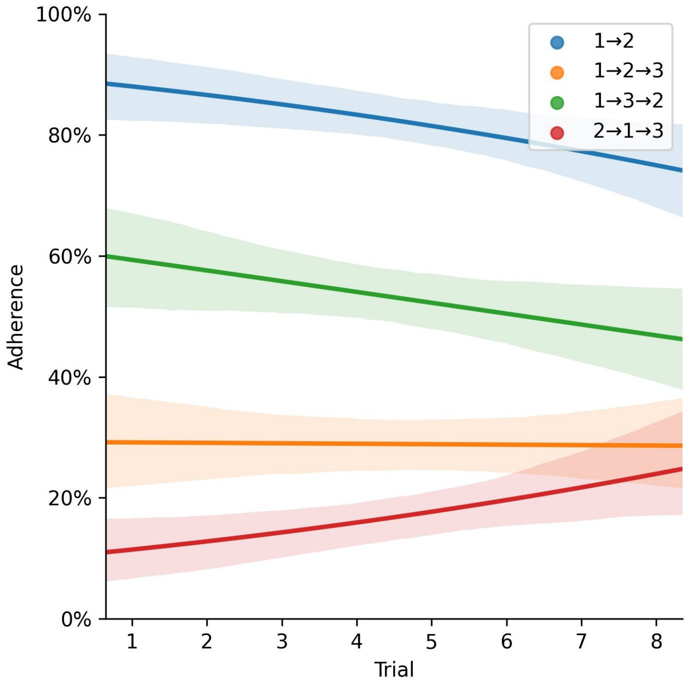
Grouping activities by priority level, only ~30% of participants initially scheduled activities with constraints before those without. Participants quickly learned to schedule C→NC for High and Medium priority activities, however, and by the end of the experiment ~60-70% of participants followed this heuristic. Additionally, a small percentage of participants (~5% at the beginning of the experiment, increasing to ~25% by the end) decided to schedule all activities C→NC, regardless of priority level.



Rescheduling participants were divided

Participants in the rescheduling task were divided in terms of which heuristics they preferred, and these opinions also changed over time.

Participants took different approaches to solve the rescheduling task. Initially, nearly all participants (1) selected high priority activities to schedule from the tasklist, then (2) unscheduled low priority activities to the scratchpad. After selecting high priority activities to schedule, participants were divided over whether to (2) unschedule low priority activities before or after (3) scheduling high priority activities. Over time, participants began to prefer to (2) unschedule low priority activities before (3) scheduling high priority activities.



Discussion

We conducted two human-in-the-loop scheduling experiments to investigate strategies and heuristics in schedulers.

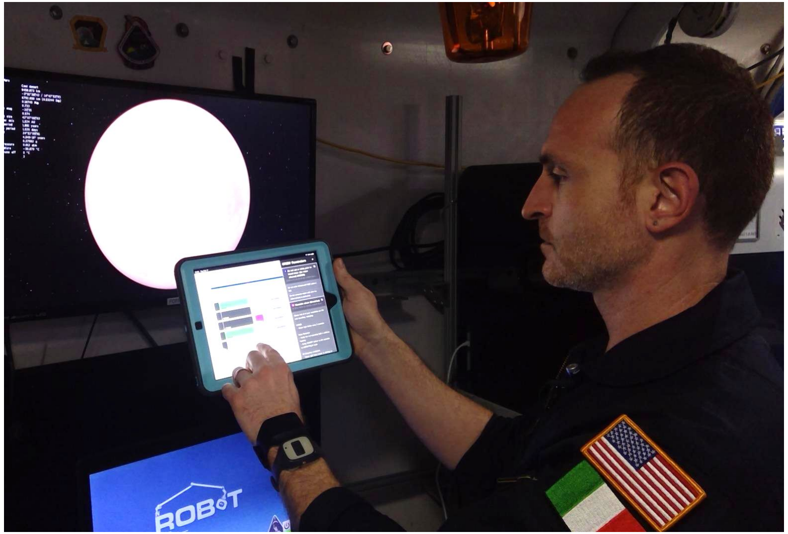
Using a think-aloud protocol, we identified seven different strategies that were common among schedulers, each of which had large impacts on scheduling performance.

Follow-on experiment prescribed a scheduling strategy for participants to follow.

- Even when participants are instructed to follow a given strategy, they rapidly develop their own self-scheduling heuristics as they learn to successfully complete the task.
- In both scheduling and rescheduling, some participants naturally learn to schedule activities with constraints first, and we find that different participants prefer different heuristics in the rescheduling task.

Future Work

- Future spaceflight missions will have schedules that are complex, heavily constrained, and with varied task priorities.
- Based on this research, future scheduling tools should support and enable the variety of emergent self-scheduling strategies.
- This will ensure that future astronauts may conduct self-scheduling, managing the nuanced changes in schedule and priority as they see fit.
- Future experiments may focus on training participants using different strategies in order to determine how these strategies quantitatively impact human performance in the scheduling task. In turn, this would identify the most successful strategies that would best support novice schedulers and astronauts.



Thank you! Questions?

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