Developing a Cognitive Assistant to Support Human Decision-Making on Aerospace Missions

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Introduction

Abstract: The objective of this research is to develop a cognitive support system to facilitate the human decision making process for off-nominal events that do not have an established procedure. Certain stages of human information processing have been targeted by existing automation support for human operators, especially pilots. This support specializes in data processing, procedure recall, and other steps that display a computational advantage.
Current automation does not, however, work constructively with the operator to facilitate the building of strategies. A human-centered design approach, focused on the problem-solving steps of decision making, formed the foundation for a Cognitive Assistant (CA) design. This study tested the CA on a tablet interface during unexpected weather situations in a flight simulator. The experiment was within-subjects across two trials. Both subjective and objective measures of performance, situational awareness (SA), and workload showed the efficacy of the Cognitive Assistant system. The results are expected to facilitate decision making and decrease workload without decreasing situational awareness. Further research can expand into other types of unexpected events to broaden the system's scope, assess other aspects of decision making, and eventually combine with other automation systems to make a more holistic in-flight assistant.

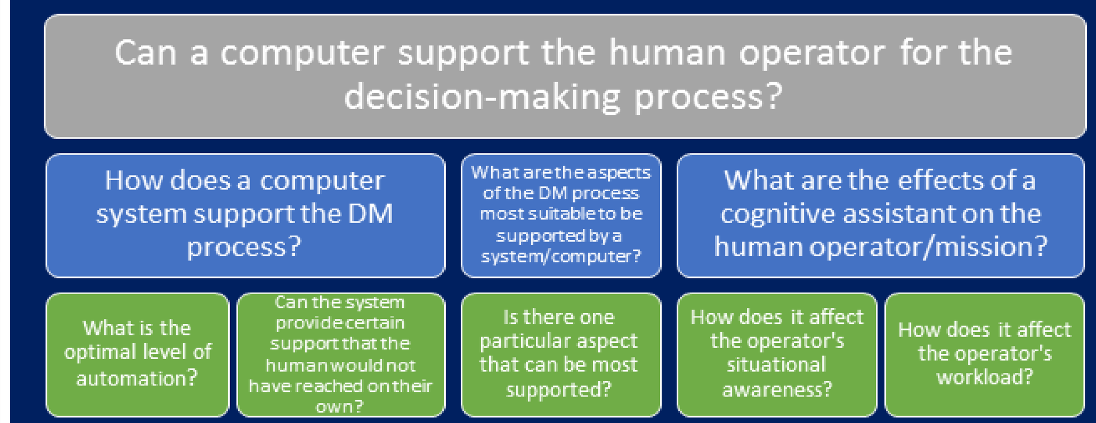

Figure 1. Research Questions

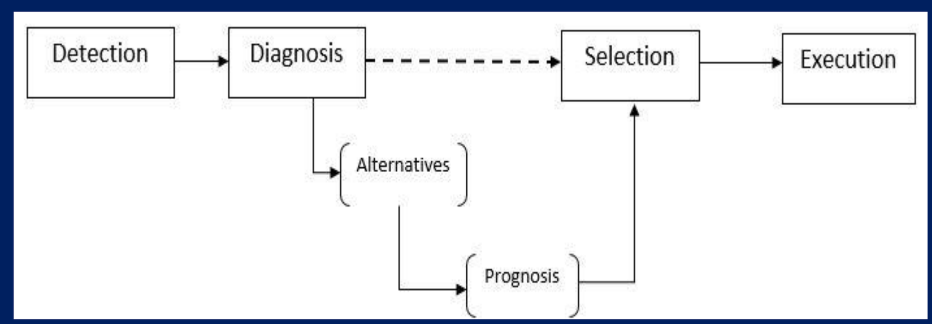

Figure 2. Decision-making model used as basis for CA design.

Prototype

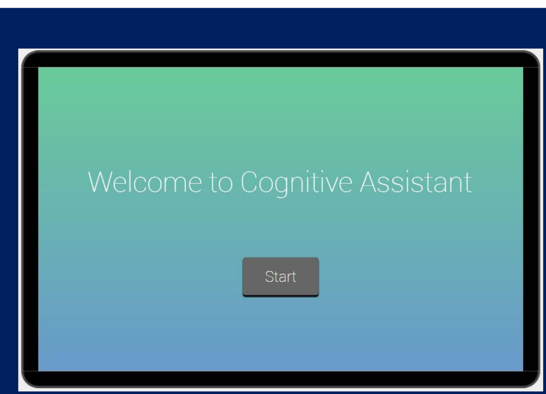

Figure 6. CA welcome screen.

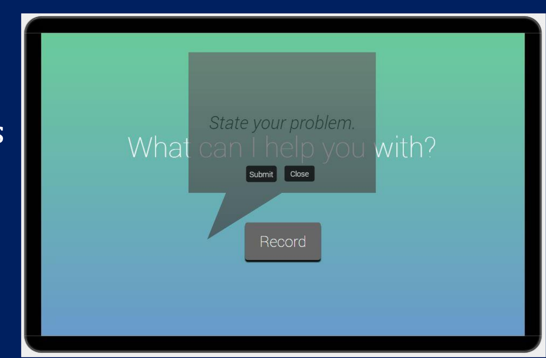

Figure 7. User inputs event verbally.

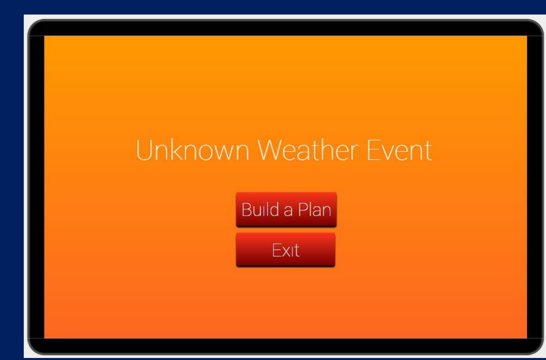

Figure 8. CA identifies event type.

Figure 9. Options in comparative table form.

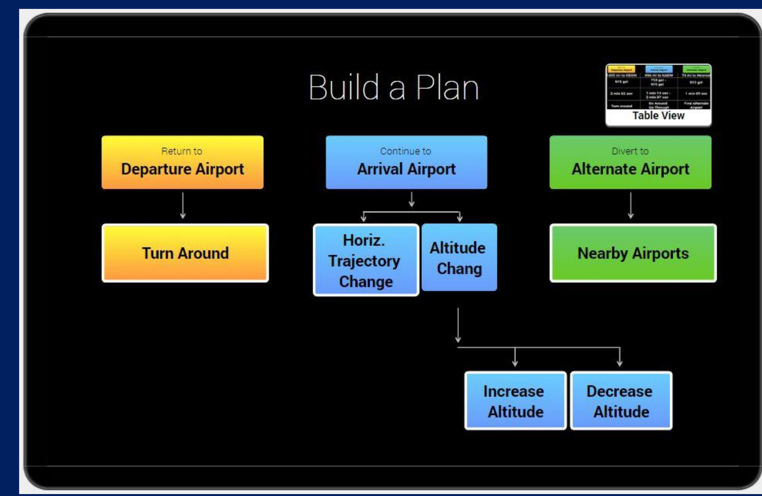

Figure 10. Options in graphical tree form.

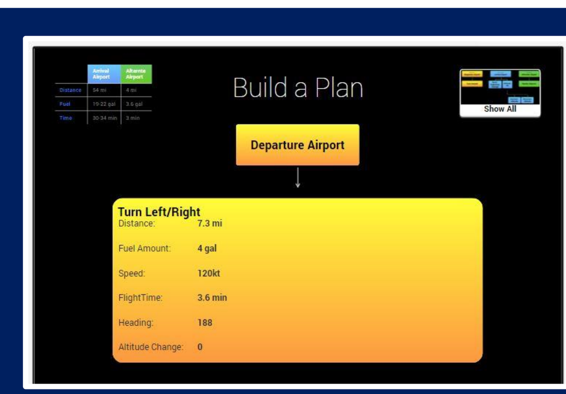

Figure 11. Selection of particular sub-option.

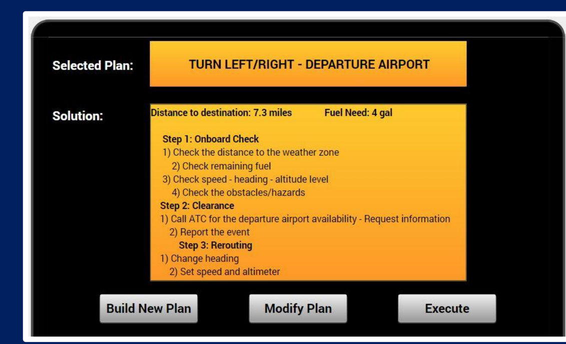

Figure 12. Detail screen for particular sub-option.

Figure 13. Execution suggestions upon plan selection.

Methods

Figure 3. Experimental procedure in flowchart form.

Hypothesis: The *presence* of a cognitive assistant will *improve* decision-making performance, and *decrease* workload *without affecting* the situational awareness of a pilot in case of an *off-nominal* event with no procedure.

Participants: 6 students, age 18-21, no flight experience | Tasks: two cruise flights, experienced unexpected weather phenomenon | Within Subjects: with Cognitive Assistant vs without Cognitive Assistant

Figure 4. FlightGear flight simulator testing environment.

DV	Metric	Data Type	Frequency
Decision-Making Performance	Completion Time	Time (sec)	From detection of storm to selection of action
	DM Process	Self-Report	Post-Task Questionnaire
Workload	NASA-TLX	21-point scale	Post-Task Questionnaire
	Biometric Sensors	EDA and ECG	Duration of Task
Situational Awareness	SART	Likert (1-7)	Post-Task Questionnaire

Figure 5. Dependent variables and their metrics.

Results

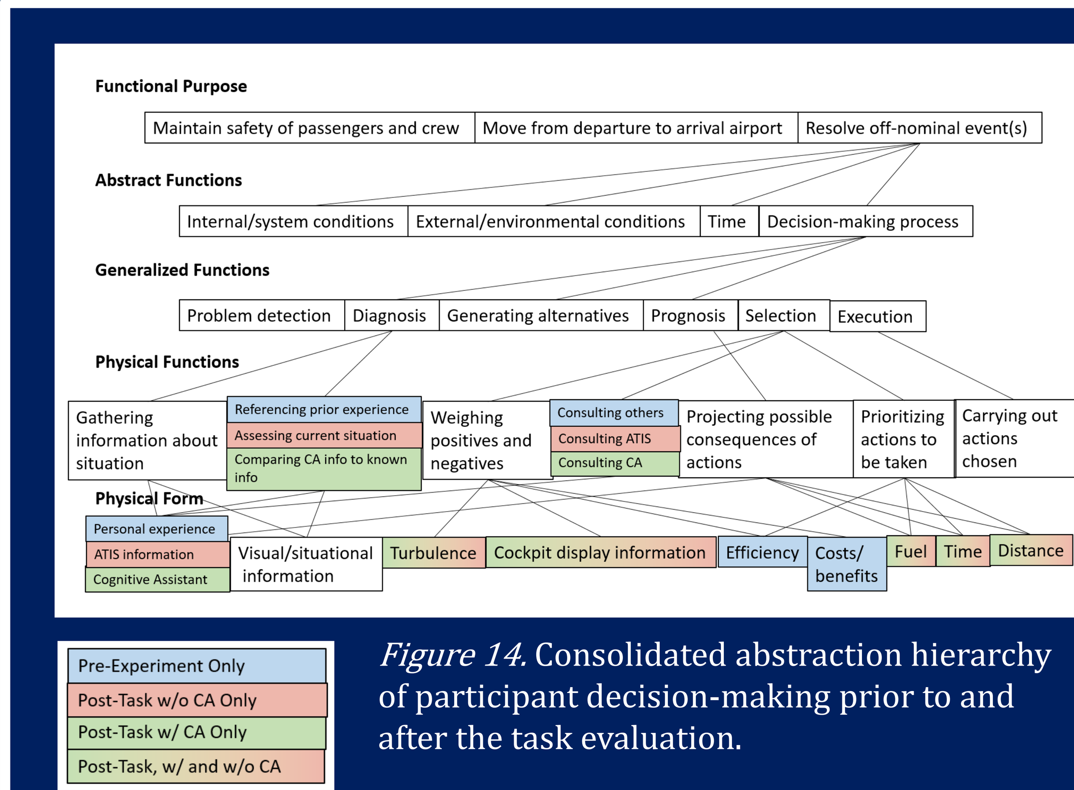

Figure 14. Consolidated abstraction hierarchy of participant decision-making prior to and after the task evaluation.

(a)	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.587	2	.793	.540	.594
Within Groups	22.030	15	1.469		
Total	23.616	17			

(b)	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.001	2	.001	.097	.908
Within Groups	.081	15	.005		
Total	.082	17			

Figure 16. ANOVA tables for a) EDA and b) ECG data (workload metric)

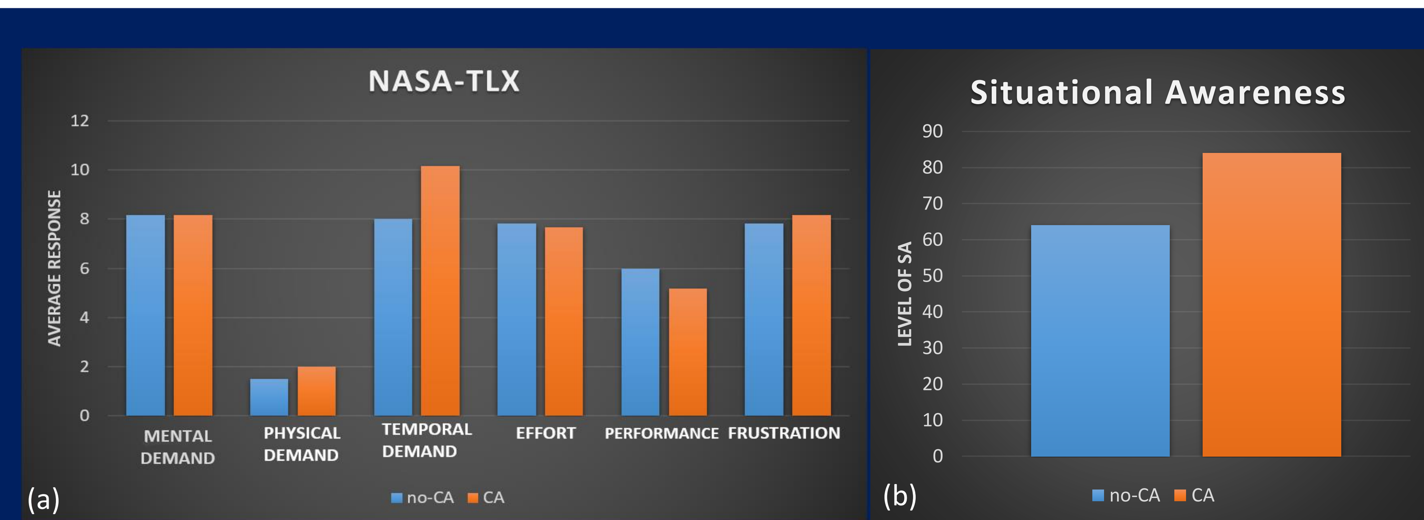

Figure 15. a) Workload analyzed with NASA-TLX, b) situational awareness analyzed with SART.

DV	Hypothesis	Result
Decision-making process	Improvement w/ CA	Partially
Workload	Decreases w/ CA	Not Supported
Situational Awareness	No effect w/ or w/o CA	Supported

Figure 17. Table of dependent variables and result of testing.

Acknowledgements

We would like to thank all participants who provided reviews of the CA prototype during pilot testing sessions. We would also like to thank our mentors Güliz Tokadlı and Dr. Michael Dorneich for their constant support, feedback, and invaluable oversight during the course of the research. The REU 2016 program is funded by National Science Foundation Grant CNS-1461160.