

Predicting Controller Capacity in Supervisory Control of Multiple UAV's

16.899 Introduction to Systems Engineering, October 23rd 2009

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Background

- Goals/Purpose
 - Determine max number of UAVs an operator can successfully control
 - Introduce notion of Wait Time
- Fan-out Equations (1), (2), (3)

$$FO = \frac{NT + IT}{IT} = \frac{NT}{IT} + 1$$

$$WT = \sum_{i=1}^X WTQ_i + \sum_{j=1}^Y WTSA_j \quad (2)$$

$$FO = \frac{NT}{IT(WTI) + WT} + 1 \quad (3)$$



Wait Times

- Wait Time – Interaction (WTI)
 - Time required to comprehend and solve problem, and implement solution
- Wait Time – Queue (WTQ)
 - Time a UAV waits while operator deals with other UAVs
- Wait Time – Situational Awareness (WTSA)
 - Time for an operator to respond to new situations



Levels of Supervisory Control

- Manual
 - Table of text with low-level information
 - Step-by-step control
- Passive
 - Text information graphically represented
 - Timeline control
- Active
 - Passive control graphics
 - Bottleneck recommendations provided
- Super Active
 - Management-by-exception



More accurate description of mission

This cartoon has been removed due to copyright restrictions.



Experimental Setup – Navigation Panel

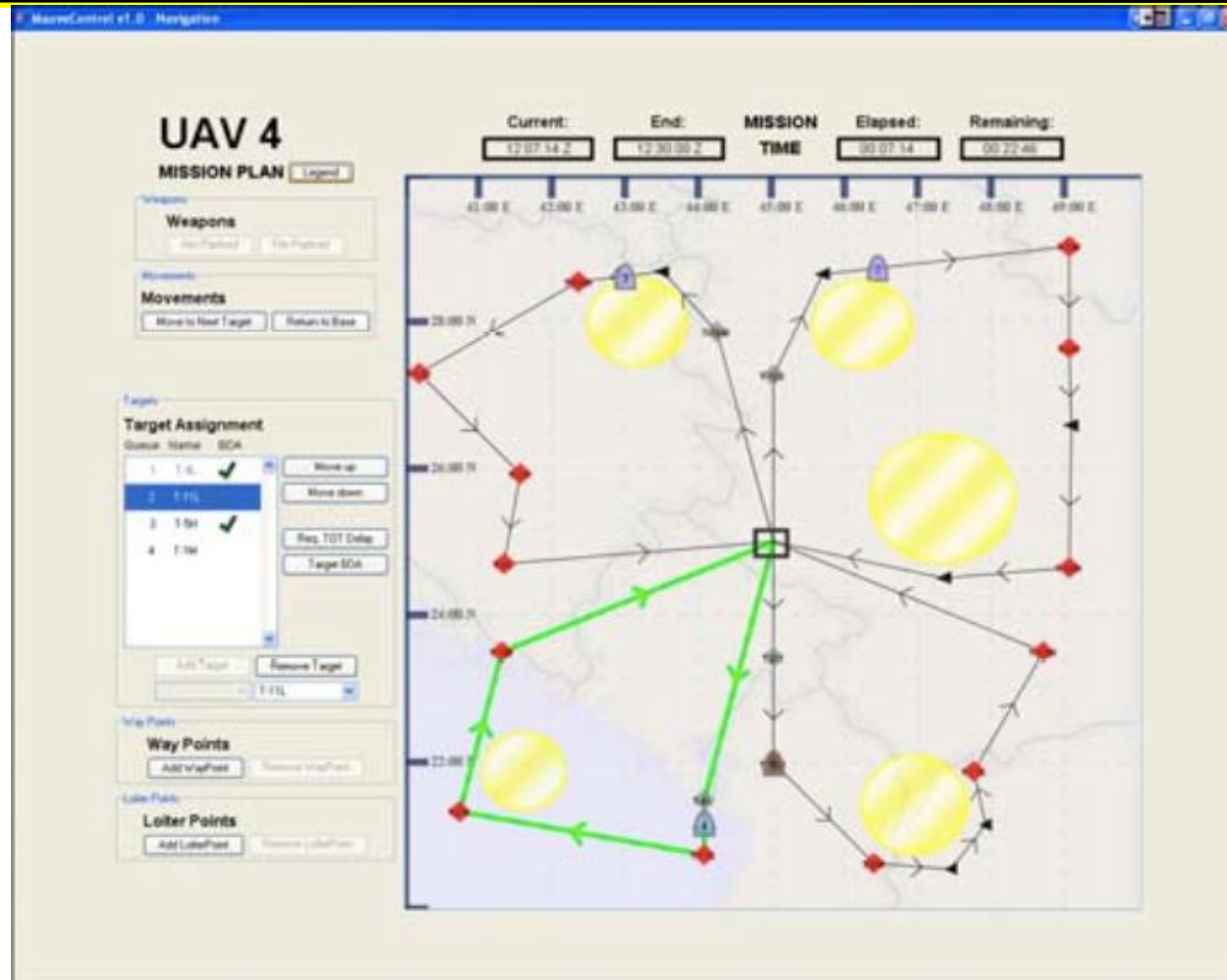


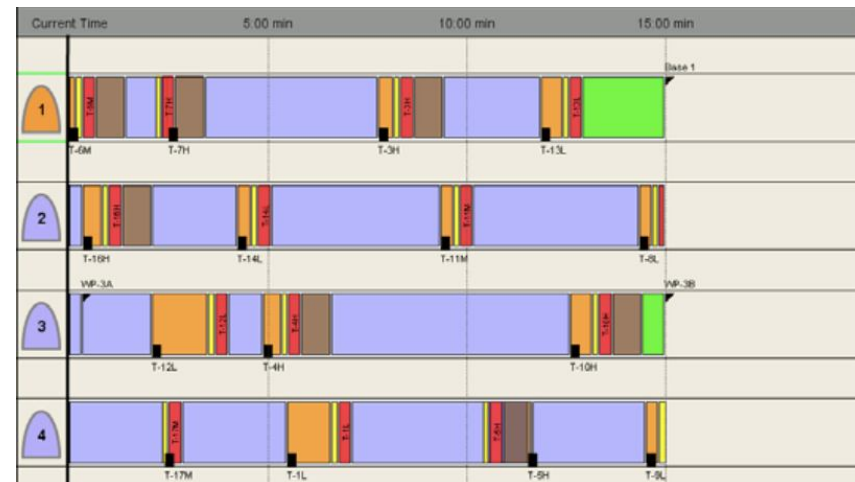
Figure 2 on p. 454 in Cummings, Mary L., and Paul J. Mitchell. "Predicting Controller Capacity in Supervisory Control of Multiple UAVs." *IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans* 38, no. 2 (March 2008): 451-460. © 2008 IEEE.



Experimental Setup – Control Panel

UAV	Current Target TOT / ETA	Next Waypoint or Loiterpoint	Next Expected Action	Upcoming Active Targets TOT / ETA			Mission Finish
1	T-6M 12:05:52Z - 12:06:15Z 12:05:34Z	-	Arming for T-6M 12:05:45 - 12:05:55	T-3H 12:13:55Z - 12:14:15Z 12:13:22Z	T-13L 12:18:10Z - 12:18:30Z 12:17:27Z	-	Base 1 12:23:36Z
2	T-16H 12:08:35Z - 12:08:55Z 12:05:55Z	-	Arming for T-16H 12:06:25 - 12:06:55	T-14L 12:10:30Z - 12:10:40Z 12:09:49Z	T-11M 12:15:25Z - 12:15:45Z 12:14:56Z	T-8L 12:20:25Z - 12:20:45Z 12:19:56Z	Base 1 12:23:00Z
3	T-12L 12:09:15Z - 12:09:35Z 12:07:41Z	WP-3A 12:05:48Z	Arming for T-12L 12:09:05 - 12:09:35	T-4H 12:11:05Z - 12:11:25Z 12:10:26Z	T-10H 12:18:55Z - 12:19:15Z 12:18:11Z	-	Base 1 12:26:19Z
4	T-17M 12:08:05Z - 12:08:25Z 12:07:53Z	WP-4A 12:06:46Z	Arming for T-17M 12:07:55 - 12:08:25	T-1L 12:10:55Z - 12:11:15Z 12:11:04Z	T-5H 12:16:10Z - 12:16:30Z 12:15:42Z	T-9L 12:20:35Z - 12:20:55Z 12:20:06Z	Base 1 12:25:19Z

Manual

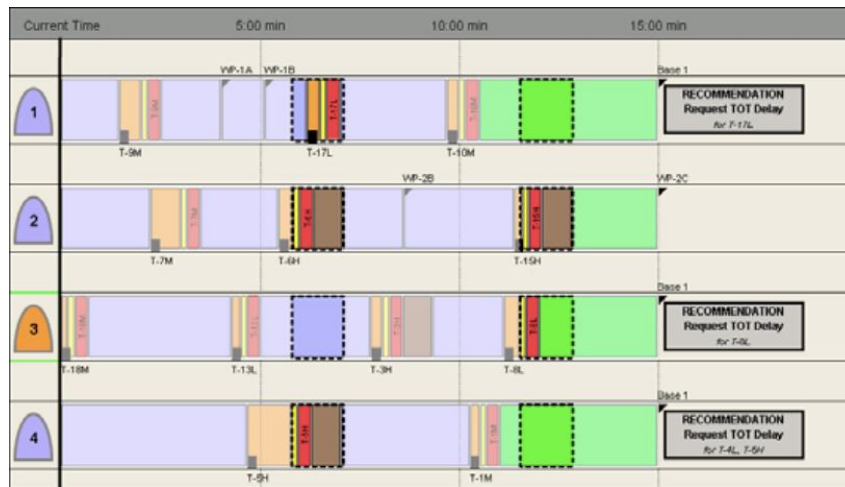


Passive

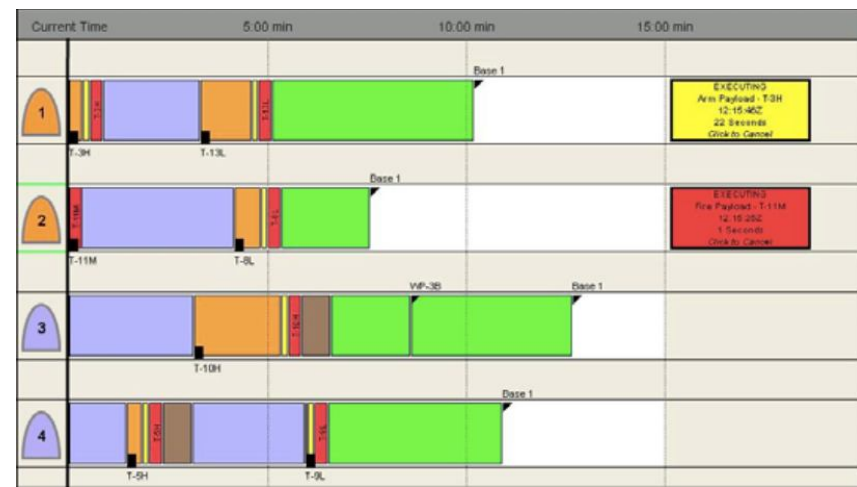
Figure 3 on p. 455 in Cummings, Mary L., and Paul J. Mitchell. "Predicting Controller Capacity in Supervisory Control of Multiple UAVs." *IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans* 38, no. 2 (March 2008): 451-460. © 2008 IEEE.



Experimental Setup – Control Panel



Active



Super Active

Figure 3 on p. 455 in Cummings, Mary L., and Paul J. Mitchell. "Predicting Controller Capacity in Supervisory Control of Multiple UAVs." *IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans* 38, no. 2 (March 2008): 451-460. © 2008 IEEE.



Experimental Setup – Design

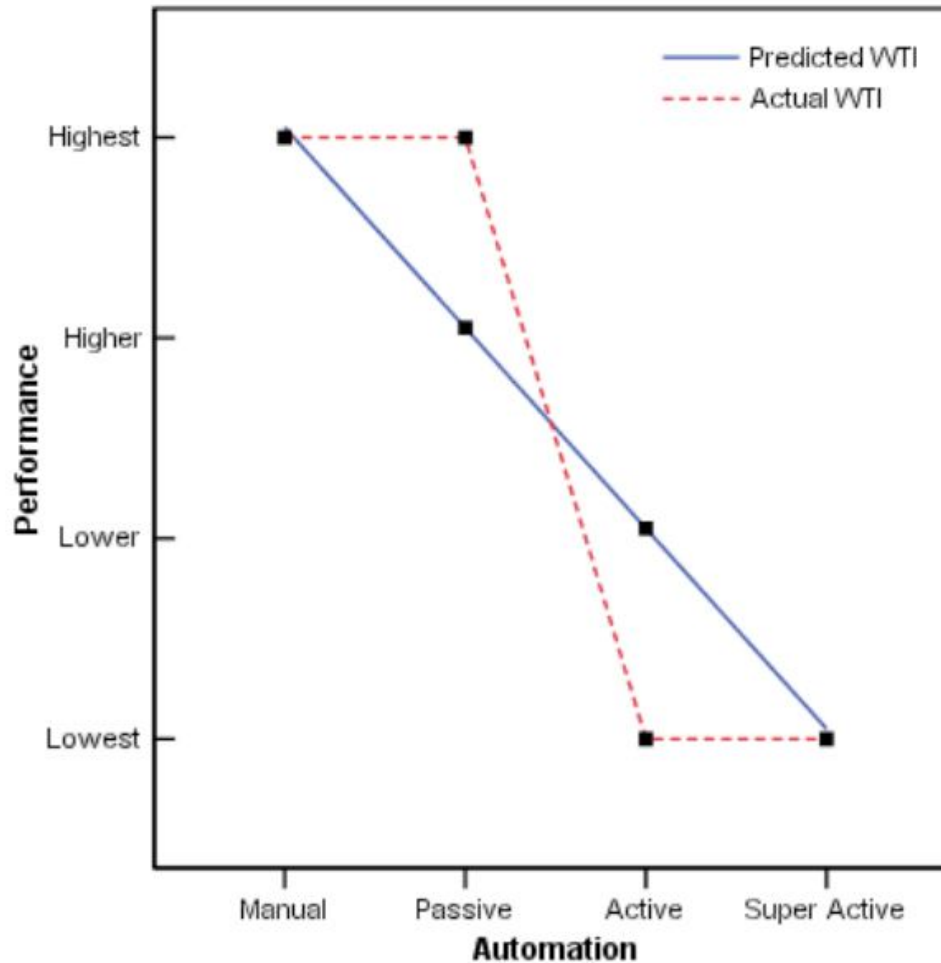
- 12 test subjects
 - 9 were pilots
 - 2 were women
 - Average age: 26.3
 - Divided into 4 groups of 3

	Manual	Passive	Active	Super Active
Low Workload	Group 1	Group 2	Group 3	Group 4
High Workload	Group 1	Group 2	Group 3	Group 4

- \$10/hour, \$50 incentive for best performance



Results - WTI

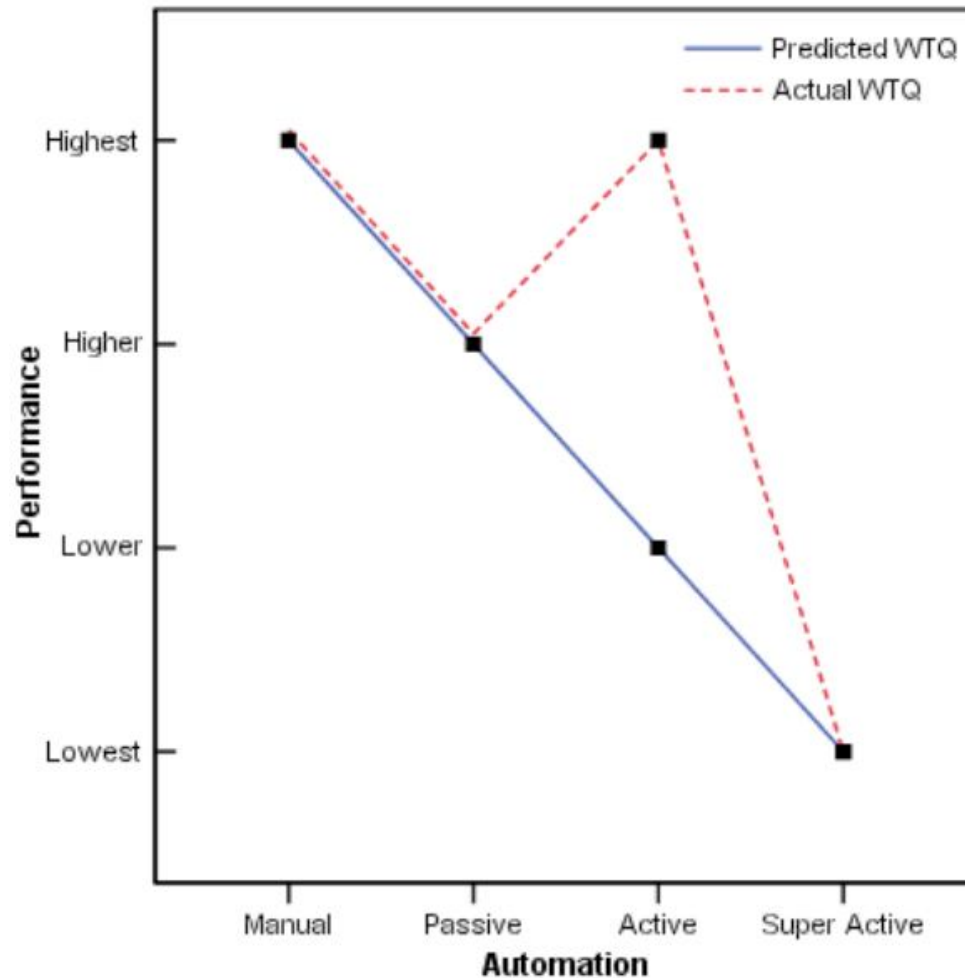


WT = Wait Time to Interaction

Figure 5 on p. 458 in Cummings, Mary L., and Paul J. Mitchell. "Predicting Controller Capacity in Supervisory Control of Multiple UAVs." *IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans* 38, no. 2 (March 2008): 451-460. © 2008 IEEE.



Results - WTQ

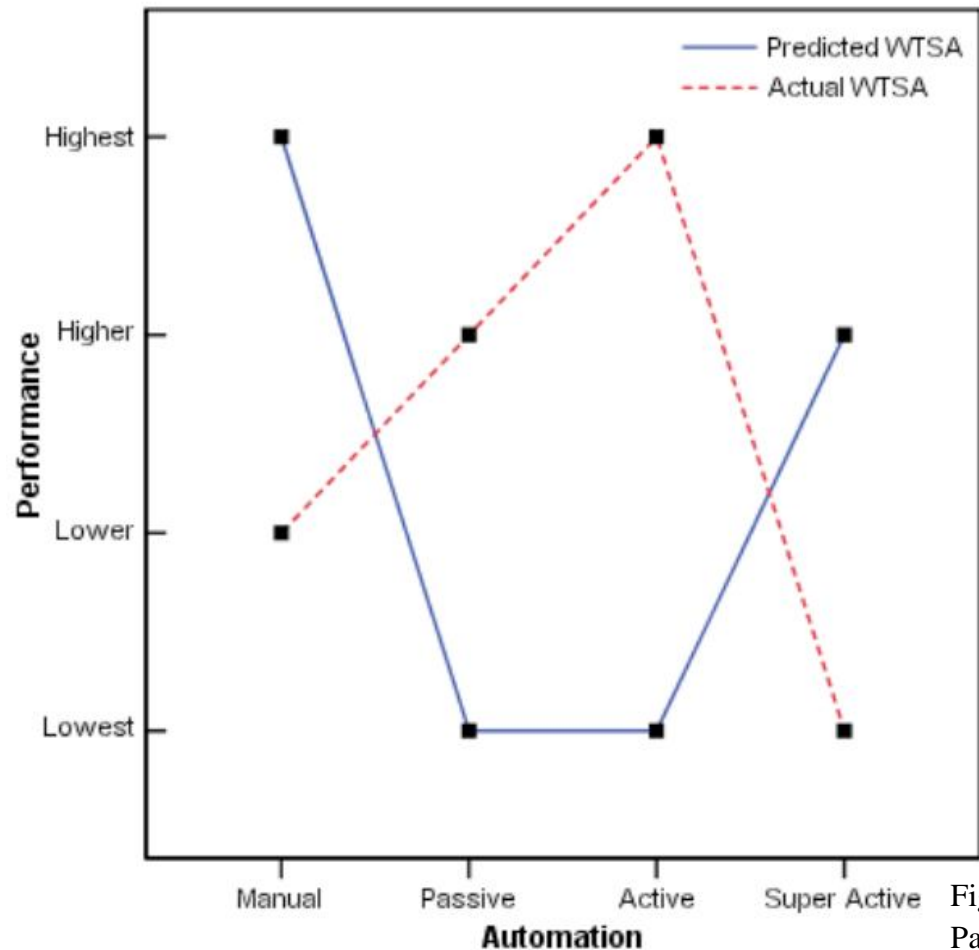


WTQ = Wait Time in the human decision-making queue

Figure 6 on p. 458 in Cummings, Mary L., and Paul J. Mitchell. "Predicting Controller Capacity in Supervisory Control of Multiple UAVs." *IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans* 38, no. 2 (March 2008): 451-460. © 2008 IEEE.



Results - WTSA



WTSA = Wait Time Due to Loss of Situation Awareness

Figure 7 on p. 458 in Cummings, Mary L., and Paul J. Mitchell. "Predicting Controller Capacity in Supervisory Control of Multiple UAVs." *IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans* 38, no. 2 (March 2008): 451-460. © 2008 IEEE.



Results – Fanout

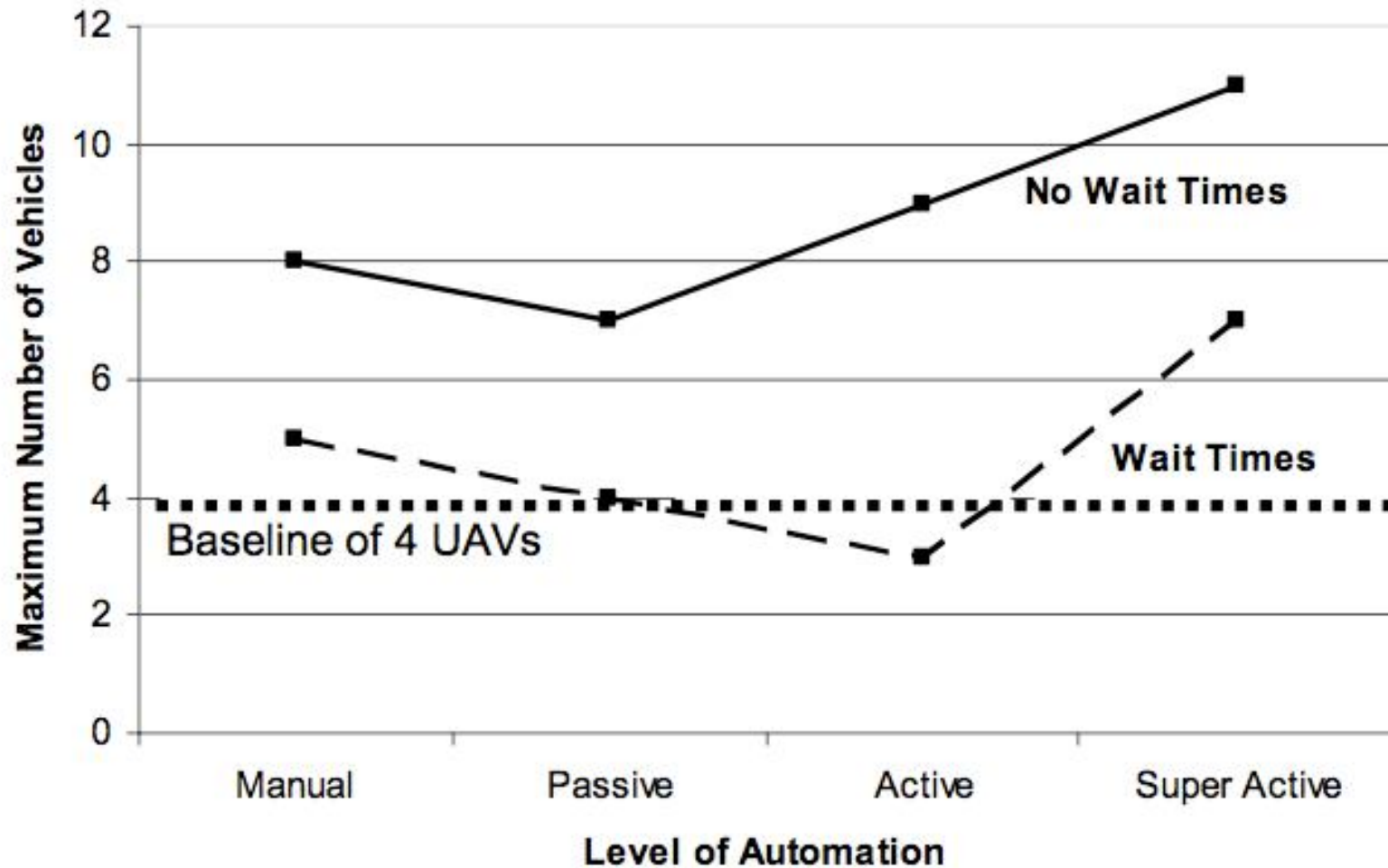


Figure 9 on p. 459 in Cummings, Mary L., and Paul J. Mitchell.

“Predicting Controller Capacity in Supervisory Control of Multiple UAVs.”

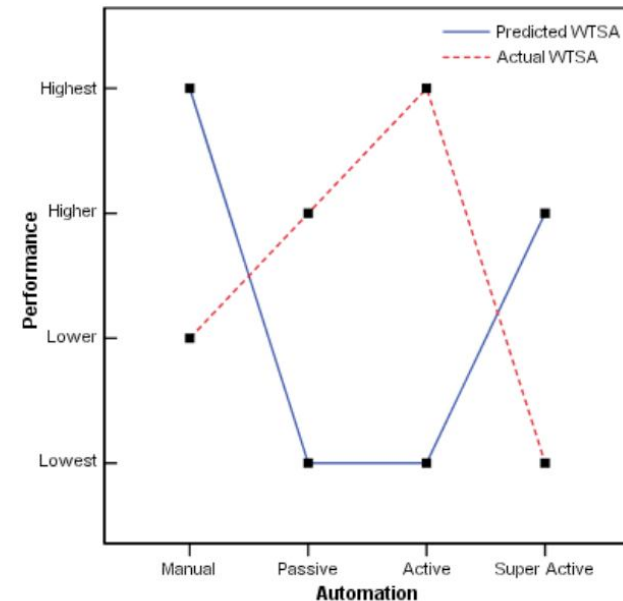
IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans 38,
no. 2 (March 2008): 451-460. © 2008 IEEE.



Discussion

- Are there any analogs to other areas? Example: Personnel Management
- How do you account for the Wait Time phenomenon in a human-in-the-loop design?
- How valid is this experiment given the small sample size?
- How does complacency (WTSA) vary with training/total operating time/familiarity?
- Should a system architect specify a system that has an operator at 100% capacity? If not, why not and what level?
- Do you think the author confused WTSA with WTCR when the hypothesis for Manual Control was formed?

Figure 7 on p. 458 in Cummings, Mary L., and Paul J. Mitchell. "Predicting Controller Capacity in Supervisory Control of Multiple UAVs." *IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans* 38, no. 2 (March 2008): 451-460. © 2008 IEEE.





Discussion

- What is your opinion of the Request TOT function? Is it something that is useful and something you would use?
- How does the time dilation affect the results of the experiment?
- Do you feel there can be modifications to Figure 1?

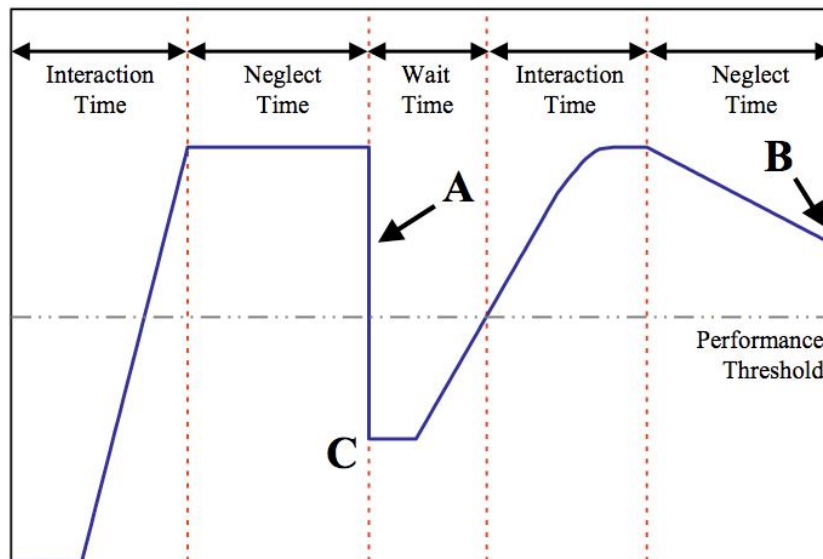


Figure 1 on p. 452 in Cummings, Mary L., and Paul J. Mitchell. "Predicting Controller Capacity in Supervisory Control of Multiple UAVs." *IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans* 38, no. 2 (March 2008): 451-460. © 2008 IEEE.

- How would one measure WTCR and differentiate it from WTI?
- How does this paper compare to what is taught in the Human Factors course?



Reference

- Predicting Controller Capacity in Supervisory Control of Multiple UAVs, M.L. Cummings, *Member, IEEE, and P.J. Mitchell*

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