Impact of Missing Information and Strategy on Decision Making Performance

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What are denied and degraded environments, and why do we care?

Example: a disaster relief planner is making decisions about resource and personnel allocation during a hurricane. Storm projections are being constantly updated, local resource stations are losing power and therefore communication, and personnel are being stranded by flood waters and debris

- Decision making does not always happen in perfect environments with perfect information
- Information processing can be restricted both artificially (time constraints, lack of expertise, too much information) or literally (hostile interference, loss of fidelity, etc.)
- In these situations, experts utilize heuristics to focus in on important information and make decisions in narrowed timeframes

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How do we define information distributions in our research?

	C1	C2	C3	C4
A	100	60	?	70
B	50	?	10	80

Total Information

How many total pieces of information are known across *all* targets. Thought to be a key predictor of decision performance[1,2]. In the above case we can see this is 6.

	C1	C2	C3	C4
A	100	?	?	70
B	50	?	?	80

Cue Balance

Occurs when some piece of information is known across targets. Sometimes referred to as Complete Attribute Pairs. In the example above, this is 2.

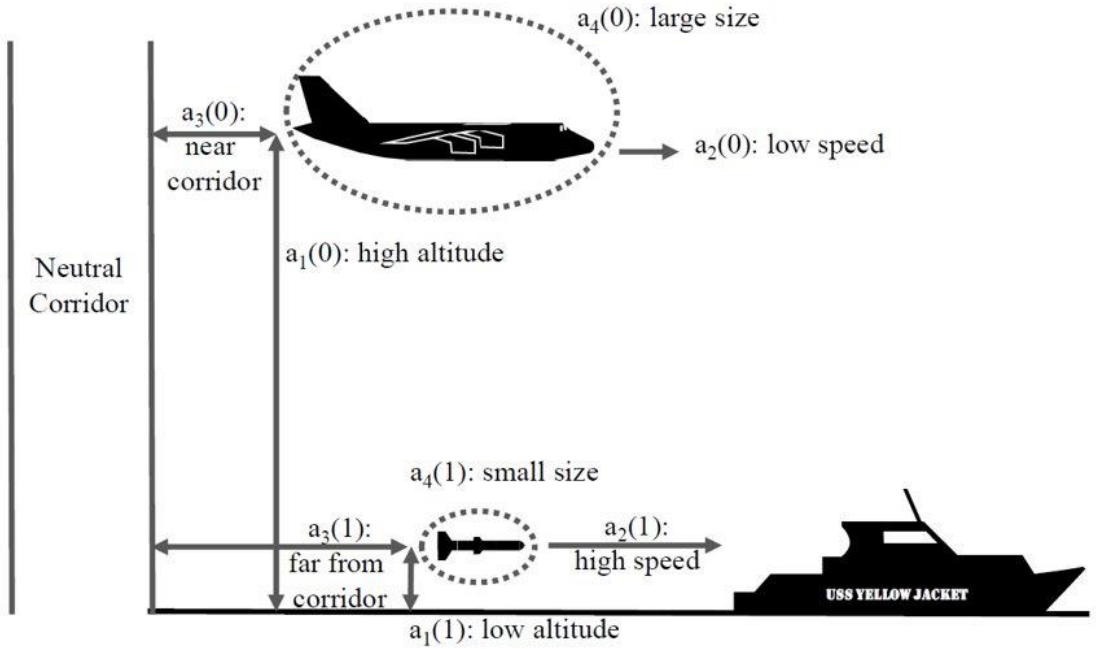
	C1	C2	C3	C4
A	100	?	25	70
B	?	?	?	80

Information Imbalance

The absence of cue balance. Occurs when some piece of information is only known for *one* target. In the example above, this is 2 as well.

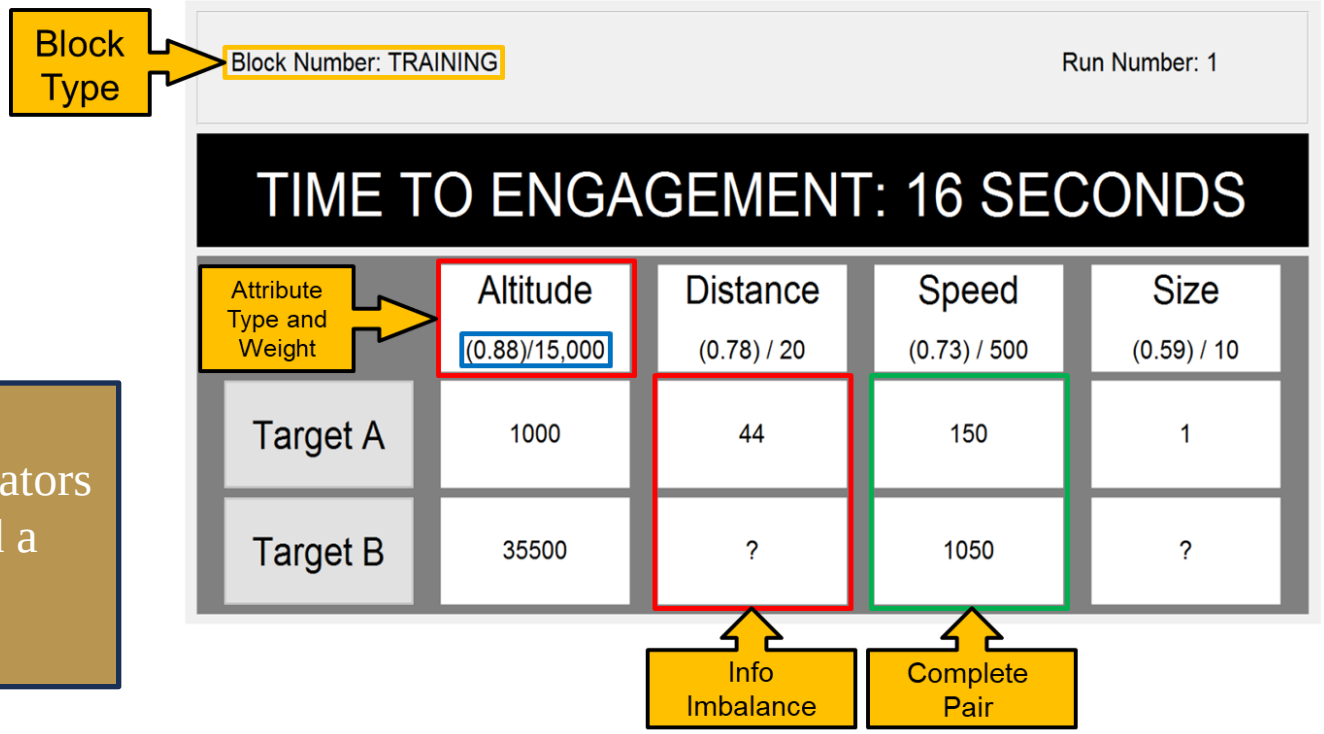
[1]Martignon and Hoffrage, 2002,
[2]Garcia-Retamero and Rieskamp, 2008

Environment Design



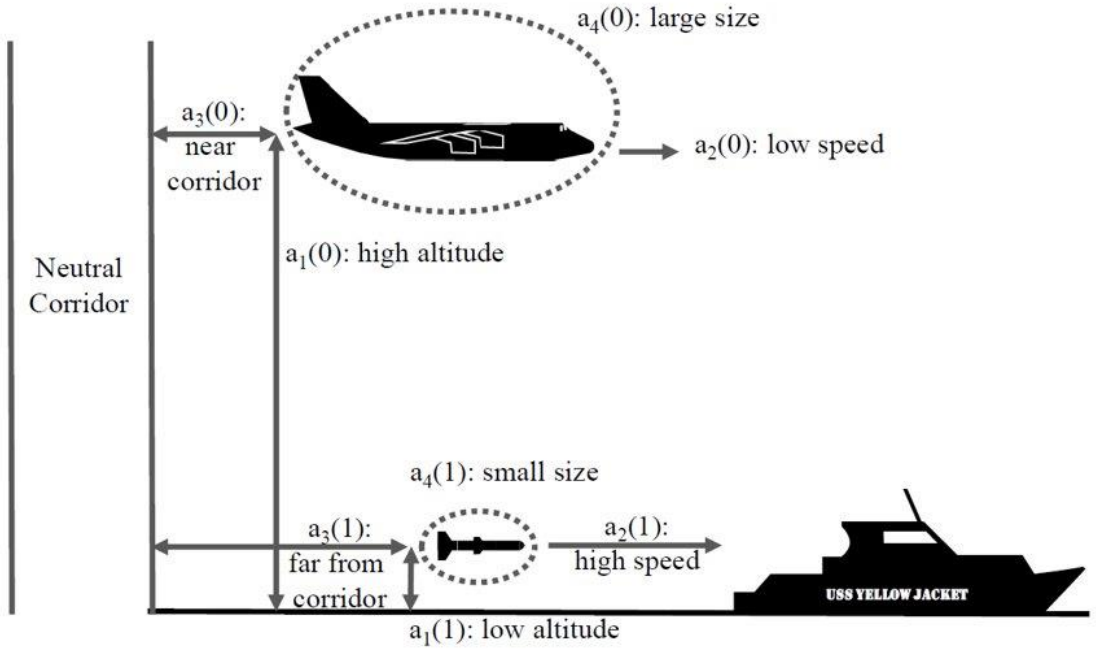
Time pressure and incomplete information formed the denied and degraded environment. Participants were briefed on which option attributes (altitude, speed, etc.) were more or less important to judging hostility.

30 participants were tasked as anti-aircraft warfare coordinators to select between two targets after deciding which posed a greater threat to their ship.



Exemplar Targets

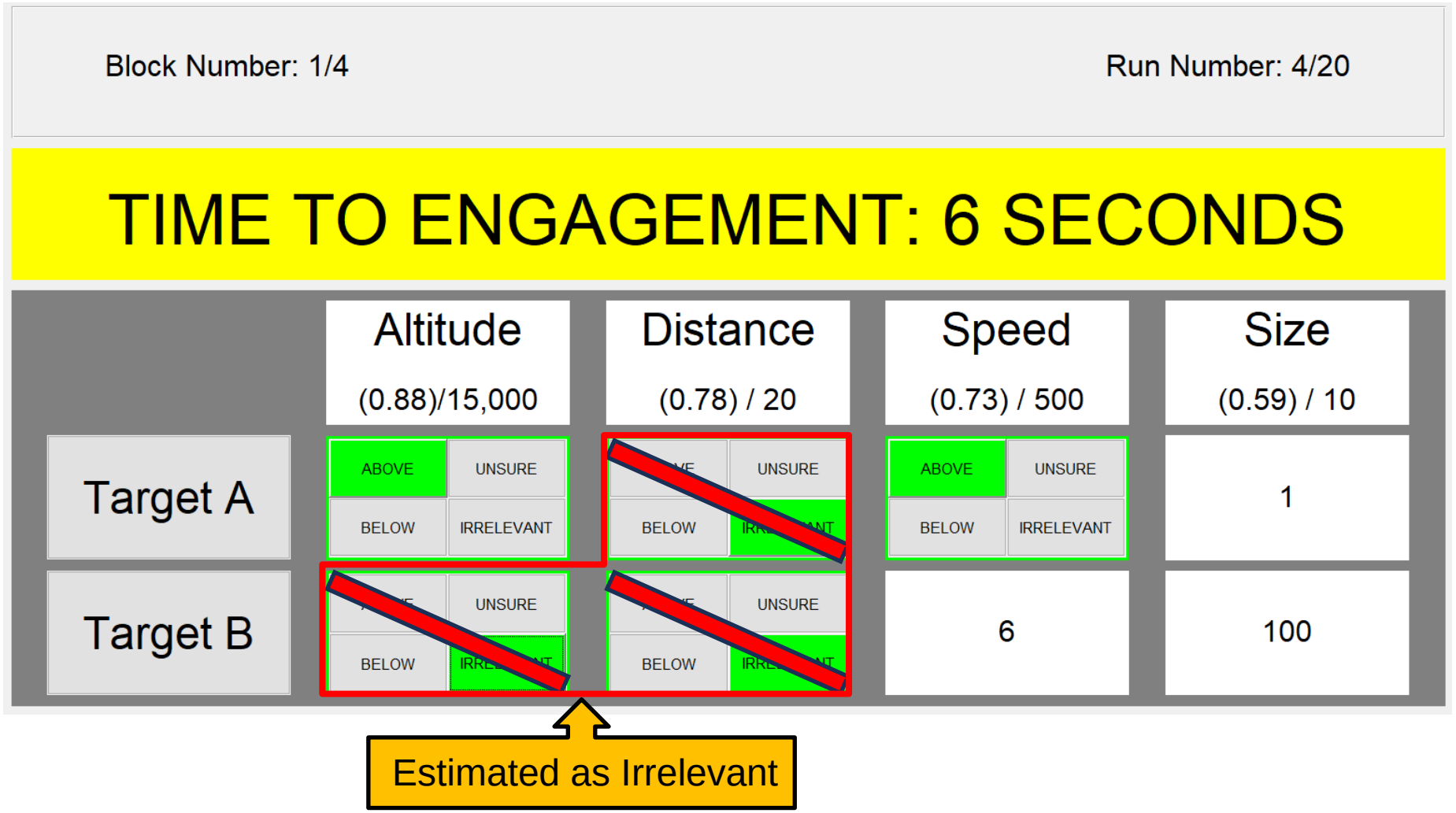
$$C = (0.6 \cdot a_1 + 0.3 \cdot a_2 + 0.1 \cdot a_4) \cdot (0.3 + 0.7 \cdot a_3)$$



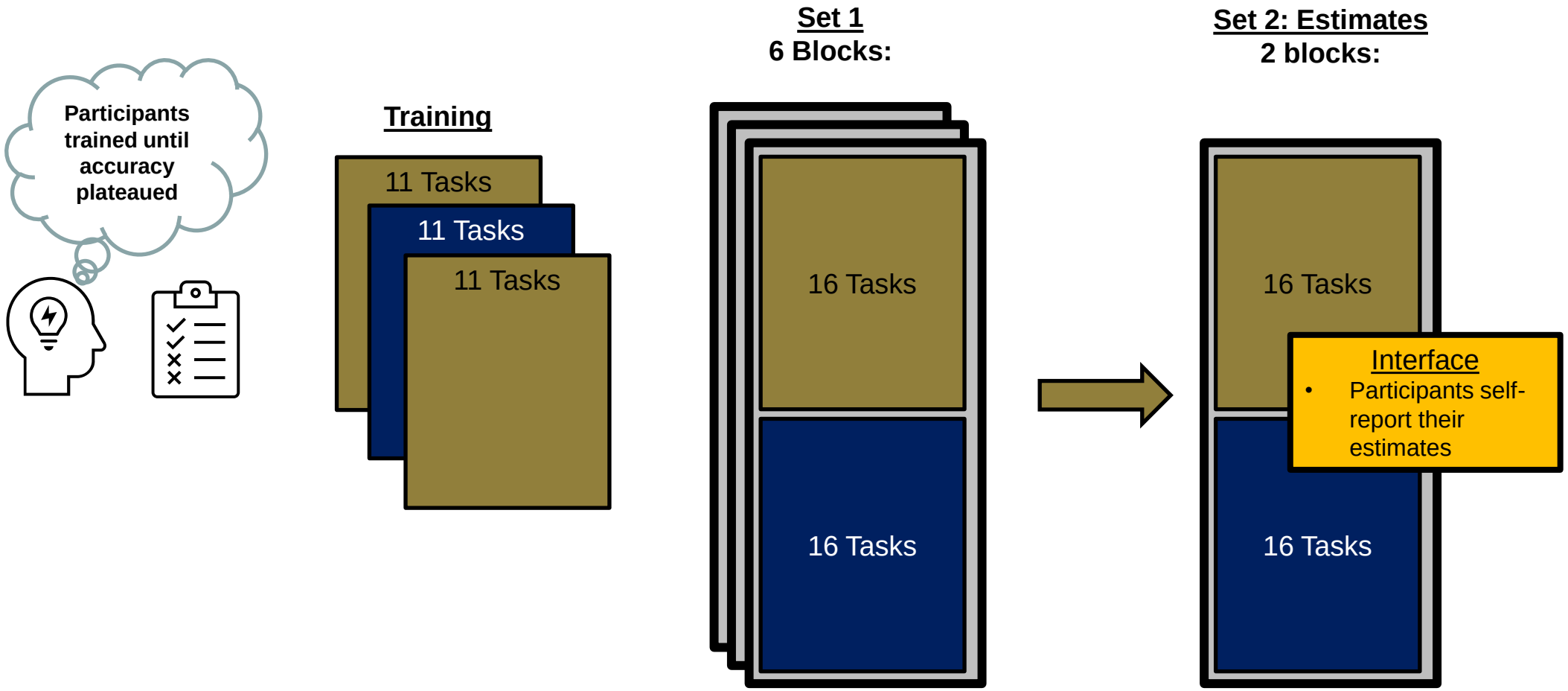
- Target: ***Missile***
  - Low Altitude (a_1=1)
  - High Speed (a_2=1)
  - Far from the Neutral Corridor (a_3=1)
  - Small Size (a_4=1)
- Target: ***Non-military aircraft***
  - High Altitude (a_1=0)
  - Low Speed (a_2=0)
  - Close to the Neutral Corridor (a_3=0)
  - Large Size (a_4=0)

Estimation Elicitation

- Eliciting direct participant feedback on estimates for missing information
- Allow for 4 estimates:
  - Above threshold
  - Below threshold
  - Irrelevant
  - Unsure
- Must provide estimates before making a decision

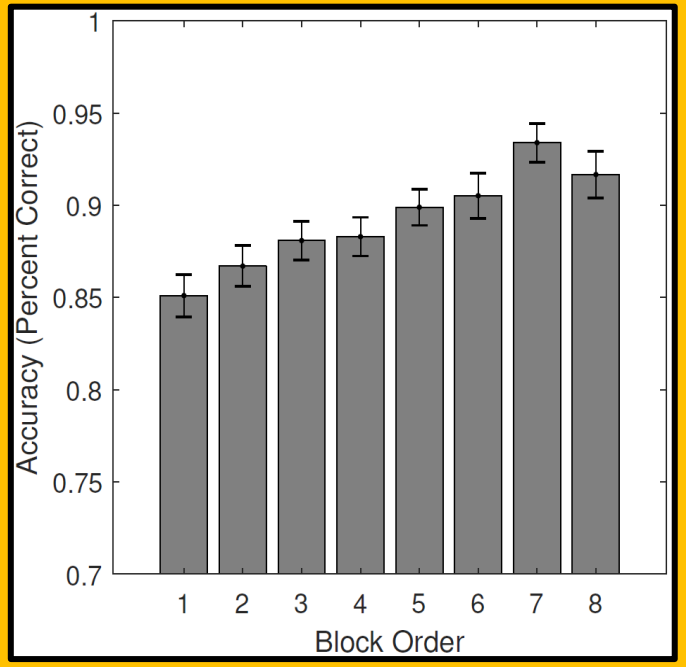


Task Design

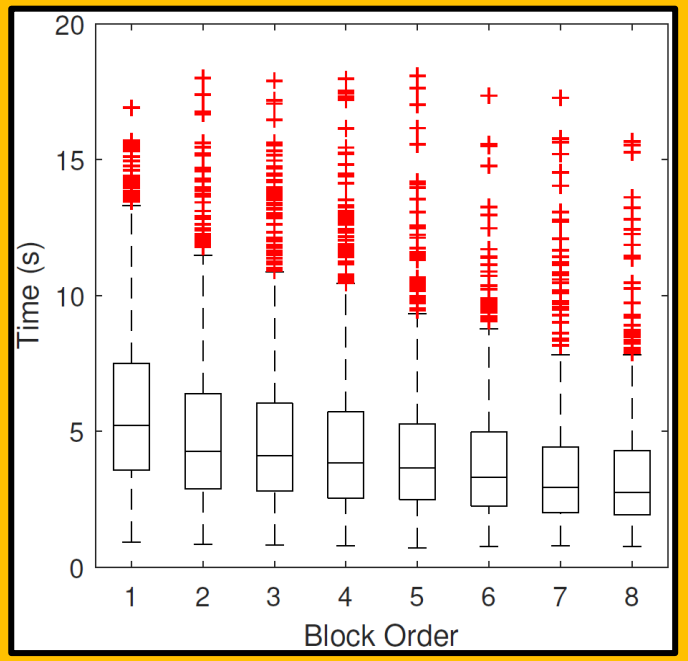

Participants trained until accuracy plateaued
Training
11 Tasks
11 Tasks
11 Tasks
Set 1
6 Blocks:
16 Tasks
16 Tasks
Set 2: Estimates
2 blocks:
16 Tasks
16 Tasks
Interface
• Participants self-report their estimates

Block order did have a significant effect on both accuracy and decision speed ($\alpha < 0.0001$)

Block Order independent of participant. BO 1 is data for every participant's *first* block



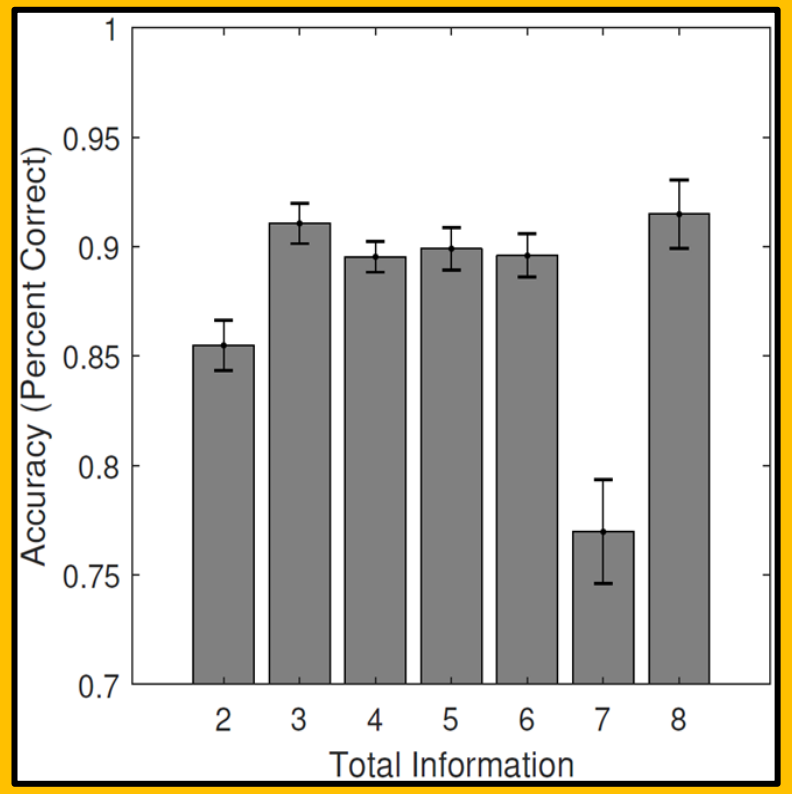
Accuracy



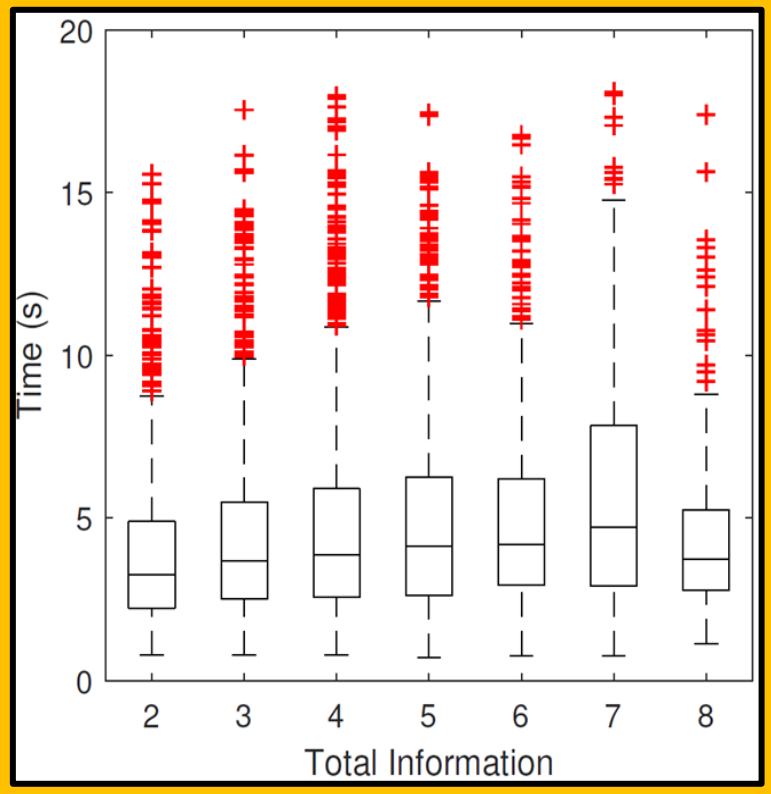
Time

Major Results Summary

Total Information had significant effect on both accuracy ($\alpha < 0.0001$) and decision speed ($\alpha < 0.0001$)



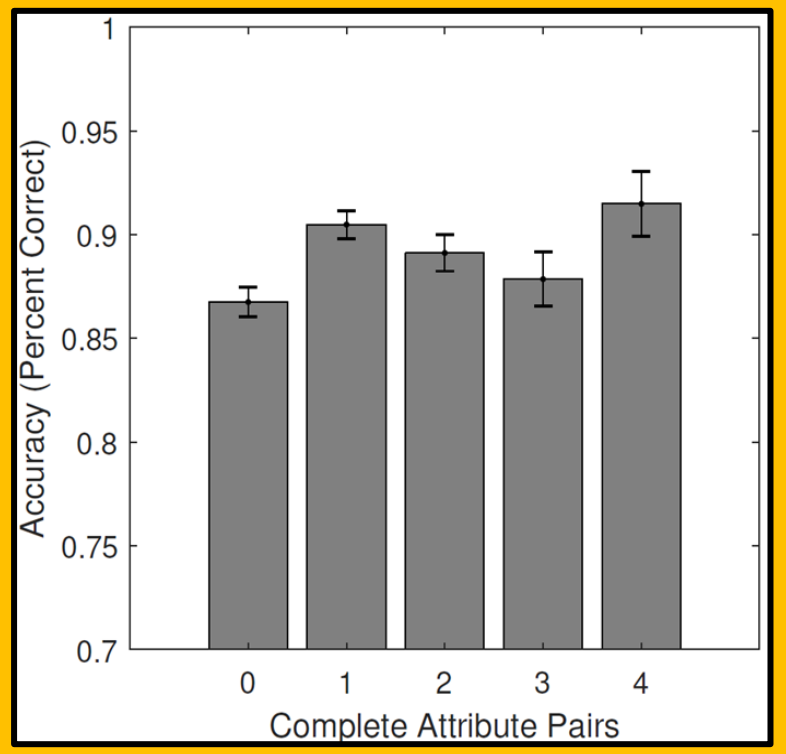
Accuracy



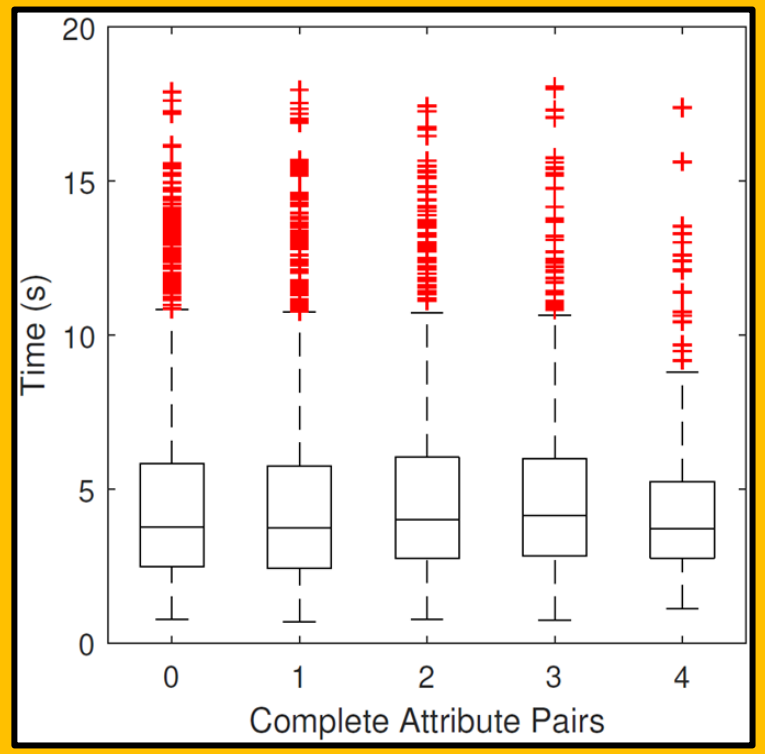
Time

Major Results Summary

Complete Attribute Pairs had significant effect on accuracy ($\alpha < 0.0004$) and time ($\alpha < 0.0002$)

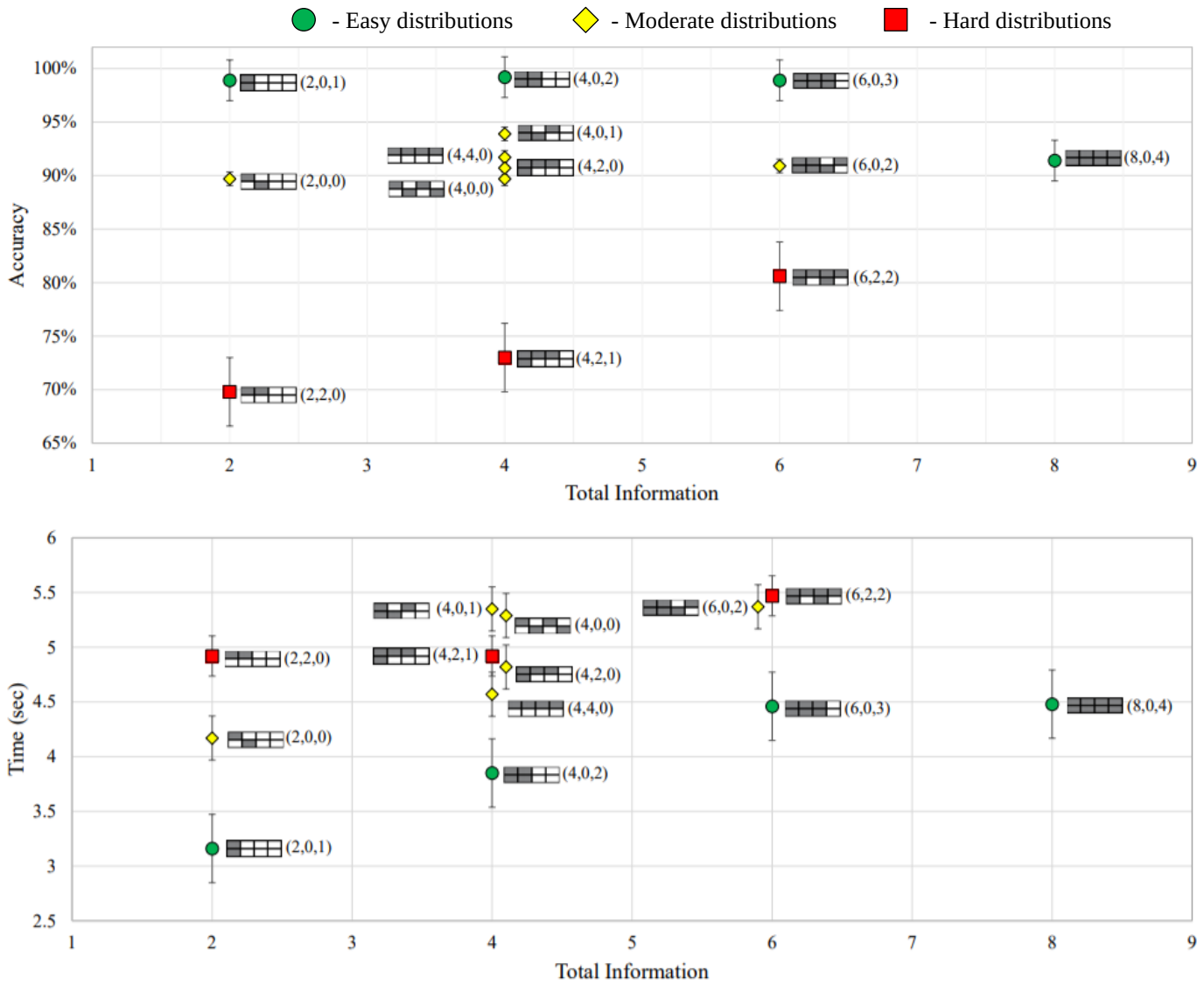


Accuracy



Time

Summary of Results



Easy tasks
- CAP maximized
- Highest accuracy and fastest reaction time

Moderate tasks
- Higher information imbalance
- Lower accuracy and slower response times

Hard tasks
- Maximized information imbalance
- Lowest accuracy, often slowest reaction times

Interestingly, we see an increase in accuracy with total information on hard tasks, and a decrease in accuracy in the easy tasks.

User Estimate Analysis

How are participants treating missing information?

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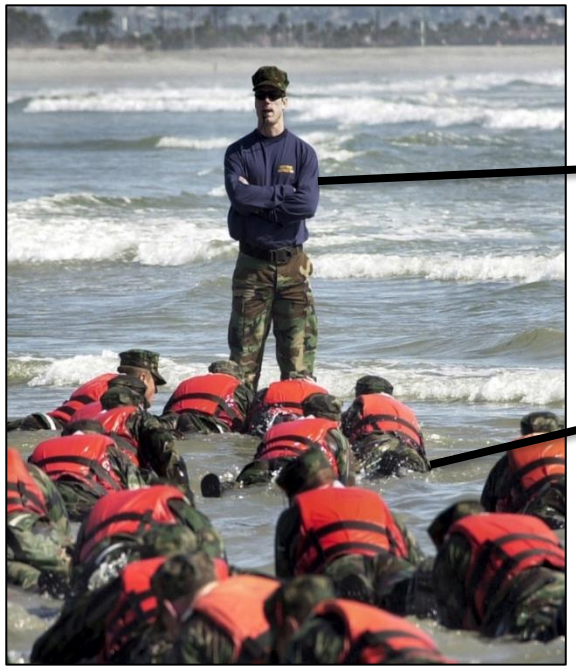
What we expect: High and Low Performers



Experts operate on aggregate knowledge gained over their careers interacting in the decision environment. Novices must weigh decisions in greater depth.

Experts tend to use naturalistic heuristics (fewer, more important cues)[3,4]

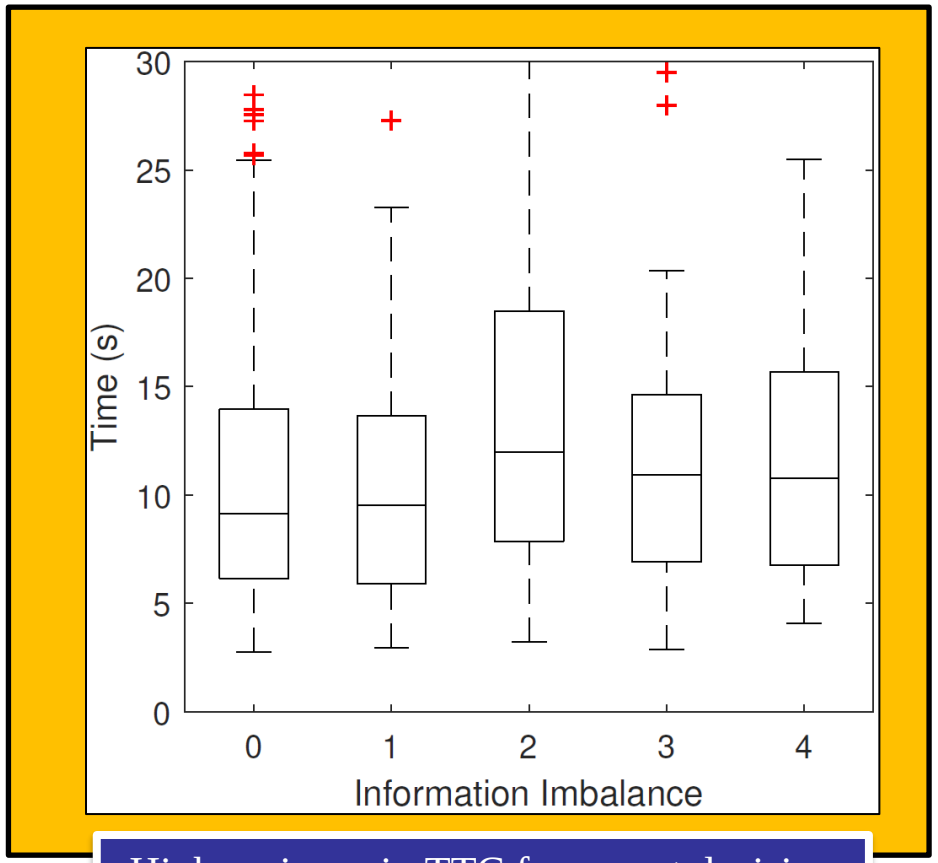
Novices tend to use normative and analytic strategies (more, less important cues)[3,4]

Expect to see novices weighing all possible information and experts operating on only important information (i.e. using only the information required to come to a correct decision)

[3]Gigerenzer and Gaissmaier, 2011
[4]Todd et al., 2012

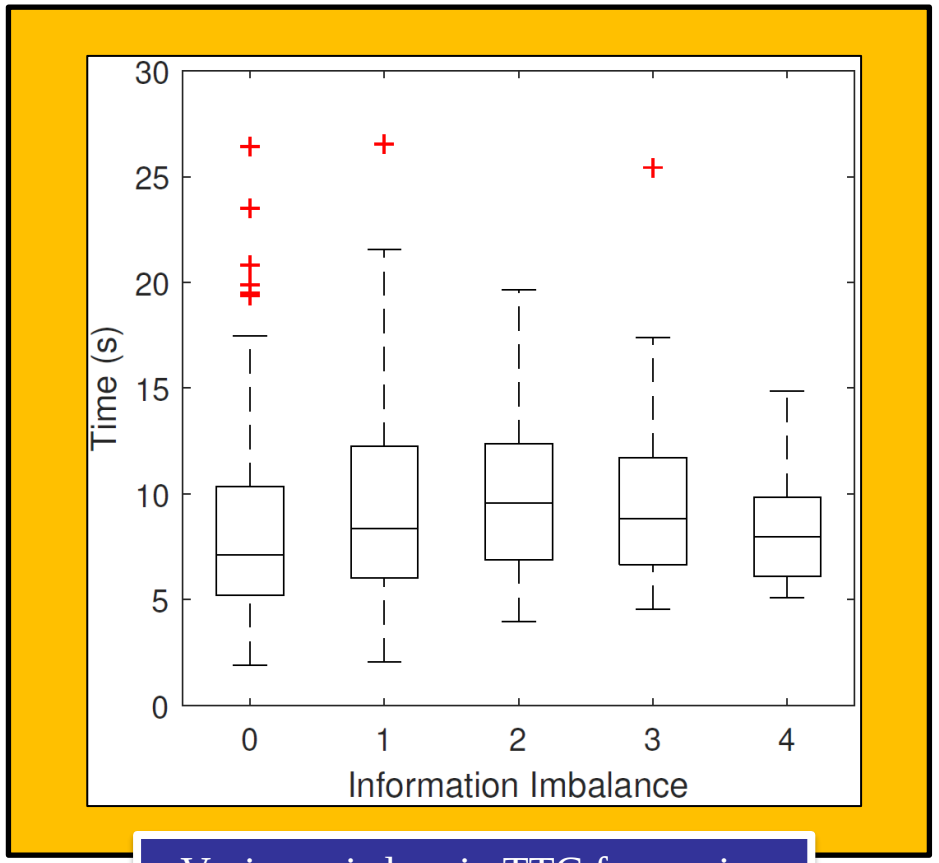
Decision Speed Variance – Information Imbalance

High Accuracy Decision Makers [Top 10%]



High variance in TTC for expert decision makers suggests they are adapting to task conditions as they go.

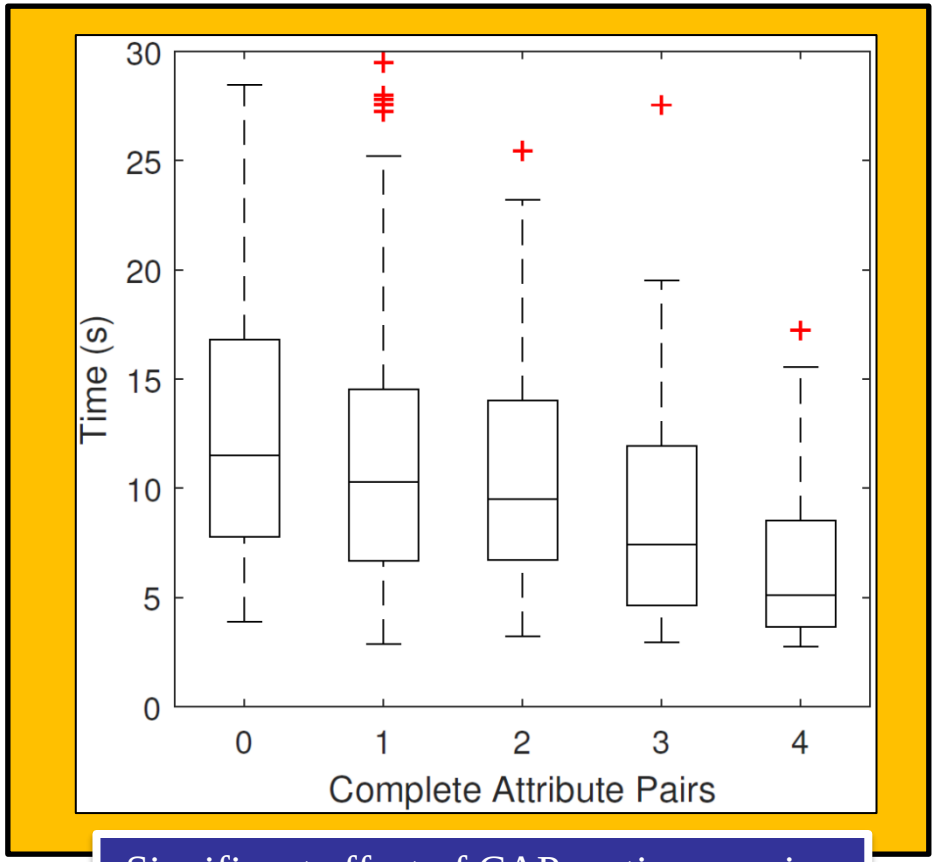
Low Accuracy Decision Makers [Bottom 10%]



Variance is low in TTC for novice decision makers. They are repeating the same analytic strategies.

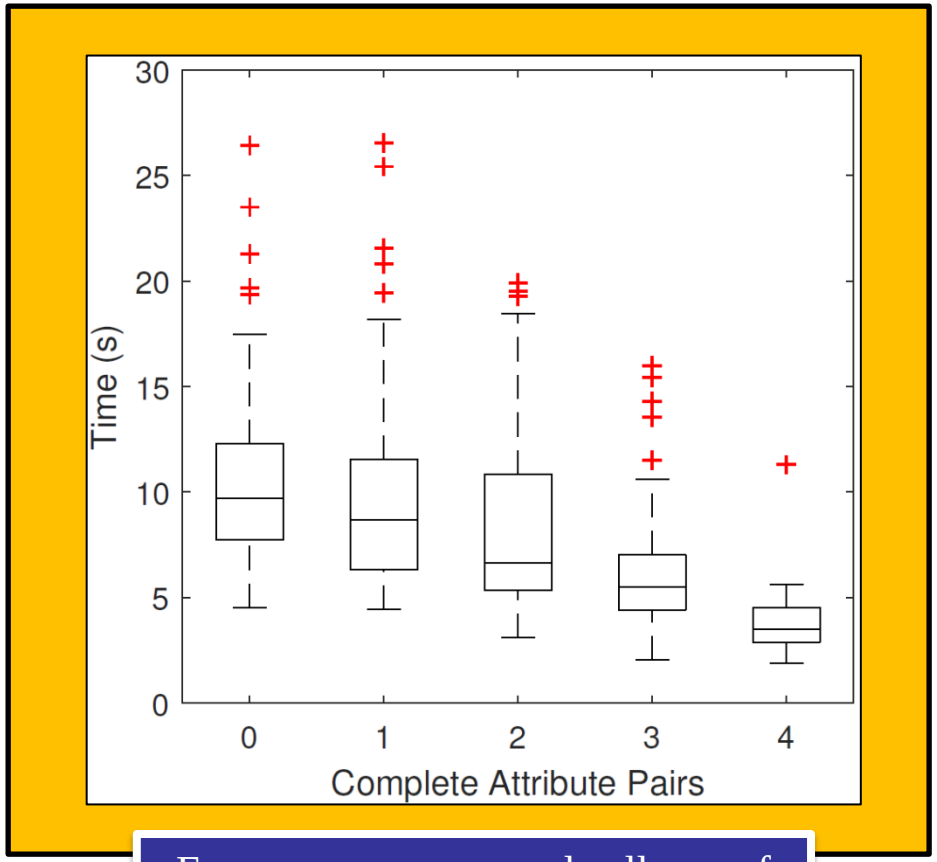
Decision Speed Variance – Complete Attribute Pairs

High Accuracy Decision Makers [Top 10%]



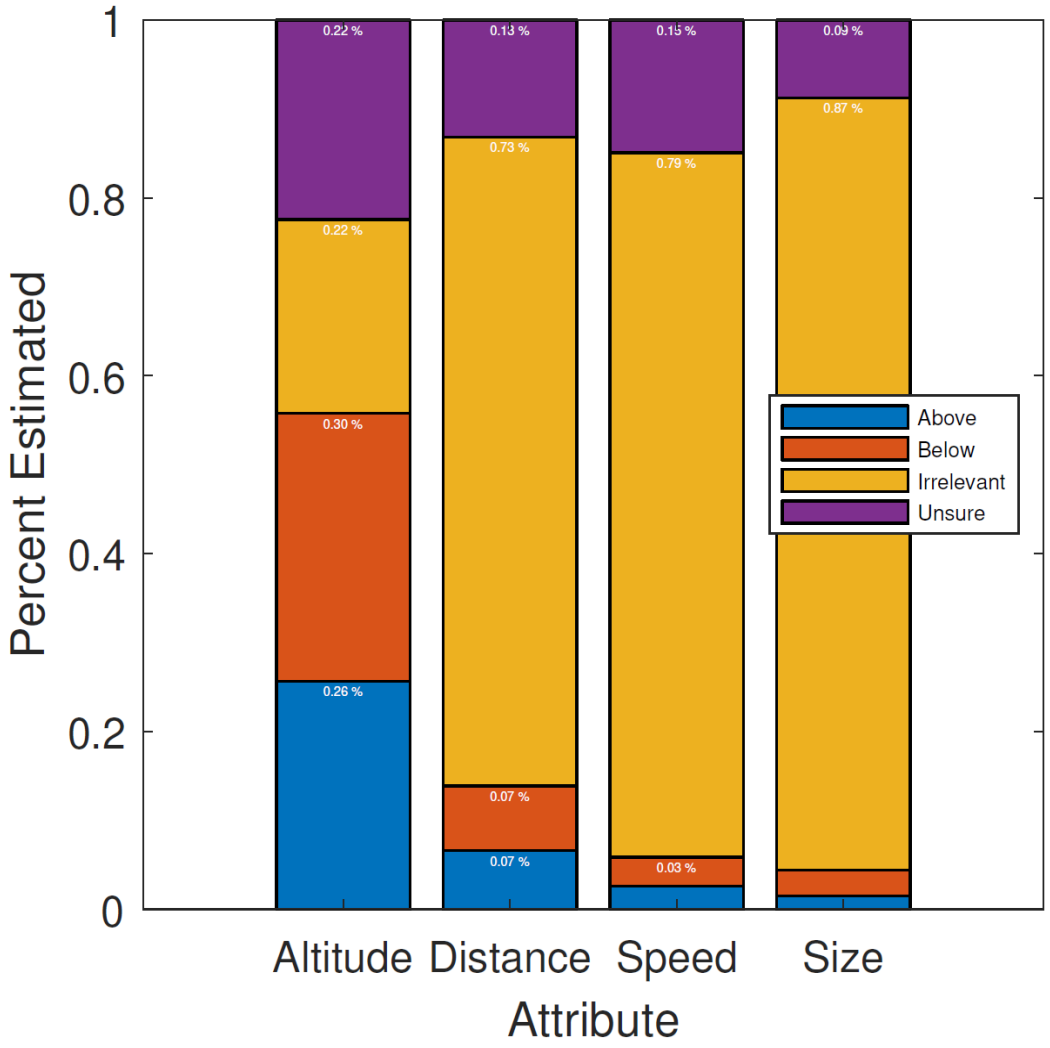
Significant effect of CAP on time coming from function of new interface. High variance still seen for experts.

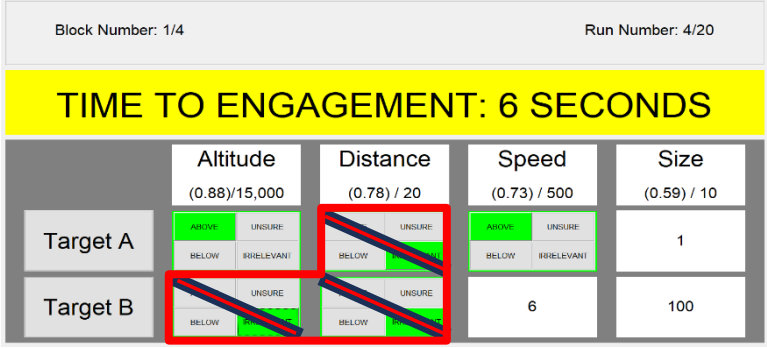
Low Accuracy Decision Makers [Bottom 10%]



Even more pronounced collapse of variance between experts and novices seen.

High Accuracy Performance

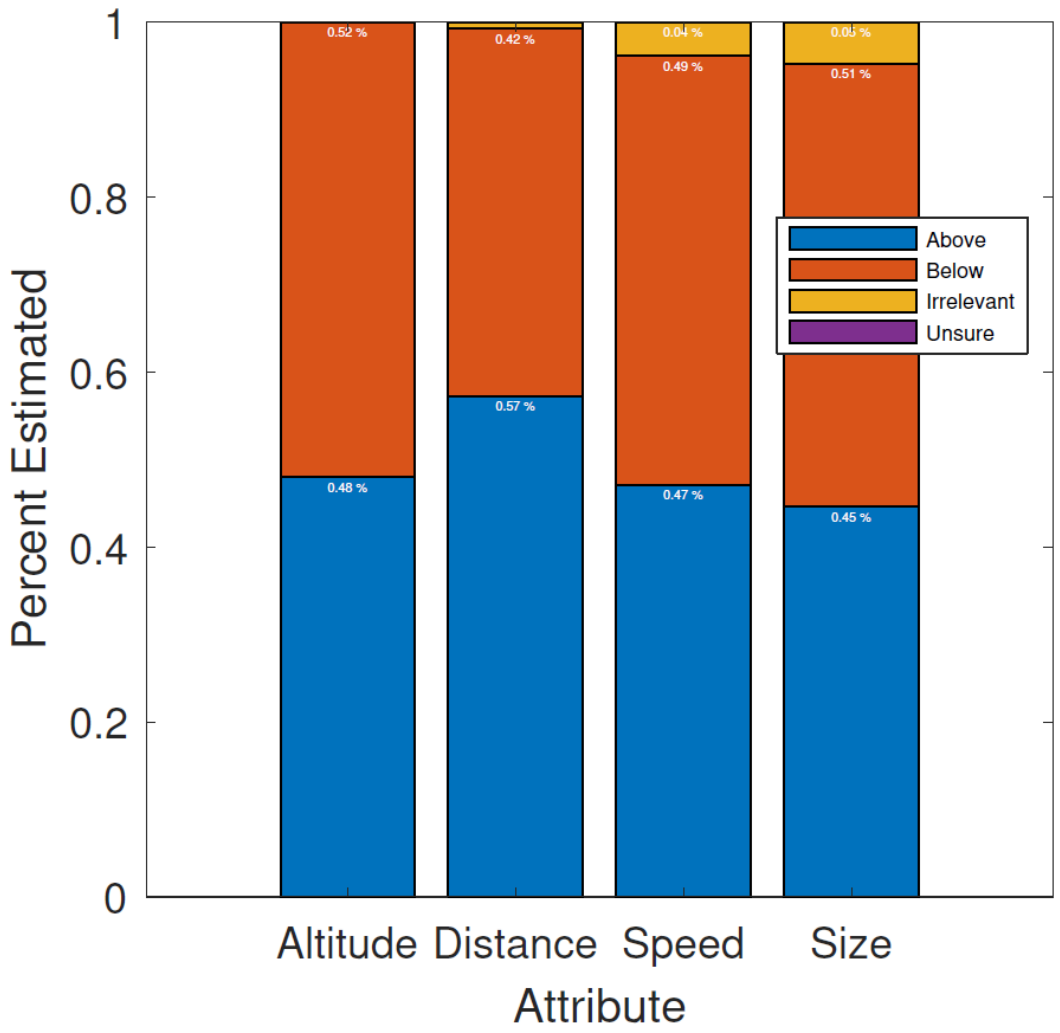


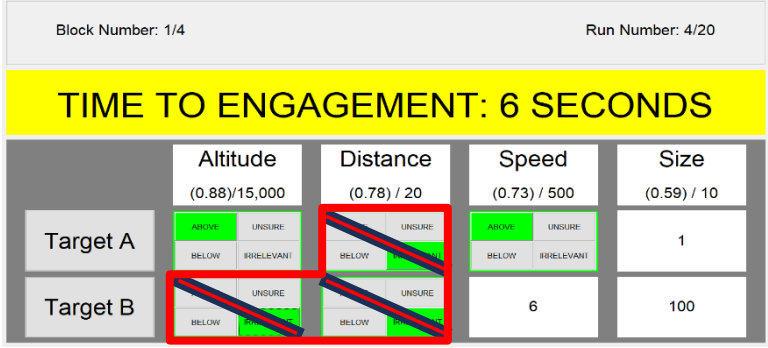


- High Performing Decision Maker
  - Consistently ignore lower valued attributes
  - Estimated information in order of rank-importance for the attributes

Trend seen across the board with high-accuracy users. Supports the idea that removing irrelevant or low-ranked information from the environment to simulate heuristic decision making may be effective.

Low Accuracy Performance





- Low Accuracy Decision Maker
  - Estimates missing information for **almost all** tasks
  - All information estimated for the highest valued attribute

Trend seen across the board with low-accuracy users. The decision maker is balancing too much information and employing an analytic decision process. Even with accurate estimates of missing information, performance suffers under time pressure.

Performance Summary

Good Accuracy
"Experts"
[0.9-0.97%]

High variance in TTC values

Use of heuristic strategy. Often skips irrelevant information (*TTB*)

Total Accuracy (%)	~Time To Choose (s)	Variance in TTC
0.97	8	High
0.93	11	High
0.9	10	High
0.85	7.5	Low
0.83	8	Low
0.8	8	Low

Poor Accuracy
"Novices"
[0.79-0.85%]

Low variance in TTC values

Almost always estimates all missing information (*Analytic - WADD*)

TTC doesn't explicitly classify a high performing decision maker, but the time variance across the tasks indicates that they adapt to the difficulty of the task while low performers are comparatively static decision makers.

Summary of Results

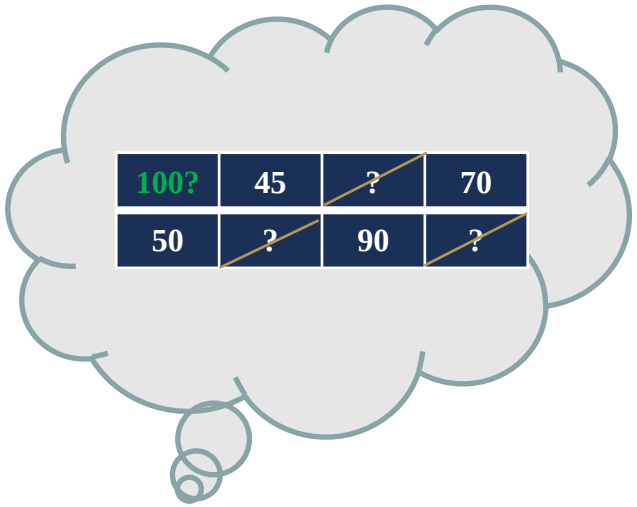
- **Decreasing incomplete information** and **increasing complete attribute pairs** in denied and degraded information environments increases accuracy

100	?	?	70
50	?	?	80

>

?	45	?	70
50	?	90	?

- **Distributions of incomplete information** and **estimation of missing information** are **not enough** to fully understand human performance in these environments
  - **Decision strategy is a key differentiator** in user performance. **Heuristic decision makers outperformed analytic decision makers** and tended to better adapt to task difficulty.



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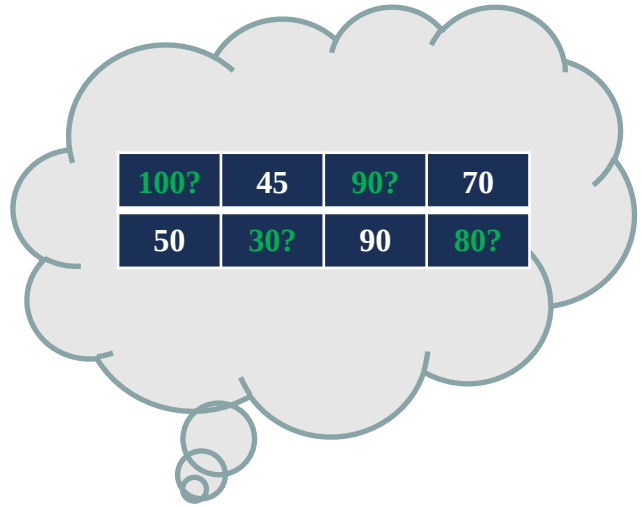

Thank you for your time!

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