THANKS TO THE OFFICE OF NAVAL RESEARCH!

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Dr. Ray Perez, Project Officer
AND TO THESE GRAD STUDENTS!

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OBJECTIVES

- Research: To identify moments in which individuals invent or create new methods which enable them to exceed their teachers.
- Application: To discover expert methods that can be formalized and taught as *Deliberate Practice* (e.g., Ericsson, 2004; Macnamara, Hambrick, & Oswald, 2014)

CITATION

Macnamara et al. (2014), “We found that deliberate practice explained 26% of the variance in performance for games.”
OBJECTIVES FOR THIS TALK

- To reintroduce *ragged learning curves* that typify individual performance during complex task acquisition
- To introduce the *Intuitive Changepoint Analysis Method* (ICAM) as a means to using those ragged curves to identifying periods of rapid change during skill acquisition
- To introduce the workflow that supports ICAM
- To provide examples of ICAM’s productivity in highlighting method invention in one complex task
ONE COMPLEX TASK: SPACE FORTRESS
A CogPsyc classic ...

1. Fly your ship quickly, but not too quickly, and stay within the hexagons if possible
2. Shoot the Fortress with specific timing, until its “vulnerability” rating reaches 10, then destroy it with a double-shot
3. Mines will appear and chase you, and must be destroyed
4. Collect bonuses via an AX-CPT-like task

Novice Player

Expert Player

Plus 30yr after the project began, a search on Web of Science™ (2016.11.07) found 52 “Space Fortress” papers. Five published in 2015 (the last full year of indexed).
Increments in *mean performance* 9 players across 31 hours (248 games) of play.
Increments in *individual performance* of 9 players across 31 hours (248 games) of play.
The average doesn’t look like any individual!
How do students exceed their teachers? – Extreme Expertise

Studying average human performance has been and will continue to be productive for some questions, but not for this one

We advocate the identification of periods of *individual* insight, invention, discovery through the use of statistical methods of *changepoint analysis*
Outline

1 INTRODUCTION

2 CHANGEPOINT ANALYSIS METHODS

3 A WORKFLOW FOR ICAM
   - An Example

4 SUMMARY AND CONCLUSIONS
Many varieties of changepoint algorithms exist. Qualities we looked for included:

- Detecting changes in cumulative slope, as opposed to other quantities, e.g. variance
- Not assuming that the underlying data followed a particular distribution, e.g. Gaussian
- Not requiring a fixed number of “zones” or separate curves to fit ahead of time
We examined about two dozen measures, including two techniques proposed by members of our community:

- Donner and Hardy (2015)
  and by
- Gallistel, Fairhurst, and Balsam (2004)

Although these served our colleagues purposes, they didn’t serve ours, so we invented the “Intuitive Changepoint Analysis Method” (ICAM).
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4 SUMMARY AND CONCLUSIONS
1. Log the location, sequence, and duration of all screen objects, behavioral events, and system events.

2. For Space Fortress: Use R to tally scores and features (i.e., “measures”) for each 5-min game of Space Fortress (e.g., number of enemy mines killed, mean distance to the Fortress, etc).

3. Next, we compare several measures against each other.

4. Apply ICAM to each of these measures.

5. Finally, visually inspect these measures looking for conflicting patterns.
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1. INTRODUCTION
2. CHANGEPoint ANALYSIS METHODS
3. A WORKFLOW FOR ICAM
   - An Example
4. SUMMARY AND CONCLUSIONS
Step 1: The data have been logged
Step 2: We have wrangled the data into $\approx 30$ measures
Step 3: We are now inspecting data for three measures (two features and one score)
Specifically for player sid3534, we are inspecting how some of the measures co-varied across games
Step 1: The data have been logged

Step 2: We have wrangled the data into ≈ 30 measures

Step 3: We are now inspecting data for three measures (two features and one score)

Specifically for player sid3534, we are inspecting how some of the measures co-varied across games.

Remember – slope is an estimate of change over time.
As befits an *intuitive* technique, ICAM is conceptually simple.

- For a given score or feature of interest, we simply compute the *changes in slope over time*.
- Compute a “rolling” or “running” slope based on a sampling of $n$ games.
- For example, for 248 total games and a rolling width of 5 games, we would compute the slope for games 1-5, 2-6, 3-7 . . . 243-247, 244-248. For a total of 244 slopes!
Each dot is the computed “running slope” for 5 games.
RULE OF THUMB . . .

- When all three factors move down at the same time, the player is probably asleep or distracted.
- When all three are following each other up and down, hard to conclude anything.
- But, when some move up at the same time that others move down, that is interesting.
The gray bands highlight periods of discrepancy – where some factors dip and others leap.

- The leftmost gray band highlights periods of discrepancy between dips and leaps in Fortress Kills and those in Mine Kills. The player discovers:
  1. If you kill the Fortress fast enough, mines will never appear.
  2. BUT, by preventing the mines from appearing you lose points on two other scores.
  3. So he tries but then rejects this strategy.
Here the player discovers and implements a new strategy.

1. Shoot the Fortress as quickly as possible to increase its vulnerability to “9” (without shooting it so quickly that its vulnerability resets).

2. Wait for the mine to appear.

3. Manage the mine as normal. (SF has two different types of mines which need to be killed in different ways.)

4. Killing the mine gives you points and also increments Fortress vulnerability by “1” making it eligible to be killed.

5. Finally, double-shoot the Fortress as quickly as possible.

Incrementing vulnerability this way saves you the cost of “one” shot while giving you points for destroying mines!!!
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4 SUMMARY AND CONCLUSIONS
ICAM – DOABLE BUT STILL LABOR INTENSIVE

- HARD WORK!!
- Researcher must be immersed in the details of the task
- Helps to have access to the subjects/players to be able to ask questions of them
- ICAM does not guarantee that it will always highlight a period of change nor does it guarantee that the researcher (or player) will always understand the nature of the change
- However, ICAM opens a new way forward for those interested in studying how individuals discover or invent new methods
100 years ago, researchers interested in strategy discovery, invention, and implementation dropped their keys and have been looking for them ever since *under the lamp of averaging-across-subjects*. It is time to stop looking for them there and to bring our lamps over to where we dropped them, over here, in one of these plateaus, dips, or leaps.
Thank You!!