

The Effects of Stimulus and Response Mappings on Identification and Decision Making Performance in Complex Environments

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Mapping

Associations from Stimuli (set of cues) to a Category (i.e., target), and from a category to a response

stimulus - category - response

A ----- target ----- click KEY

6 ----- distractor ----- don't click

Consistent and Varied Mapping

stimulus - category - response
A ----- target ----- click KEY
6 ----- distractor ----- don't click

- Stimulus mapping:
 - Consistent Mapping (CM): stimulus is always a target
 - Varied Mapping (VM): stimulus can be target in a trial and distractor in another
- Response mapping:
 - CM: Targets always elicit same response
 - VM: targets elicit one response in a trial and a different response in another trial

Complex Environments

- Multiple stimuli & responses
- Mapping is not one-to-one and not a clear cut:
 - Stimuli are defined by multiple cues
 - There are distractors!
 - Cues develop over time
- Varied mapping is common:
 - Targets may change over time (i.e., scissors in a luggage)
 - Multiple and different responses for the same target (same enemy target can be eliminated with multiple weapons)
- Environmental variables : time pressure, workload

Questions

- What is the benefit of consistency of stimulus and response mapping?
- What is the effect of mapping in conjunctive search (when the search depends on more than one cue)?
- Does consistency in stimulus mapping influence later decision making?

The RADAR task

(from Gonzalez & Thomas, 2008, inspired by Bolstad & Endsley, 2000)

The screenshot shows the 'RADAR Experiment' window. On the left is a 'Radar Grid' with concentric green circles and a central orange square containing letters F, D, G, and J. The grid has numerical values: 104, 191, 277, 363, 449, 536, 622, and 708. On the right is a control panel with several sections:

- Target Details:** Includes 'Scan' with 'ECM Jam Strength' and 'Weaponry Threat' progress bars, and 'Description' with 'Armor' and 'Size' progress bars. Arrows point to these as 'Threat Sensors' and 'Weapon System Sensors'.
- End of Shift:** A 'Submit' button and a 'Quiet Airspace Report' label.
- Performance Evaluation:** Shows 'Target Set: 4 7 6 1' and 'Target Present: 6'. A 'Target Set (Memory Set)' label points to this section.
- Response Actions:** Includes 'Guns' (4), 'Ignore' (5), and 'Missiles' (6) buttons. A 'Missiles' label points to the 'Missiles' button.
- Score:** A 'Total Block Score' of 1705 is displayed. A label points to this score.

At the bottom, the Windows taskbar shows the 'start' button, 'Microsoft PowerPoint ...', 'Program', and 'RADAR Experiment' windows, along with system icons and the time '8:51 AM'.

A video of the RADAR task

The screenshot displays the 'Radar Experiment' software interface. The main window features a green radar screen with concentric circles and a grid. A central dialog box titled 'Enemy Set' shows the symbols 'S W F K' and prompts the user to 'Press the space bar to continue'. To the right, a 'Response Actions' panel includes buttons for 'Guns' (4), 'Ignore' (5), and 'Missiles' (6), along with a 'Score' display showing '1678' and a prompt to 'Press the Space Bar to proceed to the next shift'. The Windows taskbar at the bottom shows the 'start' button, open applications, and the system clock at 11:58 AM.

Radar Experiment
Program Shift About

Enemy Set
Symbols: S W F K
Press the space bar to continue

Response Actions
Guns 4 Ignore 5 Missiles 6
Score 1678
Press the Space Bar to proceed to the next shift

start RadarTone LL_Last Radar Experiment 11:58 AM

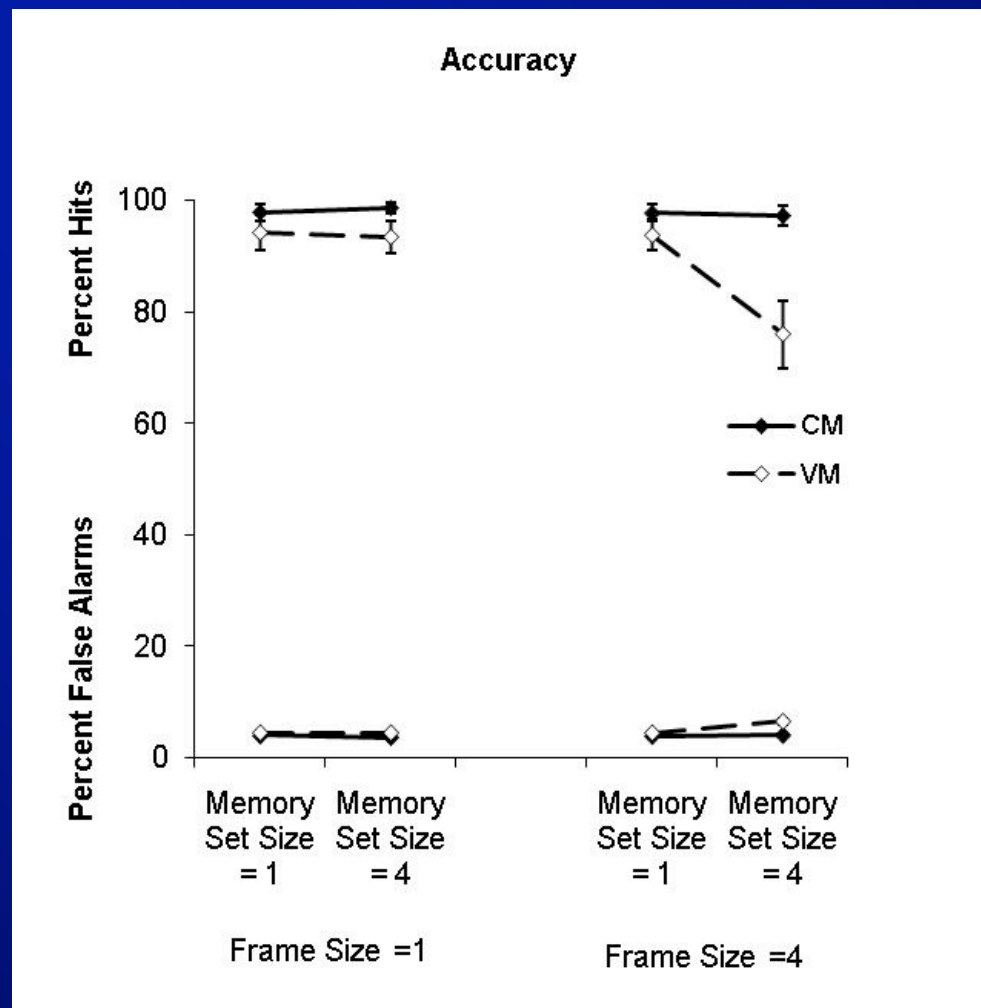
Experiments

- Experiment 1: Stimulus Mapping
- Experiment 2: Response Mapping
- Experiment 3: Conjunctive Search
- Experiment 4: Decision Making

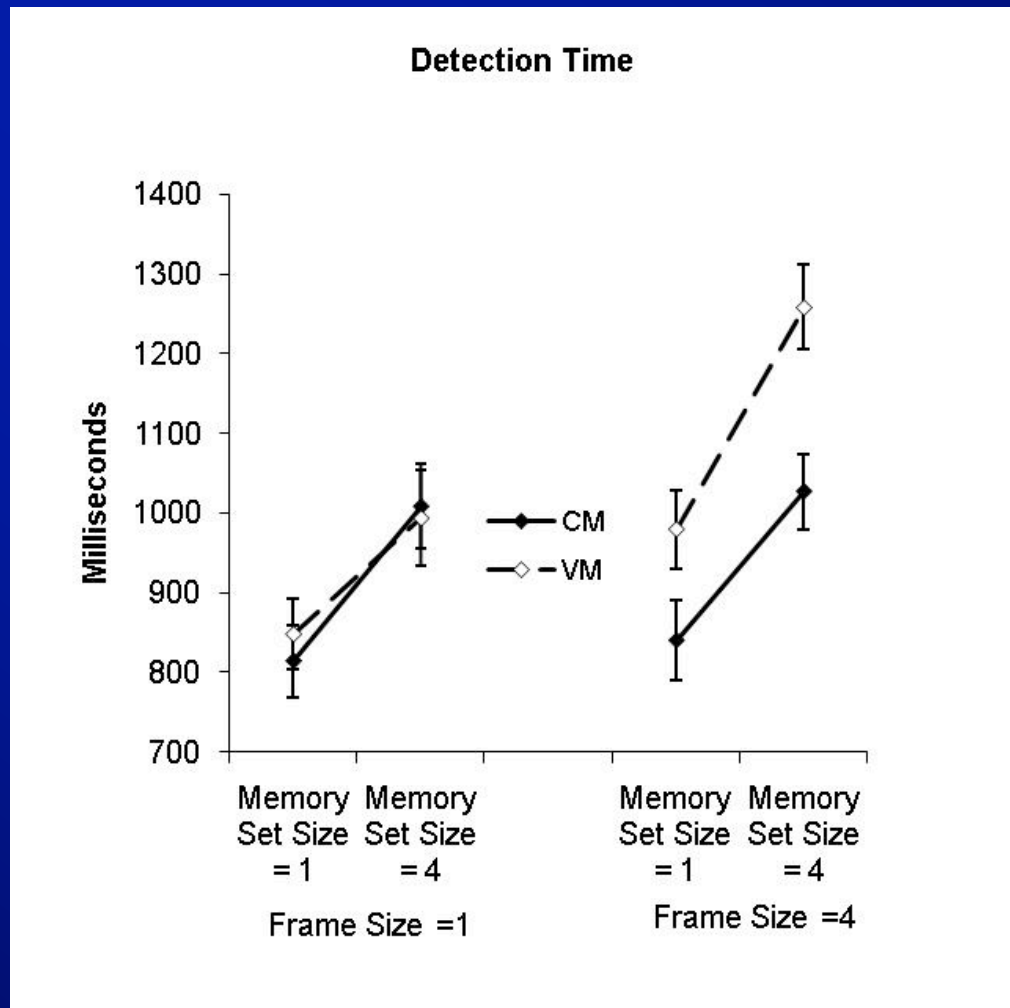
Experiment 1: Stimulus Mapping

- Stimulus mapping:
 - CM: targets were numbers (letters) distractors were letters (numbers)
 - VM: targets were letters and distractors were letters
- Cognitive Load Variables: Memory Set Size (search for 1 or 4 items).
Frame Size: 1 or 4 items on each Radar frame
- Only one possible response: pressing spacebar when target is detected
- N=9, 18 hours of practice (6 days, 3 hours each), Within-subjects experiment
- Each day: 8 blocks of 16 frames each. Each block 1 of 8 conditions formed by Stimulus mapping and Cognitive Load variables.

Results Experiment 1: Accuracy



Results Experiment 1: RT

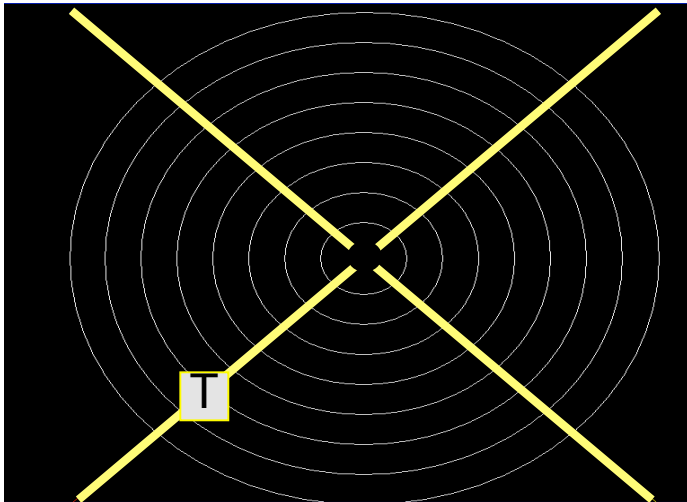


Experiment 1: Summary

- Best performance is achieved with consistently mapped stimuli
- Stimulus Mapping and Cognitive load interact in similar ways to the dual-process theory of automaticity (Schneider & Shiffrin)

Experiment 2: Response Mapping

- Response Mapping varied at 4 levels:
 - Fixed mapping (mapped to stimuli); Full mapping; Partial mapping; Random mapping
- frame time at 2 levels:
 - "slow" condition was 2,050 ms
 - "fast" condition was 1,050 ms
- Consistent Stimulus mapping only (i.e., search for numbers among letters), with Frame Size =4 and memory set size =4
- N=8, 18 hours of practice (6 days, 3 hours each). Within-subjects experiment
- Each day: 8 blocks of 16 frames each. Each block 1 of 8 conditions formed by the response mapping and time constraints conditions



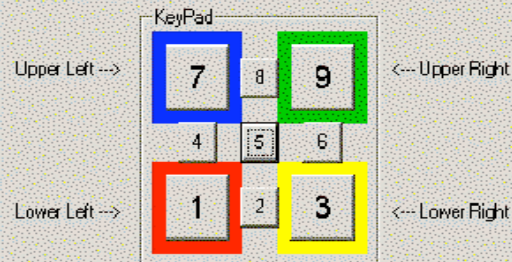
Mapped to Stimuli

Response Mapping Conditions

Welcome rick

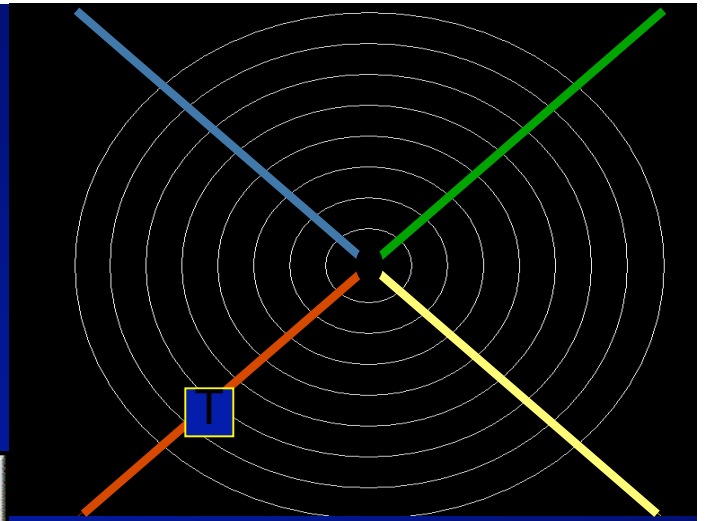
Please put your index finger on the 5 button of the keypad.

If you see a target from your memory set, use your index finger to press the number that matches the blip position that contains the target as shown here:



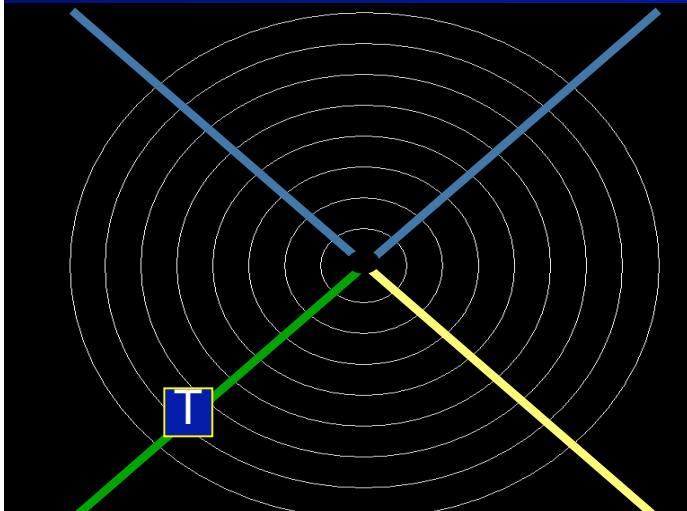
ONLY USE YOUR INDEX FINGER

Press 5 to begin

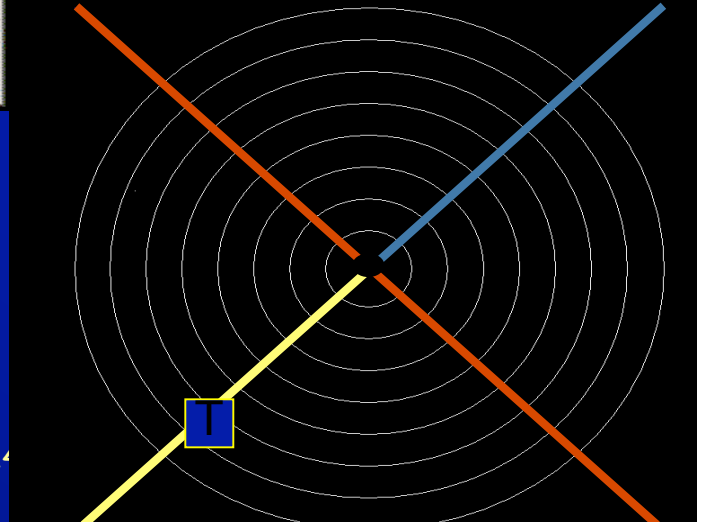


Fully Mapped to interface

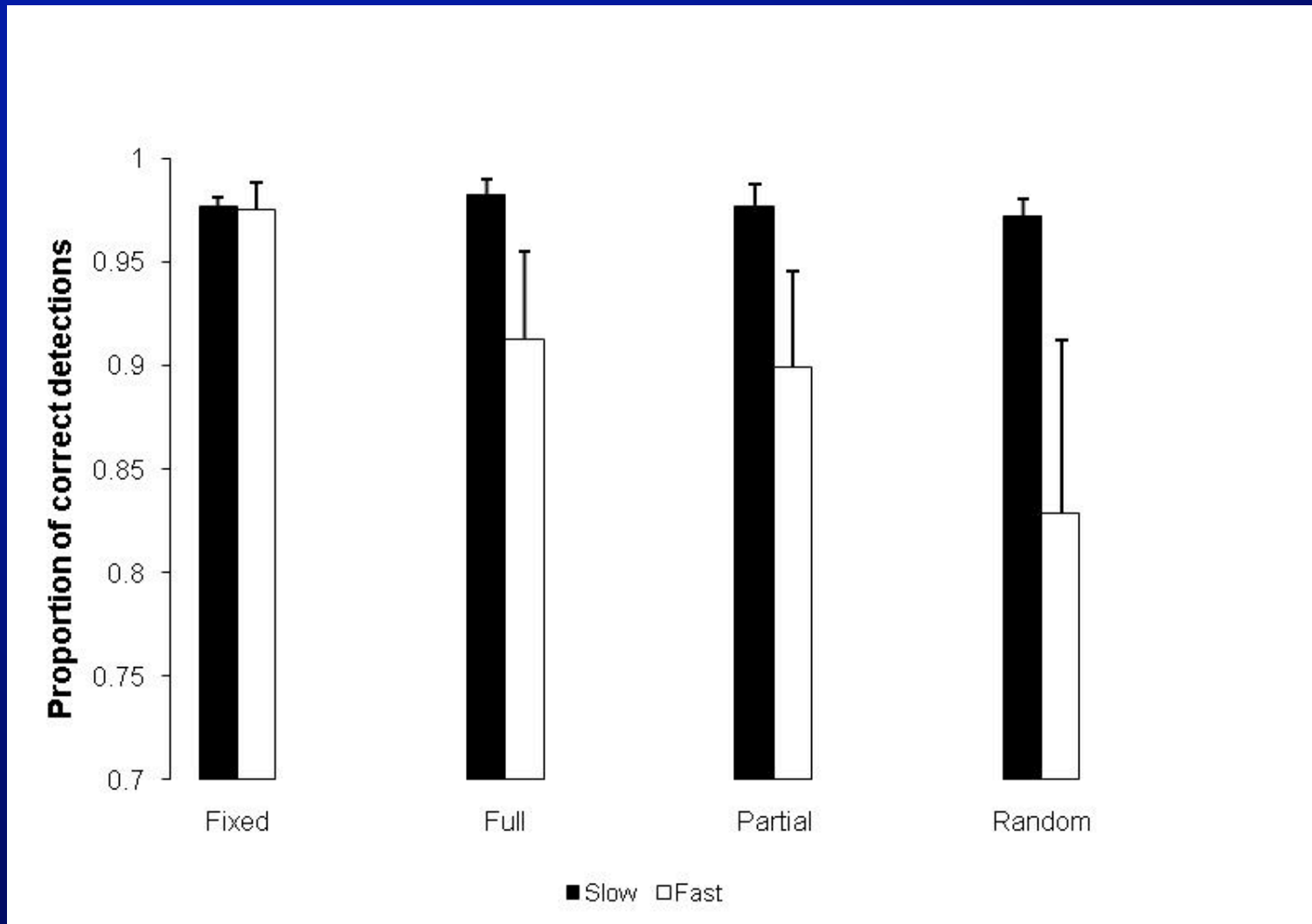
Partial Mapping to interface



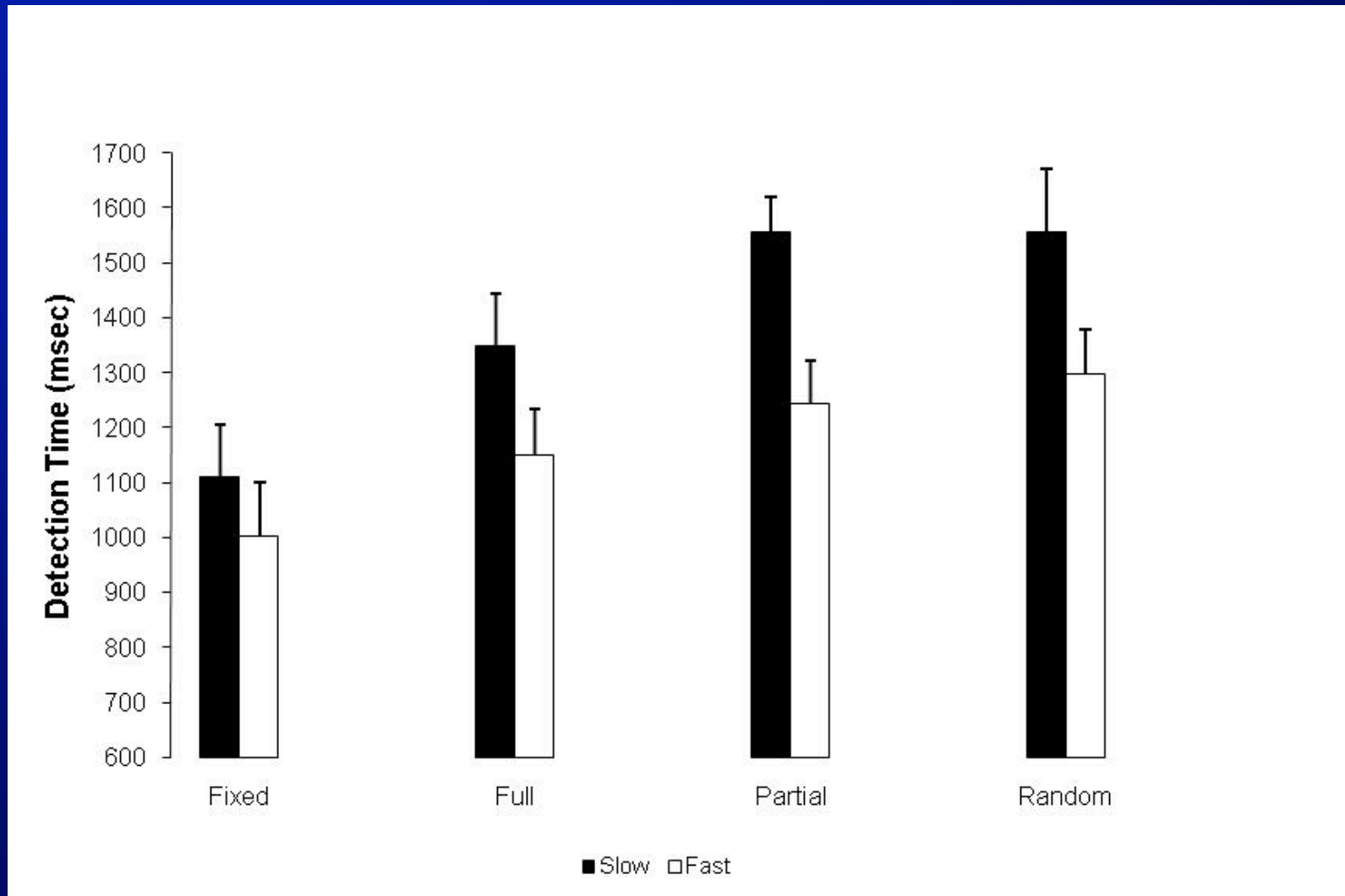
Random Mapping



Experiment 2: Accuracy



Experiment 2 : RT



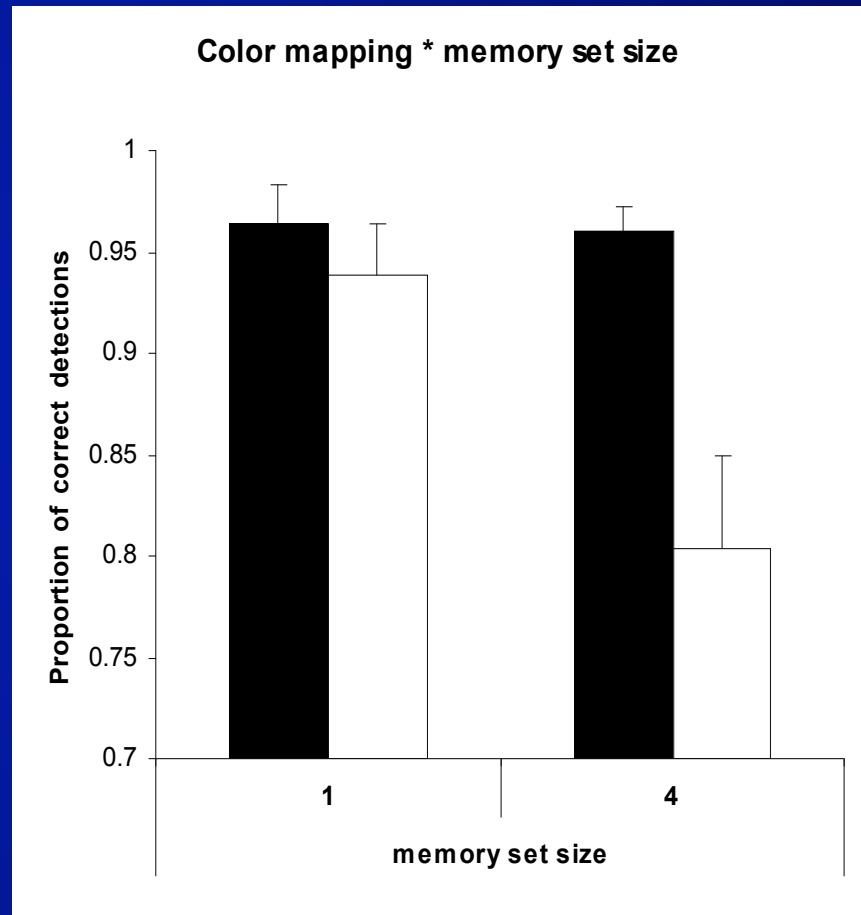
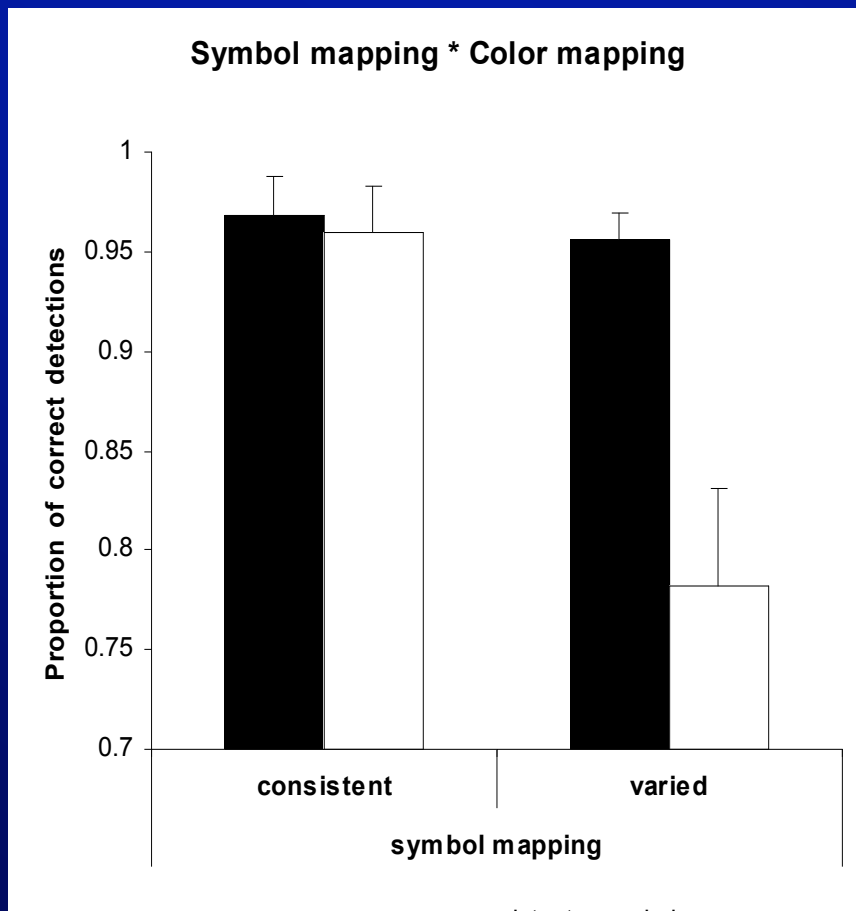
Experiment 2: Summary

- Response mapping, independently from stimulus mapping significantly influences:
 - Accuracy, in the fast condition
 - The detection time of correctly detected targets
- Thus, both, stimulus and response mapping influence performance of target detection

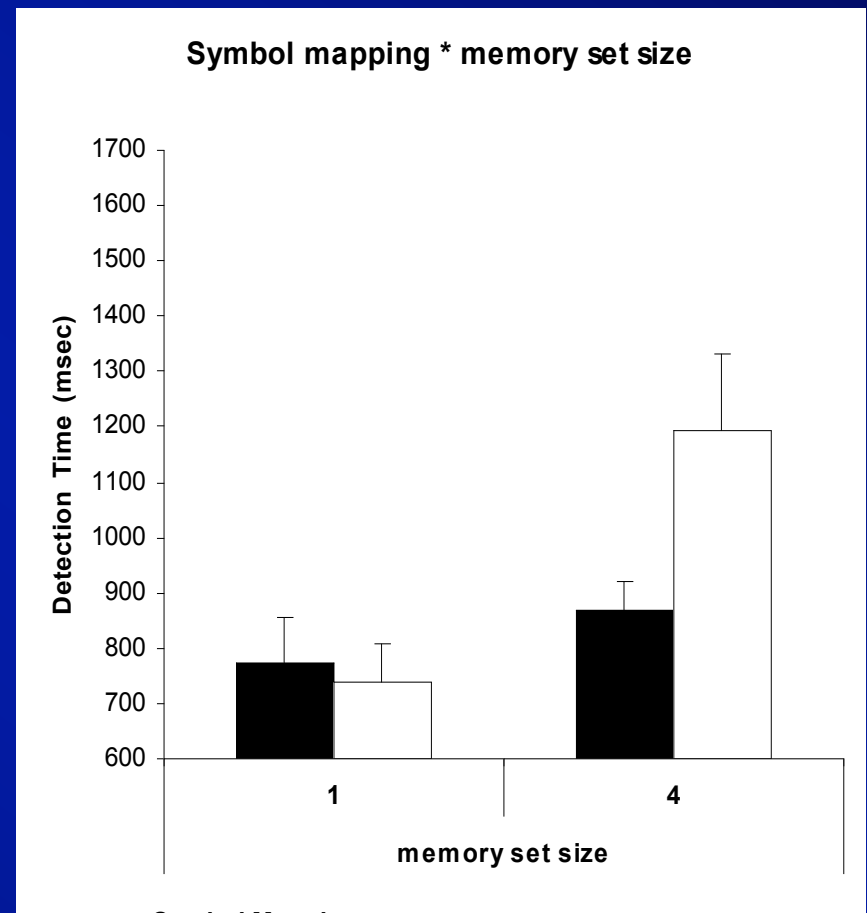
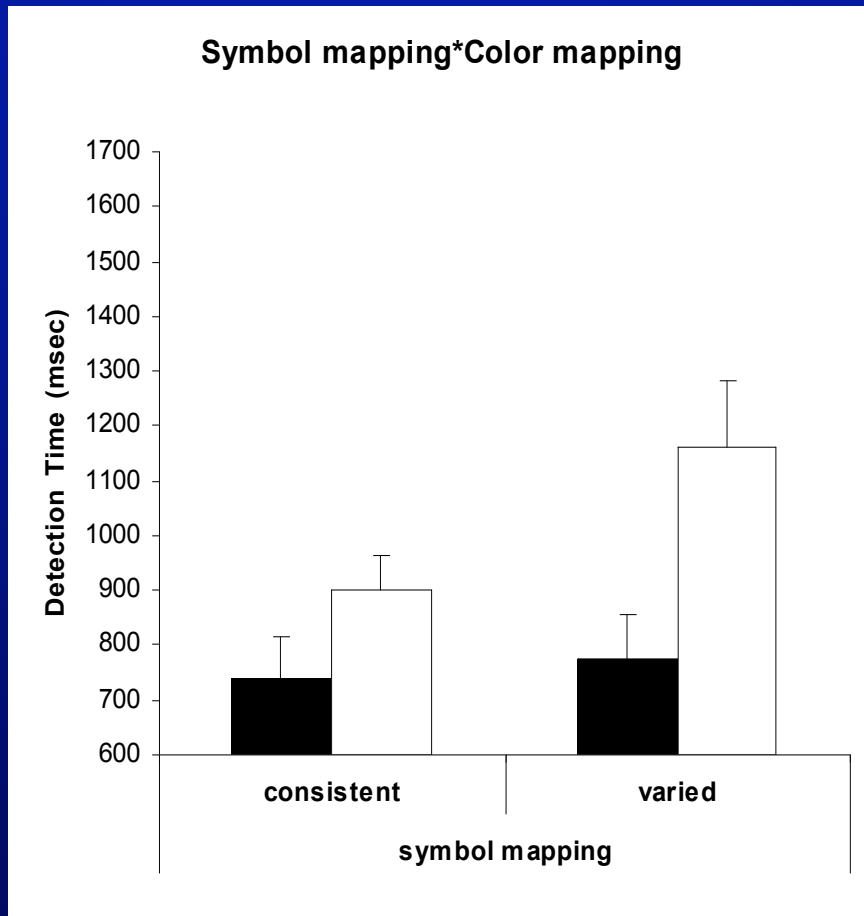
Experiment 3: Conjunctive Cues

- N=5, 18 hours of practice (6 days, 3 hours each). Within-subjects experiment
- 8 blocks of 16 frames each. Each block 1 of 8 conditions formed by:
 - Color mapping (CM or VM)
 - Symbol mapping (CM or VM)
 - Memory set size (1 or 4)
- The conjunction of two cues: color and symbol determined the target: for example, search for yellow letters among other colored numbers is a CM-CM (color-symbol) mapping

Experiment 3: Accuracy



Experiment 3 : RT



Experiment 3: Summary

- The mapping of both cues together determined performance in the task.
- When the symbol cue is varied mapped, the consistency of the color mapping can help.

Experiment 4: decision making

- How would automatic detection of a component help decision-making?
- Decision-making component required operators to analyze a sensor array of detected aircraft
- Sensor and weapon information changed dynamically

Experiment 4: Method

- Sensor Reading Task
- Determine if Target is Hostile
 - Scan Sensors
 - > 13 (Hostile)
 - < 13 (Non-Hostile)
 - Press Ignore (5-Key)
- Select Response (Weapon Systems)
 - Guns vs. Missiles
 - > 10 Missiles (6-Key)
 - < 10 Guns (4-Key)
- Quiet Airspace Report
 - No targets detected
 - Click submit report with mouse key

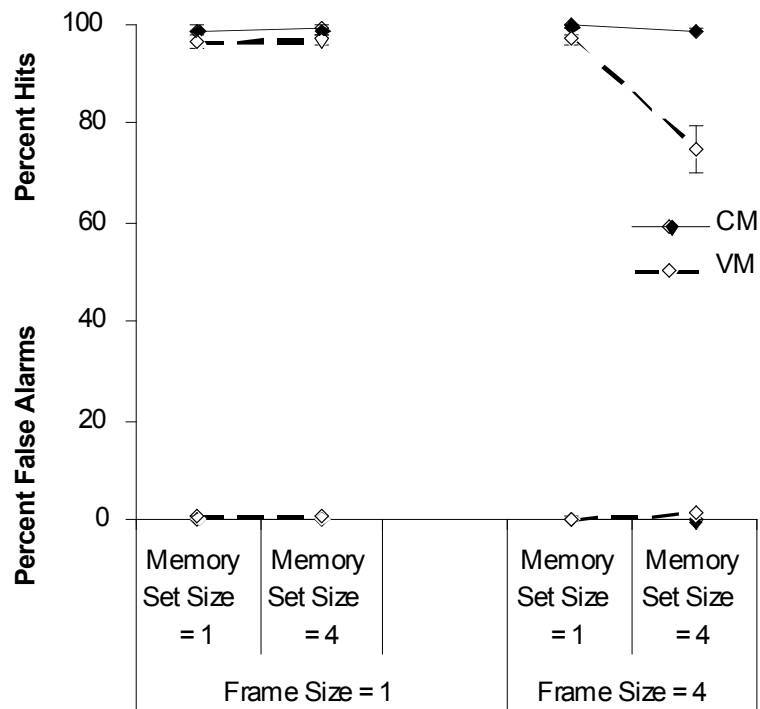


Experiment 4: Method

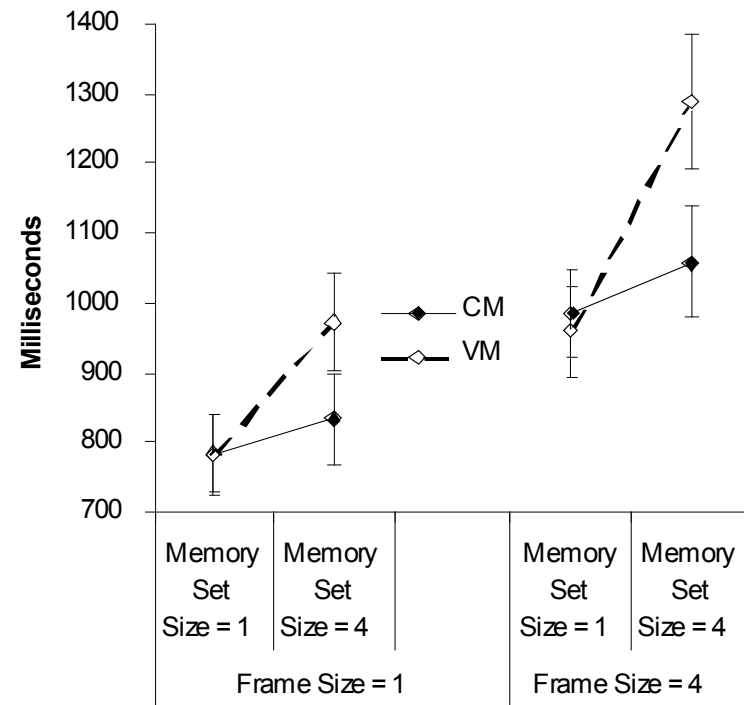
- N=7, 21 hours of practice (6 days, 3.5 hours each)
- Each day: 8 blocks of 20 frames each. Each block 1 of 8 conditions formed by the stimulus mapping conditions:
 - Stimulus consistent or varied mapping
 - Frame size 1 or 4
 - Memory Set Size 1 or 4
 - One response (space bar)
- Decision Making after detection
- Performed a Tone task in parallel in $\frac{1}{2}$ of the days: enter count of number of non-standard tones

Experiment 4: Detection accuracy and time

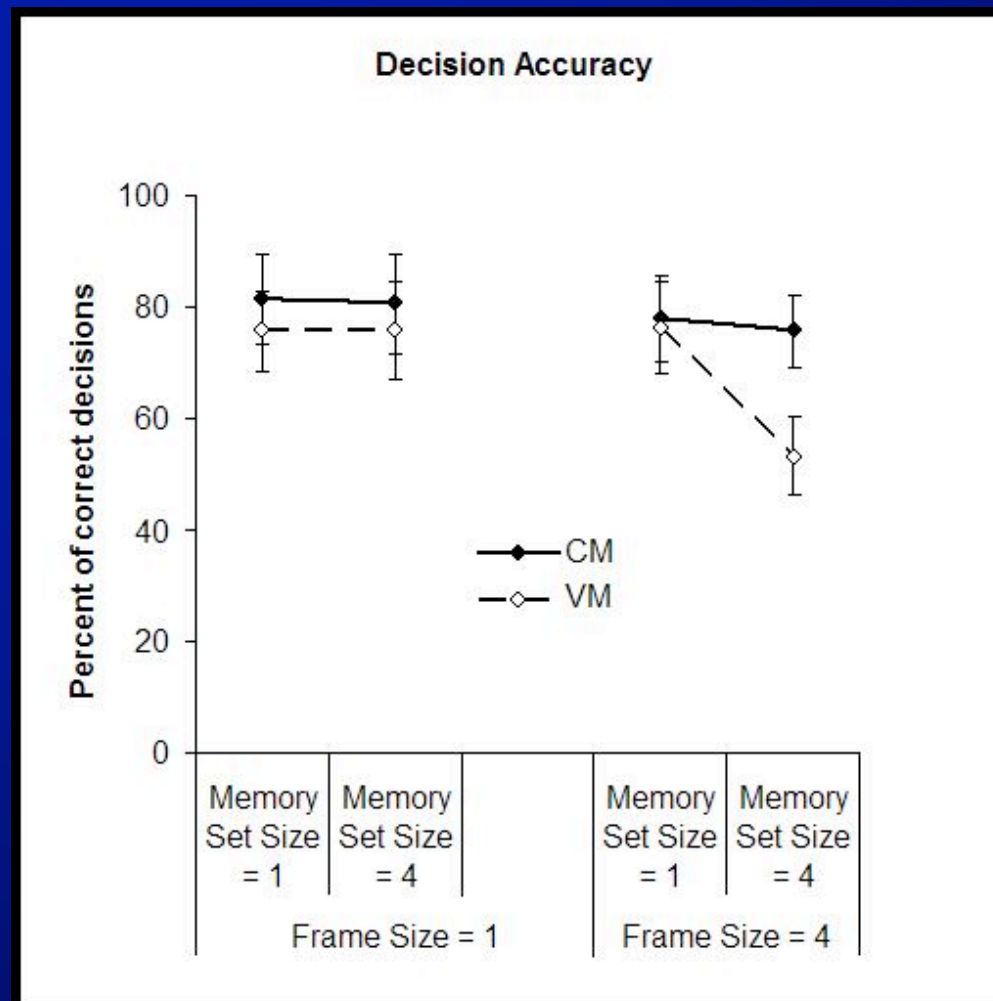
Accuracy



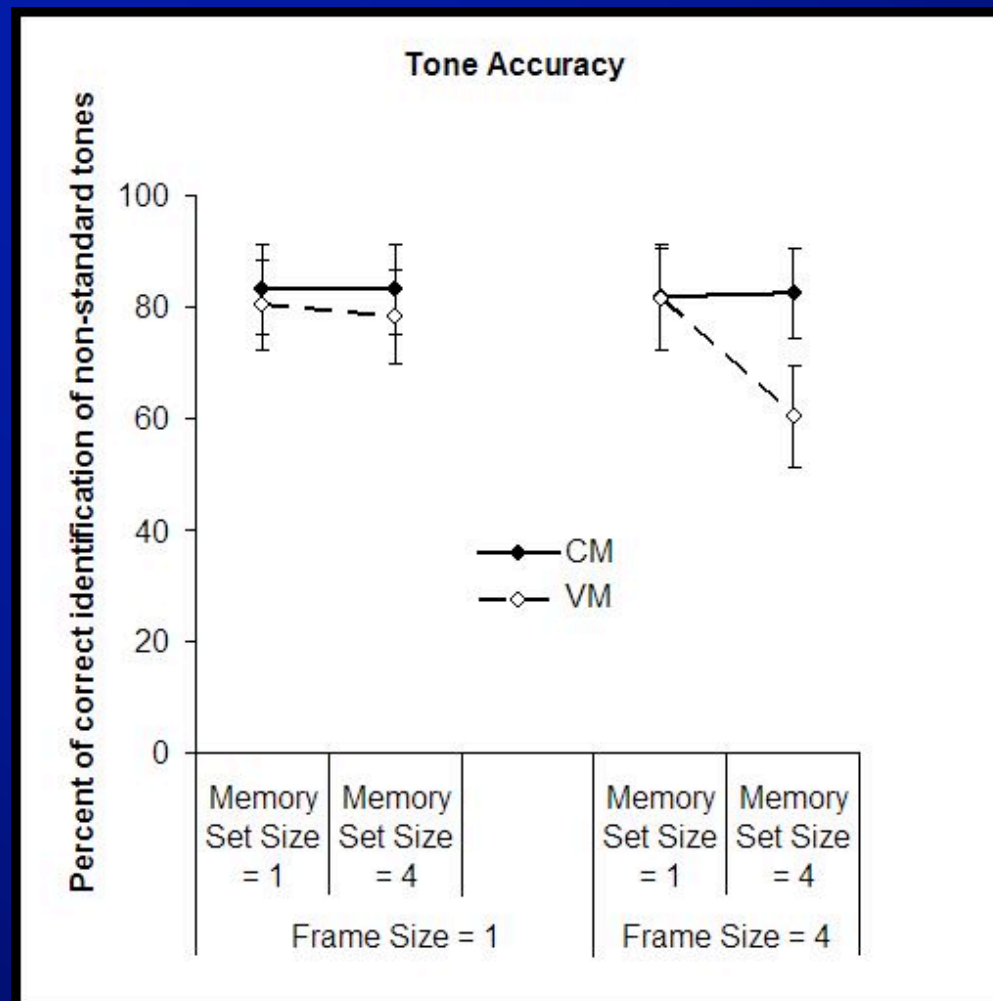
Detection Time



Experiment 4: Decision Accuracy



Experiment 4: Tone Accuracy



Experiment 4: Summary

- Consistent mapping of targets improved the accuracy of the decision-making of the task (despite the variability of the decision making task)
- The effect on the decision making task is not only due to "extra processing" time, but rather to a release of cognitive resources

Summary

- Response mapping can be critical for skill development above and beyond the consistency of stimuli
- If at least one of the cues is consistently mapped, this search can become more accurate when compared to all variable mapped cues
- Although the decision-making and auditory tasks were not consistently mapped in any way, they exhibited the benefits of the CM manipulation in the visual and memory search components of the Radar task.
- Extra time alone is unlikely the only reason for the higher decision-making accuracy