Current Metrics Initiatives

### Report Documentation Page

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<table>
<thead>
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<th>2. REPORT TYPE</th>
<th>3. DATES COVERED</th>
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<td>Current Metrics Initiatives</td>
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<th>6. AUTHOR(S)</th>
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<th>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</th>
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<td>University of Central Florida</td>
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| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) |

| 11. SPONSOR/MONITOR’S REPORT NUMBER(S) |

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### SUPPLEMENTARY NOTES

The original document contains color images.

### ABSTRACT

### SUBJECT TERMS

### SECURITY CLASSIFICATION OF:

<table>
<thead>
<tr>
<th>a. REPORT</th>
<th>b. ABSTRACT</th>
<th>c. THIS PAGE</th>
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<tbody>
<tr>
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### LIMITATION OF ABSTRACT

UU

### NUMBER OF PAGES

60

### NAME OF RESPONSIBLE PERSON

unclassified

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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18
Primary Metrics Researchers

- Kim Smith-Jentsch – UCF
- Shawn Burke – UCF
- Valerie Sims – UCF
- Nancy Cooke - ASU
Experimentation

- Refine a nomological network regarding macrocognition
  - How many distinct components?
  - How are they related?
  - How are they affected by contextual variables?
Overarching Objective

To identify a set of metrics that are unobtrusive, construct valid, incrementally predictive, and sensitive to our manipulations for use in experimentally-testing our hypotheses.
Experimental Tasks

- Validity of metrics should generalize across tasks that share substantive features

- Two task environments have been developed and pilot-tested
  - NEO scenario
  - ER simulation
Our Philosophy Regarding Metrics
## Process v. Product at Team or Individual Level of Analysis

<table>
<thead>
<tr>
<th></th>
<th>Product</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Individual</strong></td>
<td>• Concept maps</td>
<td>• Point of regard at key events</td>
</tr>
<tr>
<td><strong>Team</strong></td>
<td>• Degree of overlap</td>
<td>• Complementary point of regard at key events</td>
</tr>
</tbody>
</table>
Components of a Metric

- **Content**: for example, terms, behaviors, physiological reactions
- **Source**: for example, participant, peers, outside observers, equipment
- **Method**: for example, Likert-type scale, checklist, card-sorting task, pairwise comparisons
- **Scoring/indexing**: for example, percentage, mean, sum, correlation to expert, distance from expert
Content
Content

- Cognitive: lots of construct confusion
- Physiological: very little done in team arena, however some preliminary evidence that teams with similar reactions perform better
- Attitudinal: levels of analysis issues
- Behavioral: problems with discriminant validity
Methods
Major Methods for Measuring Cognitive Team Constructs

- Concept maps
- Pair-wise comparison ratings
- Card sorting
- Vignette-based ratings
- Think-aloud protocols
- Probes during task performance
- NEED TRIANGULATION
Concept-Map

Vegetarianism

Health Benefits
- high fiber
- low fat
- no milk allergies

Economic and Environmental Benefits
- water pollution
- deforestation
- methane
- more efficient to grow food to eat than to feed to animals

Health Dangers
- protein
- iron
- calcium

Moral Reasons
- cruelty - how livestock are treated
- killing other creatures wrong

Religion
- Buddhist
- Hindu

History
- growing knowledge of diet and health connection
- Greece
- European humanitarianism

Definitions
- vegan
- general
- ovolacto
- lacto
The hostess offered to take drink orders for the table she had just seated since the server had his hands full with a large party.
The manager recommended that the hostess open a new section to accommodate the lunch rush.

One bartender noticed another putting wine glasses into the wrong rack and showed him where the correct rack was.

The hostess offered to take drink orders for the table she had just seated since the server had his hands full with a large party.

The bartender forgot to tell the manager that they had run out of the house wine so that it could be reordered.

The kitchen updated the manager on the burns the sauté chef received during lunch and when he might be back to work.

Before beginning his shift, the server asked the kitchen and pantry if they were out of any menu items.

At the beginning of the evening, the manager told the serving staff how many of each special the kitchen had, how many reservations there were, and if there were any large parties coming in.

When the kitchen started running behind on orders, the chef asked the manager to jump in to help them catch up.

The manager suggested that the server could increase his wine sales if he picked out a few of his favorites to recommend to guests.

One server observed another slicing lemons and pointed out that he should be quartering them instead.

When the kitchen started running behind on orders, the chef asked the manager to jump in to help them catch up.

The manager instructed the kitchen to fill a particular order as quickly as possible since the guests at that table were late for a movie.

A trainer explained to a new hire how to phone in a credit card that could not be read by the credit card machine.

The manager suggested that the server could increase his wine sales if he picked out a few of his favorites to recommend to guests.
Vignette-Based

Teammate A appears to you to be overloaded and in need of assistance. If you were to offer assistance to teammate A, how likely would he/she be to:

Defensively refuse your assistance:

Politely refuse your assistance:

Gratefully accept your assistance:

Grudgingly accept your assistance:

Embarrassingly accept your assistance:

Highly unlikely 1----2-----3-----4-----5-----6

Highly likely
Relatedness Ratings

<table>
<thead>
<tr>
<th>Maintaining Separation</th>
<th>SME’s Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Minimizing Runway Delays</td>
<td>Strong Positive</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maintaining Separation</th>
<th>Participant’s Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-2</td>
</tr>
<tr>
<td>Minimizing go-arounds</td>
<td>-1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maintaining Separation</th>
<th>Participant’s Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-2</td>
</tr>
<tr>
<td>Avoiding windsheer</td>
<td>-1</td>
</tr>
</tbody>
</table>

To what degree are the following goals related and in which direction?
Major Methods for Measuring Behavioral/communication-related Team Constructs

- Likert scales
- Frequency counts
- Behaviorally anchored rating scales
- Checklists
- Communication flow/sequencing

Each have strengths and weaknesses – construct and context must be considered when determining which to use!
Frequency Counts

Number of times that backup was demonstrated:

![Likert-type Scale]

Backup Behavior Was:

Highly Ineffective  Highly Effective
1---------2--------3---------4------5--------6
Behaviorally Anchored Rating Scale (BARS)

5
Typically, in this organisation, one would expect mechanisms to have been introduced for the express purpose of cascading information systematically from top to bottom of the organisational hierarchy.

4.5
Typically, in this organisation, one would expect a management information provision unit to have been established which is constantly consulting information users on their present and future needs.

4
Typically, in this organisation, one would expect minutes of governing body meeting (e.g. Board of Governors/Council/Academic Board) to be made available to all staff, and actively circulated to those who need them.

3.5
Typically, in this organisation, one would expect information bulletins from management, and meetings, to focus primarily on developments that have already taken place, as opposed to developments in the pipeline.

3
Typically, in this organisation, one would expect there to be both formal and informal channels for information but information provision to be not always timely.

2.5
Typically, in this organisation, one would expect information produced centrally to be consigned to the waste bin frequently by recipients because it is thought to serve no useful purpose.

2
Typically, in this organisation, one would expect information provision to be ‘ad hoc’ in the sense of being provided when requested if one happens to know that it is available and the relevant party to contact.

1.5
Typically, in this organisation, one would expect little or no publicity to be given to major developments such as the setting up of a new unit or the introduction of a new facility.
### Checklists

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assisted AAWC in identifying tracks at first wave.</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Assisted AAWC in identifying tracks at second wave.</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Assisted AAWC in identifying tracks at third wave.</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Assisted AAWC in identifying tracks at fourth wave.</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Flow Patterns Change in Real-time

Before Conflict

After Conflict
Major Methods for Measuring Physiological Team Constructs

- Synchronous:
  - Eye scan/fixation
  - Pupil dilation
  - Increases in heart rate/blood pressure
  - Vocal intensity, pitch
Hospital Rules

Rule 1: Patients in the ER are not seen by a doctor on a first-come first-served basis. The triage nurse determines their order on the basis of need.

Rule 2: Patient information is confidential. Each patient has the right to decide:
- Who may see him or her
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<th>Consent</th>
<th>Medical Condition</th>
<th>Notes</th>
</tr>
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<tbody>
<tr>
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<td>Doctors day no visitors</td>
<td>Severe trauma from auto accident</td>
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<tr>
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<td>Non-publicity patient</td>
<td>Complications during miscarriage</td>
<td>Real name: Kayla Johnson</td>
</tr>
<tr>
<td>Carmen Diaz</td>
<td>Female</td>
<td>Only grandfather, Manny Diaz may see Carmen</td>
<td>Several broken bones and concussion</td>
<td>Mother suspected of child abuse. She’s not allowed to see the child.</td>
</tr>
</tbody>
</table>
Intensity analysis indicates the degree of aggressive or assertive tendencies between team members.

Participant A

Participant B (More Aggressive)

Pitch analysis indicates the degree of emotion on the person’s voice in a stressful scenario.

Participant A (More emotional)

Participant B
# Autonomic Measures and Findings

<table>
<thead>
<tr>
<th>Measure</th>
<th>Related Construct</th>
<th>Previous Findings</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate (HR)</td>
<td>Self monitoring</td>
<td>HR activity during anticipation of socially threatening situation (public speech) was negatively related to self monitoring.</td>
<td>Hofman, 2006</td>
</tr>
<tr>
<td></td>
<td>Self-efficacy</td>
<td>Positively associated with hr and unrelated to self reported arousal.</td>
<td>Gellatly &amp; Meyer, 1992</td>
</tr>
<tr>
<td></td>
<td>Personal goal level</td>
<td>Positively associated with hr and unrelated to self reported arousal.</td>
<td>Gellatly &amp; Meyer, 1992</td>
</tr>
<tr>
<td></td>
<td>Goal difficulty</td>
<td>Positively associated with HR.</td>
<td>Gellatly &amp; Meyer, 1992</td>
</tr>
<tr>
<td></td>
<td>Performance</td>
<td>HR positively associated with task performance but unrelated to self reported arousal.</td>
<td>Gellatly &amp; Meyer, 1992</td>
</tr>
<tr>
<td></td>
<td>Team performance</td>
<td>Team change in HR similarity positively predicted overall performance and errors made on a team coordination task involving robotic operation.</td>
<td>Henning et al., 2001</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>Task difficulty</td>
<td>Blood pressure higher when being observed compared to no observation while a performing difficult task. This was not found for an easy task.</td>
<td>Henning et al., 2001</td>
</tr>
<tr>
<td></td>
<td>Social Presence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Galvanised Skin Response (GSR)</td>
<td>Self Monitoring</td>
<td>GSR activity during anticipation of socially threatening situation (public speech) was negatively related to self monitoring.</td>
<td>Hofman, 2006</td>
</tr>
<tr>
<td></td>
<td>Social Threat</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Learning</td>
<td>GSR strength during training predicted learning in support of Damasio’s Somatic Hypothesis.</td>
<td>Carter &amp; Pasqualini, 2004</td>
</tr>
<tr>
<td>Cortisol</td>
<td>Stress/Anxiety</td>
<td>Cortisol sensitive to stress and anxiety.</td>
<td>Schlotz et al., 2006</td>
</tr>
</tbody>
</table>
Criteria for Metrics
Criteria for Metrics

- Construct validity
- Incremental predictive validity
- Sensitivity
- Unobtrusiveness
Construct Validity

- To what degree does a metric capture the construct of interest?

- Convergent validity: Should correlate highly with other metrics of the same construct - TRIANGULATION

- Discriminant validity: Should not correlate highly with metrics of theoretically distinct constructs.
Sensitivity

- To what degree does the metric detect differences among participants related to other variables/manipulations of interest?
- Floor and ceiling effects
- Quantity versus quality
- Ordinal versus interval or ratio scales
Unobtrusiveness

- To what degree does administration of the metric itself influence participants
- A potential source of contamination
- "Testing" threat to validity
- Can be assessed by comparing participants who were administered the metric (e.g., eyetracking) to those who were not on the dependent variables of interest
Incremental Predictive Validity

- To what degree do multiple measures of macro-cognition contribute uniquely to the prediction of team performance (explain unique variability)?

- Can be assessed using multiple regression analyses
  - Multiple metrics entered as predictors of a DV
  - Each metric significant beta when all considered together?
  - Significant change in R-squared when new metric added?
Incremental Predictive Validity

Sharing Unique Information

Variance in criterion uniquely predicted by personality
Variance in criterion uniquely predicted by heart rate

Shared variance in criterion predicted by both heart rate and personality
Approach to the Study of Metrics
Emerging Lessons

- Experimental/theoretical constructs lack clarity
- Primary focus on emergent states; lack of attention to development of team cognition or corresponding cognitive processes
- Incremental validity often not tested
- Content and method often confounded
- Over reliance on self report and single method
- Method (Messmer-Magnus & DeChurch, 2007), and indexing choices (Smith-Jentsch, Mathieu, & Kraiger, 2005) make a difference
Major Designs

- Meta-analysis (in-progress)
- Predictive validity studies (first in-progress)
- Metric “bake-off’s”
- Experimental tests of obtrusiveness
- Manipulation of task characteristics
Meta-Analysis of Prior Studies
Measuring Components of Macrocognition
<table>
<thead>
<tr>
<th>CKI Model</th>
<th>Schema Theory</th>
<th>Transactive Memory</th>
<th>Mental Model Theory</th>
<th>Situation Awareness Theory</th>
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</thead>
<tbody>
<tr>
<td>Recognizing Expertise</td>
<td>Teammate Schema</td>
<td>Teammate knowledge consensus &amp; accuracy</td>
<td>Mental models of teammates</td>
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<td>Individual Knowledge Development</td>
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<td></td>
<td></td>
<td></td>
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<td>Team Problem Model Pattern Recognition</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Team Situation Awareness</td>
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</tbody>
</table>
## Quantitative Database

<table>
<thead>
<tr>
<th>Method</th>
<th>Content</th>
<th>Elicitation</th>
<th>Aggregation</th>
<th>Potential Moderators &amp; Mediators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construct Validity</td>
<td>Knowledge Type</td>
<td>Emergent Outcome(s) Focused On</td>
<td></td>
</tr>
<tr>
<td>Mathieu et al. (2000)</td>
<td>Task</td>
<td>Declarative</td>
<td>Sharedness</td>
<td>UCINET- QAP correlation (task had two members)</td>
</tr>
<tr>
<td></td>
<td>Team</td>
<td></td>
<td>Pairwise ratings</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Self-report</td>
<td>2 person teams</td>
</tr>
<tr>
<td>Espevik et al. (2006)</td>
<td>Equipment</td>
<td>Declarative</td>
<td>IPK</td>
<td>6 person teams</td>
</tr>
<tr>
<td></td>
<td>Team</td>
<td></td>
<td>Questionnaire</td>
<td>Tactical submarine sim.</td>
</tr>
<tr>
<td></td>
<td>Team interaction</td>
<td></td>
<td>Self-report</td>
<td>Active duty officers</td>
</tr>
<tr>
<td>Marks et al. (2000)</td>
<td>Team interaction</td>
<td>Procedural</td>
<td>3-way overlap</td>
<td>Pathfinder C index for each pair of team members averaged</td>
</tr>
<tr>
<td></td>
<td>Team interaction</td>
<td></td>
<td>Concept mapping</td>
<td>3 person teams</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Self-report</td>
<td>Apache helicopter sim.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>% of shared concepts placed identically on map</td>
<td>Novice, lab</td>
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<tr>
<td></td>
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<td></td>
<td></td>
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</table>
Predicting Effective Team Problem Solving Using Metrics of Macrocognition:

How Many Distinct Constructs Exist and What are Their Relations?
Relations Among Macrocognitive Constructs

- Initial experiment designed and approved by UCF Human Subjects Review Board
- Piloted using 40 participants this summer
- Scheduled to begin actual study in two weeks
Secondary Task Environment
Experimental Tasks

- **Commonalities**
  - Non-combatant evacuation scenarios
  - Require team problem solving processes
  - Must resolve ambiguity
  - Product of the team’s performance is a plan
  - Both allow for face-to-face or distributed communication

- **Differences**
  - Team size
  - Hierarchical position in multi-team system
  - Degree to which task involves social cues
  - Distance from the disturbance
Hospital Emergency Room Simulation
Team Roles

Customer service personnel (participants)

Remote Hospital Personnel (simulated characters)

ER doctor/nurses (live confederate)

Police officer (live confederate)
Scripted Events
Shared and Unshared Data

- Participants share a common view of ER waiting room
- Participants also have access to independent data screens
- Must perform routine planning tasks while servicing customers prior to the conflict event.
Problem Solving Element

□ After interacting with video-based and live confederates, participants are faced with a hostage situation

□ Must aid police in determining how many hostages, who they are, who is involved in the disturbance and what it is about.

□ Clues are revealed as situation unfolds
Macrocognitive Constructs to be Measured in Initial Study

- Team problem models (a.k.a. situation awareness)
  - Methods: Paired comparison ratings, card-sorting

- Sharing of unique knowledge (a.k.a. information exchange)
  - Methods: Eye-tracking, communication analysis
## Relatedness Ratings

<table>
<thead>
<tr>
<th>Participant’s Ratings</th>
<th>SME’s Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2</td>
<td>1</td>
</tr>
<tr>
<td>Strong negative</td>
<td>Strong Positive</td>
</tr>
<tr>
<td>-1</td>
<td>2</td>
</tr>
<tr>
<td>Unrelated</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

-2 Strong negative
-1 Unrelated
0
1
2 Strong positive

-2 Strong negative
-1 Unrelated
0
1 Very positively
2

-2 Strong negative
-1 Unrelated
0
1
2 Strong positive

-2 Strong negative
-1 Unrelated
0
1
2
Card Sorting Task

Other Patients in Lobby

Angry People
Macrocognitive Constructs to be Measured in Initial Study

- Team problem models (a.k.a. situation awareness)
  - Method: Paired comparison ratings, card-sort

- Sharing of unique knowledge (a.k.a. information exchange)
  - Methods: Eye-tracking, communication analysis
Hospital Rules

Rule 1: Patients in the ER are not seen by a doctor on a first-come, first-served basis. The triage nurse determines their order on the basis of need.

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- Who may see him or her
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Macrocognitive Constructs to be Measured

- **Stress**
  - Methods: Heart rate, self-report

- **Communication delivery**
  - Methods: Pitch, intensity, Likert-type scales

- **Problem solving accuracy**
  - Method: Checklist
Who is still in the lobby, who is likely involved in the disturbance, what is it about?
Pilot Data from Secondary Task

- Physiological metrics correlate with communication analysis
  - Heart rate and blood pressure predict information sharing
  - Vocal intensity predicts communication delivery

- Eye tracking data accurate enough to reliably distinguish objects the following distances apart from one another:
  - 7 inches at 8 feet away (across the room)
  - 3 inches at 2 feet away (on a monitor)

- Eye tracking equipment does not bother participants
## Comfort Level of Eye-tracking goggles

1 (not at all)  -  5 (a great deal)

<table>
<thead>
<tr>
<th>Questions</th>
<th>Means</th>
<th>Standard Deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>To what degree did the eye tracking equipment obstruct your view during simulation task?</td>
<td>1.50</td>
<td>.548</td>
</tr>
<tr>
<td>To what degree did the eye tracking equipment obstruct your view during the card sort task?</td>
<td>1.33</td>
<td>.516</td>
</tr>
<tr>
<td>To what degree did you have to adjust to the eye tracker?</td>
<td>1.50</td>
<td>1.225</td>
</tr>
<tr>
<td>To what degree did the eye tracker caused discomfort or irritation to your eyes?</td>
<td>2.00</td>
<td>1.095</td>
</tr>
<tr>
<td>To what degree did the weight of the eye tracker equipment caused you discomfort?</td>
<td>1.67</td>
<td>1.211</td>
</tr>
<tr>
<td>To what degree did you feel intimated having to wear the eye tracking equipment?</td>
<td>2.33</td>
<td>1.633</td>
</tr>
<tr>
<td>To what degree did the eye tracker equipment affect your ability to use the mouse during your tasks?</td>
<td>1.00</td>
<td>0</td>
</tr>
<tr>
<td>To what degree did the eye tracker equipment affect your ability to use the keyboard during your tasks?</td>
<td>1.50</td>
<td>.548</td>
</tr>
<tr>
<td>To what degree did the eye tracker equipment make you feel awkward or uncomfortable while interacting with co-workers, patients &amp; supervisors in the simulation?</td>
<td>2.00</td>
<td>1.265</td>
</tr>
<tr>
<td>To what degree did the eye tracker equipment distract your overall performance?</td>
<td>1.50</td>
<td>.837</td>
</tr>
<tr>
<td>Overall, how uncomfortable was it to wear the eye tracking goggles?</td>
<td>2.17</td>
<td>.983</td>
</tr>
</tbody>
</table>
Summary

- Seeking to uncover a measurable and parsimonious model of macrocognition
- Searching for converging results across research methodologies
- Triangulation of measurement strategies