APPENDIX A: RCAT Development and Design

Assessing human performance is a complex multi-factorial process. Tests to measure the limits of physical characteristics are well documented and well-studied. However, although there are numerous tests to assess cognitive performance, there are several drawbacks that prevent them from being used in a high performance or real-time scenarios. First, most of the tests are highly specific and may require a battery of tests to achieve a meaningful overall assessment of cognitive state. Thus, the tests usually require a large amount of time to complete, and cannot be used for instantaneous assessments of an individual's cognitive state during a specific performance, status, stressor or task. Most tests output a final score that is dependent upon the entire task being completed and cannot be used to monitor cognitive performance in real-time. The other major problem with these tests is they are not fun; hence, the subject may not be fully engaged and as a result does not perform at maximum capacity. Not only do subjects lack incentive, but they can become bored or distracted and hurry carelessly to get the test completed.

For this reason, our group has designed a cognitive assessment test (Rapid Cognitive Assessment Tool - RCAT) that uses a videogame to gage performance with real-time feedback. The test engages the user and gives insight to several cognitive metrics that are integrated with physiologic metrics under varying conditions of stress, both mental and physical. Current cognitive assessment tests assess various psychological and psychomotor functions such as hand-eye coordination, response time, spatial awareness, situational awareness, auditory awareness, valuation and decision making. Some tests currently used include Trials A&B, Stroop Color Word Test, Complex Figure Test- Copy, Simple

Arithmetic, Controlled Oral Word Association, Wombat and Winscat. The first five tests examine specific psychological skills and memory ability. The Wombat is a psychomotor test for situational awareness used primarily in the military. The Winscat is also a military oriented performance test developed by NASA to assess a broad range of psychological skills. In studies where cognitive performance needs to be assessed quickly before/after defining points in a high performance protocol, running successive or lengthy psychological tests would be too time consuming. The RCAT provides an instantaneous window of analysis while engaging the user to perform at their maximum.

I. Game Design Characteristics

There are several key design characteristics that were intentionally included in the RCAT. These characteristics were also incorporated with future progress and investigation in mind.

1- The game is fun and provides an engaging environment in which the user is tested seamlessly without feeling the pressure of being tested. People are more likely to perform at their maximum if they are fully engaged in the task at hand.

2- The game is modifiable to fit the needs of the experiment and the subject population. With adjustable difficulty tuning, the game can be used as a competitive arena or as an enjoyable relaxed test depending on the need. Psychologic metrics to be assessed can be modified with changes of in-game obstacles to meet the demands of the experiment.

3- The game displays cognitive metrics of performance in real time. These metrics include but are not limited to: accuracy, response time, and overall

performance. A replay of the game will also be viewable afterwards and the performance can be analyzed in detail along with numerical data.

4- The game tests hand-eye coordination, speed, response time, spatial awareness, situational awareness, valuation, decision making and potentially auditory awareness.

5- The game is able to offer instantaneous cognitive performance metrics in non-standard environments. This allows for real-time monitoring of cognitive performance when the situation (psychological or physiologic) is constantly changing.

6- The game is on a modifiable platform so that it will continue to evolve and meet the needs of the testers.

II. Game Design and Testing Challenges

One of the classically difficult aspects of cognitive performance testing is isolating all external factors that would affect performance within the task. Several key factors were incorporated into the design to achieve a more accurate estimation of cognitive performance or degradation in the individual's current state:

1- **Asymptotic Learning Curve**: To minimize the effect of learning, subjects will be given 10-20 minutes of training before the first scored tests. This will consist of a series of 3-9 runs on which we can establish a baseline performance assessment with the game. During this portion of the test, the game will auto-scale to the individual's skill level. The game utilizes randomized targets to inherently minimize the effect of learning. The game is also based heavily on an individual hand-eye coordination capabilities, a trait fixed in the same way a person's 40 yard

dash is. Although a person can improve such traits, it takes extended periods of training to do so.

2- **Constant Game Difficulty:** Maximum performance of an individual can be accurately estimated from the initial baseline performance games. During the study to test for performance stability, improvement, or degradation, game difficulty will be set to 75 % of their max plateau performance. Difficulty will not change throughout the duration of the game. Hence we are more certain that any changes in score reflect actual changes in performance rather than difficulty of the task changing, a common problem with other cognitive tests.

3- **Eliminate Mental Fatigue:** Individuals can optimally focus on a specific task for short periods of time. Otherwise mental fatigue will begin to affect their performance. To minimize this effect, we will use short 1 minute bouts to capture our metrics.

4- **Minimize Boredom:** Many cognitive tasks are not challenging enough to test an individual's maximum capabilities, and the ones that are can be considered dull by many people utilizing them. The video game design should help make the task more entertaining. The variable adjusting difficulty and the percent of max performance used in the test should also help mitigate this. Most subjects will find the game competitive and engaging, also minimizing boredom accumulation over time.

5- **Minimize Distraction:** It is recommended that the subject play in a quiet room, free from distractions. The subject should also be in a comfortable position if possible.

6- **Create Incentive:** The game uses a competitive score bases system that provides people with incentive for exceeding their own as well as other individual's performance.

7- **Hardware Failure:** The setup is designed to be operated with minimal requirements and potentially with any operating platform. The setup has also been rigorously bug-tested for minimal crash and errors. Constant update and support is planned to keep the program running smooth in all operative environments.

III. Game Description

There are several squares that repeatedly spawn and must be targeted by the user. Color differentiation is essential during several portions of the game. The current preferred method of interaction is a mouse and keyboard, but there are also a touchpad and joystick versions programmed and tested. The graph on the right depicts several metrics which are being tracked in real time. Depending on the scenario and the aspect of cognitive performance evaluated, different metrics can be combined to get the best assessment of cognitive function. The major cognitive metrics to be reported in the analysis interface are:

1- **Response Time:** This measures the amount of time it takes users to target squares from the instant they spawn. Response time can also be categorized into color based responses for attention and awareness focused tests.

2- **Accuracy:** This measures the ratio of user correct actions to incorrect actions i.e. miss-clicks.

3- **Speed:** This measures the number of target/actions that the user is able to perform over a fixed period of time.

4- **Overall Performance:** This is a continuously recorded score that combines values from the other metrics of performance and is capable of displaying a final output at the end.

IV. RCAT Variability

In order to detect a change in RCAT performance during the imposition of external stressors such as hypoxia, headache, and AMS, baseline variability of the test was established in lab. Eleven subjects each played nine games after familiarization with the RCAT, for a total of 99 games with up to a month in between games. Conditions were constant throughout the testing. The average standard deviation in score for multiple performances within the same subject was 10.8%. Metrics such as accuracy and speed had deviations of 2.3% and 8.1% respectively.