Investigating the Impact on Fluid Intelligence by Playing N-Back Games with a Kinesthetic Modality

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Abstract— **Fluid Intelligence relies on working memory, and it is prominent in problem-solving activities. It was thought to be immutable in adulthood until recently, but new studies have shown that playing an N-Back memory game every day for several weeks increases a user's performance on standard Fluid Intelligence tests, regardless of age.**

But most variations of the game are tedious, and many players become bored and stop practicing before there is any significant gain in their working memory capacity. The BrainRank application seeks to increase users' time on task by introducing a novel kinesthetic interface to the N-Back game, in addition to leveraging established videogame motivators, such as leader boards and achievement badges.

New research has also shown that physical exercise enhances memory performance. The objective of the BrainRank project is to assess the impact of sustained physical exercise on working memory playing N-Back games through a tangible computer interface.

The BrainRank application records both user performance data and time on task for comparison to classic versions of the N-Back game that use a keyboard or mouse for input.

Keywords: Fluid IQ, Working Memory, Cognitive Training, Kinesthetic, Dual N-Back, Multimedia, Videogame

I. INTRODUCTION

Brain Rank is a multimedia application that seeks to measure the impact of a kinesthetic interface on user performance in the Dual N-Back memory game. The application leverages recent research in improving Fluid IQ and the effect of physical exercise on working memory.

The Dual N-Back game is a memory game of recalling sequences of audio and visual stimuli (Dual), with the increasing difficulty of remembering sequences several steps ago (N-Back). Recent studies have confirmed that persistent practice with Dual N-Back games increases working memory capacity, and improves Fluid IQ. It has been documented that the average N-Back steps that a player can remember after three weeks of training, twenty minutes per day, is typically N=4.5, significantly higher than non-players [1].

In light of this new research, numerous consumer applications have been released that promise to increase IQ or improve memory function [2]. But the repetitive nature of the N-Back memory games leads to user fatigue rapidly, and limits the effectiveness of the intervention.

The developers of BrainRank have developed a version of the Dual N-Back game using a dance pad as the input device. The novel interface acknowledges recent research indicating that enhanced cognitive performance, particularly in memory functions, is associated with persistent moderate physical exercise [3].

The target demographic for this project is teenagers, a group that research indicates is close to their peak of Fluid Intelligence, and whose Fluid IQ will then decline, absent intervention, as they advance into adulthood. The application has been designed to cater to this demographic group, using established videogame motivators, to encourage maximum practice with the N-Back memory game.

The objective of this effort is to address the research question of the impact of physical exercise on working memory. If a positive correlation between physical activity and time on task in an N-Back game is found, as measured by performance on a Fluid Intelligence test, then the BrainRank prototype will provide a model for further investigation and development.

II. THE IMPACT OF DUAL N-BACK TRAINING AND PHYSICAL EXCERSISE ON GENERAL INTELLIGENCE

A. General Intelligence

General Intelligence, as proposed by Raymond Catell and his student John L. Horn (Raymond Cattell, 1941; Horn 1965), is the measure of a person's Intelligence Quotient (IQ) [4]. General Intelligence is broken down into two components, Fluid Intelligence and Crystallized Intelligence. Fluid Intelligence, or Gf, relates to a person's reasoning and problem solving skills. Fluid Intelligence will peak in early

adulthood and then decrease in a person over their lifetime and is dependent on a person's working memory capacity. Crystallized Intelligence, or Gc, relates to a person's learned knowledge and generally increases with age. Fluid Intelligence is often tested using Matrices tests such as the Raven's Standard Progressive Matrices.

B. Dual N-Back Game

The classical Dual N-Back proposed by Susanne Jaeggi of Michigan University in 2008 presented the player with two independent sequences in different modalities. One sequence required users to remember positions on a grid, while the other sequence required players to remember spoken letters [5]. Players must remember N letters and positions back. Position/Letter pairs are "visible" for several hundred milliseconds and then disappear. The next pair is then presented after several hundred more milliseconds. Once the user is presented with a new position/letter pair they must compare it to the position/letter pair that was presented N pairs ago. They do so by pressing a button if the position matches, and another button on their keyboard if the letter matches.

C. Improving Fluid Intellegence

Playing the Dual N-Back was shown to increase the players' Fluid IQ. A study by Susanne Jaeggi, the creator of the Dual N-Back game, involving 70 people showed the average increase in IQ after 19 days of training was over 4 points [1]. But according to Dr. Jaeggi, "…the biggest challenge we have as researchers in this field is to get people engaged and motivated to play our working-memory game and to really stick with it." [10]

D. Excersise and Cognitive Tasks

Studies have also shown that regular exercise increases academic achievement and IQ test scores. A study by researchers at Michigan State University showed that Middle School Students enrolled in a Physical Activity class scored approximately 10% higher on Standardized Terra Nova tests than students who were not enrolled in any PA classes [6]. A study conducted with Dartmouth undergraduate students showed significantly improved memory for the treatment group who exercised on a regular basis and who also exercised right before the test [7]. Researchers at the University of British Columbia found that moderate exercise over a six-month study improved the memory function of older adults [8].

III. BRAIN RANK: IMPLEMENTATION AND DATA COLLECTION

BrainRank is a multimedia application that uses a dance pad as an input device. The design of the user interface borrows from traditional video games in terms of features, design, and audiovisual content. Players choose from three variations of N-Back games to play after they login, and they can also view their current game stats. Leader boards are featured prominently in each game's interface, along with other game elements that encourage players to attain high scores through increased practice.

A. Technical Specifications

BrainRank is a standalone desktop application for OS X and Windows computers, and was developed using a rapid-prototyping IDE from Adobe Systems called Director. Input from the dance pad is processed like a joystick device through a USB connection. The application requires a minimum 1200 X 800 display. The application stores user performance data locally in a text file.

B. N-Back Variations

Lost in the Woods – Players control an avatar lost in the woods. They are presented with a list of N directions and they must remember them in the order they are shown. After the last direction is shown they are asked to re-enter the directions in the correct order. Unlike most watch-and-repeat games the player cannot enter all the directions immediately. Instead they must wait for the avatar to retrace each step before entering the next direction in the series. This forces the player to hold the N-Back in memory for a longer period of time, and requires more long-term attention and concentration then the average N-Back. The N increases after the successful set of directions has been entered, and the player then encounters a map with at least one more direction than the previous set. (Four buttons of the dance pad are used.)
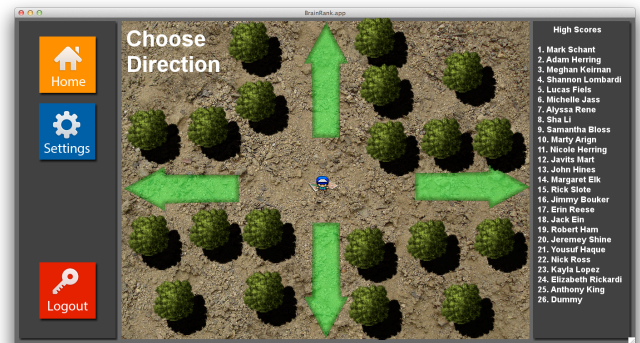

Figure 1 – Lost in the woods game

Dual N-Back – The classical Dual N-Back game is presented to the user. Emphasis in this module is speed of response, because the audio-visual pairs are presented with increasing frequency. (Two buttons of the dance pad are used.)
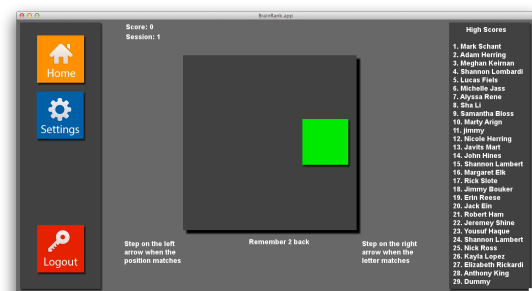

Figure 2 – Dual N-Back game

Dance Back – N Dance moves will be presented to the player in a particular sequence. The player must remember these moves in order and after N arrows are presented the player is then told to repeat the dance steps in order, at the same tempo in which they were presented. The emphasis in this module is not only to remember the correct sequence of steps but the time intervals between them. As soon as a player dances N steps the game engine determines the hit/miss ratio, and increases or decreases difficulty by adding or removing steps in the series. (The 4 directional arrows are used.)
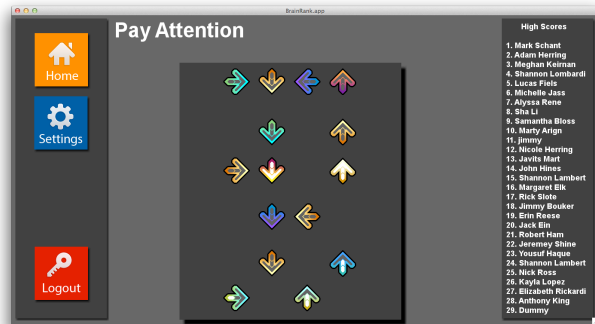

Figure 3 – Dance Back game

C. Data Collection

BrainRank stores the user's screen name and game scores with a time and date stamp in a local XML-formatted document. The application then calculates the user's total time on task per game, and to date, and writes it to the file. BrainRank averages the game scores for each game, and calculates total average score, at the end of each play session when the user logs out. Current players' scores are sorted and displayed in a leader board in the game interface when the application is launched or when a new player logs in.

D. Usability

BrainRank was presented at the Undergraduate Research and Creative Activities event (URECA) at Stony Brook University in April 2013. Approximately twenty players used the application for various lengths of time throughout the day, with some users returning to play more than once. The users found the interface to be intuitive, and the game play was perceived to be enjoyable and engaging. Players who played more than once were particularly attentive to their scores in the leader board and their ranking relative to other players.
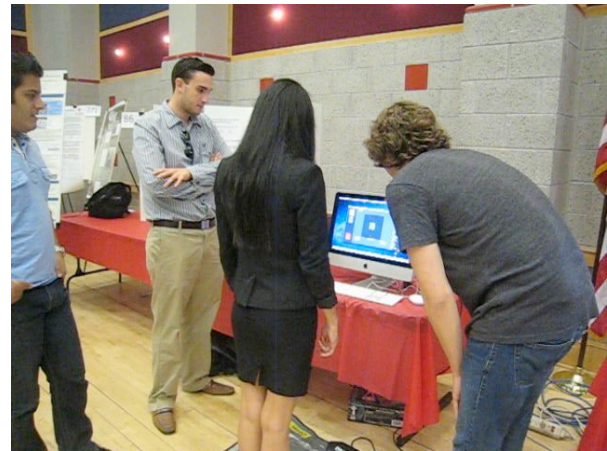

Figure 4 – BrainRank at URECA

IV.   FUTURE WORK

As a continuation of this project, the authors envision conducting an experimental study with a control group of users who play memory games using a traditional GUI, and a treatment group of users who use BrainRank. Users take a pre- and post- test version of Raven's Progressive Standard Matrices test to gauge any improvement in their Fluid IQ scores over time. The study, to be conducted through Eastern Suffolk Board Of Cooperative Educational Services (ES BOCES), will measure the impact of physical activity on memory function in high school students. An associated study could in the future measure the impact of the intervention on the GPA of students involved in the research.

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