The Development of an Eye-Tracking Program to Examine Working Memory During Gameplay

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Computer Science

Sample

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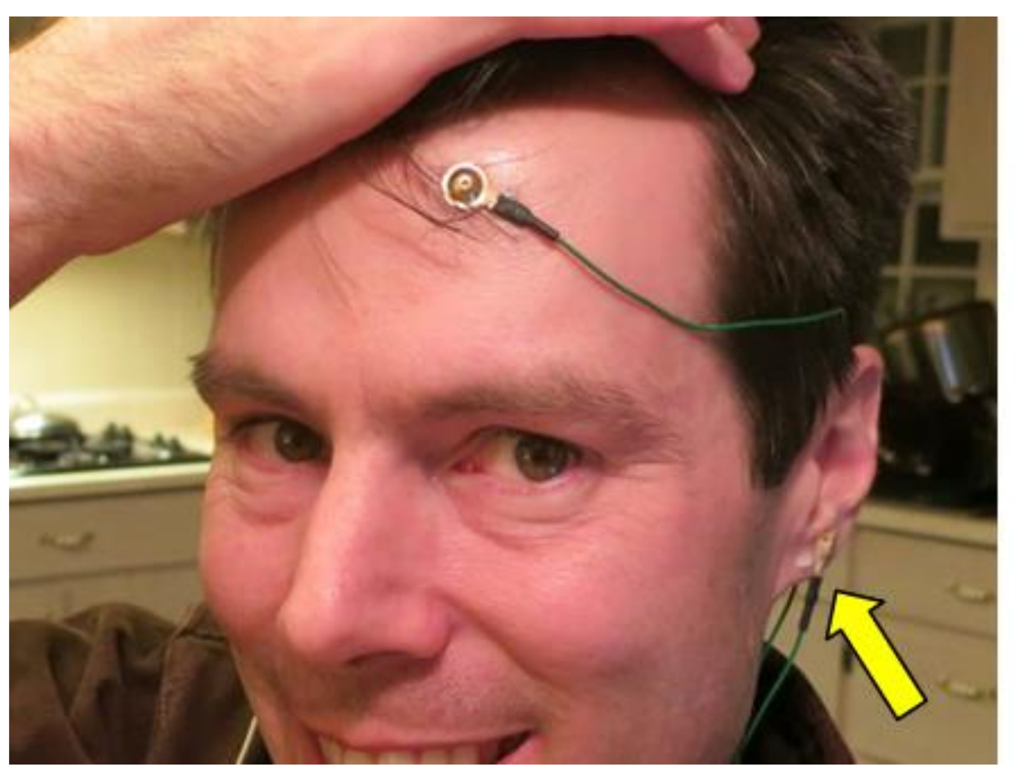
Introduction

In this experiment we work to examine brain activity and cognitive resources, by using a visual resource (virtual game of Mahjong) to study human working memory. Working memory is the process used to manipulate and maintain information so that the information can be used to carry out tasks (Baddeley, 1974) Many studies have shown that performance on working memory tasks are able to be correlated with performance on reading comprehension, intellectual aptitude tests, general intelligence, reasoning ability factors, and even moral judgments (Daneman & Carpenter, 1980; Oberauer, Wilhelm, Schulze & Sub, 2005; Kane & Engle, 2003; Kyllonen & Christal, 1990; DeCaro, Thomas & Beilock, 2008; Moore, Clark & Kane, 2008). Furthermore, poor visual working memory, the small amount of visual information held in the mind to carry out cognitive tasks, has been connected to disorders like Attention-deficit/hyperactivity disorder . (Castellanos & Tannock, 2002; Rapport, Alderson, Kofler, Sarver, Bolden & Sims, 2008).

It is possible that cognitive differences influence individual eye movement differences. For example, differences in intelligence, speed of processing, or working memory can influence the speed and direction of the eye during tasks.

Eye coordinates, or gaze information, informs visualization. Eye tracking is the process of measuring the relative motion of the eye or the point of gaze of the subject. Eye tracking technologies are used in a many avenues, from camera operation to military weapon operation. In scientific research eye trackers, devices used for measuring eye positions, are used in study of the visual system. Previously research has used eye tracking to gain information on the cognitive resources of a subject. For example, tracking the eyes during a PowerPoint presentation to study correlations between information retention and the gaze of the eye (Slykhuis, Weibe, Annetta 2005). In this study I've created an eye tracking system to study the working memory and cognitive differences with the purpose of provided insight into the reasoning behind individual working memory performance differences.



Objectives

The fluxuation in Alpha and Beta neural oscillations and the cognitive abilities of participants were investigated in correlation to eye movements during gameplay to study the relationship between working memory, brain activity and game performance. The purpose of this experiment is give insight into the causes of differences in individual working memory performance. The subjects sat in a shielded room with Electroencephalography (EEG) electrodes placed along the frontal bone to target occipital lobe activity. The subjects' Alpha and Beta waves were monitored during closed eye rest, open eye rest and gameplay. The subjects' eye movements were tracked during gameplay using an original program paired with the Eye Tribe Eye Tracker monitoring device. The program was written in C++ and developed in Visual Studio. The program received and stored gaze coordinate data during two, three minute gameplay sessions. My specific role was to create the code used in the eye-tracking program. The code effectively captured the participant's eye position up to 45 frames/second.

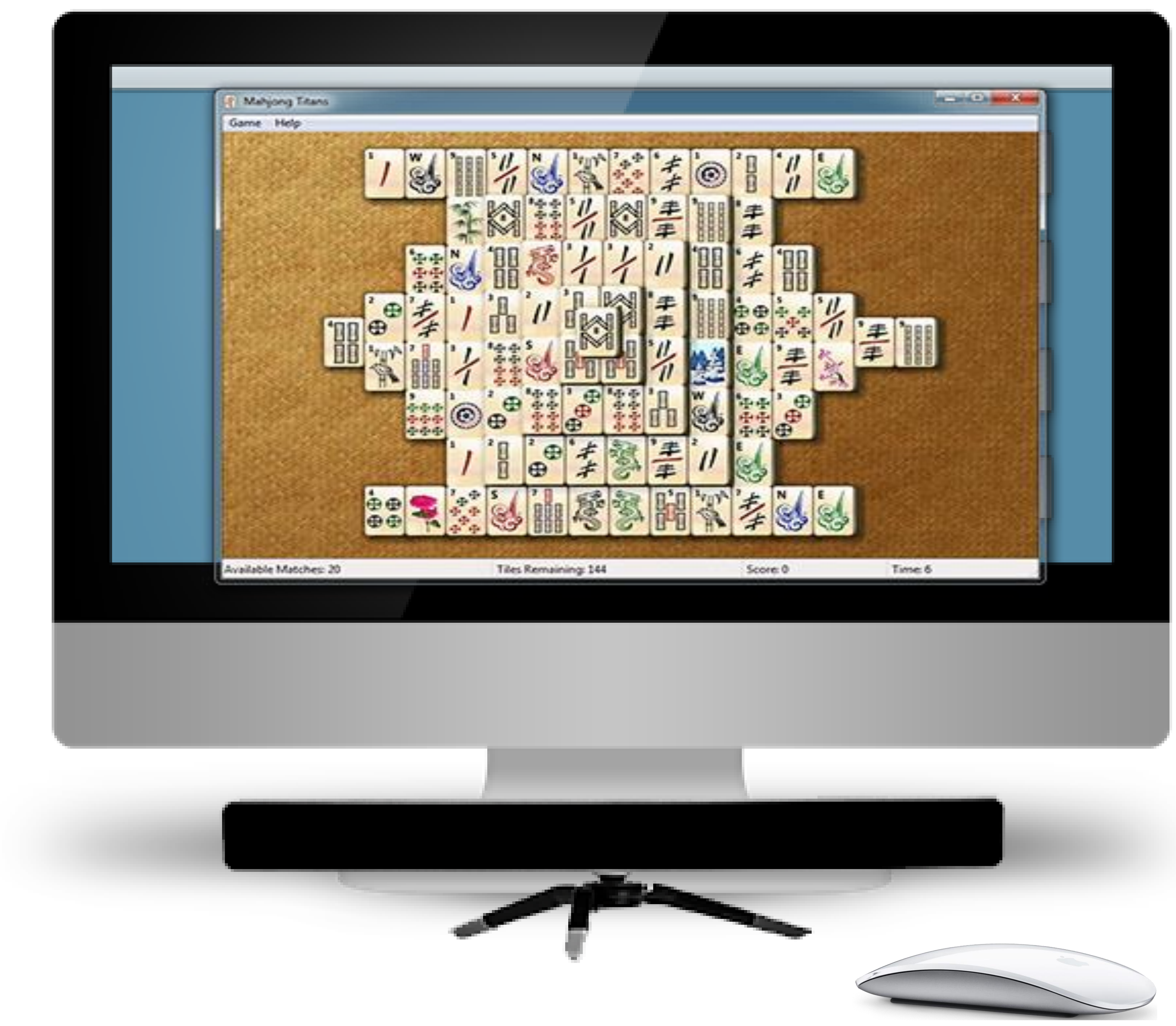
Materials and Methods

Materials

We used a Shielded room, 32-Channel EEG System, Eye Tribe Eye Tracker, Dell P Series 22 inch 1680 x 1050 Monitor, 2 Toshiba Satellite 15.6 inch Notebooks, and Standard Computer Mouse to complete the experiment.

Methods

In creation of the eye-tracking program, the coordinates are passed from the Eye Tribe Gaze API. They are then filtered to account for off-screen glances, blinks and any other user disengagement with the screen on which the game if being played. Each coordinate is time stamped for later use when it is being matched with the screen capturing of the game and EEG signal being recorded.



Test Protocols

Experiment was carried out in a shielded room. Four EEG nodes were placed on participant, two behind the ears and two along the frontal bone. EEG signals were recorded for two minutes during closed eye rest and open eye rest. We then calibrated the eye tracker, taking about two minutes. The EEG signals and eye coordinates were then captured for two additional two-minute sessions of virtual Mahjong gameplay. During gameplay the computer screen was also captured on video using screen-capturing software. The experiment took about ten minutes for each of the six participants

The code used to track eye movement was written using the Visual Studio Development environment. It was continuously tested and peer reviewed to ensure eye coordinates captured reflected the X and Y coordinates of display device. Once the screen capturing program was selecting, the code was updated again to have the capturing boundary as the screen capturing software.

Results

At start time, the program verifies its connection to the Eye Tribe Tracker system. The program then sets constraints of the eye coordinates it will receive based upon the size of the display. The real time coordinates of the participant's individual eyes are captured, as well as the average between the two eyes that represents the participant's point of gaze. The gaze coordinate along with a timestamp are stored every 1/45 seconds. Below is a sample of the correlating code to these functions.

```
struct Eye
   {
      Point2D raw; ///< raw gaze coordinates in pixels
      Point2D avg; ///< smoothed coordinates in pix
      float psize;  ///<pupil size
      Point2D pcenter; ///< pupil coordinates normalized
   };

   struct GazeData
   {
      enum
      {
         GD_STATE_TRACKING_GAZE      = 1 << 0,
         GD_STATE_TRACKING_EYES      = 1 << 1,
         GD_STATE_TRACKING_PRESENCE  = 1 << 2,
         GD_STATE_TRACKING_FAIL      = 1 << 3,
         GD_STATE_TRACKING_LOST      = 1 << 4
      };

      int time; ///< timestamp
      bool fix; ///< is fixated?
      int state; ///< 32bit masked state integer
      Point2D raw; ///< raw gaze coordinates in pixels
      Point2D avg; ///< smoothed coordinates in pix
      Eye lefteye; ///< data for left eye
      Eye righteye; ///< data for right eye

      bool operator == ( GazeData const & rhs ) const
      {
         return 0 == memcmp( this, &rhs, sizeof( GazeData ) );
      }

      bool operator != ( GazeData const & rhs ) const
      {
         return 0 != memcmp( this, &rhs, sizeof( GazeData ) );

struct CalibPoint
   {
      int state; ///< state of calibration point
      Point2D cp; ///< coordinates in pixels
      Point2D mecp; ///< mean estimated coords in pixels
      struct { float ad; float adl; float adr; } acd; ///< accuracy in
degrees
      struct { float mep; float mepl; float mepr; } mepix; ///< mean
error in pixels

  struct { float asd; float asdl; float asdr; } asdp; ///< average std
deviation in

      bool operator == ( CalibPoint const & rhs ) const
      {
         return 0 == memcmp( this, &rhs, sizeof( CalibPoint ) );
      }
   };

   struct CalibResult
   {
      bool result; ///< was the calibration successful?
      float deg;  ///< average error in degrees
      float degl; ///< average error in degs, left eye
      float degr;  ///< average error in degs, right eye
      std::vector<CalibPoint> calibpoints;

      bool operator == ( CalibResult const & rhs ) const
      {
         return result == rhs.result &&
            deg == rhs.deg &&
            degl == rhs.degl &&
            degr == rhs.degr &&
            calibpoints == rhs.calibpoints;
      }

      bool operator != ( CalibResult const & rhs ) const
      {
         return result != rhs.result ||
            deg != rhs.deg ||
            degl != rhs.degl ||
            degr != rhs.degr ||
            calibpoints != rhs.calibpoints;
      }

 void clear()
      {
         result = false;
         deg = 0.0f;
         degl = 0.0f;
         degr = 0.0f;
         calibpoints.clear();
      }
   };

 struct Screen
   {
      int screenindex;    ///< Screen index
      int screenresw;     ///< Screen resolution width in pixels
      int screenresh;     ///< Screen resolution height in pixels
      float screenpsyw;   ///< Screen physical width in meters
      float screenpsyh;   ///< Screen physical height in meters

      void set( int index, int resw, int resh, float psyw, float psyh )
      {
         screenindex = index;
         screenresw = resw;
         screenresh = resh;
         screenpsyw = psyw;
         screenpsyh = psyh;
      }

      bool operator == ( Screen const & rhs ) const
      {
         return 0 == memcmp( this, &rhs, sizeof( Screen ) );
      }

      bool operator != ( Screen const & rhs ) const
      {
         return 0 != memcmp( this, &rhs, sizeof( Screen ) );
      }
   };

   struct ServerState
   {
      enum
      {
         TRACKER_CONNECTED = 0,
         TRACKER_NOT_CONNECTED = 1,
         TRACKER_CONNECTED_BADFW = 2,
         TRACKER_CONNECTED_NOUSB3 = 3,
         TRACKER_CONNECTED_NOSTREAM = 4
      };

      bool push;
      int heartbeatinterval;
      int version;
      int trackerstate;
      int framerate;
      bool iscalibrated;
      bool iscalibrating;
   };
```

Summary & Conclusion

The study sought to determine if a relationship exists between individual differences in working memory, eye movement measures, and EEG signals. To determine if a correlation could be found, a working memory game was administered to participants while their eyes movement and brain activity was monitor. My specific role was to create the code used in the eye-tracking program.

Overall, the program efficiently and elegantly stored the gaze data of the participant. The program written to track eye movement was accurate up to the 45 frames per second capturing rate limit defined by the Eye Tribe monitoring device used. These technical limitations, limited the accuracy during rapid eye movement. In addition, the program was able to capture only eye movements across a standard desktop monitor screen, incapable of recording coordinates beyond the screen. In result, further iterations of this experiment require faster capturing and larger monitoring capabilities to produce relevant results. The program produced could also be used for other studies in which eye movements need to be captured from participants. For example, in research for the development of tools to be used by patients with limited head and eye movement, able-bodied people are often used for testing. This program could be used to ensure testing participants stay with the the limited eye movements that replicate patients with disabilities.

Acknowledgments

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