Encephalogames™ (Brain/Mind Games): Inclusive health and wellbeing for people of all abilities

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***Abstract*—Meta-sensing (the sensing-of-sensing or sensing-of-senses) with EEG (ElectroEncephaloGram) gamification forms the basis for a variety of games. to help with health and wellbeing for people of all abilities. First we develop a simple low-power ESP32-based Internet of Things (IoT) capture device for EEG and other data directly from devices such as the InteraXon Muse™and Muse2™or Neurosky Mindwave™. The device eliminates the need to have a smartphone to use technologies like the Muse or Mindwave that otherwise require a smartphone. This makes technologies accessible to people who have challenges using smartphones, and also facilitates health care interventions and data logging in places such as retreats or spa facilities where cellphone use would be disruptive. Secondly, we create a series of games that encourage the development of assistive technologies. One such game is "MoBrain™" which is a meditation competition based on mind-controlled motors, which we hope will lead to the development of wheelchair + mobility technologies for quadriplegics. Other games include "Mind Flow™" or "MoFlow™" in which brainwave-controlled water pumps provide increased flow when a player's mind is in a state-of-flow, and "Mind's Eye™" in which we create games that cause the human eye to become a camera.**

I. Background and Related Work

Electronic media, such as games, have been designed as a means for health intervention[1], [2], and have been customized, e.g. use of photographs of a child's home, clothes, etc., in game design for health intervention[3]. Virtual reality, augmented reality, and blended reality have also been used for game design[4], [5], including serious game design for therapy [6]. Brain-sensing technologies show great promise for immersive games [7], assessing flow in games [8], and healthcare intervention such as relaxation training to treat ADHD [9].

A. Brain-sensing technology

Electroencephalography (EEG) is the capture of electrical brain activity, which ranges from about 10 to 100 μV as measured on the scalp surface. EEG devices also pick up many artifacts, the largest of which is typically muscle artifacts, often around 10 mV. Blinking and jaw clenching events are noted by the device and are usually fairly short duration.

For the purpose of this paper we focus mainly on alpha and beta waves. Alpha waves have a frequency between 7.5 and 13 Hz, emanating from posterior regions of the head, being higher in amplitude on the dominant side. It appears when closing the eyes and relaxing, and usually disappears when opening the eyes or alerting by any mechanism (thinking, calculating), although, with proper training, it is possible to maintain high alpha wave activity while concentrating. Alpha wave activity is the major rhythm seen in normal relaxed adults. Beta waves are "fast" activity with a frequency of more than 13 Hz, and emanate frontally from both sides. It is the dominant rhythm in persons who are alert or anxious or have their eyes open [10].

B. Internet of Things

We will use brainwaves to control various IoT (Internet of Things [11], [12], [13], [11], [14]) devices in the context of physical computing.

C. Physical Computing

Physical Computing [15] is the "seamless integration of computing with the physical world via sensors and actuators" [15] at the intersection of electrical engineering, computer science, mechanical engineering, robotics and DIY hobby projects.

D. Physical Meditation

Physical meditation, physical mindfulness, or "computational telekinesis" is the application of physical computing to brain-computer interfaces. Examples include a radio controlled car that can be operated by a brain-computer interfaces [16]. This work by Dudley, and others, is obviously fun and playful, but it is also practical and useful because it inspires other developments such as brain-computer interfaces for mobility. It also provides a broader context for important work such as technologies that allow quadriplegics to operate wheelchairs using brainwaves [17].

E. Physical Metaphors

A physical metaphor makes what is normally only a metaphor into a physical reality. We draw great inspiration from Lisa Park's performance art in using brainwaves to control vibrations in pools of water [18]. This is an example of a physical metaphor in which the "stillness" metaphor of a clear mind is made physical in the pools of water. Another example of a physical metaphor is the Bright Ideas which makes physical the metaphor we often find in cartoon drawings where a light bulb appears over someone's head when they think of an idea. The physical metaphor in Bright Ideas is an actual real light bulb that lights up when the brain-sensing headband and machine learning algorithm detects that the wearer has thought of a new idea [19]. Bright Ideas is a fun playful project that helps to raise awareness of important research in brain health, such as work being done to characterize brain activity during creative problem solving [20].

II. Mind over motor for state-of-flow

We build on other work in Physical Computing, Physical Meditation, and Physical Metaphors to create some new game concepts that we hope will raise awareness of, and get people thinking creatively about, physical and mental health and wellbeing for people of all abilities.

We produced a series of games, which we call flowgames. Flowgames™are games in which participants compete by getting themselves into the state of mental flow, and staying in the state-of-flow.

> Flow is the sense of inspired freedom that comes when one is lost in an activity, allowing time, duty and worry to melt away. For writers, words pour out in a continuous, creative stream... – Susan Perry, Writer's Digest [21]

The mental state-of-flow has been well-researched [22], [23], and we wanted to embody the double-entendre of a Physical Metaphor on flow, so we built a system in which a water pump was driven by a speed controller in such a way that the pump increased its speed as players went into a deeper state of flow. The simplest embodiment of this game involves two pumps at opposite ends of a small pool in which two players, facing each other, wear a Muse EEG headset and each control a water pump that causes water to flow toward the other player. The goal of the game is to "push" a floating object toward an opponent. The winner is the one who first pushes the object to the other player, using hydraulic flow from the water pump.

Each pump is controlled by an output from a spectral analysis in which the speed of the pump is directly controlled by the product of energy in the alpha band and energy in the beta band of brainwave frequencies. In this way, a state of mental flow (simultaneous high alpha and high beta, i.e. simultaneous relaxation and concentration) produces a high quantity of water flow in the pump.

Expanding upon the richness of Physical Metaphors, we then decided to perform the multiplication in physical devices rather than software.

In particular, we created two physical systems, one called the *Concentrator*, that provided physical feedback to indicate beta wave activity, and the other called the *Relaxer*, that provided physical feedback to indicate alpha wave activity.

Since we wanted a Physical Metaphor in each case, we used a magnifying glass to "concentrate" the sun's (or other light source's) rays onto a fireproof brick with a high-heat photocell detecting the degree of "concentration". We used beta wave activity levels to adjust the focus of the lens, so that the sun's rays came to a point on the photocell when the user was highly concentrated. When the user was less concentrated, the lens went out-of-focus and the sun's spot broadened so that most of the energy missed the photocell. A water pump was driven by a buffered output of the photocell so as to pump more water when the user was more concentrated.

For the relaxation metaphor, we used an iris that opened when the user was relaxed and closed when the user was not relaxed. This function is similar to the iris of the human eye, in which the muscles must relax in order for the iris to open [24]. A similar muscular process is involved in urination, in which the sphincter muscles must relax in order to allow urine to flow [25].

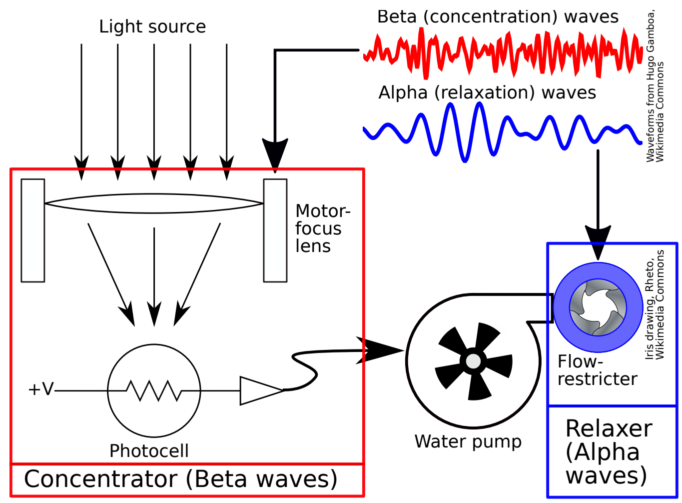

Fig. 1. The *Physical Metaphors* for Flowgames: (1) Beta waves are strongest when a user is concentrating. So we constructed a physical metaphor using a lens to *concentrate* the sun's rays to a single point on a heat-resistant photocell mounted to a flameproof block. (2) The photocell controls a water pump, so that the water pump runs more strongly when the user is concentrating. (3) In order for the water to exit from the water pump, the user must relax, because there is a naturally-closed restrictor that only opens in the presence of high alpha wave activity (relaxation). In this way, (1) mental concentration causes concentration of the sun's rays that the user can clearly observe; (2) A state of physical water flow is only achieved when there is a state of mental flow through relaxer (3).

In our system, we first had the iris in the lens, so that the user had to both relax to let the lens open up, and also concentrate to let the sun's rays come to a point on the photocell. However, we found that when the iris was closed, the user was unable to see the spot size of the concentrator, so we moved the iris to the output of the water pump, as a restrictor of flow. Thus the user had to concentrate the sun's rays and relax the flow restrictor, at the same time, in order to get water flow. See Fig 1.

As an added element of purpose, we connected the water pumps to hydraulophones (water-based musical instruments) so that players could control the flow of water in a creative endeavour (creating music). See Fig 2.

III. Sousveillant Technology

Finally, we introduce the concept of sousveillant technology, to build on the concept of veillance games [26].

Sur**veillance** (overslight) [27], [28] is an established research and business practice. The word "surveillance" ("oversight") is more than 200 years old [29], from French "sur" meaning "over" or "from above" and "veillance" meaning "watching".

Sous**veillance** (undersight) is a much newer concept [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], where the French prefix "sous" means "under" or "from below" (as in words like "sous-chef").

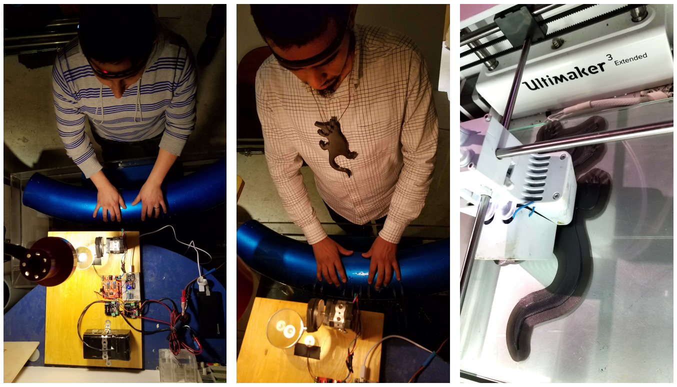

Fig. 2. Flow games: Participant Diego competes against participant Tamer. In order to eliminate the distraction of cellphones and cellphone applications from the meditation process, we developed our own neckwork wearable computer, in the shape of a crocodile. The neckworn computer repeatedly tries to establish a wireless connection to the Muse headset and serve the data to the game cloud. The crocodile is a metaphor for a voracious appetite for data that establishes a tenacious connection, while leaving the user completely free to stay in the state-of-flow without being distracted by technical details.

Metaveillance is the sensing of sensors and sensing their capacity to sense, and has also emerged as a recent area of research [42]. Meta is a Greek prefix that means "beyond". For example, a meta conversation is a conversation about conversations, and meta data is data about data. Metaveillance is the veillance of veillance, and more generally, metaveillance is the sensing of sensors and the sensing of their capacity to sense. Examples of metaveillance include the photography of cameras and microphones to reveal their capacity to sense [43], [44], [45], [46].

IV. Sousveillant motors

We introduce the concept of sousveillant motors, i.e. motors which reveal their inner workings. In order to do this, we apply the S.W.I.M. (Sequential Wave Imprinting Machine [45], [47], [48]) technology to motors. A new way of understanding electric motors is facilitated with one or more rotating SWIMs. The result is that a human observer can directly see the rotating magnetic field in a motor.

For the study of 3-phase motors, we constructed three SWIMs, one made from 100 red LEDs, another from 100 green LEDs, and a third SWIM made from 100 blue LEDs. We mounted these at 120 degree angles on a flat surface, perpendicular to the motor's shaft, but attached to the motor's body to rotate with the body of the motor.

V. Mind-controlled sousveillant motor

Finally, we implemented a neurofeedback system in which mindfulness drives the rotation of a motor with a SWIM, so that the user can see and understand the rotating magnetic field in the motor while directly affecting it through brain activity. See Fig 3.

We constructed a number of wheelchair sculptures based on this principle. We then used these in various forms of game play in which players meditate and apply mindfulness to the

Fig. 3. Motor mindfulness. Top image: participant not in the state of flow, motor not turning. Next image: participant's brainwaves causing the motor to turn, while it also reveals its internal rotating magnetic field. Here we can see the field rotating around the 72 stator slots of this two-pole three-phase motor. Photograph taken with electronic flash. Typically, however, the experience takes place in a dark room with the lights off, as shown in the photographs on the bottom row, for various electric field currents and motor speeds as controlled by neurofeedback.

Fig. 4. Wheelchair sculpture shown here being controlled by brain-sensing headwear (Neurosky). Multiple players compete to calm the electrical signals fed to the motor, and provide purposeful rotary drive. On this wheel there are six SWIMs (Sequential Wave Imprinting Machines), which allow others to see the rotating magnetic field in the motor, and thus infer some aspects of the participant's brainwaves.

control of the electric motors that drive the wheels of the wheelchairs, as shown in Fig 4

This system can be extended to a multiplayer interactive art installation, e.g. where multiple players' brainwaves compete for control of a single motor, or where multiple players control multiple motors or other devices.

The system architecture is based on the principle of human-in-the-loop intelligence, also known as Humanistic Intelligence (HI) [49], as illustrated in Fig 5.

The overall system architecture is illustrated in Fig 6 showing the following layers:

1) Embeded devices layer that includes the ESP32-based wearable computer in the shape of a crocodile. The crocodile is paired over Bluetooth (BLE or classic) with an EEG device, eliminating the need for a smartphone or other similar device. A motor controller that is connected to a physical device, e.g., the wheelchair or water pump, can be used in various game scenarios.
2) On-premises game servers layer that represents a hub for all collected real-time data. The data is used to command a motor controller according to the game logic.
3) Cloud data pipeline that collects all game events at scale, aggregates real-time scores and provides global game statistics. The pipeline also stores historical data for future analysis.

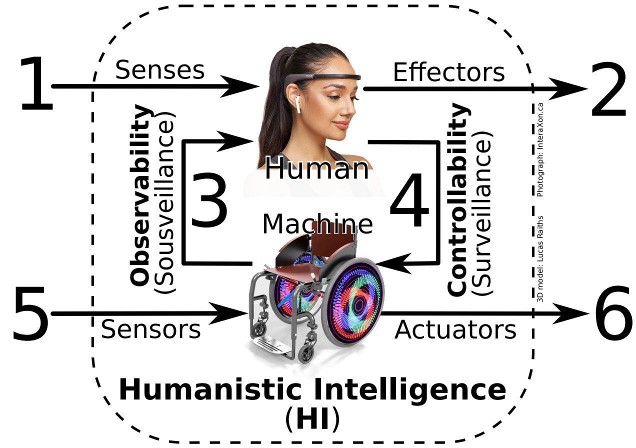

Fig. 5. Human-in-the-loop intelligence, also known as Humanistic Intelligence (HI) is a form of human-machine interaction in which intelligence arises by having the human being in the feedback loop of the computational process [49]. 1. Humans have Senses (e.g. sight, hearing, etc., depending on ability), and 2. Effectors (e.g. hands, legs, etc., depending on ability). These senses and effectors allow the human to operate a machine through the ability to sense the machine (3. Observability) and affect the machine (4. Controllability). 5. Machines have Sensors and 6. Actuators, which allow them to be sensed by the human (3. Sousveillance) and to sense the human (4. Surveillance).

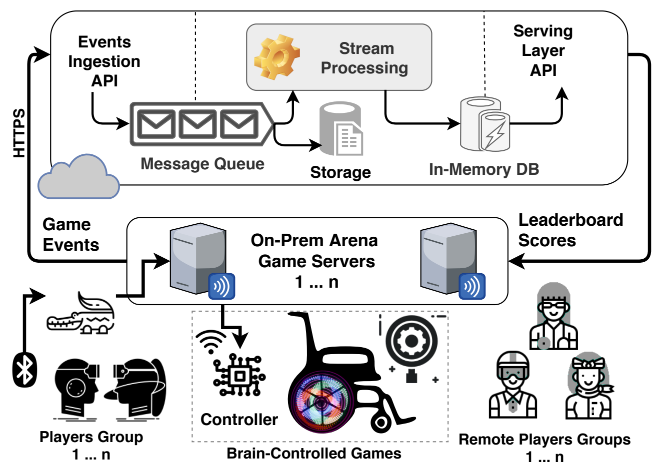

Fig. 6. System architecture. Each player wears an EEG device paired with a control device (crocodile-shaped wearable computer). The crocodile tenaciously keeps trying to re-connect if ever the connection is dropped. It consumes EEG data over Bluetooth, then sends the data to a game server. The game server commands a motor controller over WiFi to do actions according to the game logic. Game events are uploaded in real-time to a cloud data pipeline to aggregate data and calculate global game statistics such as scores and leaderboard.

The architecture was built for flexibility and scalability (to include also large-scale gaming events). Horizontal scaling is achieved by assigning each group of players to a game server. The number of servers can be increased as more players join. The cloud data pipeline is an open system where demand increases if there is concurrent events at different venues. The elasticity of the cloud-based architecture allows compute power to be acquired and released as demand fluctuates.

The crocodile enables the machine, e.g. wheelchair, to sense the human by monitoring a player's EEG brain signals. In this implementation, each crocodile is linked to one Muse device by its Universally Unique Identifier (UUID). This one-to-one relationship is to ensure that each connection can be reliability established and maintained with minimum distribution in the data flow. New generations of Muse EEG are Bluetooth Low Energy (BLE) devices that expose data via a BLE service with multiple characteristics. Each characteristic represents a single data type that can be streamed from the Muse to the connected logger. For example, all 5 EEG channels, accelerometer, gyroscope and heart rate data are declared as separate characteristics. Additionally, there is another control characteristic that is used to command the Muse to start/stop streaming the data that the logger subscribed to receive. Data may be used for studies in brain health and wellness.

In this architecture, data can be stored in multiple locations for redundancy and flexibility of deployment. The crocodile has an SD Card. Similarly the game server have a larger storage capacity. Data transmission is also flexible: the crocodile can upload data directly to a cloud server or can send it to an on-premises server inside the gaming arena, for example during a gaming event or a show. For a large-scale gaming event, this architecture can scale horizontally by adding more game servers to each group of participants.

In the current experimental setup, we used User Datagram Protocol (UDP) for communication between crocodiles and game servers for speed and low latency. The communication between the game server and the motor controller was first over HTTP (Hypertext Transfer Protocol), but we changed to UDP because it allows the game server to keep sending the data even when the motor controller is not running (which leads to connection timeout in the HTTP case). However, the architecture is protocol agnostic. Other protocols such as MQTT can be used. The decision of the appropriate protocol is a function of the scale of the deployment and the required latency and desired throughput.

The software running on the game server can be implemented with a message-based *actor model* [50] to scale as the number of concurrent users increases. Additionally, each player can be represented by a single persistent actor to maintain the game state of the player which makes the code easier to understand and maintain.

VI. Motor/Mind Games for people of all abilities

When a sousveillant motor (i.e. a motor equipped with SWIM) is set in motion, the rotating magnetic field is stretched across time, as illustrated in Fig 7.

It is our hope that the fun and merriment of games will help get more people interested in addressing issues of mobility

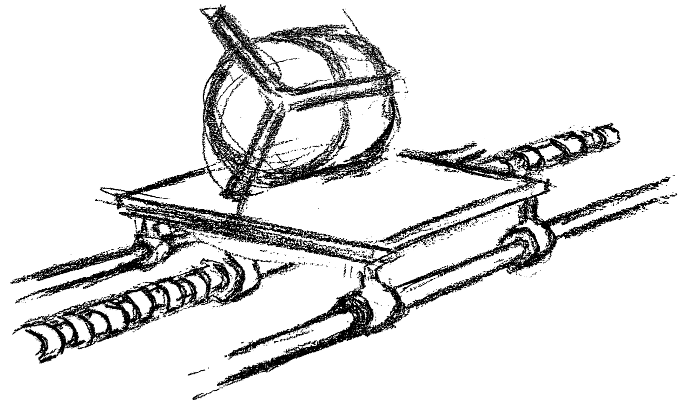

Fig. 7. Sousveillant electric motors in motion trace out a pattern which makes visible the otherwise invisible relationships of the powertrain driving the motor: concept sketch for three SWIMs on a 3-phase motor-in-motion (M. Zandwyk and S. Mann).

for people of all abilities. For example, we might expand our games toward the space of mobility scooters. Accordingly, we have outfitted a number of mobility devices with SWIMs and other devices for biofeedback-based sensing. The SWIM in motion also creates a trace or record of the powertrain function as it moves through space.

VII. Metaveillant Systems: Games from the Mind's Eye

Sousveillant systems lay bare the inner workings of machines, so that humans can easily understand the machines.

Metaveillant systems lay bare sensors and senses. Metaveillant systems™are systems for:

- sensing sensors, such as by allowing us to see a camera's capacity to see (camera metavision™); or
- sensing senses, such as by allowing us to see the human eye's capacity to see (human metavision).

We now present a variety of games that come from metaveillant systems that are based on human vision.

By sensing the senses (such as vision), we can make the sensing of senses into a game engine. Consider, for example, SSVEP (Steady-State Visual Evoked Potentials) or CTVEP (Chirplet Transform Visual Evoked Potentials) [51], [52], [53], [54].

One aspect of human metavision is metaveillography of a human observer, i.e. photographing a human's capacity to see.

We created a special kind of 3D plotter for human metaveillography. The "print head" of the 3D plotter contains two objects:

- a front-facing smartphone with a flashing checkerboard pattern, typical of SSVEP or CTVEP experiments; and
- a rightward-facing RGB (Red Green Blue) LED (Light Emitting Diode),

as shown in Fig 8.

The smartphone displays four or 16 squares flashing at a fixed frequency such as 12 Hz for SSVEP, or at various chirp-rates, parameterized by starting frequency, f_{beg} and ending frequency, f_{end}. Originally we used light-and-dark squares, but later found we obtained better results using two complimentary colours such as red and cyan.

We developed a "Brady chair" analogous to the "Brady stand" used in the early days of photography. The chair helps to fixture the observer's head, from behind, while a chin rest fixtures the front of the face. See Fig 8. The observer either affixes their gaze at an alphanumeric LED display that occasionally and briefly flashes a number or letter the observer must concentrate on (where we're photographing attentional central foveal gaze) or is allowed to follow the smartphone display with gaze.

In a game situation we have competing players, and the alphanumeric LED display helps to prevent cheating.

The display moves from nearfield (very close to the eye) to farfield in sweeping arcs up-and-down, and sometimes also sideways.

In some versions of the game the display moves continuously, while in other versions the display dwells at fixed points and moves digitally to points on a discrete quantized spatial lattice.

An initial vision picture is created prior to the match, so that each contestant has an "eye portrait" (ayinograph) taken with the screen moving 5mm/sec up-and-down, and 0.5mm/sec away, traveling 21cm.

The observer wears a Muse wearable EEG headband manufactured by Interaxon (a company founded at MannLab Canada on 330 Dundas St. W. in Toronto, by S. Mann and some of his students, and others, http://wearcam.org/interaxon.htm). The Muse is modified with additional EEG electrodes attached to a 3D printed holder in a flexible headband that positions it over the occipital lobe of the wearer, on O1, Oz, and O2 (according to the commonly used 10-20 system of EEG placement [55]).

SSVEP or CTVEP [52], [51] is captured while the observer views the flashing stimulus. Windowed FFT (Fast Fourier transform) or CT (Chirplet Transform) data is captured over a window size of 2 to 10 seconds. A simple machine learning algorithm is applied to the Fourier or Chirplet signal against the background noise, and the output is used to vary the colour of the rightward-facing LED attached to the moving carriage. The colour change is also applied to the stimulus, illuminating the face of the observer during the photograph.

The rightward-facing LED faces a camera that takes long-exposure photographs of the person's face (side-view), and their right eye (though both eyes are sensed). See Fig8. The exact position of the smartphone display and LED is recorded to generate both a database of position and SSVEP signals, as well as the long-exposure photograph.

A. Encephelkustinda: SSVEP tug-o-war

Encephelkustinda™is a game based on the Greek concept of helkustinda (tug-o-war) played with the VEP. As such it is a contest of visual capacity to see and concentrate on the flashing stimulus which is attached to the X-Y-Z plotter. Here a larger plotter was constructed at MannLab Canada. The plotter was built from oak (base, table) and aluminium (frame), in which the Z-axis is the table height (motorized table legs) and the X-Y axes are by stepper motors in the frame having a approximately 10,000 by 9,000 pixel resolution.

The carriage houses an RGB LED and platform for the stimulus, here a smartphone display with flashing chekerboard pattern. The game works with 2 to 4 players gathered around the table, one player on each side. If there are only 2 players, they face each other. Fig 11 shows the game with four players.

Another of our meta-sensory games is a variation of the Parker Brothers (now Hasbro, Inc.) game, "Ouija", but using deliberate conscious brain activity rather than relying on unconscious movements (ideomotor effect) of the players. See Fig 12. In one variation of the game, justice is served in a Game of Thrones scenario using VEP and crowd-funded justice, in which a jury of a dozen Muse2 wearers decide the fate of the accused. See Fig 13.

B. Mind's Eye

Finally we developed a game that causes the eye itself to function as a camera. The game functions a lot like Pictionary (by Hasbro, and now Mattel), in that two person teams are formed by a "painter" and a "guesser". The painter is given a secret image (simple picture) that the guesser cannot see. The painter looks at the image and the guesser must read the painter's mind to see the image, and draw it. The guesser looks at a video screen showing an image formed by the painter's EEG output.

The images are simple shapes like a white circle on a black background, or a white polygon on a black background, etc., and the "painter" looks at the image under flashing light (illuminated by a flashing light source, or seen through shutterglasses).

The "painter" looks at rasterized prescribed grid points in sequence, and the VEP signal strength is read out. The premise is that light-colored areas of the image will produce a stonger VEP, akin to pixel values in a camera. In this way the eye itself functions as a camera and takes a picture of the secret shape and conveys it to the partner by video display. Whichever partner can successfully guess the shape defines the winning team. The objective of the game is essentially to cause one's eye to function as a camera and capture and convey a picture to one's team partner. See Fig 14.

In another variation of the game, teams are formed with multiple "painters", e.g. each team has two painters and one guesser. Painters on a given team each wear an EEG headset and look a secret shape. See Fig 15.

VIII. Conclusions and Future Directions

We presented a number of "brain games" ("encephalogames™") that use encephalogram input signals (EEG, i.e. brainwaves), evoked potentials, and the like, in new and creative ways. We've used sousveillant systems and metaveillant systems for games. Sousveillance games and metaveillance games are games based on sensing-of-sensing, which is the sensing of sensors or the sensing of our senses, and the sensing of our visual attention. Author S. Mann

Fig. 8. **Prototyping from salvage scrap: a lesson in extremely fast spontaneous 90-minute spinting with whatever can be found here and now.** Ayinographic apparatus constructed by Grade 11 high school students at MannLab Canada: 3D plotter holds a smartphone's display to face an observer. The smartphone display flashes a checkerboard pattern while it is moved up-and-down, starting close to the observer and moving slowly away from the observer with each sweep. An RGB LED is attached to the side of the smartphone. The LED faces directly to the right to illuminate for the camera at the right that also captures a side-view of the observer's face and eye(s). The camera captures a long exposure photograph of the veillance flux [56] (observer's capacity to see).

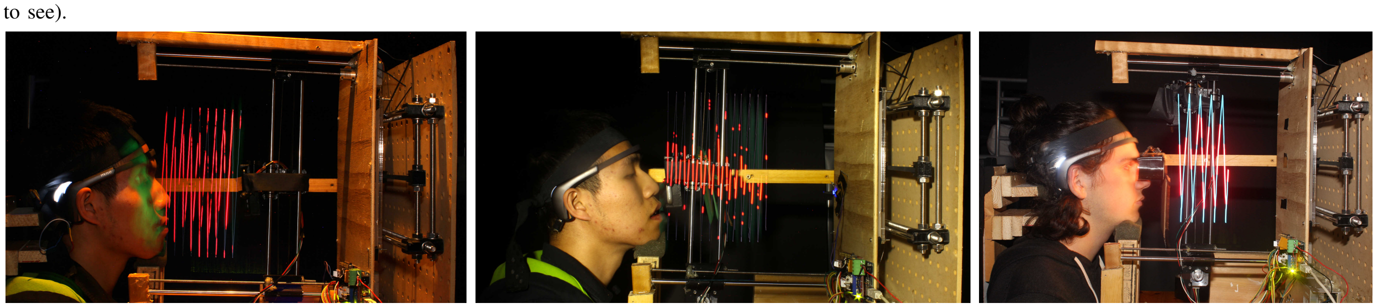

Fig. 9. Bright red (RGB LED) shows where EEG picked up strong SSVEP signal locked to the smartphone screen's stimulation. Left: observer followed the moving phone with eyes looking up and down, while head fixed. Strong SSVEP is seen throughout visual field. Middle: observer focuses on a single point directly ahead, and lets smartphone move in and out of peripheral vision. The long-exposure photograph shows only a narrow beam of sight approximately equal to the height of the phone. Right: the observer wears two cardboard tubes (empty half-length toilet paper rolls covered in black tape), so their vision is vignetted. Part of the visual field is occluded with the occluding tubes around the eyes. We see here the capacity to see has become more narrowed, indicating a veillance shadow [57] cast by the cardboard tubes. The camera's flash has also been activated, illuminating the setup as well.

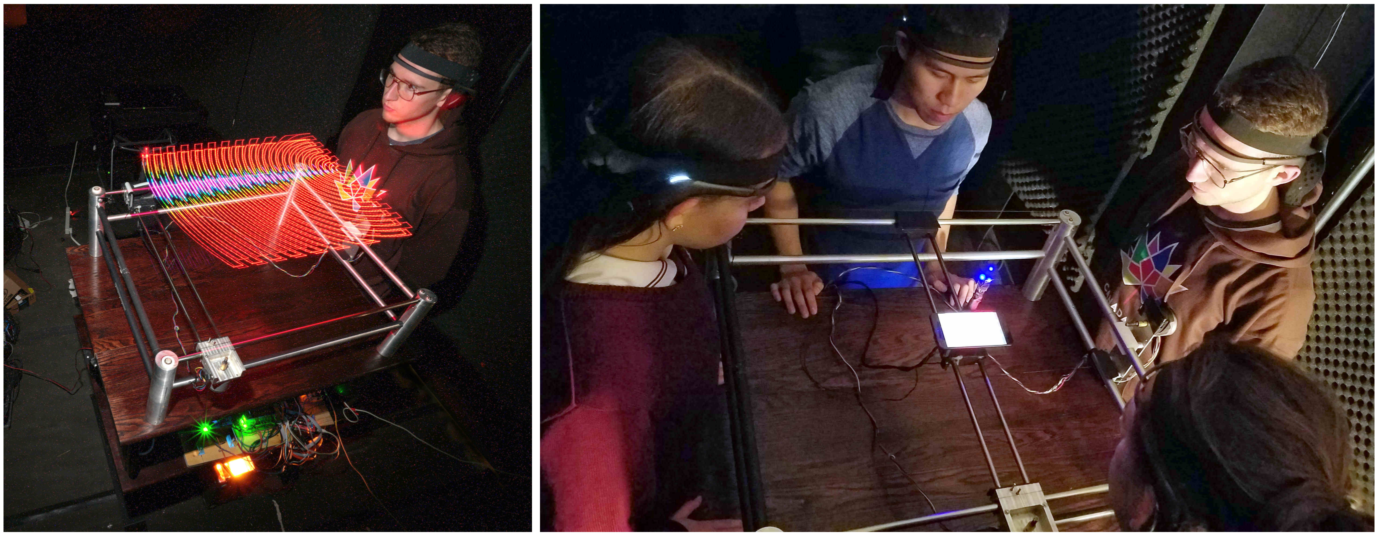

Fig. 10. Meta-sensory tug-o-war setup. Left: Initially players do a vision test where each player is photographed together with their ayinograph, i.e. a metaveillograph that shows the player's ability to see. This is analogous to the "weigh-in" in a wrestling match, as it establishes the general ability at the game. Right: contestants gather around the table to play. Initially they all concentrate on the screen in the center.

Fig. 11. Meta-sensory tug-o-war game. Left: A long-exposure photograph. The carriage homes to the lower-left, then goes to the center and the game begins. The photograph shows that Christina is the clear winner, as the carriage with the flashing stimulus went directly to her quickly. Wins tend to be decisive because, as the the winner brings the carriage closer, it subtends a larger visual angle, allowing the winner a better view of it. Right: In some variants of the game, teams of two compete to "pull" the carriage to their corner. Here Christina and Jeremy bring the carriage into their corner, defeating the other two players.

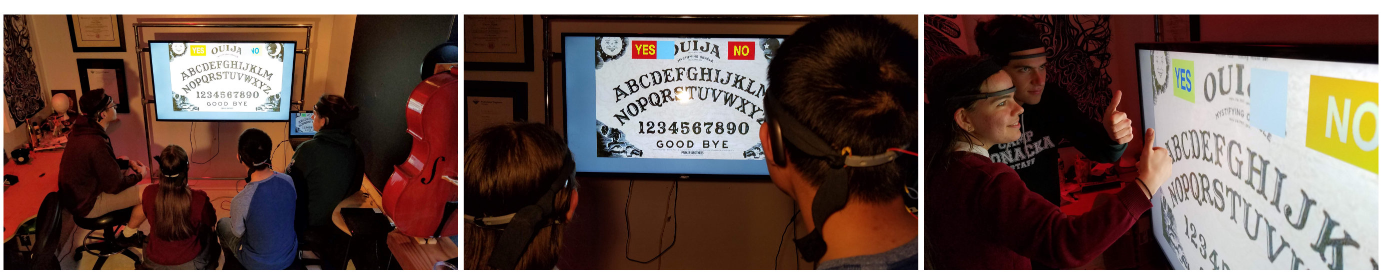

Fig. 12. A common parlour game is Ouija by Parker Brothers (now Hasbro Inc.) in which players act often subconsciously through the *ideomotor effect*. Our variation of this game works at the conscious level where each symbol flashes at a different frequency, and a large group of up to 12 players (each wearing a Muse2 headset) look at the flashing symbols. A virtual planchette (cursor) is moved by virtual forces, each force deriving from total VEP signal strength at each of the frequencies, associated with each of the spatial positions.

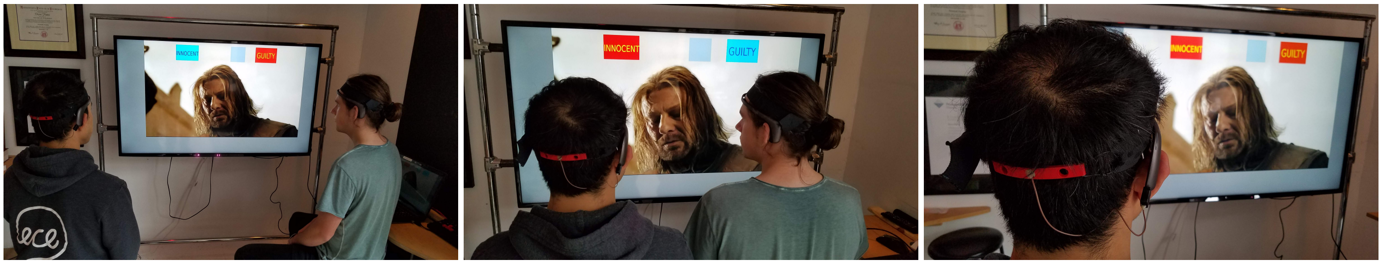

Fig. 13. Variation on Game of Thrones using VEP for crowd-funded justice. “Guilty” and “Innocent” flash at different rates, and the collective collaborative total VEP signal strength of each is compared, moving a virtual planchette to one or the other state: (1) actuating a virtual trap door in a virtual scaffold so the prisoner is hanged if deemed guilty, or (2) automatically setting the accused free if deemed innocent.

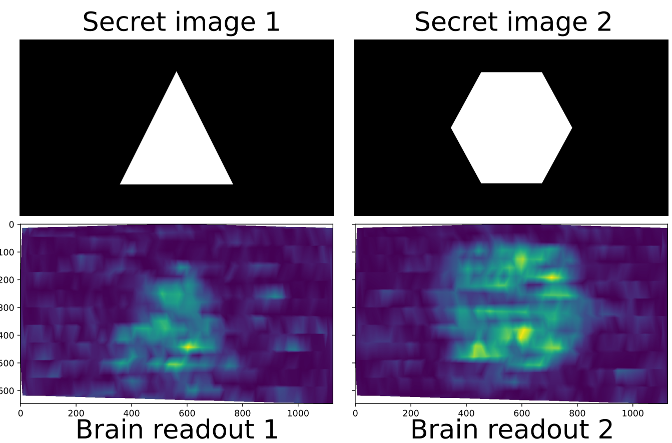

Fig. 14. **World’s first pictures captured using the human eye as a camera.** No eye-tracker or other sensor was used. The only sensor used to capture these pictures was a Muse 2 headset with occipital lobe electrode! In the Mind’s Eye™game, a sliding cursel™(cursor pixel) moves across the image in a raster-scan order, while a highly suspenseful story plays out on it: “Gallows rental app...”. This draws the reader to concentrate. The cursel is one pixel of the Mind’s Eye. As the cursel moves over the subject matter, the lightness or darkness of that part of the real world is derived from the VEP.

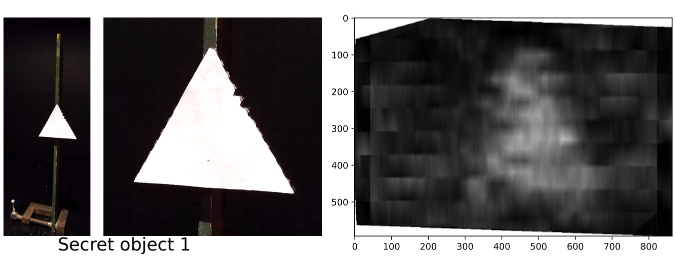

Fig. 15. Here each team is comprised of multiple people wearing EEG headsets and aggregating their EEG signals together to paint a collective mind’s eye picture. The secret object here is a polygon cut out of white paper and affixed to a polygonal perfboard attached to a stand.

has proffered the notion of “attentement™” which is the time-integral of attention (akin to his notion of absement and momentement™= the time-integral of momentum), and VEP tug-o-war can be regarded as an attentement game. These encephalogames will create a marketplace that grows mental health, wellness, and fitness through metavision, meta-sensing, and sousveillant systems, as well as giving us new insight into the human mind, human vision, human visual attention, and collaboration.

Metavision games will hopefully welcome many players of widely differing ability, such as those confined to a wheelchair, to participate at full intensity. We’re also working on a mind-controlled wheelchair or hoverboard that has just one single spherical wheel that floats (hovers) on a cushion of magnetic flux, so that it can go in any direction. By approaching this project as a game, we’re building small “toy” prototypes as quick low-risk, low-budget experiments for students to competitively explore, using gamification as a way to stimulate exploration of technologies that might someday help people of all abilities.

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