Exploring a Methodology for Automatically Detecting Positive or Negative Events in a Virtual Racing Game

Jessica O. Sugay[1]
jsugay@ateneo.edu

Francis Jan P. Macam[1]
f_macam@yahoo.com

Thomas T. Dy[1]
thatsmydoing@gmail.com

Ma. Mercedes T. Rodrigo[1]
mrodrigo@ateneo.edu

ABSTRACT
We describe a work-in-progress that attempts to detect anxiety in drivers while exposed to a virtual racing game. The detection system is a combination of two Nintendo Wii Balance Boards, parallel video recording of in-game events and facial expressions, and the OCZ Technology's Neural Impulse Actuator (NIA) brain-controlled headset. We attempt to establish a relationship among the various physiological and physical signals with occurrences of anxiety as coded by human observers when viewing video recordings of facial expressions.

Categories and Subject Descriptors
H.1.2 [**User/Machine Systems**]: Human Factors

General Terms
Affect, Anxiety, Detection, Measurement, Human Factors

Keywords
Anxiety, Drivers, Affect Detection

1. INTRODUCTION
Driver stress is a major contributor to traffic accidents [7],[16]. Some of the main sources of driver stress are time pressure, congested roads, prolonged driving time [29], and high-speed driving [11]. Along with stress, these factors also induce negative moods and affective states such as aggression, irritability, frustration, [10] and anxiety. Studies have linked these with the impairment of decision-making capacities and cognitive performance [16],[1] decrease in situational awareness, alertness [4] and ability to identify road hazards [11],[26] and delay in response rate. The presence of these driver performance disruptions indicate a reduction in safety while the degree of severity of these disruptions increase the chances of an accident to occur.

To study and manage in-vehicle information systems, researchers have made use of sensors in real-world fighter pilot tasks [23] and automobile driving tasks [12], as well as in simulations [26] and virtual environments (VEs) [15]. Data collection using simulations and VEs offers several advantages over data collection in live vehicles. Among these are increased safety, decreased expense and greater control over variables.

The preliminary study discussed in this paper combines several approaches to the study of driving tasks and the use of sensors [12], the use of VEs [15], and anxiety [1]. It is mostly an adaptation of Healey and Picard's study [12], with the following differences: We use a VE instead of real-world situations. We use a racing environment, instead of regular driving tasks. We also use a different combination of sensors: Wii Balance Boards for posture, the NIA headset for brainwave signals, video recording for facial expressions and field of view, and human observations for manifestations of anxiety.

2. RESEARCH GOALS, SCOPE AND LIMITATIONS
The long-term goal of this study is to build a model for driver anxiety. However, the scope of this paper is limited to a discussion of the instruments and methods that we use to collect and label data. We also present a an initial attempt at analyzing data to determine which of the sensor data correlate with positive or negative incidents in the simulation, and what set of features is most parsimonious for detecting anxiety. We acknowledge that these methods are still exploratory at the moment and may not be the best methods available for analysis.

The use of a race concept VE also limits the applicability of findings to real-world contexts. A race does not represent real-world driving conditions. The controls used for the VE do not replicate the feeling of an actual steering wheel, pedals, and gear shift. The VE does not have the same environmental conditions as the real world—inclement weather, road repairs, interactions with other vehicles and pedestrians and so on. We acknowledge that, because of these differences, the model we derive will not generalize from the VE to the real world. The experimental set up discussed in detail below, though, requires drivers to sit on Wii Balance Boards and wear a headset. We also had to mount at least two cameras in the immediate vicinity of the driver—one facing forward to record the driving conditions and one facing the driver to record his/her expressions. We were concerned that all this equipment would distract the driver and put him/her in harm's way. We therefore decided to use the VE principally so that we could assure the safety and security of our test subjects.

3. METHODS
The preliminary experiment was conducted with eight individuals (seven male and one female), with aged 20 to 29. All participants have prior experience with racing games possessing similar environments. Each participant knew how to drive, most do so

regularly. Each participant performed the experiment tasks on an individual basis.

Before the start of the experiment, we prepared the environment and equipment (Figure 1) and synchronized the time on the computers with the time on the clock (Figure 2). At the start of each individual's turn, the participant is asked to sit in a chair to which the Wii Balance Boards had been attached – one is strapped to the chair's seat, and the other is strapped to the backrest. The participant was then asked to put on the NIA headset. We verified that the NIA headset and the Wii balance Boards were ready and able to record signals from the participant.

We oriented the participant on the tasks to be performed within the game, the different game stages to be completed, and the different controls needed to interface with the racing game (Figure 2). We then cued two video recorders with a timestamp to establish a synchronization point.

The participant proceeded with each stage in the game. The video recorders and sensors stopped recording data once the last stage is completed.

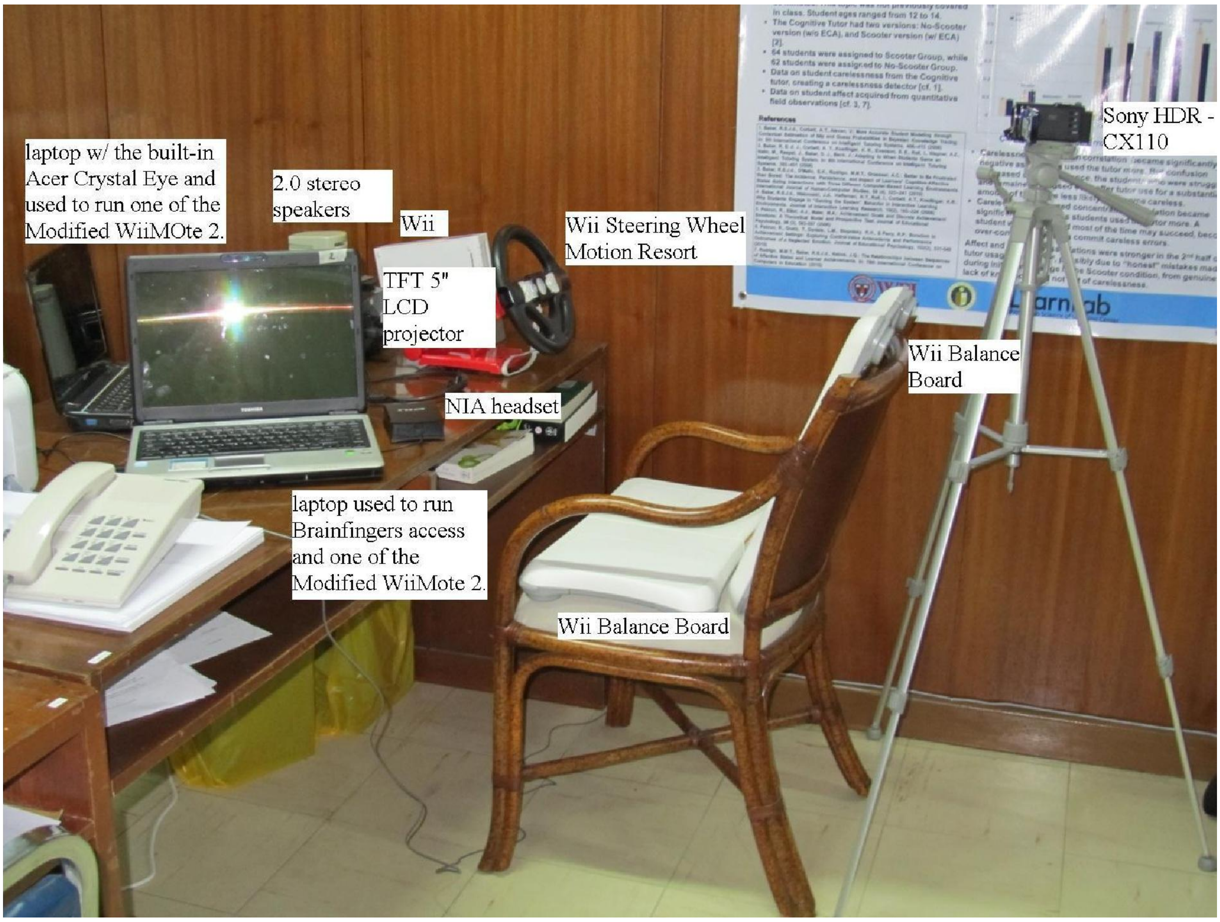

Figure 1. The experimental set up.

3.1 Racing Game Platform

For this experiment, we used the game Need for Speed Hot Pursuit for the Nintendo Wii, by Electronic Arts Inc [18] (Figure 2). The player controlled the car with a table-mounted generic steering wheel controller, to which a WiiMote was attached. The entire run for each experiment consisted of four races: Eliminator, Time Attack, Hot Pursuit, and Rush Hour. All participants used the same in-game car setup (the game's default) to eliminate differences in car capabilities. The four races are described below.

3.1.1 Eliminator

The Eliminator stage involved racing against three other non-player vehicles. The player must achieve a specific rank within the given time limit to avoid being eliminated from the race. The racing environment included incidental traffic. If the player was unable to attain the specified position within the time, the player was eliminated and the race ended. This stage allowed the participant to get acquainted with the game environment and controls.

3.1.2 Time Attack

The Time Attack stage did not involve any non-player vehicles or a time limit. The player's objective was to complete a set route in the shortest possible time. This stage was used in this study to establish a participant's baseline. Each participant was instructed to focus on completing the route and not on the speed.

Figure 2. A clip from one of the video recordings showing the field of view of the driver.

3.1.3 Hot Pursuit

The Hot Pursuit stage involved three competitive non-player vehicles, incidental traffic, and police cars that pursue a racer under certain conditions. The objective was to complete three laps along a prescribed route and place first in the race. If the player was pursued by police cars, he/she can maneuver to avoid being caught. If the player is caught by the police, he/she resumed the race course at the point of capture. There was no time limit for this stage.

3.1.4 Rush Hour

The Rush Hour stage involved competing with 99 other vehicles. The route did not include police cars or incidental traffic. The player's objective was to overtake other non-player vehicles and achieve a certain position within the prescribed time limit.

3.2 Equipment and Software

For this experiment, several pieces of equipment, together with software packages, were used and operated simultaneously.

3.2.1 Wii Balance Boards and Modified WiiMote2

The Wii Balance Board is an accessory for the Wii Console created by Nintendo [20].This experiment made use of two Wii Balance Boards to collect data on the shifts in the participant's posture. Each Wii Balance Board was connected to a notebook computer via Bluetooth. The notebook computer was equipped with the Modified WiiMote2 v1.5.2.0 software package [21], which records the data signals transmitted by the Wii Balance Board.

We elect to include posture data because posture has been shown to correlate with affective states such as boredom and flow [6]. While these are not direct indicators of anxiety, posture might imply its absence in the driver.

3.2.2 Neural Impulse Actuator (NIA) and Brainfingers Access

This experiment used the Neural Impulse Actuator (NIA) from OCZ Technology [19] to collect data on facial expressions, eye movements and brainwave activity. The NIA was connected to a notebook computer equipped with the Brainfingers Access v2.05.24 NIA 1.0 software package [5]. This recorded the data from the NIA headset.

3.2.3 Video Cameras

Two video cameras were used in this experiment: one (Sony HDR-CX110) to record the participant's field of view as a driver, and the other (Acer Crystal Eye) to record the participant's facial expressions.

Note that the game events were not automatically logged. They were recorded by video and were annotated after the fact.

3.2.4 Elan Linguistic Annotator

After the experiment, the Elan Linguistic Annotator v4.1.0 was used to synchronize the video recordings of the participant's facial expressions and the participant's field of vision (Figure 3) showing the game events. Human observers coded in-game events and occurrences of anxiety for each second [12] of video.

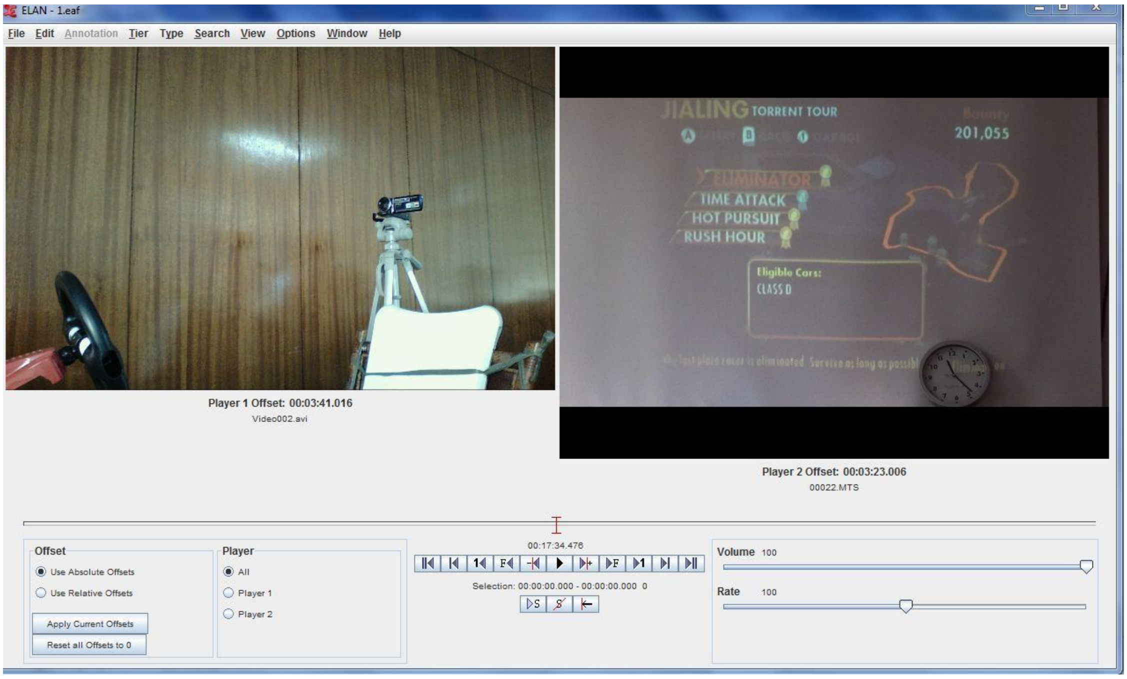

Figure 3. A screenshot of the two synced video recordings using Elan Linguistic Annotator.

3.3 Data Collected

This section describes the various data sets collected from the equipment used in this experiment.

3.3.1 Data from Wii Balance Board

The Wii Balance Board provided data on the participant's posture, which is derived from his/her weight distribution along the four quadrants of the board and the center of gravity. Data is sampled at a rate of nine readings per second. The features recorded from the Wii Balance Board are described below.

Top Left, Top Right, Bottom Left, Bottom Right: The participant’s weight, in pounds, as distributed among the four quadrants of the board

Weight: The total weight of the participant in pounds.

Center of Gravity X: The center of gravity along the X-axis

Center of Gravity Y: The center of gravity along the Y-axis

3.3.2 Data from NIA

Data from the NIA headset was recorded using the Brainfingers Frequency View feature. The data included brainwave signals such as EOG, EEG, and EMG. Data was sampled at a rate of 244.3 readings per second. The features collected are described below.

RAW: Raw data from the human interface device (HID). EOG, EEG, and EMG are derived from this signal.

EOG: The ElectroOculoGraphic signal tracks eye movement based on the retina. It is the lowest frequency channel among the three derivatives of the RAW data [6]. Glance Direction and Glance Magnitude are derived from this signal.

EEG: The ElectroEncephaloGraphic signal tracks the electrical activity along the scalp. EEG is the second derivative of the RAW data [6]. Its frequency range is from 1 to 500 Hz, where Alpha1, 2, 3 and Beta1, 2, 3 are derived.

EMG: The ElectroMyoGraphic signal tracks the electrical potential produced by skeletal muscle cells when neurologically active. EMG is the third derivative of the RAW data [6]. Its values and facial muscle activity are directly proportional. Its derivative is the Muscle Joystick signal.

GlDirJs: The Glance Direction Joystick data corresponds to horizontal eye movement. Glance Direction Joystick is a derivative of EOG. High values correspond to glancing in the right direction while low values correspond to glancing in the left direction.

GlMagJs: The Glance Magnitude Joystick data corresponds to the depth of the eyes' glance. Another derivative of EOG, its recorded values and intensity of the subject’s glance are directly proportional.

A1Js, A2Js, A3Js: The Alpha1, Alpha2, and Alpha3 joysticks, centered at 7.75Hz, 9.5Hz, and 11.25Hz, referred to the three Brainfingers recorded as the Alpha Brain Resonance [6]. Alpha brainwaves usually range from 9 to 14 Hz [6]. Known as an indicator of mental state, high Alpha values often suggest wakeful relaxation or closed eyes, while low Alpha values signifiy open eyes, drowsiness, sleep, or intention to move.

B1Js, B2Js, B3Js: The Beta1 (16.5Hz), Beta2 (21.25Hz), and Beta2 (25.0Hz) joysticks refer to the three Brainfingers recorded as the Beta Brain Resonance [6]. Beta brainwaves usually range from 13 to 22 Hz [6]. Known to indicate awareness state activity, beta values are associated with muscle contractions over the motor cortex prior and during movement. High Beta values can correspond to a voluntary suppression or resistance of movement. Low Beta values suggest activity, anxiety, or active concentration.

MuscleJs: The Muscle Joystick signals, centered at 200 Hz, correspond to facial muscle tension, including contractions of the jaw muscle and eyebrow movements.

3.3.3 *Data Labeling by Human Observers*

Using Elan, two human observers viewed the synchronized videos at the same time. By consensus, they labeled the in-game events and occurrences of anxiety.

3.3.3.1 *In-Game Events*

The game flags in-game events with text messages that appear on the game screen. These text messages signal to the player that he/she has advanced in the game or has done something wrong. "Airtime" for example, means that he/she has sped off an incline and has launched the car into the air for a second or two. Human coders classified these in-game events as either positive or negative. Positive events corresponded to achievements in the racing game, while negative events were those that impeded the driver from accomplishing the stage's goals.

Some positive events are Escape Cops, Race Leader, Broke Roadblock, Drift, Winner, and Checkpoint Cleared.

Negative events included Airtime, Traded Paint, Crash (or Totaled), Criminal Damage (or Critical Damage), Repair Your Car, Stall, Eliminated, Hit Cone, Close Call, Impact (or Major Collision), Speed Camera (driving beyond 110mph), Turn Around (heading toward the wrong direction), and Tilt (vehicle moves while not leveled on the road).

3.3.3.2 *Occurrences of Anxiety*

Human observers coded the occurrences of anxiety based on facial expressions, verbal utterances, and changes in posture.

Furrowed eyebrows, pursed or bitten lips, and opening or closing of the mouth are examples of facial expressions.

Verbal utterances included audible expressions like sighing or interjections like "argh" and "grrr" as well as words such as cursing and loud vocalization.

In this experiment, anxiety included frustration and surprise, usually stemming from negative in-game events.

3.4 Data Synchronization, Cleaning and Aggregation

During the typical start of a data collection session, the data collection features of the devices were activated sequentially and not simultaneously. Some early readings from the devices therefore did not have counterparts from other devices. We deleted all data rows for which the readings were incomplete.

We laid out all four data streams (Wii data from the seat, Wii data from the back, NIA data, and labeled data from human observers) on an Excel spreadsheet, using the time stamps to synchronize them. As mentioned earlier, the clocks of the computers were synchronized. This eliminated the need for synchronization using sliding time windows [6].

We divided the remaining rows into one-second time slices. The one-second time slice size was selected arbitrarily. Because the data from the NIA and the Wii were floating point values with three or more decimal places each (weight distribution, alpha readings, beta readings, etc.) we normalized these readings by averaging them for each time windows.

4. PRELIMINARY ANALYSIS AND RESULTS

We conducted a preliminary analysis of the data using RapidMiner 5.1.008. We examined the correlations between each individual feature and the incidence of positive or negative events in the game, but found none.

We then attempted to reduce the dimensionality of the feature set by using the RemoveCorrelatedFeatures operation. We set the sensitivity to an r=.5, meaning any feature correlated at the .5 or greater level with another feature was removed. Of the 30 original features, 7 were removed and 23 remained:

- BackTopLeft
- BackTopRight – correlated with BackBotRight (r=.74) and BackWeight (r=.98)
- BackX – correlated with BackY (r=-.98)
- BotTopLeft – correlated with BotTopRight (r=.66) and BotWeight (r=.93)
- BotBotLeft
- BotBotRight – correlated with BotX (r=.57)
- BotY
- RAW
- EOG – correlated with EEG (r=-.58)
- EMG
- GIDirJs
- GIDirMagJs
- A1Js, A2Js, A3Js
- B1Js, B2Js, B3Js
- MusclesJs

We then created two decision trees: One to predict the incidence of negative events, and the other to predict the incidence of positive events. We evaluated the trees using batch-level cross validation.

To predict negative events, the tree had an accuracy of 89.75%. To predict positive events, the tree had an accuracy of 94.10%. Unfortunately, in both cases, kappa values were 0, meaning the predictions were at the level of chance.

5. NEXT STEPS

There are several ways in which the experiment methodology can be improved. The baseline stress level of the drivers recorded during the Time Attack phase should be compared with the stress levels during the competitive phases of the game. This will establish whether there indeed was a difference in the way players were feeling or if there was no change.

The hard surface of the Wii balance boards may have introduced a level of discomfort that may in turn have added noise to the readings. This can be remedied by having the drivers sit on a pad or cushion, placed on top of the board.

A possible reason why kappa values were low was because the grain size of the data might have been too fine. We will try experimenting with the dilation of time around each positive and negative event to see whether that will affect the results.

A wider sample of readings might be more telling of stressful events. For instance, the average speed of the drivers during the time dilation may have an impact on the model.

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8. AUTHORS' INSTITUTIONAL AFFILIATIONS

[1] Ateneo Laboratory for the Learning Sciences, Department of Information Systems and Computer Science, Ateneo de Manila University, Loyola Heights, Quezon City, Philippines, +63 (2) 426-6001 loc 5666, http://penoy.admu.edu.ph/~alls