

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

Jessica O. Sugay¹
jsugay@ateneo.edu

Francis Jan P. Macam¹
f_macam@yahoo.com

Thomas T. Dy¹
thatsmydoing@gmail.com

Ma. Mercedes T. Rodrigo¹
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 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.

GIDirJs: 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.

GIMagJs: 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 signify 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.

6. ACKNOWLEDGMENTS

The authors thank Juan Miguel Andres, Diane Marie Lee, Dr. Ryan Baker, Dr. Sidney D'Mello, Dr. Andrew Olney, and the Ateneo de Manila University's Department of Information Systems and Computer Science. We thank the volunteers for their participation in this study. We thank the reviewers of this paper

for their helpful comments and suggestions. We thank the Department of Science of Technology's Philippine Council for Advanced Science and Technology Research and Development for the grant entitled, "Development of Affect-Sensitive Interfaces."

7. REFERENCES

- [1] Baddeley, A. Selective attention and performance in dangerous environments. *British Journal of Psychology* 63 (1972), 537-546.
- [2] Barniv, Y., Aguilar, M., and Hasanbelliu, E. Using electromyography to anticipate head motion for virtual-environment applications. *IEEE Transactions on Biomedical Engineering* 52, 6 (2005), 1078-1093.
- [3] Bishop, S., Duncan, J., Brett, M., and Lawrence, A. D. Prefrontal cortical function and anxiety: controlling attention to threat-related stimuli. *Nature Neuroscience* 7 (2004), 184-188. DOI=10.1038/nn1173
- [4] Blagrove, M., Alexander, C., and Horne, J.A. The effects of chronic sleep reduction on the performance of cognitive tasks sensitive to sleep deprivation. *Applied Cognitive Psychology* 9 (2005), 21-40.
- [5] Brainfingers: How It Works, 2008. Retrieved July 11, 2011, from Brain Actuated Technologies: <http://www.brainfingers.com/>
- [6] Brainfingers: Technical, 2011. Retrieved July 28, 2011, from Brain Actuated Technologies: <http://www.brainfingers.com/technical.htm>
- [7] Cartwright, S., Cooper, C.L., and Barron, A. The company car driver: occupational stress as a predictor of motor vehicle accident involvement. *Human Relations* 49 (1996), 195-208.
- [8] D'Mello, S., Taylor, R., Tapp K., King, B., and Graesser, A. C. Posture as a Predictor of Learners' Affective Engagement: Boredom and Flow. Presented at the 2007 Annual AERA Meeting (2007).
- [9] Dalton, K.M., Kalin, N.H., Grist, T.M., and Davidson, R.J. Neural-Cardiac Coupling in Threat-Evoked Anxiety. *Journal of Cognitive Neuroscience* 17, 6 (2005), 969-980.
- [10] Dishman, R.K., Oldenburg, B., O'Neal, H., and Shephard, R.J. Worksite physical activity interventions. *American Journal of Preventive Medicine* 15 (1998), 344-361.
- [11] Dorn, L., and Brown, B. Making sense of invulnerability at work-a qualitative study of police drivers. *Safety Science* 41 (2003), 837-859.
- [12] Gunes, H. and Piccardi, M. Observer annotation of affective display and evaluation of expressivity: face vs. face-and-body. *HCSNet Workshop on the use of vision in human-computer interaction* 56 (2006), 35-42.
- [13] Healey, J.A. *Wearable automotive systems for affect recognition from physiology*. Ph.D. Dissertation. Massachusetts Institute of Technology. 2000.
- [14] Healey, J.A. and Picard, R.W. Detecting Stress During Real-World Driving Tasks Using Physiological Sensors. *IEEE Transactions on Intelligent Transportation Systems* 6 (2). 156-166.
- [15] Maiano, C., Therme, P., and Mestre, D. Affective, anxiety and behavioral effects of an aversive stimulation during a simulated navigation task within a virtual environment: A pilot study. *Computers in Human Behavior* 27 (2011), 169-175.
- [16] Matthews, G., and Desmond, P.A. Personality and multiple dimensions of task-induced fatigue: a study of simulated driving. *Personality and Individual Differences* 25 (1998), 443-458.
- [17] Mota, S.A. *Automated Posture Analysis For Detecting Learner's Affective State*. Masters Thesis. Massachusetts Institute of Technology. 2002.
- [18] Need for Speed Hot Pursuit: Game Information, 2011. Retrieved July 11, 2011, from Electronic Arts: <http://www.ea.com/need-for-speed-hot-pursuit>
- [19] NIA Game Controller: Description, 2011. Retrieved July 11, 2011, from OCZ Technology: <http://www.ocztechnology.com/nia-game-controller.html>
- [20] Nintendo Wii Accessories: Balance Board, 2011. Retrieved July 11, 2011, from Nintendo: <http://www.nintendo.com/wii/console/accessories/balanceboard>
- [21] Olney, A.M. and D'Mello, S. Interactive Event: A DIY Pressure Sensitive Chair for Intelligent Tutoring Systems. *Intelligent Tutoring Systems, Lecture Notes In Computer Science* (2010), 456.
- [22] Picard, R., Vyzas, E., and Healey J. Toward machine emotional intelligence. *IEEE Transactions on Pattern Analysis and Machine Intelligence* 23, 10 (2011), 1175-1191.
- [23] Skinner, M. J. and Simpson, P.A. Workload issues in military tactical aircraft. *International Journal of Aviation Psychology* 12, 1 (2002), 79-93.
- [24] Sluiter, J.K., van der Beek, A.J., and Frings-Dresen, M.H. *Workload of coach drivers. [Werkbelasting touringcarchauffeurs]*. Rep. No. 97-03, Coronel Institute for Occupational and Environmental Health, Academic Medical Center. Amsterdam (1997), 1-71.
- [25] Taylor, A.H., Dorn, L. Stress, Fatigue, Health, and Risk of Road Traffic Accidents Among Professional Drivers: The Contribution of Physical Inactivity. *Annual Review of Public Health* 27 (2006), 371-391.
- [26] Vidulich, M., Stratton, M., and Wilson, G. Performance-based and physiological measures of situational awareness. *Aviation, Space and Environmental Medicine* (1994), 7-12.
- [27] Walonoski, J A., and Heffernan, N.T. Detection and Analysis of Off-Task Gaming Behavior in Intelligent Tutoring Systems. *ITS 2006, LNCS 4035*. (2006), 382-391.
- [28] Wilson, G.F., Lambert, J.D., and Russell, C.A. Performance enhancement with real-time physiologically controlled adaptive aiding. *Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting* 3 (1999), 61-64.
- [29] Winkleby, M., Ragland, D., Fisher, J., and Syme, L. Excess risk of sickness ease in bus drivers. *International Journal of Epidemiology* 17 (1988), 255-262.

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>