Can The Mind and Body Be Trained Using Virtual Reality?

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Problem: Fear; an unpleasant emotion caused by the belief that someone or something is threatening, dangerous, or likely to cause pain or death.

Solution: Expose the user to their fear/weakness in a believable virtual world until they are trained to no longer fear, or have turned their weakness into a strength. This can be applied to virtually anything, such as:

- Car Permit License Training for Teens
- Surgical/Medical Field
- Aviation Training
- Metro transportation Training
- Emergency Response Training
- Psychotherapy

Purpose: This project could provide people with a better understanding of the unlimited potential virtual reality holds in its applications and future uses.

Hypothesis: The results after testing should conclude that virtual reality can indeed train the physical body and mind to complete a task and become better at it through trial-and-error.

Abstract

The objective of this project was to determine if a person can be trained both physically and mentally using virtual reality. In this case, a full-motion driving seat was built, alongside a newly released virtual reality headset called the Oculus Rift, stereo headphones with 7.1 surround sound software, a 4-point racing harness, a full force feedback steering wheel, and a set of pedals. This was to give the user a full-fledged experience of actually sitting in, and racing, a luxury sports car. The full-motion virtual reality driving simulator is able to give a user the ability to look around the car's cockpit in 360 degrees, along with full stereoscopic 3D. The user experiences physical feedback through the steering wheel and motion seat completely dependant on how the car is driven in the simulator. This means the user feels actions such as losing grip in the tires, driving over rumble strips and into grass or dirt, gear changing errors, weight transfer, heavy braking, and almost any other movement the car experiences in the simulation. This project could provide people with a better understanding of the unlimited potential that virtual reality holds in its applications and future uses.

Background

For as long as humans have been alive, there has always been the desire to live in the imagination. The place where anything can happen, be it standing on top of the tallest building in the world to overcome one's fear of heights, or sitting in an F1 car on the famous Silverstone race track to train one's self for the upcoming Grand Prix World Championship. This is where virtual reality comes into play. Since 3D environments have been around, people have been trying to create new innovations to allow users to transport themselves into new worlds. These innovations have been somewhat gimmicky, extremely over-priced, and the technology hasn't quite been there to actually create a believable experience. However, because of technology's amazingly rapid development over the past few years, computing power is getting smaller, more powerful and precise, and display technologies are rapidly advancing. This is allowing virtual reality to finally see the light of day through the development of an immersive virtual reality headset.

What are the main factors that go into creating an immersive virtual reality headset? Field of view, head tracking, latency, display technology, and stereoscopic 3D are the core factors in creating a believable experience. Field of view being the extent to which the observable world can be seen at any given moment. The sweet spot for most human eyes is 110 degrees. Head tracking allows the user to be able to rotate their head 360 degrees in every direction and their point of view in order to follow where they're trying to look in-game, therefore giving the user a physical and mental presence of where they are. Latency is the time it takes the physical movement of a user's head and updated photons from a head mounted display to reach their eyes. This is one of the most critical factors in providing a high quality experience as it can cause motion sickness if the latency it too high. Twenty milliseconds is the most ideal latency since humans can't detect time differences any faster. Display technology is one of the most crucial factors in virtual reality as it's what the user is seeing at all times while using the headset. The most fitting and practical resolution for a display is at or above 1920 by 1080 pixels. Reaching display resolutions that meet the resolution of the human eye and being able to keep the screen size down to around seven inches is far beyond any tech company's budget at this time. Last but not least is stereoscopic 3D. Stereoscopic 3D means creating an image where the user would be able to fully understand the scene-depth and the size of objects in the environment. This is primarily dependent on software to achieve this effect.

Luckily, in August of 2012, a new company named Oculus released their first developer kit of a virtual reality headset called the Oculus Rift. The Oculus Rift took all of the core fundamentals of a virtual reality headset and cleverly squeezed them all into a single, light-weight product, while maintaining a very affordable price-point. Since its release, it has been named one of the top 10 innovations of 2013 by many, and has sold over 40,000 developer kits world-wide. Because of the Oculus Rift, the idea for this project was created.

The next step was to determine the best solution for testing physical interaction in a virtual world. This meant finding something that could physically interact with the user and help them complete a task in the virtual world in which they would be immersed. The solution to such a problem was driving. While driving, a person is stationary, as the only actions it takes to operate is turning a wheel and pressing pedals. The physical interaction a driver experiences is all caused by the person's driving decisions and the vehicle's limitations, making use of a full-motion driving simulator an ideal solution.

Full-motion driving simulations have actually gained popularity in the simulation racing community over the past few years. This is due to motor technology becoming more affordable and the ability for open-source software to translate virtual world movement into real-world movement. The only problem was most, if not all, of the motion seat frames that people build use machined metal, which is not cost effective and needs heavier machinery and expensive tools to assemble. This lead to the idea of using wood as the frame, because it is sufficiently sturdy, cost effective, and doesn't require a vast array of machines and tools to assemble and alter.

What movements does a driver experience and how can those be translated to a driving simulator? Since a driver is sitting stationary, there are only six axes on which they can experience motion. These motions are pitch, roll, yaw, surge, sway, and heave. Pitch is the tilt of the car forwards or backwards, roll is how much the car is dipped to the left or right, and yaw is the heading of the car (North, East, South, and West). These three are measured in degrees since they are dependent on rotational axes. Surge is the longitudal acceleration of the car, sway is the lateral acceleration of the car, and heave is up and down acceleration. These three motions are measured in g-forces as they do not move on an axis, rather they move in space. Knowing these principle movements allows one to single out which directional movements can be used depending on the type of motion simulator that is being built. The most commonly built motion simulators are two-degrees-of-freedom simulators, otherwise called 2DOF simulators. These types of simulators consist of two separate mechanical forces acting upon the seat which sits on a pivot. Because of the pivot, this provides the ability to emulate the most prevalent forces in a driver's seat; pitch and roll.

The last piece to creating a believable virtual reality experience is the presence of sound. Imitating how sound is sent to human's ears is an extremely difficult task and can't be done by simply placing a speaker next to each ear. There aren't very many solutions to this problem as the source that records the sound is what determines whether it can be used for true surround sound. Currently, the only headphones that even come close to providing accurate surround sound are priced over $300, which is excessive to say the least. The best, and cheapest solution, is to convert a pair of nice stereo headphones into 7.1 surround sound headphones using software. Software surround sound has just recently emerged in the audiophile world and has been adopted by many gamers world-wide, making it the viable solution for use with the driving simulation.

The combination of visual immersion, virtual world physical feedback, and a decent source of surround sound can cause one to come as close as possible to experiencing another world; in this case driving a luxury sports-car at high speeds. This experiment should not be used as a benchmark for what virtual reality can achieve, as it is only the tip of the iceberg in terms of the possibilities that lay ahead. Skydiving, aeronautical flight, emergency response, car permit licence practice, surgeon practice, space simulations, psychotherapy, and military training are just a fraction of what's possible with such technology.

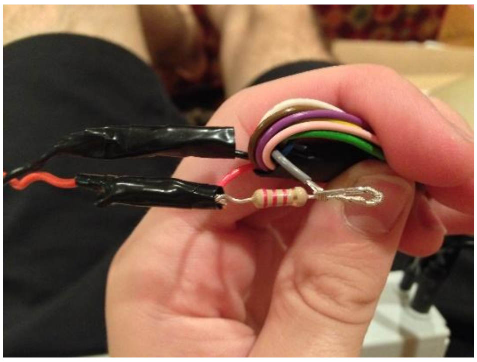
Procedure

1. *Build Motion Racing Simulator*

   A. Wiring the 24 Volt power supply with 100mm SCN5 actuator power cable.

1. Single out the Positive (Red), Negative (Black), and Ground (Light Grey) wires on the power cable of the actuator.
2. Strip the wires to expose the bare silver wire.
3. Solder Negative (Black) 22 gauge hook-up wire to Negative (Black) actuator power wire.

4. Solder one end of 2.2 Ohm Resistor to Red 22 Gauge Hook-up wire and the other end to Light Grey ground wire from the actuator power wire.



5. Solder Positive (Red) 22 gauge hook-up wire to Positive (Red) actuator power wire.
6. Solder Negative (Black) 22 gauge hook-up wire to Negative (Black) actuator power wire.

7. Wrap up with electrical tape to prevent accidental electrocution or electrical interference.
8. Connect Positive hook-up wire to V+ connection on the 24v power supply.
9. Connect Negative hook-up wire to V- connection on the 24v power supply.
10. Strip 120v power cable to reveal Power (Black), Neutral (White), and Ground (Green) wires. Strip those wires to expose the bare copper.
11. Connect Power to L on the 24v power supply.
12. Connect Neutral to N on the 24v power supply.
13. Connect Ground to ⏚ on the 24v power supply.
14. Repeat the same process for the other 100mm SCN5 actuator.

B. Wiring the 100mm SCN5 actuator data cable with RS485 USB converter.
1. Single out the Ground (Black), Data+ (White), and Data+ (Green) wires on the data cable of the actuator. The Red cable is used for an extra 5 volts which is not needed, so it will be ignored.
2. Strip the wires to expose the bare silver wire.
3. Strip USB data cable on both ends to expose the Ground (Black), Data+ (White), Data+ (Green), and +5v (Red). Ignore the Red once again.
4. Strip the Ground, Data+, and Data- wires on both ends to expose the bare silver wire.
5. Solder the corresponding colors from the USB cable to the actuator data cable being sure to ignore the 5v (Red) wire.
6. Connect the White wire from the data cable to the Data+ (Center) connection port on the RS485 USB converter.
7. Connect the Green wire from the data cable to the Data- (Right) connection port on the RS485 USB converter.
8. Connect the Black wire from the data cable to the Ground (Left) connection port on the RS485 USB converter.

9. Wrap up any exposed wires with electrical tape.
10. Repeat the same process for the second RS485 USB Converter.

C. Making sure the actuators are receiving data from the PC.
1. Download and install RS485 USB converter drivers for Windows from: http://www.ftdichip.com/FTDrivers.htm
2. Using two printer USB cables, plug one end into RS485 USB converter and the other end into an available USB port on the PC. Do this for both converters and

data cables being sure the LEDS on the converters light up once plugged in and Windows makes a confirmation sound that they've been successfully connected.

3. Windows should then notify "Device has been successfully installed."

4. Turn on the 24v Power Supply. When on, the Green LED on the power supply should be lit up.

5. To confirm that the actuators have power running to them, give them a tug. If the rods can be pulled out, that means there is no power going to them. If they can't be pulled out, that means they are correctly wired and power is running to them.

6. Download and install SimTools Motion Simulator software from: http://www.xsimulator.net/simtools-motion-simulator-software/

This software will allow vehicle and player positional data to be extracted from the test game Assetto Corsa and converted to the actuators, creating a 1:1 feeling of terrain and vehicle movement when driving.

7. Download and install Assetto Corsa SimTools Plugin

a. Download plugin from: http://www.xsimulator.net/community/marketplace/asseto-corsa-plugin.10/

b. Open SimTools Plugin Updater

c. Drag contents of Assetto Corsa Plugin .zip file into SimTools Plugin Updater

8. Open SimTools Game Manager.

9. Open SimTools Game Engine

10. Navigate to the "Interface Settings" tab.

a. Under "Interface1" select "SCN" as the Output Type.

b. Under "ComPort" select "COM3".

c. Under "Packet Rate" select "1"

d. Under "Assigned Axis" select "Axis 1"

e. Set Speed to 10000

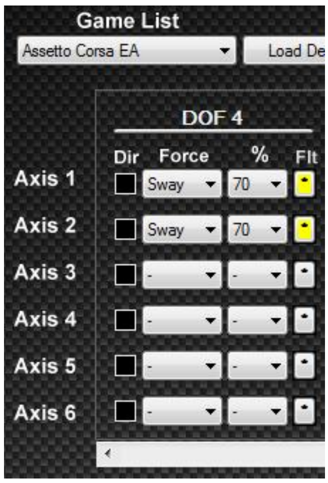
f. Set Acceleration to 500

e. Repeat the same process with "Interface2" except select "COM4" as the ComPort.

11. Navigate to the "Axis Assignments" tab

a. Under Game List choose Assetto Corsa EA

b. Use the following settings:

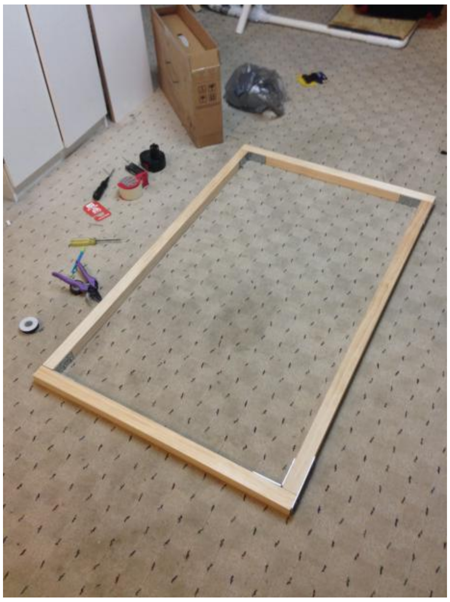


12. Navigate to the "Axis Limitations" tab and change the Axis 1 and Axis 2 limitations to 95%. This will prevent from possibly pushing the actuators too hard and causing failure.
12. Restart SimTools Game Engine.
13. The SimTools software should search for the connected actuators. Once found, the software should run a test on them and the actuators should slide out and then back in to confirm that they are indeed successfully connected to the PC and calibrated.

D. Setting up the Assetto Corsa driving simulation.
   1. Install Assetto Corsa through Steam.
   2. Go to Program Files (x86)\Steam\SteamApps\common\assettocorsa\cfg
   3. Open control.cfg in a notepad editor & change the following to these values:
      - [FF_ENHANCEMENT]
      - CURBS=1.0
      - ROAD=1.0
      - SLIPS=1.0
   4. This allows for realistic feedback to be sent to the wheel, allowing the user to understand what's happening with the cars steering.
   5. If the tracking seems to be drifting off track, hit Ctrl + Spacebar on the keyboard to reset the Oculus Rift tracking to the position it's currently at.

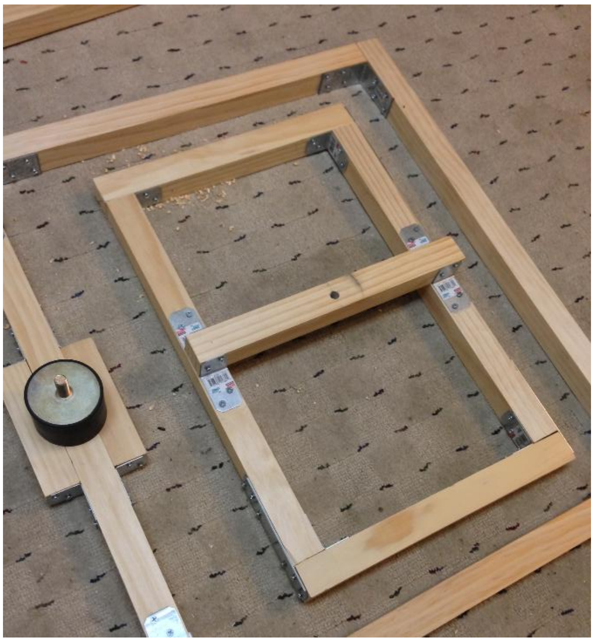
E. Building the Motion Seat frame using 2 x 2 wood.

Base-Frame

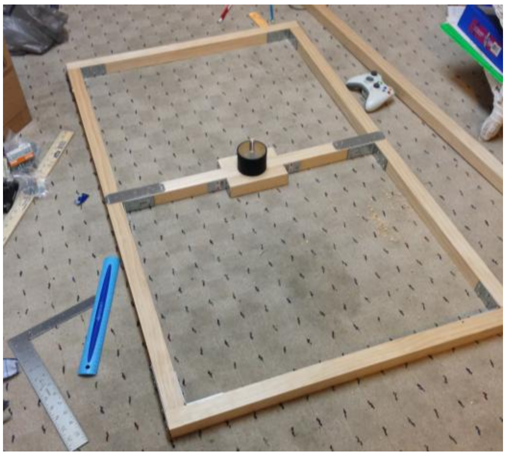


Base-Frame with center bar for stability and mount for the rubber pivot

Seat-Frame with center beam to attach to rubber pivot



Base-Frame with rubber pivot

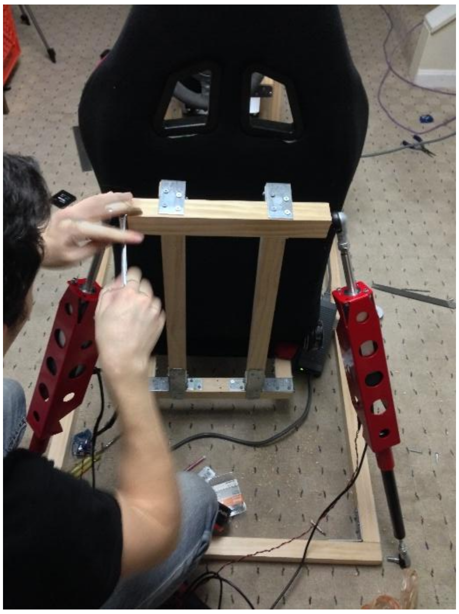


Pedal, wheel, and shifter mount added along with mounting the seat

Actuator mounts + mounting parts

Finishing seat-frame

Mounting actuators and actuator mounts to seat-frame



The finished product

F. Reducing what is known as the Screen Door Effect on the Oculus Rift. Since the current Oculus Rift's resolution is only 1280 by 800 pixels, the once seemingly imperceptible spaces between pixels are able to be seen due to the lenses that magnify the display around the user's vision. As newer versions are released in the future, the resolutions will increase and this effect will eventually no longer exist. For now, though, there are "fixes" that can help reduce this effect if one isn't satisfied with the visual clarity.

By using a monitor privacy-filter and placing it about a Millimeter above the Oculus Rift's screen, the display's pixels are slightly diffused causing the spaces between pixels to decrease.

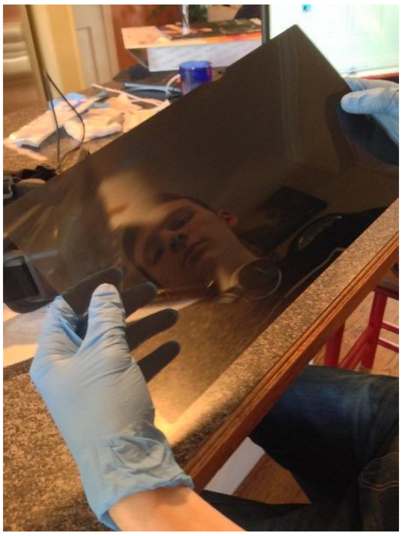
The Oculus Rift

A can of cleaning duster, scissors, microfiber cleaning cloth, non-powdered gloves, 3M Double Sided Tape, 3M LCD Monitor Privacy-Filter, a file just in case the privacy screen-filter doesn't fit properly, needle-nose pliers, and a small flat-head screwdriver were needed to achieve this task.

Prying open the Oculus Rift to reveal the display

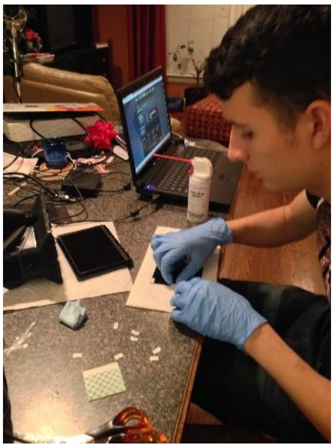
The inside of the Oculus Rift's display unit

Handling the privacy screen-filter with care as it needs to be as flawless as possible. Any significant damage and the flaws could be magnified by the lenses, creating an even worse image.

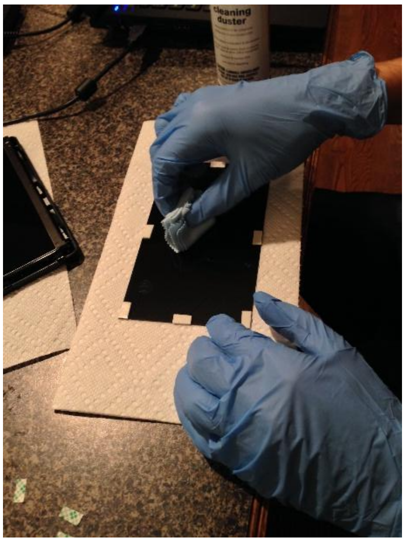


Privacy screen-filter cut down to 7" diagonally to fit the Oculus Rift's display

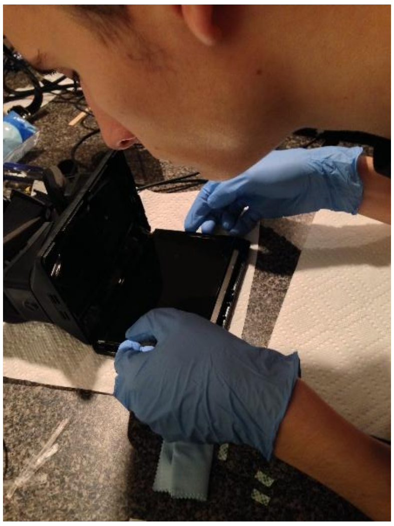
Placing the 3M double-sided tape onto the privacy screen-filter first as this will make it easier to accurately place over the display.



Wiping off any dust that may have flown onto the privacy screen-filter



Placing the privacy screen-filter onto the Oculus Rift's display, being extremely cautious to place it perfectly.



The privacy screen-filter placed approximately one Millimeter about the display

The final product

2. *Experimentation*
   A. Test subjects played Assetto Corsa using an Xbox 360 Controller and a 2D 32" LCD monitor.
      1. Each test subject raced the same race track and completed 10 laps.
      2. The times of their 10 laps was recorded and averaged to create an overall lap time with the Xbox 360 controller and no Virtual Reality headset (Oculus Rift).
      3. Heart Rate was monitored using a heart-rate chest monitor and the peak and lowest point of their heart rate was recorded at the end of the 10 laps. (Resting heart was taken as a control before testing started)
   B. Test subjects played Assetto Corsa using the full-motion seat, force feedback wheel, pedals, surround sound headset, and 2D 32" LCD monitor.
      1. Each test subject raced the same race track and completed 10 laps.
      2. The times of their 10 laps were averaged to create an overall lap time with the full-motion seat, force feedback wheel, pedals, surround sound headset, and 2D LCD monitor.
      3. Heart Rate was monitored using a heart-rate chest monitor and the peak and lowest point of their heart rate was recorded at the end of the 10 laps. (Resting heart rate was taken as a control before testing started)
   C. Test subjects played Assetto Corsa using the full-motion seat, force feedback wheel, pedals, surround sound headset, and the Virtual Reality headset.
      1. Each test subject raced the same race track and completed 10 laps.
      2. The times of their 10 laps was averaged to create an overall lap time with the full-motion seat, force feedback wheel, pedals, surround sound headset, and the Virtual Reality headset.
      3. Heart Rate was monitored using a heart-rate chest monitor and the peak and lowest point of their heart rate was recorded at the end of the 10 laps. (Resting heart was taken as a control before testing started)

Results

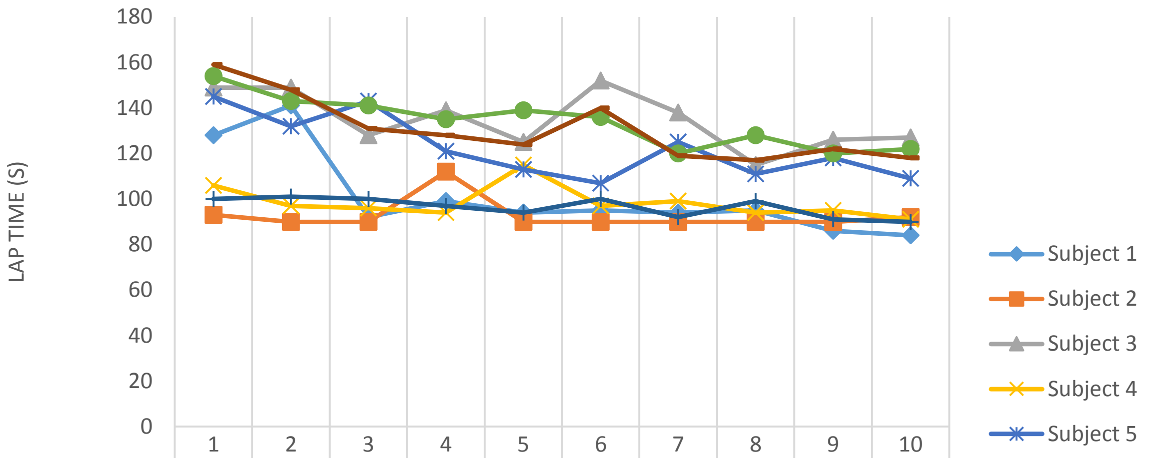
According to the data and the feedback that was received by the test subjects, the conclusion can be drawn that virtual-reality can in-fact train the mind and body to complete a task, and become better at it through trial-and-error. In this case driving a sports-car to achieve the fastest lap-time. The following points are the reasoning why this conclusion was drawn:

- By using the controller and an LCD monitor, the test subjects experienced very inconsistent times due to a single thumb-stick being used to control the car's steering wheel and a lack of physical feedback from the car. This led to very easy mistakes as the test subjects couldn't feel the weight transfer of the car as they were turning or braking.
- When the test subjects used the full-motion seat along with the force-feedback steering wheel, pedals, headphones, and virtual reality headset, their much heightened sense of speed and depth allowed them to better judge how fast the vehicle was moving, how hard they were braking, and whether or not they were pushing the car beyond its limits.
- It was observed through trial and data that across all test-subjects, their times consistently decreased as their laps went on while using the virtual reality headset and the full-motion seat showing that they were learning the physics of the car and its limits.
- All test subjects reported that using the virtual reality headset along with the full-motion seat, wheel, pedals, and headphones was profoundly more immersive than using the LCD monitor and that it felt eerily similar to driving a car.

- Overall, the test subjects experienced an average 90.9% peak in their heart rate from an average 66 BPM (Beats Per Minute) to an average of 126 BPM peak while using the virtual reality headset and the full-motion seat. The maximum heart rate increase that was reached was 114.5% increasing from a resting heart rate of 62 BPM to a peak of 133 BPM. The lowest increase in heart rate being 77.3% from a resting heart rate of 66 BPM to a peak of 117 BPM.
- The average over-all heart rate throughout the virtual reality headset and full-motion seat was 96 BPM meaning that the overall average increase in heart rate was an approximate 46.2%.
- The data and graphs displayed that there was a more distinct rapid learning curve while using the motion-seat than using the controller.
- The average lap-time decreased from 113.74 seconds using the controller, to 107.1 seconds using the motion-seat along with the LCD monitor, to 105.14 seconds using the motion-seat and virtual reality headset.

Graphs and Tables

2D LCD TV, XBOX CONTROLLER, AND HEADPHONES



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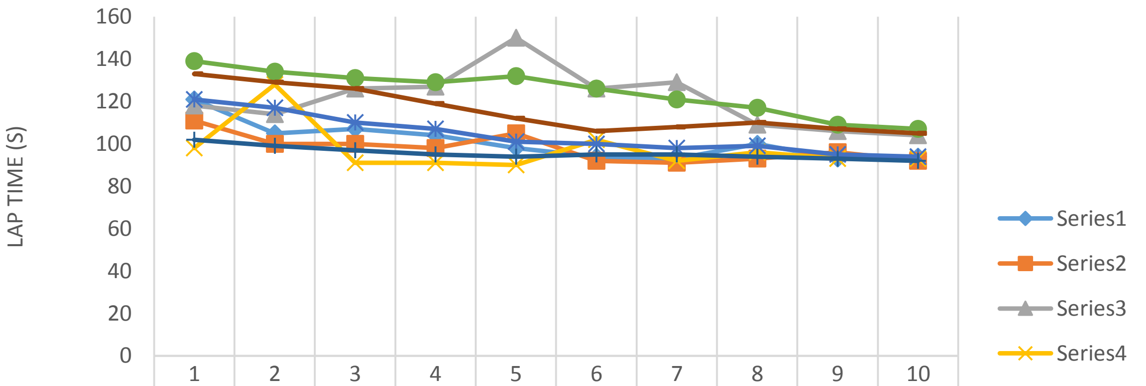
Subject 1	128	141	92	99	94	95	94	95	86	84
Subject 2	93	90	90	112	90	90	90	90	90	92
Subject 3	149	149	128	139	125	152	138	115	126	127
Subject 4	106	97	96	94	115	97	99	94	95	91
Subject 5	145	132	143	121	113	107	125	111	118	109
Subject 6	154	143	141	135	139	136	120	128	120	122
Subject 7	100	101	100	97	94	100	92	99	91	90
Subject 8	159	148	131	128	124	140	119	117	122	118

NUMBER OF LAPS

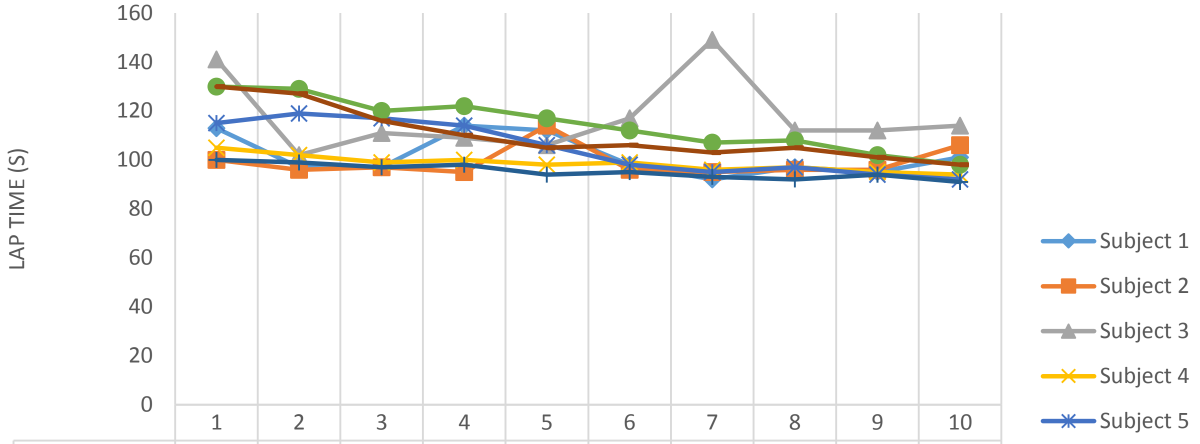
2D LCD, FFB WHEEL, PEDALS, MOTION, AND HEADPHONES



	1	2	3	4	5	6	7	8	9	10
Series1	121	105	107	104	98	94	93	100	93	94
Series2	111	100	100	98	105	92	91	93	96	92
Series3	118	114	126	127	150	126	129	109	106	104
Series4	98	128	91	91	90	102	92	96	93	93
Series5	121	117	110	107	101	100	98	99	95	94
Series6	139	134	131	129	132	126	121	117	109	107
Series7	102	99	97	95	94	95	95	94	93	92
Series8	133	129	126	119	112	106	108	110	107	105

NUMBER OF LAPS

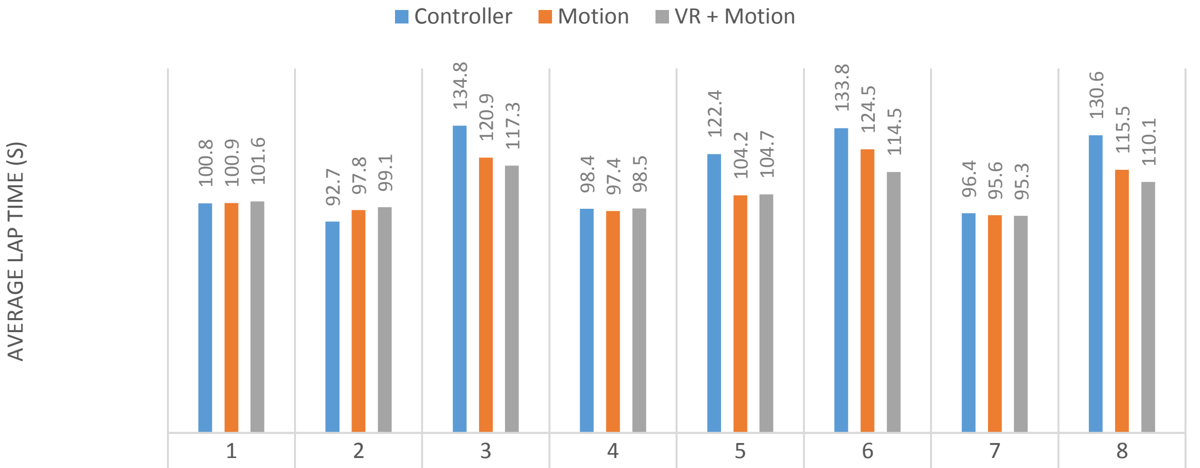
VIRTUAL REALITY HEADSET, FFB WHEEL, PEDALS, MOTION, AND HEADPHONES



	1	2	3	4	5	6	7	8	9	10
Subject 1	113	97	97	114	112	98	92	97	95	101
Subject 2	100	96	97	95	114	96	95	96	96	106
Subject 3	141	102	111	109	106	117	149	112	112	114
Subject 4	105	102	99	100	98	99	96	97	95	94
Subject 5	115	119	117	114	106	98	95	97	94	92
Subject 6	130	129	120	122	117	112	107	108	102	98
Subject 7	100	99	97	98	94	95	93	92	94	91
Subject 8	130	127	116	110	105	106	103	105	101	98

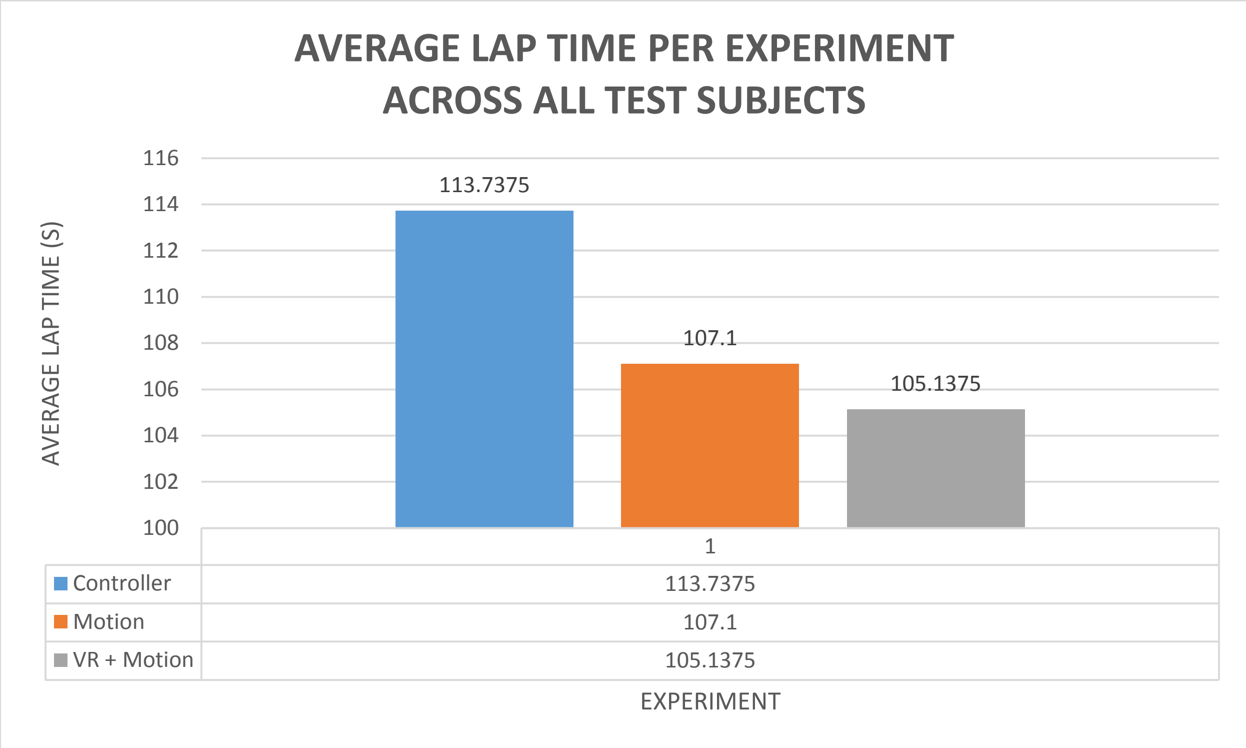
NUMBER OF LAPS

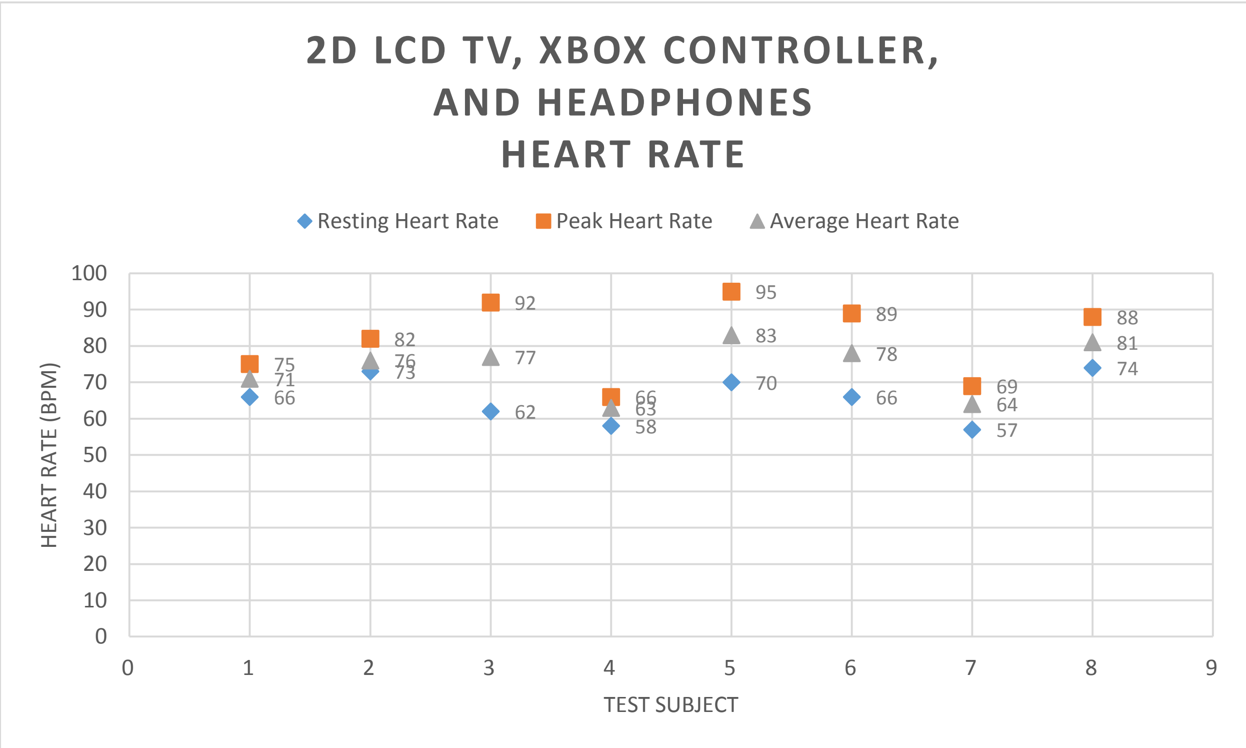
AVERAGE LAP TIME PER TEST SUBJECT



	1	2	3	4	5	6	7	8
Controller	100.8	92.7	134.8	98.4	122.4	133.8	96.4	130.6
Motion	100.9	97.8	120.9	97.4	104.2	124.5	95.6	115.5
VR + Motion	101.6	99.1	117.3	98.5	104.7	114.5	95.3	110.1

TEST SUBJECT


AVERAGE LAP TIME PER EXPERIMENT ACROSS ALL TEST SUBJECTS
AVERAGE LAP TIME (S)
116
114
112
110
108
106
104
102
100
113.7375
107.1
105.1375
1
Controller 113.7375
Motion 107.1
VR + Motion 105.1375
EXPERIMENT


2D LCD TV, XBOX CONTROLLER, AND HEADPHONES HEART RATE
Resting Heart Rate
Peak Heart Rate
Average Heart Rate
HEART RATE (BPM)
100
90
80
70
60
50
40
30
20
10
0
75
71
66
82
76
73
92
77
62
66
63
58
95
83
70
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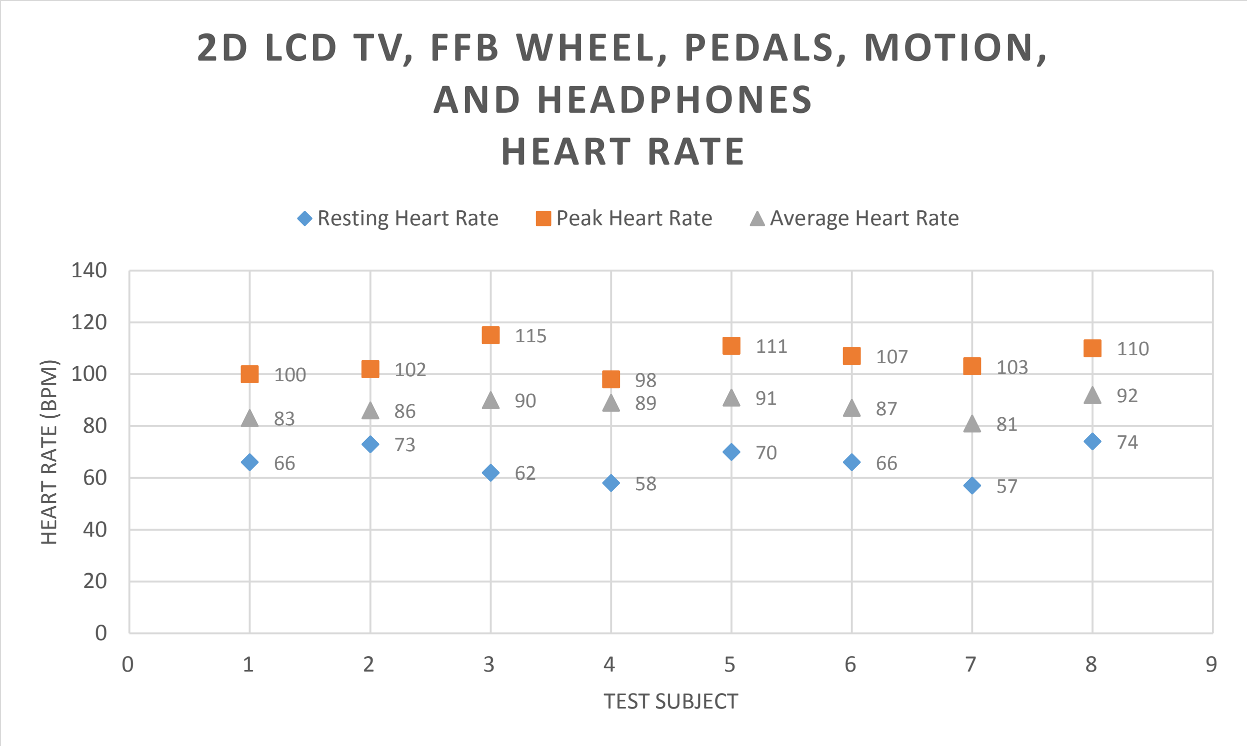
9
TEST SUBJECT


2D LCD TV, FFB WHEEL, PEDALS, MOTION, AND HEADPHONES
HEART RATE
Resting Heart Rate
Peak Heart Rate
Average Heart Rate
HEART RATE (BPM)
TEST SUBJECT
100
102
115
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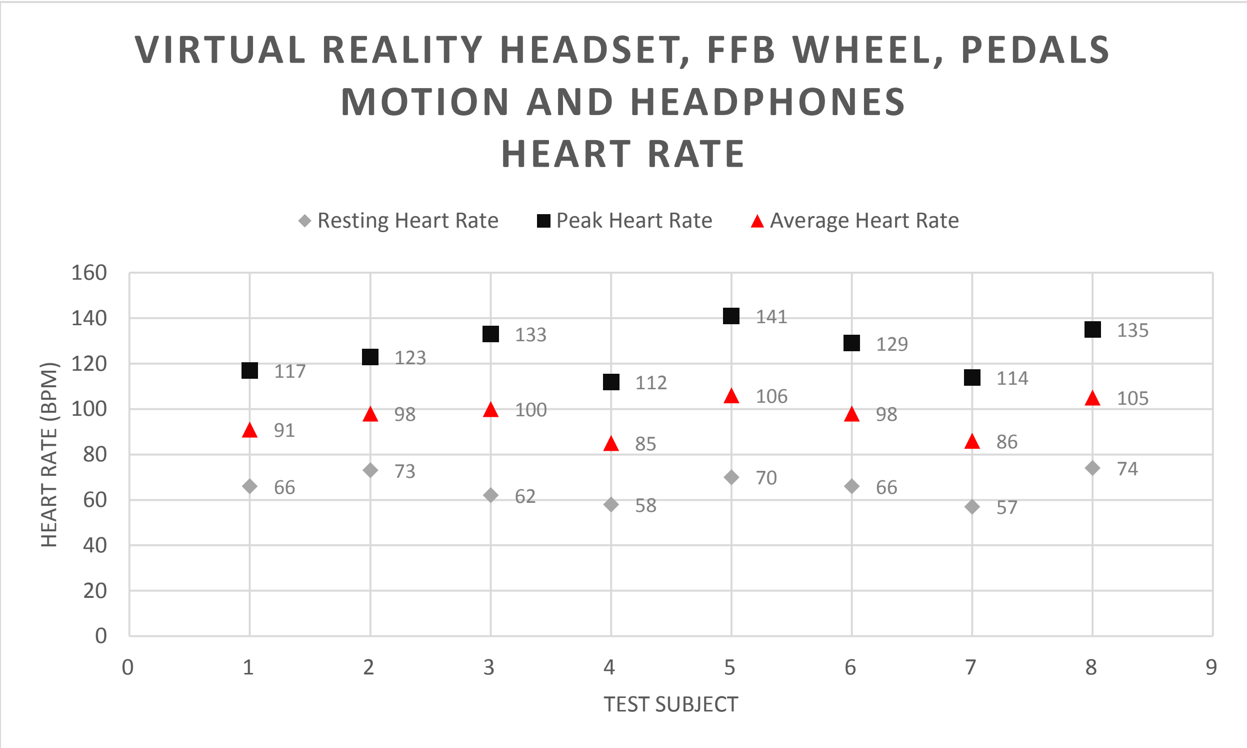
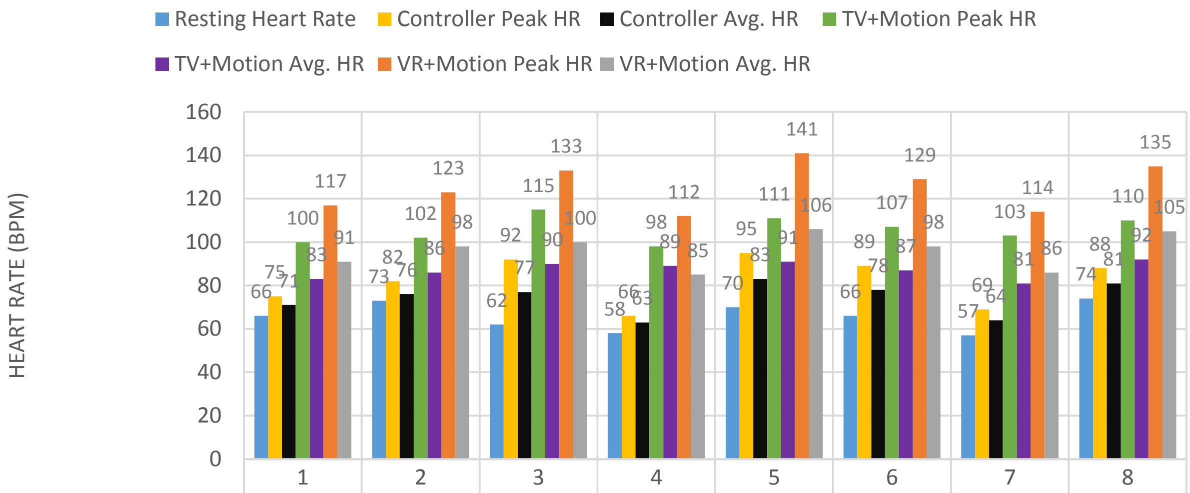

VIRTUAL REALITY HEADSET, FFB WHEEL, PEDALS MOTION AND HEADPHONES
HEART RATE
Resting Heart Rate
Peak Heart Rate
Average Heart Rate
HEART RATE (BPM)
TEST SUBJECT
117
123
133
112
141
129
114
135
91
98
100
85
106
98
86
105
66
73
62
58
70
66
57
74

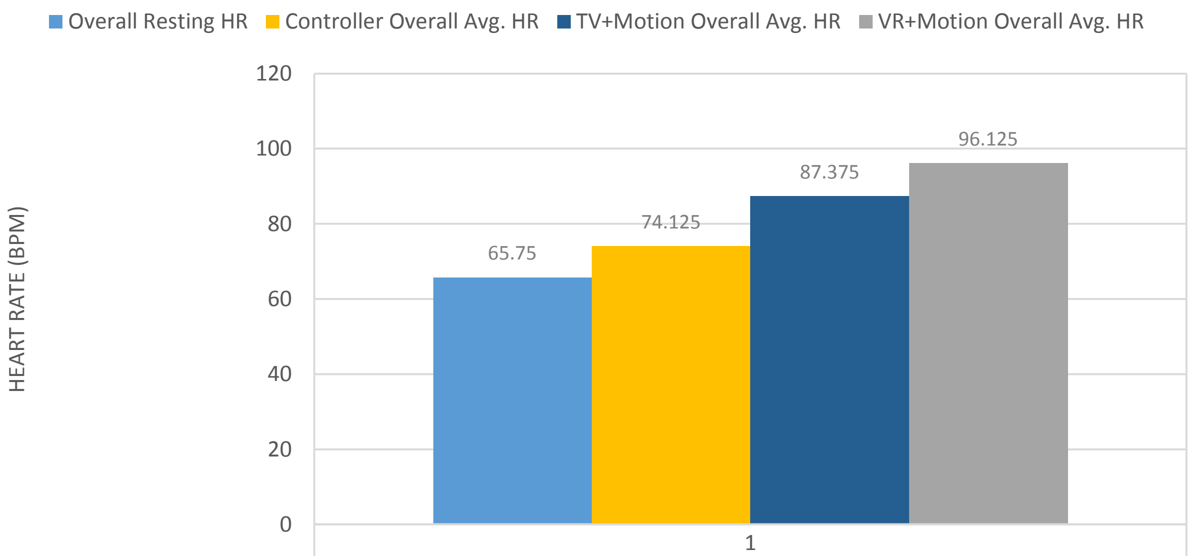
EACH EXPERIMENT HEART RATE COMPARISON



	1	2	3	4	5	6	7	8
Resting Heart Rate	66	73	62	58	70	66	57	74
Controller Peak HR	75	82	92	66	95	89	69	88
Controller Avg. HR	71	76	77	63	83	78	64	81
TV+Motion Peak HR	100	102	115	98	111	107	103	110
TV+Motion Avg. HR	83	86	90	89	91	87	81	92
VR+Motion Peak HR	117	123	133	112	141	129	114	135
VR+Motion Avg. HR	91	98	100	85	106	98	86	105

TEST SUBJECT

EACH EXPERIMENT OVERALL AVERAGE HEART RATE COMPARISON



	1
Overall Resting HR	65.75
Controller Overall Avg. HR	74.125
TV+Motion Overall Avg. HR	87.375
VR+Motion Overall Avg. HR	96.125

ALL TEST SUBJECTS

Acknowledgements

I would like to thank the amazing inventor of the World-Wide-Web, Tim Berners-Lee, and all of its users that exponentially populate it with new information every single day. Without it, this entire project and its ideas wouldn't have been formed or even materialized. I would also like to thank the friends and family that participated in the experimentation. Without them, I would've just had a really cool toy sitting in my basement.

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