Telemetry-based Optimisation for User Training in Racing Simulators

Conference Paper · September 2017

DOI: 10.1109/VS-GAMES.2017.8055808

3 authors:

Keith Bugeja
University of Malta

Sandro Spina
University of Malta

François Buhagiar

Telemetry-based Optimisation for User Training in Racing Simulators

Keith Bugeja*, Sandro Spina†, François Buhagiar
Department of Computer Science
University of Malta
Email: *keith.bugeja@um.edu.mt, †sandro.spina@um.edu.mt

***Abstract*—Motorsports require training and dedication to master, supplemented by hours of rote learning and mentoring by experts. This study explores the question of whether a serious game is a powerful enough pedagogical tool to be gainfully employed in the training of race drivers. A system of heuristics is proposed for a novel telemetry-based feedback model for contextual real-time suggestions. The model has been integrated into a racing simulation game and a study of its performance is reported here. The study consists of 27 participants, partitioned into two groups, to provide a control for the experiment. Two questionnaires have been used to acquire demographic information about the participants and help control for factors such as experience. Quantitative results show that there is an improvement for the group using the feedback system, although this improvement dissipates when the feedback is disabled again for the experimental group. Analysis of the initial results are encouraging, with the model showing promise. Additionally, the lack of cognitive retention on behalf of the participants when feedback was disabled merits further investigation and future work.**

I. Introduction

The gamification of areas of activity such as marketing, problem solving and education [14] has validated the use of serious games beyond their initial military use in training strategic skills [6]. Serious games simulate real-world processes designed for the purpose of solving a problem, making their main purpose that of training or educating users. Their popularity has been steadily increasing, as has their adoption, with military [6] and emergency service providers (e.g. firefighters [14]) employing them to train for specific scenarios that might be encountered on the respective jobs. Vogel et al. [17] shows how the use of computer games and simulations for learning results in high cognitive gain for learners.

Motorsports cover a broad range of activities and vehicles, and as with all major forms of sporting activities, require training and dedication, with a pedagogic aspect arising in rote learning and mentoring by experts. The arenas in which motorsport events take place are called circuits; there is a large selection of the latter, ranging from purposely-built race tracks to public roads to natural formations such as hills and quarries. There is also a diverse selection of vehicles that take part in motorsports, with the greatest demarcation existing between motorbikes and cars. The focus of this work is that of unifying serious games and motorsport racing; specifically, we will try to show whether a serious game is a powerful enough pedagogical tool that can tangibly improve the performance of race drivers. The scope of the project is limited to four-wheeled cars, racing on purposely-built confined circuits with a smooth tarmac surface.

II. Aims and Objectives

In order to establish whether it is possible to use serious games to teach a particular brand of motorsports, we formulate the following research question:

Can the serious games paradigm of active learning be coupled to a racing simulator game and an active feedback system to train inexperienced drivers in motorsport racing?

To answer the question, a number of objectives have been laid out. In particular, we set out to:

1) research and develop a model for assessing race driver performance;
2) develop a system of heuristics for providing feedback from the aforementioned model;
3) devise an experimental methodology for evaluating how effective the feedback model is (if at all) in training race drivers;
4) design and develop the main software and support tools for integrating the feedback model into a racing simulation game;
5) carry out a user study based on devised experimental methodology to gather data for analysis;
6) perform statistical analysis on the gathered data to answer the research question.

III. Background

In circuit motorsport racing, motorised vehicles go round a course for a set number of times. There are various racing disciplines or series, each one having its own specific rules. However, at the core, participants in all disciplines aim to complete a full lap of the circuit in the shortest time. This paper will focus on one such discipline, that of confined car racing, which takes place on smooth asphalt surfaces in purpose-built race tracks where the aim is to perform the fastest lap possible.

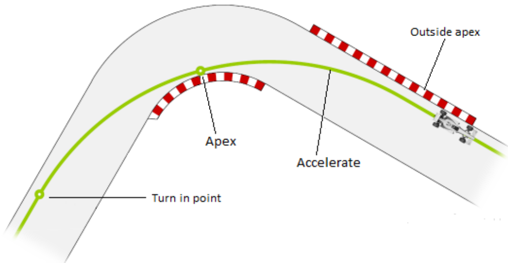

Fig. 1: Green line showing racing line in and out of a corner

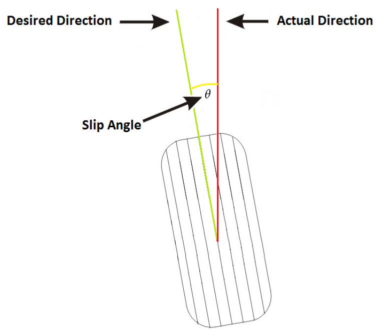

Fig. 2: Slip angle

A. *Car and Circuit Dynamics*

The *racing line* is the best path through a circuit: if followed, it is the path that can yield the shortest time at the highest average speed [3]. It is also one of the fundamental techniques a race driver needs to learn and perfect [12], with corner segments being the hardest to master. These corner segments are generally split into three phases or sections; the first section is the breaking part, where the car needs to sufficiently decelerate in preparation for the *turn-in point*. The second partition of the racing line at a corner is the segment between the turn-in point and the apex point, which is the inside mid-point of the corner (see Figure 1). Beyond the turn-in point, the driver aims for the apex point. The final section of the racing line in a corner lies from the apex point onwards, where the driver must gradually accelerate out of the corner, while still turning, aiming for the outside apex (see Figure 1).

As the driver gets acquainted to the racing line, usually at sub-optimal speeds, he must find the limit of the car, which is the highest speed the car can be driven to while still retaining some measure of control. Various studies have been carried out to define such a limit in terms of the physical properties of the car and its environment [3]. One of the most important properties thus identified is the level of grip the car can achieve and sustain on track. A number of factors contribute to this; most notably, the tyres factor highly as they are the only contact the car makes with the track, and allow for braking, accelerating and turning forces to be transferred to the asphalt. Each tyre has two properties which are of particular interest: the *slip ratio* (s_r) and *slip angle* (s_a). The slip ratio refers to the level of slip occurring between tyre rotational velocity and the asphalt, which occur during acceleration and deceleration. The slip ratio is expressed as a percentage: a slip of 100% means that the tyre is rotating but the road is stationary. In jargon, this is called *wheel spin*. On the other hand, a slip of -100% indicates that the tyre is not rotating but the road beneath is moving (with respect to the tyre). This can occur when braking too hard and is called *locking the wheels*. A driver should avoid both wheel spin and locking the wheels as they not only result in excessive wear and tear, but also impact negatively on the performance of the car. For an optimal braking procedure, the slip ratio should be between 10% to 15% [12] and no slip should occur during acceleration. The slip angle (see Figure 2) is the angle between the tyre's desired direction (perpendicular to the axis of rotation of the wheel) and the tyre's actual direction (the direction the car is moving in). Given both the actual direction of travel ($\mathbf{d}_t$) and the desired direction ($\mathbf{d}_d$) are known, the slip angle is calculated as follows:

$$s_a = \frac{180}{\pi} \cos^{-1}(\hat{\mathbf{d}}_d \cdot \hat{\mathbf{d}}_t) \frac{\hat{\mathbf{d}}_d \times \hat{\mathbf{d}}_t}{||\hat{\mathbf{d}}_d \times \hat{\mathbf{d}}_t||}, \quad (1)$$

where $\hat{\mathbf{d}}_d = \mathbf{d}_d/|\mathbf{d}_d|$ and $\hat{\mathbf{d}}_t = \mathbf{d}_t/|\mathbf{d}_t|$ are the normalised direction vectors for desired and travel directions respectively; $\mathbf{d}_d, \mathbf{d}_t \in \mathbb{R}^2$. Whenever the slip angle is above $0°$ ($s_a > 0$) the tyre is said to be in an understeering situation. Understeer can be caused by active factors such as cornering speed, throttle application, braking, steering inputs and weight transfer. A tyre has an optimal slip angle at which grip is maximised during cornering. The optimal slip angle for a road tyre is about $5°$, whereas for a slick tyre, which is purposely constructed for racing, this is approximately $8°$ to $10°$ [3]. An oversteering situation may arise from lack of grip; while understeer is caused by a lack of grip in the front tyres, oversteer is cause by a lack of grip on the rear tyres. Oversteer is usually denoted by the rear end of the vehicle becoming unstable, resulting in its rotation such that the driver is facing towards the inside of the corner. Similarly to understeer, the active factors causing oversteer are also cornering speed, throttle application, braking, steering inputs and weight transfer. Oversteer is usually induced by braking during a corner or accelerating too hard in a rear wheel drive vehicle. Figure 3 illustrates both under and over steering.

B. *Telemetry Data*

In motorsport, telemetry data contains measurements of vehicle dynamics from the engine and other components, and is transmitted to receiving equipment for remote monitoring. These measurements can serve to monitor and reconstruct the vehicle state at a particular point in time. Telemetry data in motorsports usually accounts for measurements of speed, engine speed, component temperatures, slip angles, slip ratios, etc. Telemetry is widely regarded as the most important source of information by motorsports engineers; analysing this data can lead to a better understanding of the respective strengths and weaknesses of the car and the driver [9]. In this work, we posit that through the real-time analysis of telemetry data,

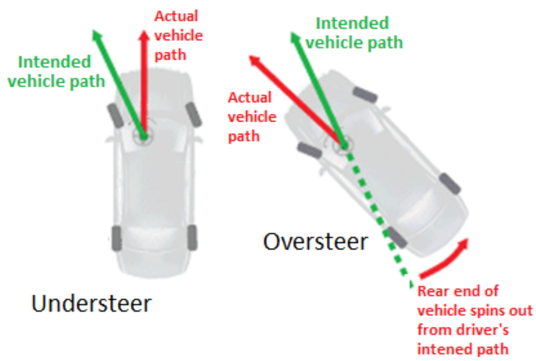

Fig. 3: A car in understeer and oversteer conditions. $\mathbf{d}_d$ refers to the desired direction of travel (green arrow), $\mathbf{d}_t$ refers to the actual direction of travel (red arrow)

the pedagogical aspect of sim racing can be exploited to teach race driving to non experts.

C. Racing Simulation Rigs

The racing simulation rig (sim racing rig) is a piece of equipment designed to mimic the cockpit of a real-world car. The quality of a sim racing rig is dependent on its authenticity (how similar it is to a real-world car) and its build quality. These rigs come in various shapes, forms and sizes, from hangar-sized hydraulic-driven car chassis costing in the millions of euros, to the more modest, built from off-the-shelf commodity hardware. Minimally, a rig should provide a steering wheel, seating and a display. More sophisticated rigs augment the user experience by employing gear shifters, and clutch, throttle and breaking pedals. The more advanced components are furnished with a force feedback mechanism, a form of haptic technology used to replicate the sense of touch by applying forces or vibrations, or motions to the user [11].

IV. Related Work

Racing simulation games such as Asseto Corsa [15] and Project CARS [16], while providing the player with various driving aids such as the racing line, traction control and stability, do not actively engage in providing a pedagogic experience to the user; instead, any learning experience is passively transferred, since the player is never made aware of his mistakes. Grace et al. [8] use a racing game to assess in-game advertising retention, concluding that different types of gaming experience correlated with brand processing differently. Ciceri et al. [4] explore the effect of racing simulation games on the way users visually explore real urban roads and conclude that the virtual experience does not help or provide any improvement. Adejumobi et al. [1] examine whether the knowledge and skills gained from a racing game module inserted into an entertainment video game can transfer into real life usage. A scavenger hunt was organised for the participants; the test group played a racing video game with the targets corresponding to the locations of the scavenger hunt. The study was not conclusive and showed marginal differences between test and control groups. Li et al. [11] have specifically investigated how car driving in computer games can provide traffic education to users. The authors are not aware of any other work that studies serious games and motorsports training.

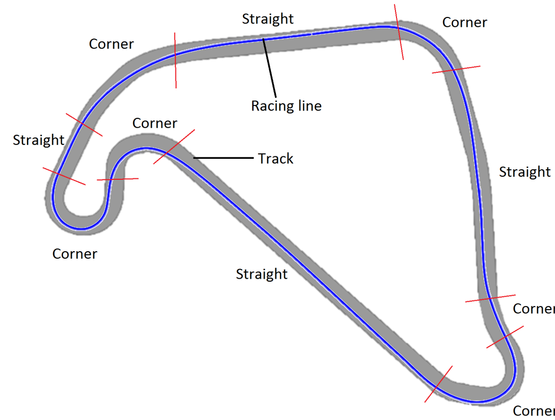

Fig. 4: Racing line with track partitioned into corner and straight sections

V. Car Handling Model

The car handling model designed for this work is used to monitor for a number of vehicle states: braking, understeer, oversteer, car positioning with respect to racing line and gear shifting. The following sections describe how telemetry data related to these states is used to determine how the driver is handling the racing car.

A. Braking

Braking and acceleration behaviours are monitored using the slip ratio values as follows:

- Braking too hard:

$$slipratio_f > 15\% + tolerance_f \tag{2}$$

- Braking too light:

$$slipratio_f < 15\% - tolerance_f \tag{3}$$

- Losing traction to the drive wheels by applying too much power:

$$slipratio_r < -10\% \tag{4}$$

The front and rear slip ratio values ($slipratio_f$, $slipratio_r$) are averaged over the period between an activation event and a corresponding termination event (see §VI). The $tolerance_f$ value changes as the user improves; through empirical observation it is initially set to 7%.

B. Car Positioning

Since corner sections in the track are the hardest to master and contribute mostly to variance in lap times, the model monitors for any divergence of the car from the racing line only in corner sections and is able to determine the following car handling behaviour:

- Braking in corner:

$$braking \times cornering > 0, \quad (5)$$

where $braking, cornering \in \{0, 1\}$; zero signifies false, one signifies true. $cornering$ is determined from the current position of the car in the track (see Figure 4).

- Incorrect race line during corner:

$$cornering \times dist > tolerance, \quad (6)$$

where $cornering \in \{0, 1\}$; zero denotes a straight section, one a corner. $dist$ is the average car distance from the racing line for that section. The $tolerance$ is initially set to 10 metres, and is decreased as the user improves. The activation event triggers when the user transitions from a straight into a corner section ($cornering$ becomes 1).

- Too aggressive during a corner:

$$cornering \times slipangle_f > 8^\circ + tolerance, \quad (7)$$

where $slipangle_f$ is the average (over the corner section) slip angle for the front wheels.

- Too slow during a corner:

$$cornering \times slipangle_f < 8^\circ - tolerance, \quad (8)$$

where $slipangle_f$ is the average (over the corner section) slip angle for the front wheels.

C. Gear Shifting

This component detects user gear changes, and is able to monitor the following car handling behaviour:

- Changing gear too soon:

$$8000 \times (1 - shift_{up}) + rpm < 8000, \quad (9)$$

where $shift_{up} \in \{0, 1\}$; one denotes a gear change, and rpm is the number of revolutions per minute of the car engine.

- Changing gear too late:

$$shift_{up} \times rpm > 8500, \quad (10)$$

where $shift_{up} \in \{0, 1\}$; one denotes a gear change, and rpm is the number of revolutions per minute of the car engine.

- Taking too long to transition from one gear to another:

$$time_{neutral} > 0.5\text{s}, \quad (11)$$

where $time_{neutral}$ is the contiguous time spent in neutral gear position.

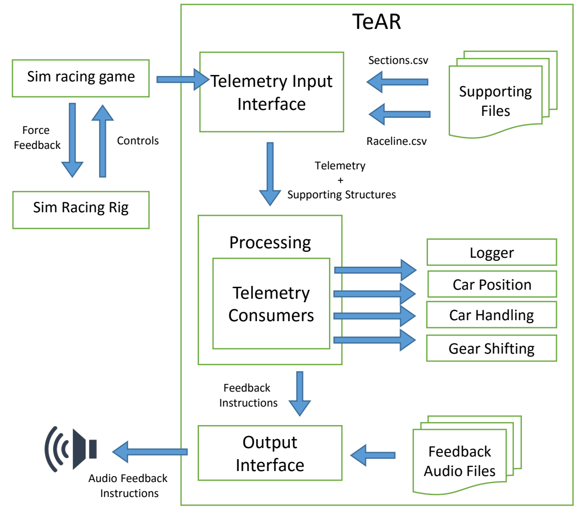

Fig. 5: Overview of the architecture components in TeAR

VI. Telemetry Assisted Racing

This section gives a brief overview of *Telemetry Assisted Racing (TeAR)*, the software artefact developed for this work. The system architecture of TeAR is shown in Figure 5; TeAR is comprised of three main modules: (i) the Telemetry Input Interface, (ii) the Processing module and (iii) the Output Interface.

The **Telemetry Input Interface** is responsible for handling the telemetry data stream coming from the racing simulator. The module also handles supporting files that place telemetry data into context, such as race track geometry and its respective annotations (e.g. racing line). The system uses IPC to access telemetry data from the simulator during a race. The telemetry data is then filtered and rearranged for further processing by the **Processing** module, which coordinates a number of sub-modules each consuming the same telemetry data in a different way (e.g. Logger, Car Handling Feedback). These sub-modules run on separate threads and communicate and synchronise with the main Processing module using shared memory. Any feedback notification raised by the sub-modules is captured by the Processing module, which in turn forwards the message to the **Output** module. The feedback processing sub-modules possess a common structure; each module is bound to a telemetry event. These events may be triggered by changes in one or more of the incoming telemetry data values. When an event is triggered, the respective sub-module will start the analysis process related to the respective telemetry information. Eventually, when the corresponding termination event (not necessarily tied to the same telemetry data as the activation event) is triggered, a decision is taken as to whether to provide feedback or not, and if so, which feedback. The system operates using two feedback tiers; initially, at the first tier, only feedback related to the racing line is provided. As the user masters the racing line, the system will switch to the second tier and suggest more advanced feedback.

The final component in TeAR's pipeline is the **Output**

Interface, through which feedback suggestions coming from the Processing module are presented to the user. This module connects to a repository of audio soundbites that map to the input feedback from the previous module. The audio files in the repository were generated using a free online text-to-speech tool. By design, the module does not support concurrent playback of audio feedback to avoid overwhelming the user. Furthermore, since feedback is topical, buffering was intentionally omitted.

VII. Methodology

This section introduces the methodology employed in this experimental study, followed by an overview of the hardware and software used during the experiments, and an explanation of the experiment procedure. The section concludes with the statistical tests chosen for analysis.

A. Experiment Design

In the experiment, the same car and racetrack were utilised for all participants. Bastow et al. [2] suggest that cars equipped with a front wheel drivetrain may be easier to handle, and motivated in part by these findings, the Fiat Abarth 500 was chosen. It is a relatively low-powered car and thus, suitable for novice drivers. The Silverstone National race track (see Figure 6) has the desirable properties of being flat and smooth, without uneven surfaces or bumps which may result in loss of control in unexperienced drivers. Furthermore, the way the track is structured, with wide run-off areas located along the circuit where drivers are most likely to lose control of the car, allow the car to slow down before colliding with barriers or other stationary objects. Two feedback mechanisms have been considered for this experiment, *visual*, through the use of a heads-up-display (HUD) superimposed on the simulation display, or *auditory*, by means of descriptive speech projected through loud speakers. Leahy et al. [10] argue that auditory feedback is less intrusive than visual clues; based on these findings, it was decided that the system should provide feedback using succinct auditory clues; as an example, when a participant takes a corner at a slower speed than required, the feedback suggests to "*try going faster during corner*".

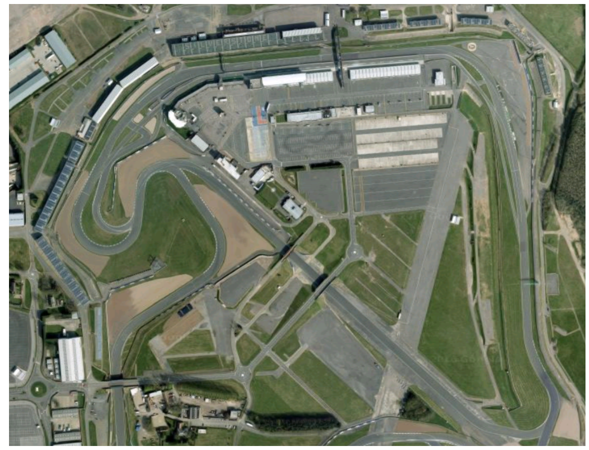

Fig. 6: The Silverstone racetrack used in this experiment

B. Experiment Procedure

Participants were gathered through various methods, ranging from word-of-mouth to mailing lists. Each participant would reserve an experiment time-slot and randomly be apportioned to one of two groups: the *feedback group*, or the *control group*. The procedure is enumerated below.

1) **Introduction** - Each participant is introduced to the setup and some basic racing terms (e.g. racing line), and given an overview of the experiment procedure.
2) **Demographic Questionnaire** - The experiment starts by having the participant responding to a brief questionnaire, aimed to gather more insight about the general participant demographics.
3) **Rig Configuration** - The user climbs inside the rig; the seating position is adjusted to accommodate the user, making sure they are sitting comfortably. Participants are given a second, more in-depth overview of the components of the rig and how they operate.
4) 1^{st} **Session, Practice (10 minutes)** - The participant is given ten minutes to get used to the rig setup, track and car.
5) **Break (5 minutes)** - A short break (5 minutes maximum) is given to each participant.
6) 2^{nd} **Session (10 minutes)** - In this session, the participant drives the racing car around the track for ten minutes. Participants in the feedback group have the feedback system turned on, while for the control group, this is turned off.
7) **Break (5 minutes)** - A short break (5 minutes maximum) is given to each participant.
8) 3^{rd} **Session (10 minutes)** - A second ten minute session is held; participants in the feedback group have the feedback system turned on, while for the control group, this is turned off.
9) **Break (5 minutes)** - A short break (5 minutes maximum) is given to each participant.
10) 4^{th} **Session (5 minutes)** - A final five minute driving session; the feedback system is turned off for participants in both groups.
11) **Feedback Questionnaire** - The experiment concludes by the participant responding to a questionnaire about experiment structure, apparatus quality, performance perception and free-form feedback.

C. Data Collection, Sampling and Analysis

The data collected during the experiments consists of two questionnaires and four batches of telemetry data per participant. Each batch represents the telemetry data collected in a particular driving session. In order to evaluate the performance of each of the two groups (control and feedback) and perform meaningful statistical comparisons between them, the collected data were subjected to the Independent T-Test [7] and the Mann-Whitney U Test [13]. These are appropriate tests for independent groups [5]. In our case, the groups are indeed independent because a participant from the control group may not make part of the feedback group and vice versa. The null hypothesis is that there is no significant difference across the groups, while the alternative hypothesis is that there is significant difference across the groups.

Fig. 7: Assetto Corsa by Kunos Simulazioni

VIII. Evaluation

In this section findings from the user study are presented. A custom-built simulation racing rig was used for this experiment, with Logitech G25 input devices mounted on it (see Figure 8). A 32” LCD HD Samsung display with $2 \times 10\mathrm{W}$ speakers was employed for visual and auditory output. The racing simulator used was Assetto Corsa by Kunos Simulazioni (Figure 7), running in full HD resolution at 60 frames per second (fps). This simulator was chosen because it provides a realistic driving model, driving aid customisation, high-fidelity graphics, real-world tarmac circuits and intuitive telemetry data access through an interface using a UDP connection. Simulation driving aids (e.g. racing line and traction control) were switched off; tyre wear and tear was also disabled. The hardware platform running the simulator was an Intel Core i7-940, with $8\mathrm{GB}$ of RAM and an Nvidia 660Ti video card with $2\mathrm{GB}$ of VRAM. The machine was running the retail version of the Windows 10 Professional operating system.

A. Sample Demographic

27 participants took part in the user study, mostly males in their early twenties. Out of 27 participants, 2 did not hold a driving license; 25 held a driving license, although most of them hadn’t been driving for more than a year. 22 participants claimed to play video games, from which 18 stated to have played racing video games. Out of these 18, a majority of 15 played mostly arcade sim racing games, while the remaining 3 regularly played simulation racing games. 7 out of 27 participants had previously used a racing rig. Random assignment was used to split the participants into the control and feedback/experimental group. The control group had 13 participants, while the feedback group had 14.

B. Experiment Results

The dataset of the first session (practice), shown in Figure 9, was subjected to the Kolmogorov-Smirnov Test resulting in a p-value of 0.36; with a significance level of 0.05 the null

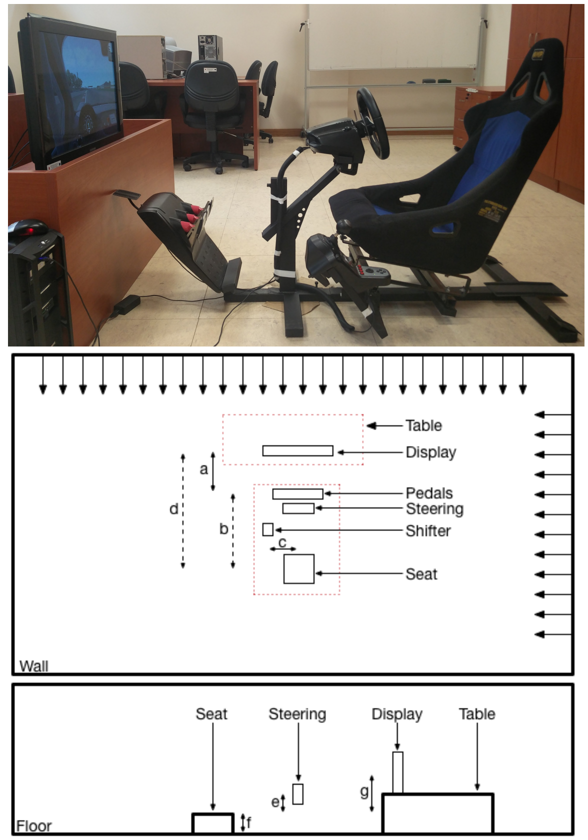

Fig. 8: Racing rig used by participants, with a=45cm, b=75cm, c=36cm, d=120cm, e=20cm, f=30cm, g=35cm

hypothesis is accepted. Having confirmed that the groups share the same distribution, the Mann-Whitney U Test was then used to determine differences between them. Results are given in Table I. For the first session these show a p-value of 0.057, with a confidence interval of 0.95 resulting in no statistical difference between the groups (p-value > 0.05, thus rejecting the alternative hypothesis). The tests for the second and fourth session have a p-value of 0.054 and 0.539 respectively; both values are above the significance level of 0.05, resulting in the null hypothesis being accepted. Conversely, the third session has a p-value of 0.029 and the alternate hypothesis is accepted, suggesting statistical differences in group performances.

C. Participant Feedback

The participants reported a good experience overall. The rig setup was found to be realistic and easy to use. With respect to the difficulty of the race track, an overwhelming majority of the respondents reported having issues mastering the second and third corners (referred to as the *s-bend*; see Figure 4). When the feedback group was asked about TeAR,

TABLE I: Mann-Whitney U Test result for Experiment

Session	Lap Time			
	1^{st}	2^{nd}	3^{rd}	4^{th}
Asymp. Sig. (2-tailed)	.057	.054	.029	.539

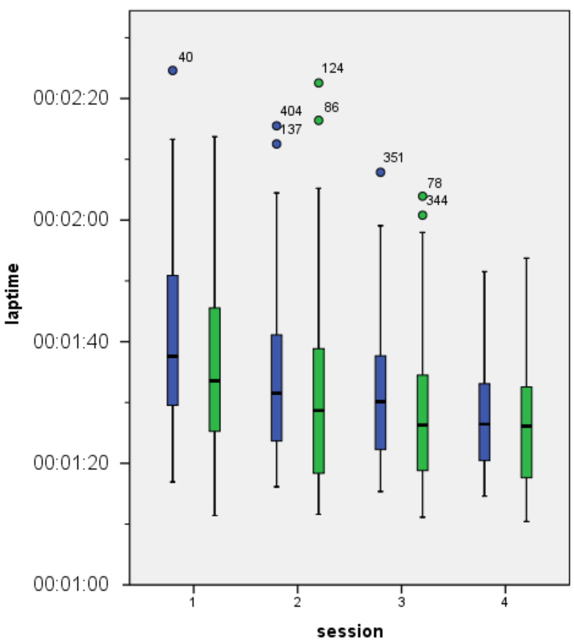

Fig. 9: Blue : Control Group, Green : Feedback group
Lap times vs session, clustered by group

they reported the feedback and the output quality of the audio to be intelligible, accurate and helpful. They also said that the feedback hints were somewhat easy to apply. Lastly, when asked whether the feedback was intrusive and possibly distractive, 10 out of 14 respondents reported that it was neither intrusive nor distractive.

D. Discussion

The rig setup has been well received, with participants enjoying the driving and awarding it a high score in terms of realism. This suggests that is it possible to achieve a good level of realism using simple off-the-shelf hardware. Both groups show a noticeable improvement from one session to the next, except for the final session in which the shorter time slot allocated might have put additional pressure on the participants, hindering their performance. For the second session, the tests show no statistical differences in the performance of the two groups, albeit this changed for the third session. The lower average lap time for the feedback group suggests that after familiarising with the feedback system, the group started following its instructions more closely, thus improving their performance. The available sample of participants is too small to test for correlation between gaming experience and lap times. The same argument can be made for a possible correlation between holding a driving licence and driving performance, since all but two participants are in possession of a driving licence.

IX. Conclusions

The skills required to become a good motorsport driver are generally learned through practice, and suggestions provided by more experienced drivers. Our hypothesis for this work is that an automated telemetry-based feedback system can be used to simulate this process and thus, to possibly help novice drivers assimilate this knowledge at a higher rate. For this purpose, TeAR was developed, which using a static expert system, presents auditory suggestions to drivers underlining the driving mistakes they are currently making. An experiment was set up to verify this hypothesis with 27 participants taking part. From the data gathered in this experiment, it appears that the real-time feedback was effective to some extent; however, the participants seemed to be having difficulty retaining and applying the suggestions once it was switched off. This lack of cognitive retention may be due to a number of reasons, which could be investigated in future work.

A. Future Work

At present, TeAR presents feedback only when the driver is performing something wrong. It would be interesting to determine whether a system which also presents positive feedback, for instance letting the driver know that a previously reported mistake was actually corrected, would lead to any improvements. Furthermore, it is also possible to experiment with a variety of feedback methods, both visual and auditory, on the assumption that different feedback presentation media can lead to changes in the learning rates. Combining both auditory and visual feedback could help in increasing the clarity of the feedback provided. The feedback mechanism of TeAR is entirely based on telemetry data provided by the racing simulation software. However, a number of mistakes cannot be directly extracted from this data. For instance, during the experiment it was noted that some of the participants lacked some basic driving skills such as keeping both hands on the steering, not crossing hands while steering and not resting hands on the shifter. This additional information could be collected through the use of a motion tracking camera which directly feeds TeAR.

TeAR is currently intended to help drivers improve their motorsport driving skills. A future direction could also look into the possibility of using TeAR to automate the driving process of a racing car. One possibility is that of using neural nets and fuzzy logic controllers, with both models learning how to drive via the feedback provided by TeAR.

References

[1] B. Adejumobi, N. Franck, and M. Janzen. Designing and testing a racing car serious game module. In *International Conference on Serious Games Development and Applications*, pages 192–198. Springer, 2014.

[2] D. Bastow, G. Howard, and J. P. Whitehead. *Car suspension and handling*. SAE international Warrendale, 2004.

[3] B. Beckman and N. B. R. Club. The physics of racing, part 5: Introduction to the racing line. *[online] http://www.esbconsult.com.au/ogden/locust/phors/phors05.htm*, 1991.

[4] M. R. Ciceri and D. Ruscio. Does driving experience in video games count? hazard anticipation and visual exploration of male gamers as function of driving experience. *Transportation Research Part F: Traffic Psychology and Behaviour*, 22:76 – 85, 2014.

[5] M. De Smith. Statsref: Statistical analysis handbook-a web-based statistics. 2015.

[6] D. Djaouti, J. Alvarez, and J.-P. Jessel. Classifying serious games: the g/p/s model. *Handbook of research on improving learning and motivation through educational games: Multidisciplinary approaches*, pages 118–136, 2011.

[7] W. S. Gosset. The probable error of a mean. *Biometrika*, 6(1):1–25, March 1908. Originally published under the pseudonym "Student".

[8] L. D. Grace and J. Coyle. Player performance and in game advertising retention. In *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology*, page 55. ACM, 2011.

[9] B. Knox. *A Practical Guide to Race Car Data Analysis*. Createspace Independent Pub, 2011.

[10] W. Leahy, P. Chandler, and J. Sweller. When auditory presentations should and should not be a component of multimedia instruction. *Applied Cognitive Psychology*, 17(4):401–418, 2003.

[11] Q. Li. Can driving in games translate to driving in real life? a study of game based traffic education. *Developments in Business Simulation and Experiential Learning*, 42, 2015.

[12] C. Lopez and D. Sullivan. *Going faster!: mastering the art of race driving*. Bentley Publishers, 2001.

[13] H. B. Mann and D. R. Whitney. On a test of whether one of two random variables is stochastically larger than the other. *The annals of mathematical statistics*, pages 50–60, 1947.

[14] D. R. Michael and S. L. Chen. *Serious games: Games that educate, train, and inform*. Muska & Lipman/Premier-Trade, 2005.

[15] K. Simulazioni. Assetto Corsa your racing simulator, 2017. Available at http://www.assettocorsa.net/en.

[16] S. M. Studios. Project CARS - Home, 2017. Available at http://www.projectcarsgame.com.

[17] J. J. Vogel, D. S. Vogel, J. Cannon-Bowers, C. A. Bowers, K. Muse, and M. Wright. Computer gaming and interactive simulations for learning: A meta-analysis. *Journal of Educational Computing Research*, 34(3):229–243, 2006.