Evaluating Added Sonifications for Racing Simulators

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ABSTRACT

This study evaluated the improvements in performance resulting from a system that sonifies environment data from a racing simulator. The pool of study participants were three individuals with varying degrees of experience in physical racing and little to no experience in racing simulators. This study also evaluated the systems impact on user confidence and driving behavior.

Results were inconclusive as to whether this system has a substantial effect on performance and behavior. However, a more thorough followup study could potentially produce a more clear result.

1. INTRODUCTION (What are the research questions)

This study is an evaluation of a system to create added sonifications for environment data in a racing simulator. The primary research question is **(RQ1) Will added sonifications improve user performance (in lap times)?** This question is answered by measuring user performance on courses with and without sonfications and then comparing the margin of improvement between first and second attempts on a course. As a followup question, **(RQ2) Will users feel more confident driving with added sonfications?** And also, **(RQ3) Will users change their driving behavior while being exposed to the added sonifications?**

2. METHODS

2.1 Participants

I recruited 3 participants, who have little to no exposure to racing simulators. My three participants also have varying degrees of exposure (minimal exposure, moderate exposure, and regular exposure) with racing in physical contexts (such as go kart racing). This pool of participants perhaps had a sub-optimal amount of experience in racing simulators to rule out performance irregularities being a result from progressive acclimation to the simulator used in testing.

2.2 Setting

The study was conducted in person with participants who have been fully vaccinated for COVID-19. Participants were using the RaceRoom racing simulator.

2.3 Systems

2.3.1 Description of Sonifications

There are three main environment values and variables being sonified.

The user's distance from the ideal path for the course (built per course and displayed by RaceRoom) is mapped to a sawtooth wave. The amplitude of the wave is defined by a function that takes in the distance from the optimal line as input. The function can be modified by inputs available in a software interface. The resulting wave sound is then panned left/right to imply the direction of the line relative to the user's current position on the course.

The time until the next brake or acceleration event are sonified by a series of bell sounds that function as a countdown. This countdown consists of several short tones followed by one longer tone that is at a higher pitch. The total counts and tempo of counts can be modified by controls available in a software interface. The final tone of each countdown is intended to line up in time with the ideal time where a vehicle should begin braking or accelerating in order to achieve an optimal time for the course. (Examples of calculation of ideal path and brake/acceleration timing can be found here)

The final sonification is of lap time performance relative to previous best times. If a recently completed lap has a better time than the previous best time for a course then a positive sounding bell is played. Otherwise a negative sounding buzzer is played. Both of these sounds are also put through a reverb filter. The room size value for this filter is adjusted by the margin of time difference between the recently completed and best time. After one of these two tones are played a text-to-speech alert is built from the time margin and then played to the user (ex. "two seconds slower").

2.3.2 Sonficiation Controls

The sawtooth wave for ideal line offset has four input parameters in the software control interface. One slider for the threshold for the distance at which to set the amplitude of the wave to be greater than zero. A second slider to define a constant to determine the curve at which the amplitude of the curve should increase for the wave given the distance from the line. The function for the amplitude is:$A = (|x| - t)^c$, where A is the resulting amplitude of the wave, x is the distance from the ideal line, t is the threshold defined by a slider, and c is the curve constance defined by a slider. A third slider allows the final amplitude of the wave to be scaled by some percentage. The fourth slider is used by someone conducting an experiment to manually set the participants distance from the ideal line. This slider value is also set by JSON streams that could be directed from separate software systems.

The countdown sounds have three input parameters. One slider for the total integer number of counts that should occur (*n-1* being the short tone, and *1* being the long tone). A second slider for the tempo at which these counts should occur. In a system where the upcoming ideal time for a brake/accel event is known these two variables can be modified to ensure that the final tone lines up with the time at which the user should begin an action. The triggering of a countdown can be set by a button, or a stream of JSON data should have the distance in time to the next event and this distance can be used to calculate when the countdown should be started.

The lap time sounds have no real controls. The sounds can be triggered by a button press on the software control interface or by a JSON stream that provides data for a recently completed time and the current best lap time.

2.3.3 Participant Interfaces and Equipment

Participants were seated in front of a computer running RaceRoom. Added sonifications were run from a separate laptop operated by the experimenter. The sound from both computers were both passed through an interface to participants wearing Phillips open-back headphones.

2.4 Procedure

Participants were first allowed a few minutes to become accommodated with the simulators interface

Participants ran through four different courses. Two of these courses were performed without any added sonficiations, the other two were performed with added sonifications (alternating between without/with sonifications). Each course involved three laps: a warm-up lap for the participant to become accommodated with the general shape of the course, a timed lap to function as a baseline for performance on the course, and then a final lap to measure performance improvement over time.

During testing participants were asked to attempt to provide live feedback to how they were reacting to sounds. After testing all participants took a short survey (see Table 1.)

Table 1.

Interview Questions
Q1: On a scale from 1-5 how confident did you feel while driving on courses without the added sounds?
Q2: On a scale from 1-5 how confident did you feel while driving on courses with the added sounds?
Q3: On a scale from 1-5 how useful did you find the added sounds?

2.5 Measures

During testing on the computer running RaceRoom a screen recording was made, as well as all keyboard and mouse inputs recorded with timestamps. An audio recording was also made for each participant in order to record their live responses to sonfications. Lap times were pulled from the screen recording. Additionally participants survey responses were recorded to measure their confidence driving with and without the added sonfications, as well as how useful they found the sonifications to be. Although these survey responses could possibly be subjected to conscious or unconscious bias from participants.

3. RESULTS

Below (Table 2) are the raw results from all participants. The times were pulled from the screen recordings for each participant. The percent improvement was calculated as $\frac{(t_1 - t_2)}{t_1}$. Courses A and C were run without added sonifications, while B and D were run with added sonficiations. The data from this table is intended to be used to answer **RQ1**.

Survey responses are also included in a separate table below (Table 3). The data from this table is intended to be used to answer **RQ2**. Some excerpted highlights from the live comments on sonifications:

I think it (the sonification for offset from ideal line) *would be a lot more helpful if I didn't have the line displayed to me.*

I think that while turning it (the countdowns for turns) *comes in a bit late. It would be nice to have a bit of a head start on the corners.*

I like when the sound (sonification for offset from ideal line) *comes in so I get back on the line. I think it's most helpful for exciting turns.*

I wish that I could have had the countdowns on the other course where there were lots of turns you can't see until you come over a hill.

I think a heads up would be more helpful if it were more focused on when I should start breaking, rather than an upcoming turn.

I feel more likely to naturally move towards the line since I'm aware that the sound will play if I'm too far away from it.

General observations from mouse input data are included (Table 4, Table 5). The data from this table is intended to be used to answer **RQ3**.

Table 2.

Times and percent improvement for each participant on each course as well as average times and average improvements for each course and lap

	P1	P2	P3	Average
A - Lap 1 (s)	86	126	90	100.7
A - Lap 2	79	91	81	83.7
A - Improve %	0.814	0.278	0.100	0.153
B - Lap 1 (s)	47	70	52	56.3
B - Lap 2	55	75	46	58.7
B - Improve %	-0.170	-0.071	0.115	-0.042
C - Lap 1 (s)	126	132	109	122.3
C - Lap 2	111	112	103	108.7
C - Improve %	0.119	0.152	0.055	0.109
D - Lap 1 (s)	120	126	123	123
D - Lap 2	114	124	117	118.3
D - Improve %	0.050	0.016	0.049	0.038

Table 3

Survey responses per participant. (For questions see *Table 1*)

	P1	P2	P3	Average
Q1	4	2	4	3.3
Q2	5	5	5	5.0
Q3	3	5	3	3.6

Table 4

Average mouse movement speeds (measured as distance in pixels moved per measurement) per course

	P1	P2	P3	Average
A	516	396	326	412.67
B	627	488	435	516.67
C	748	439	399	528.67
D	591	340	363	431.33

Table 5

Average mouse speeds (measured as distance in pixels moved per measurement) for courses with sonifications with and without added sonifications

	Average Speed
Without Sonifications	470.67
With Sonifications	474.00

4. DISCUSSION

RQ1: Will added sonifications improve user performance in terms of lap times?

According to the data in Table 2, the system does not appear to be successful at improving user performance in regards to lap time improvements over time. This could be for a variety of reasons.

The most prominent issue from this system that could have contributed the most to a lack of improvement is the system's lack of direct access to simulator data. Because the simulator doesn't have a direct interface with variables tracked in the simulator software (such as vehicle speed, position, etc.) the sonifications had to be externally choreographed by the experimenter. This requires visually observing the participants' driving while adjusting sonification parameters through the interface. An interface that was directly receiving data streams from simulator software would likely solve this issue. As addressed in the live excerpt of live participant feedback, participants felt that the timing was off.

Another observation is that users seemed to be more comfortable in their driving abilities by the second timed lap. Additionally, all participants reported being more confident in their driving with the added sonifications (Table 3). These boosts in confidence could result in a Dunning-Kruger type of effect where participants become more confident and thus more relaxed and less focused on their driving. All participants having very little exposure to racing simulators could also contribute to a lack of consistent driving, which would lead to a nullifying of any possible improvements from sonficiations.

Another potential explanation could involve course selection. All participants drove with sonifications on the same courses. As mentioned in the live participant feedback, there could potentially be some courses that are more well suited for sonifications. Courses that have more hills and walls obscuring a user's view of the course would clearly benefit from having additional data provided to the user that could potentially make up for visually obscured data. In this case courses may have been selected sub-optimally to have added sonifications for. In this case it is possible that performance is consistent across courses because the sonifications potentially made difficult courses easier and created a more even distribution of course difficulty than existed naturally.

RQ2: Will users feel more confident driving with added sonfications?

All participants self-reported feeling more confident while driving with added sonifications as opposed to without them (Table 3). However, possible reporting bias from participants could have occurred and effect survey responses. Ideally more physical measurements should have been taken of participants while driving to better measure confidence as a lack of physical indicators of stress. Mouse movements were an attempt to measure one possible marker of driving behavior, however it is uncertain of how well this metric could be used to indicate user confidence. Additionally, the observed consistent averages in mouse movement speeds across courses with/without sonifications could be the result of similar issues as described above for distribution of course difficulty.

RQ3: Will users change their driving behavior while being exposed to the added sonifications?

There were no substantial differences in driving behavior resulting from the data that was collected (Table 4; Table 5). More thorough measures for behavior or a different approach to processing existing data possibly could have indicated a different result. Additionally, the observed consistency in mouse movement speed across courses with/without sonifications could also be a result of the issue described above for inadvertent evening of course difficulty distribution.

5. CONCLUSION

The results from this study indicate that this specific implementation approach may not be beneficial to user performance (RQ1). However it could have still had an improvement to user confidence despite sup-optimal implementation (RQ2). Whether this system had a substantial effect on driving behavior is unclear with the given data and analysis approach (RQ3).

In a future study, sonifications should be directly connected to simulator environment data. This would require finding a simulator with more open access to internal variables tracked in software, performing processing of environment data that openly presented to users from a simulator (i.e. using a computer vision approach for processing), implementing a simple racing simulator. Additional measurements and more rigorous analysis would also be needed to more accurately measure participant driving behaviors. More iterations of testing would also be needed in order to correct for any issues that may arise from course difficulty and participant behavior as well as participants with more or less experience in racing simulators. This would require having several more participants, ideally with some exposure to racing simulators and performing many more laps per course.