OPTIMISATION OF BLIND DRIVING WITH AUDIOSYSTEMS

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Abstract

This research aims to gather knowledge concerning auditory systems that can be used to support the driver in lane-keeping, when not having access to visual information ('blind driving'). Three parameter sets were experimentally investigated: (1) prediction in the feedback (0, 1, 2, & 3 s prediction time), (2) feedback method (graded-volume vs. graded-frequency feedback), and (3) corner support. Two experienced drivers tested the systems in a fixed based driving simulator. The results showed that a prediction time of 2 s yielded the highest lane-keeping accuracy. The linear volume feedback gave the best lane-keeping accuracy among the feedback methods. The investigated corner support systems did not have any substantial effects on the lane-keeping accuracy. A number of suggestions for further investigations are proposed.

1. Introduction

Driving is predominantly a visual task. The aim of this research is to gather knowledge concerning audio systems that can be used in the lane-keeping task when not having access to visual information ('blind driving'). This research may be a start in the development of systems that support people with poor eyesight, not only in the driving task, but also when walking or cycling. Another potential application can be found in warning systems used in cars. When a person falls into sleep, a warning signal with directional information could awake and support him/her. This is because information from the ears reaches the brains faster than other sensory information [5].

There are several parameters in the feedback that influence the behaviour of the driver. A prediction time in the feedback is often used [2,3]. It is also advisable to use graded (increasing with absolute lane error) feedback [4]. A variation in these parameters is evaluated.

2. Method

Apparatus. A test environment was set up using a fixed based driving simulator (Green Dino, The Netherlands). An interface was programmed in Matlab and Simulink r2015a to retrieve data from the Green Dino simulator and generate audio output via Creative Sound Blaster Tactic 3D Alpha headphones.

Speed and gearbox settings. An automatic gearbox was used. The speed profile was predetermined so there was no need for the drivers to use the gas or brake pedals. The drivers were able to hear sounds from the car and environment, but had the simulator LCD projectors turned off.

Dependent variables. The performance of the drivers was evaluated using three measures of lane-keeping accuracy: 1) the in lane percentage (ILP), calculated as the time the driver is in the lane divided by the total time of the trial; 2) the Root Mean Squared Error (RMSE) of the lane centre error in metres; 3) the number of resets. A reset occurred when all wheels of the car were off the road. Data from 0 to 5 s after a reset was removed to prevent influence from resets on RMSE and ILP. After 5 s, the predetermined speed was reached again.

Road. The tests took place on a two-lane 7.5-km road without intersections and without other vehicles. The lap contained straight segments, as well as 25 sharp 90-degree curves (radius 15–20 m). The lane width was 5 m. There are two starting points, yielding two different segments. The order in which these two segments were driven was randomly determined. In each trial, the participants drove 3 km and one trial lasted for 4.8 ± 0.65 min.

Participants. The participants were two experienced drivers with good knowledge of the auditory concept, so there was no presumed learning effect. Every test condition was done once by each of the two participants on both track segments. Thus, each participant tested each condition twice.

The three parameters under investigation. In this research, three parameters were investigated: (1) the degree of prediction in the feedback, (2) the method of feedback (volume feedback vs. frequency feedback), and (3) the corner support. The method of feedback used in this research was off-target bandwidth feedback with a threshold of 0.5 m [1]. This means that in all tests, auditory feedback was provided only when the car was deviated from the lane centre for more than 0.5 m.

In the first test, the prediction time was evaluated using a ABCDABCD design [6]. The *A* stands for a trial with a prediction time of 0 s, *B* is a trial with a prediction time of 1 s, *C* with a prediction time of 2 s, and *D* with a prediction time of 3 s. The feedback was generated for the predicted position of the car, based on its current speed. Linear graded volume feedback was used as the baseline in this test.

The second test involved volume feedback versus frequency feedback, both evaluated with a linear and exponentially graded profile. Again, the ABCDABCD design was used. The order in which the feedback methods were evaluated was determined randomly at the beginning of the test. A 2 s prediction time was used as the baseline in this test.

The third test concerned systems for corner support. A 2 s prediction time and linear graded volume feedback was used. It was completed with the ABCABC design. *A* was a system without any form of corner support. In system *B*, a beep would be generated when entering and leaving a corner. This was done to make the drivers aware of a corner, allowing them to distinguish between small corrections on straights and large steering actions in corners. System *C* provided a beep when crossing the lane centre. This system only functioned in corners. When the drivers crossed the centre of the lane, they heard a sound. This was done to indicate when to stop steering.

3. Results

Figures 1–3 show the results of the tests. It should be mentioned that 2 s prediction time in Figure 1 used the same method of feedback as the VL in Figure 2 and None in Figure 3. In figure 4 the 6 trajectories of these runs are plotted at track segment 1.

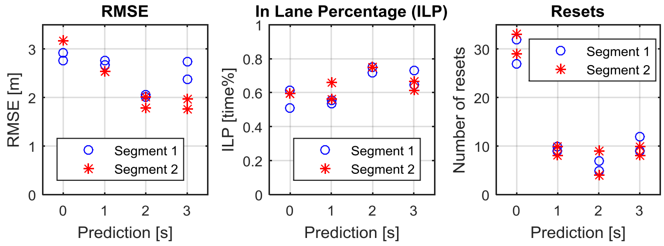

Figure 1. Results of Test 1: Prediction Time

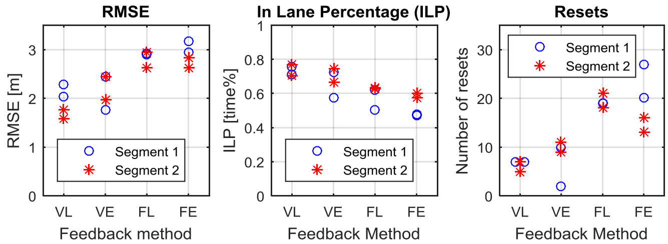

Figure 2. Results of Test 2: Feedback Method. VL = volume feedback linear, VE = volume feedback exponential, FL = frequency feedback linear, FE = frequency feedback exponential.

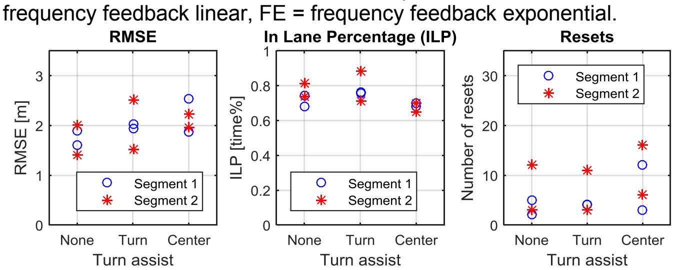

Figure 3. Results of Test 3: Corner Support. None = no corner support, Turn = beep when entering and leaving a corner, Centre = beep when crossing lane centre in a corner.

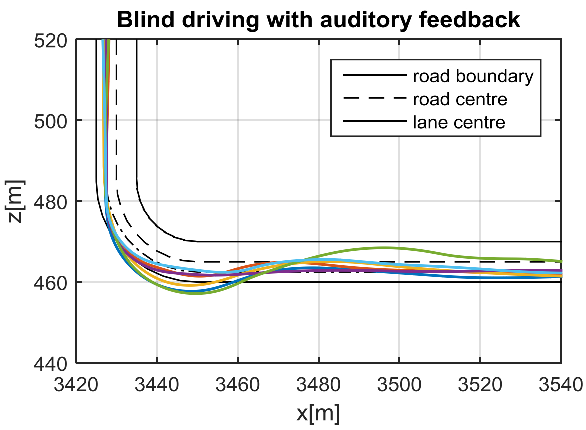

Figure 4 Track segment 1, the 6 equivalent runs.

4. Discussion

Figure 1 shows that the RMSE is at its lowest with a prediction time of 2 s at track segment 1. At track segment 2, the mean RMSE with a prediction time of 2 s is the same with a prediction time of 3 s. From the RMSE, the ILP and the number of resets on both segments, the presumption is made that a prediction time around 2 s gives the highest lane-keeping accuracy. Further research is necessary to confirm this because the differences are quite small. These results are the foundations for using a 2 s prediction time in test 2 and 3.

Figure 2 shows that volume feedback gives better lane-keeping accuracy than frequency feedback. However, the differences between the linear graded volume feedback and the exponentially graded volume feedback are small. At both track segments the in lane percentage with a linear volume profile gives a higher lane-keeping accuracy compared to exponentially graded volume feedback. Regarding the resets, one of the participants drove very well when using the exponential volume feedback, but this can be interpreted as a positive outlier, because, even when using various support systems (Figure 3), a lower number of resets was never achieved. At track segment 2, the number of resets was lower when using a linear volume feedback profile. These results support the use of the linear volume feedback profile in the third test.

Figure 3 shows that there are no substantial differences between the systems with or without corner support. It should, however, be realized that drivers heard that the engine sound became quieter, when approaching a corner.

It should be mentioned that these results only apply to the two participants used, so the results cannot be generalized to the entire population of drivers.

Further improvement of the system may be achieved by taking into account that most of the errors were made in corners. Moreover, the same errors were made in corners with the same radius. For example, the corner in Figure 4 was always taken somewhat oscillatory. It could be helpful to give the drivers more information about the type of corner they are approaching.

5. Recommendations

Based on the research the following recommendations can be made for the development of auditory systems for blind driving:

- A substantially higher lane-keeping accuracy is reached when using a prediction time. The hypothesis is that a prediction time around 2 s gives the highest lane-keeping accuracy.
- Regarding the method of feedback, the hypothesis is that increasing volume feedback gives a higher lane-keeping accuracy than increasing frequency feedback. The differences between linear graded feedback and exponentially graded feedback are not substantial.
- The investigated corner support systems do not yield substantially better results in comparison with the system without corner support, possibly because of the presence of engine sound that also functions like corner support (sounds became quieter when approaching a corner).

References

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