# Detection of objects by means of sound

W. van Haarlem (4254988), H. Quraishi (4242149), C. Berssenbrugge (4243838), J. Binda (4226313)

The detection of objects by means of auditory feedback was studied. During this research we performed three experiments and analysed different methods of the usage of auditory feedback. Three different methods were studied: (1) Increasingly Frequent Repetition (IFR), (2) Monotonic Volume Change (MVC) and (3) Monotonic Frequency Change (MFC). The goal of the research was to investigate which method would result in the smallest difference between the actual location of the object and the location chosen by the participant. From the conducted paired t-tests in Experiment 1 and 2 we observed there was only a statistically significant difference between IFR and MVC in Experiment 2. We did however find that there was a statistically significant difference between the equivalent methods in Experiments 1 and 2.

## Introduction

In this project, we studied the effects of information transmission by means of auditory feedback. Auditory feedback is currently used in the parking sensor of a modern car, where an increasingly frequent beep is introduced to the driver to indicate the distance of the car to an object. However, auditory feedback can be used in a broad spectrum of appliances, such as: vehicles in which visual feedback is restrained or other applications where additional feedback may be of use. Think of airplanes and cars in low visibility areas, or even surgical procedures where visibility is restricted. The effects of auditory feedback have been studied many times before. One of the papers we consulted was about auditory feedback in an aircraft simulator [1]. However, in this research we will emphasize the usage of auditory feedback a 2D plane.

For this research we formulated three hypotheses.

- In a sound-based distance test, with the object located in front of the participant, IFR will result in the smallest percentage error between the object's location and the chosen location.
- In a sound-based distance test, with the object located in the 180 degree 2D field in front of the participant, IFR will result in the smallest percentage error between the object's location and the chosen location.
- The simultaneous use of auditory and visual feedback will result in a lower/faster reaction time, than the use of visual feedback only.

These hypotheses were tested using three separate experiments. In these experiments a sound, depending on the distance to the object, could have different levels of volume and frequencies and furthermore it could be continuous or discontinuous. If the sound is not coming from a point directly in front of the participant, as is the case in Experiments 2 and 3, the sound will be louder in one ear. We utilized this effect to indicate the azimuth angle in the experiments.

## Method

**Apparatus.** The research was conducted using a computer simulation created with Unity (version 4.6.1f1). The experiments were conducted with Razer Electra headphones.

**Auditory feedback.** Three types of auditory feedback were tested. The first type was Increasingly Frequent Repetition (IFR), where the range was 0.91 to 10 tones per second (corresponding to respectively the top and bottom of the screen). This resembled the feedback in a parking sensor, in the sense that it "beeps" faster as you are closer to an object. Secondly, we tested Monotonic Volume Change (MVC), where the volume intensity increased from 0% to 100% as the object approaches the participant. Thirdly, we tested the Monotonic Frequency Change (MFC) where the frequency range varied from 200 Hz to 1200 Hz. The frequency of the sound increases as the object approaches the participant.

Each sub-experiment consisted of ten trials.

**Experiment 1.** In the first experiment the participant heard a sound (equally loud in both ears), indicating that the object was located in front of him/her. During each of the three sub-experiments a different method was tested. The participant was asked to locate the object as accurately as possible (Fig. 1). The goal of the first experiment was to determine the method that results in the smallest percentage error in determining the distance.

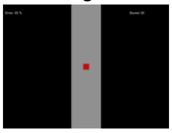

*Figure 1: Exp. 1*

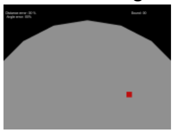

*Figure 2: Exp. 2*

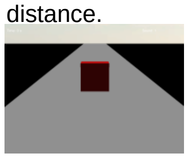

*Figure 3: Exp.3*

**Experiment 2.** The second experiment was similar to the first, but this time the participant has to locate the object in a two-dimensional plane (Fig. 2). This means that not only the distance but also the (azimuth) angle had to be estimated. To represent the angle, we used the volume difference between both ears. If the sound is equally loud in both ears, the object is in front of the participant. If there is only sound in the right ear, the object is on the right. Sound only in the left ear means that the object is located on the left. Everything in between can be derived from the linear difference in volume between the two ears.

**Experiment 3.** The third experiment was divided into two sub-experiments. In one of the sub-experiments the participant saw a block appearing on the screen (Fig. 3). It could either appear on the left, on the right, or in front of the participant. The participant had to press on the left, right, or up arrow key as fast as possible. All the data from participants with an error percentage higher than 30% was declared invalid. This was to prevent the participants from guessing in an attempt to be as fast as possible. The second sub-experiment was similar to the first one. However, during this sub-experiment the participant heard a sound corresponding to the location of the block, and was presented with a visual representation of the block as well.

All participants conducted the experiments in the ascending numerical order. To neutralize the effects of the learning curve, we decided to randomize the sequence of the sub-experiments. We did however decide to have the same sequence for the sub-experiments in Experiment 1 and 2, in order to prevent participants from testing the same method subsequently.

For the experiments we recruited 29 participants (21 males, 8 females) with a mean age and a standard deviation (SD) of respectively 29.59 and 15.67 years.

## Results

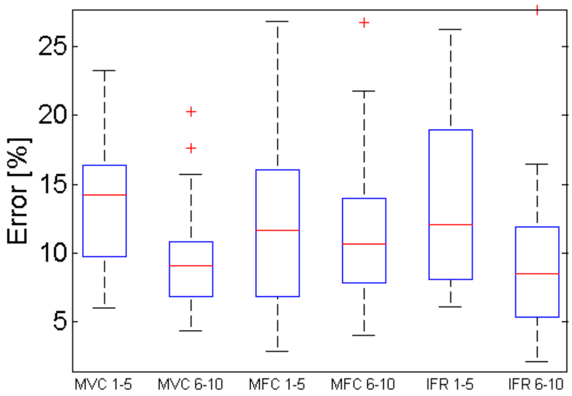


*Figure 4: Both halves of the trials split*

Figure 4 shows the percentage error for the first and last five trials in Experiment 1. With the use of paired samples t-tests we observed no statistically significant differences in percentage error between the three methods for the first sets of five sounds and the last sets of five sounds. Nor was there a statistically significant difference between the complete sets of ten sounds in both Experiments.

The percentage error in distance of the second experiment was analysed identically to the first experiment. Paired t-tests between the complete sets of ten sounds show that there was a significant statistical difference in percentage error between IFR and MVC ($p = 0.017$). The mean distance error and values of the standard deviation from Experiments 1 and 2 are shown in Table 1.

The percentage errors in angle of the second experiment were analysed with paired t-tests as well. The results of the t-tests show that there is no significant statistical difference in percentage error between the three methods.

Paired t-tests on the data of Experiment 3 showed no statistically significant difference in reaction time between the tests with and without sound. The mean reaction times had the values 0.619 s (with sound) and 0.666 s (without sound). The respective SD values were 0.233 s and 0.267 s.

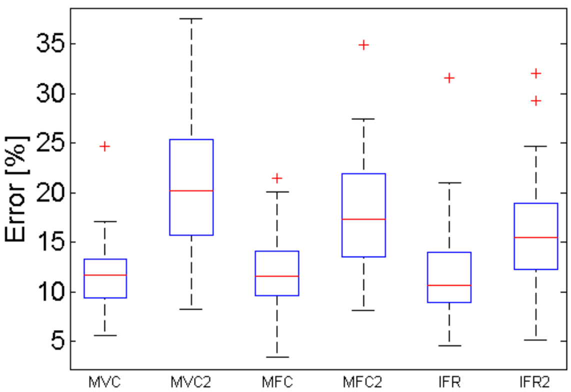


*Figure 5: Mean error of Experiment 1 and 2*

Figure 5 shows the comparison of the data from Experiment 1 with the distance error from Experiment 2. Both experiments used the same range for both the distance and sound. We subjected all methods from Experiment 1 with the matching methods from Experiment 2 to a paired t-test. These are the resulting statistical probabilities: MVC $p = 2.60e\text{-}06$, MFC $p = 8.96e\text{-}05$ and IFR $p = 5.60e\text{-}03$. This data tells us that there is a definite significant statistical difference between the methods in Experiment 1 and 2.

| | **Experiment 1** | | **Experiment 2** | |
|---|---|---|---|---|
| | **Mean** | ***SD*** | **Mean** | ***SD*** |
| **MVC** | 11.8 | 3.9 | 20.2 | 7.6 |
| **IFR** | 11.9 | 5.3 | 16.0 | 6.4 |
| **MFC** | 12.0 | 4.1 | 18.5 | 7.5 |

*Table 1: Mean distance percentage error and standard deviation*

## Discussion and conclusions

Our goal was to investigate which auditory method yields the smallest percentage error between the object's location and the chosen location. The data from our experiments did not reveal the most accurate method. However, we can conclude that in a situation similar to the simulation environment of Experiment 2, using IFR will result in a significantly lower percentage error than MVC.

The participants grew accustomed to our audio methods. We observed a decrease in the percentage error in the first experiment. If this were the only factor altering the error, we would expect the mean percentage error in Experiment 2 to be lower than in Experiment 1. Our data however shows the contrary. The mean distance error is statistically significantly higher in Experiment 2 than in Experiment 1. We think that it can be explained by the requirement to multitask in Experiment 2. This means that the participants had to divide their focus on determining the distance and the corresponding angle. We believe that the difference in sound intensity in the ears could make it harder for the participants to estimate the distance of the object.

## References


1 Bronkhorst, A. W., Veltman, J. H., & Van Breda, L. (1996). Application of a three-dimensional auditory display in a flight task. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 38*, 23–33.