DIY HRTF measurement using an iPhone

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I PREPARATION OF THE EQUIPMENT

In this setup you use an iPhone to collect all the necessary data. Fixed to the head, the movement of your head is monitored using the internal IMU of the smartphone, while the smartphone is also recording the stereo audio data provided by the in-ear microphones.

a. Stereo recording

In order to record in stereo on your iPhone, you need:

- A **pair of stereo in-ear microphones.** You can buy them off-the-shelve, but they are rather expensive. Therefore, we assembled our own binaural microphones. If you want to build them yourself at a low cost (10 euro), we have included a DIY manual on the website.
- A **USB sound card**. A standard smartphone can't record stereo. For this reason, you need an extra sound card, and we have opted for the Griffin Griffin iMic, which costs about 30 Euro's. Although they do not give any support for it, the iMic is compatible both with iPhone and Android. The iMic also has a powered input for a microphone, which is necessary in case of the condenser microphones that we use.
- An **USB OTG connector** from USB-C to either 30-pins (iPhone 4) or lightning connector (iPhone 5 and higher). In order to connect the USB sound card to the smartphone, you need a connector which allows to transfer data (camera adapter). You might already have such a connector at home, and if not, check whether you can borrow it from one of your friends. Make sure the cable allows data transfer, as some cables allow only charging your smartphone.
- An **app which allows to record in stereo**. We use the free Zoom Handy Recorder app.

Plug the binaural in-ear microphones jack in the Input of the iMic, choose Mic (and not Line in), and connect the iMic to the smartphone using the OTG cable. If you then start the app, you should be able to record audio form the in-ear microphones. Always make sure that the iMic is plugged in the iPhone BEFORE you start the app. Always check if it is recording in stereo and whether the timer is running.

b. IMU recording

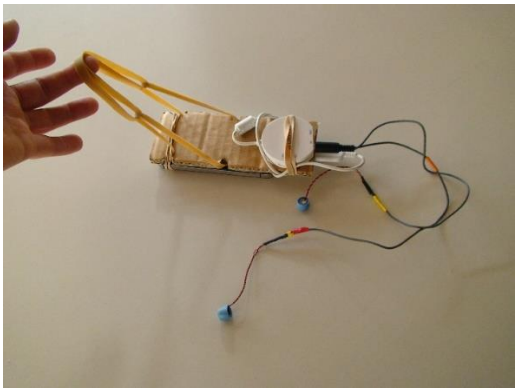
In this setup we use the internal IMU of the smartphone to collect data on the head orientation. So all you need to do is to install the Data Collection app (1 Euro). To

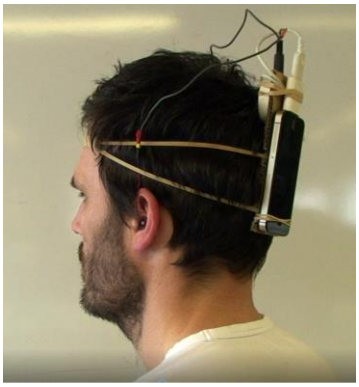
start recording the orientation data, first set the sample rate to 120 Hertz (which is the default), next press 'Go', and you will see that the app monitors the accelerometer, gyroscope and magnetometer. Start the actual recording by swiping the button in the right-corner to the right. The data should no longer be updated visually. Make sure that you do not minimize the screen, because then the app will stop monitoring. After the measurement, you stop the monitoring by swiping the button to the left. If the app asks if the collected data should be emailed, select No.

Before you start collecting data, make sure the smartphone is in flight-modus, all alarms are off, all apps are closed and that the screen does not switch off automatically (because this may stop one of the apps.)

c. Head mount

To fix the smartphone to the head, we use a simple piece of strong cardboard and four elastic straps, see the figures below. First, you cut the cardboard as shown in the drawing below. It should be able to accommodate the smartphone and the iMic. The indentations below are to fixate the elastic strap. Next, arrange the smartphone, the iMic and the four elastic straps, and fix it to your head. Make sure that the smartphone does not move when you move your head in all directions. The elastic straps should not be too tight, for you will have to wear the head mount for about 15 minutes ... Insert the in-ear microphones from top-down under the elastic strip, and insert them in your ears. Make sure they are sufficiently fixed, so they won't come out during the experiment. We also included a video which shows how to assemble the hardware and head mount and fix it to the head.





II PREPARATION OF THE ROOM

You need a single **loudspeaker** connected to a **sound system** to produce the stimulus signals. The loudspeaker shouldn't be too large (in fact: as small as possible), for in the measurement it is considered to be a point source. (Also, beware of loudspeakers with different speakers, as they may interfere and cause additional interference patterns. This is especially problematic if the speakers cover the same frequency range, as is sometimes the case in portable powered loudspeakers. The sound system is preferably an ordinary amplifier connected to a music player that can handle wav-

files: an mp3-player, your computer (preferably an Apple, we had sometimes problems with other pcs as they had lower quality sound cards) or a cd-player. The sound file to be played should be downloaded from our website. To make sure that only this one loudspeaker is used, it is advised to disconnect all other speakers.

The measurement can be carried out in an ordinary room in your house, which **should be silent**—no radio on, no friends chattering in the back. During the measurement, you are seated on a **swivel chair,** directly in front of a loudspeaker, as shown in the setup in Fig. The loudspeaker should be facing the swivel chair, at a distance of about 1.25-1.5m from the (rotation axis of the) chair, and it should be at approximately the same height as your ears. It is important that the swivel chair does not move during the measurement, except for rotations around its axis. You could also do it without swivel chair, just standing up straight and rotating on the spot, but in that case it is necessary to mark a cross on the floor, so that you do not move away from this center.
In order to be able to remove room reflections, you have to make sure that the room is free of objects: no reflecting walls, no garbage bins, etc., in the grey ellipsoid area shown in Fig. 1. The reason is that we only want to measure sound from the direct path and not from sounds reflecting on objects or walls. So the room should be at least (l, w, h) =(3m, 2.5m, 2.5m) in size, and as empty as possible in the area surrounding the action.

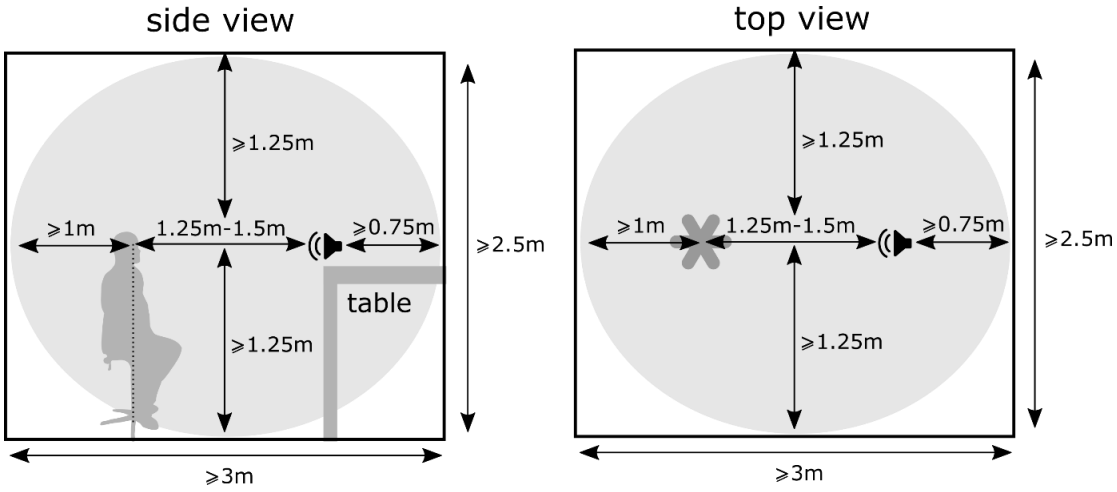


Figure: Room setup, top and side view. The grey ellipsoid volume should be free of reflecting objects/walls (except for the table, the loudspeaker and yourself).

III HEAD MOVEMENTS AND CHAIR ROTATION

You sample the different directions of your HRTF by moving your head with respect to the loudspeaker. Obviously, it is important that you sample the whole sphere surrounding you, but how to do that? The difficulty is that (at the moment) you don't get any feedback on which areas have been sufficiently sampled and which not. So, based on our experience so far, we have come up with some guidelines on how to move your head, such that if you follow these, you can be confident that your

personal sphere will be sampled sufficiently. How to move your head is shown in the video, included on your website.

To summarize: (1) make sure that that you keep your shoulders fixed to the chair; (2) scan the environment but don't move your head too fast; (3) make sure that you sample the sphere above and below, by pushing your neck to the limits, as an exception you can slightly move your shoulders if necessary and (4) rotate on the chair after every up/down movement. And just to be on the safe side: (5) don't fiddle with the microphones during the experiment, don't touch your ears and avoid making noises.

IV THE ACTUAL MEASUREMENT

The instructions on how to do the actual measurement are shown in the video in attachment. The different steps are listed below:

- Prepare the room, the equipment.
- Start the Zoom Handy Recorder app and start recording.
- Start the Data Collector app and start the recording (do not minimize the screen).
- Fix the smartphone to your head (without touching the screen, for it may stop the app). Put the microphone cables from top down underneath the head strap, so there is no strain on them during the head movements and insert the in-ear microphones in the entrance of the ear canal, as deep as possible. Make sure that they are sufficiently fixated; you don't want them to pop out during the experiment.
- Start the mp3 player, play the sound file and set the volume as loud as possible, without being uncomfortable (if you have a headache afterwards: it was too loud). After having set the volume, replay the sound file from the beginning.
- Hurry to the swivel chair and sit down, directly facing the loudspeaker.
- Start moving your head when you hear START.
- Move your head in the way described above for about 15 minutes. Make sure you sample the whole sphere. The instructor will count down from 15 to the end of the measurement.
- After you have heard 'END OF THE MEASUREMENT' you can switch off the mp3-player.
- Remove the in-ear microphones, take off the smartphone.
- Check if the Data Collector app is still monitoring. Stop the monitoring, don't email the data, and stop the app.
- Check if the Zoom Handy Recorder app is still recording. Stop the recording and stop the app.

V UPLOAD THE DATA

- Plug your smartphone in your computer (using the USB data connector cable) to download the collected data from your smartphone to your computer.
- You can access the data via iTunes,
    - select the iPhone icon,
    - select: Apps, if you scroll down, you'll see a list of apps that have stored data on your iPhone.
    - select: DataCollection, select the proper txt- file and extract it to a local directory.
    - select Zoom Handy Recorder, select the proper wav-file and extract it to the same local directory.
- Compress the two files into a zip-file. BEWARE: It is important that you do not move nor copy the two files before zipping, because otherwise important information on the time of creation of the files is lost, which is necessary to synchronize both the audio and IMU data when extracting the HRTF.
- Send the zip-file to us, e.g. using We-transfer.