# Heart Rate Training using Sonification

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Bachelor of Science Thesis
Stockholm, Sweden 2012

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DD143X, Bachelor's Thesis in Computer Science (15 ECTS credits)
Degree Progr. in Computer Science and Engineering 300 credits
Royal Institute of Technology year 2012
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URL: www.csc.kth.se/utbildning/kandidatexjobb/datateknik/2012/palsson_marten_OCH_sohlberg_henrik_K12054.pdf

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**Abstract**

Besides social activities such as sports and games exercise is becoming more and more important as a way of staying healthy with our increasingly more sedentary lifestyle. This has given rise to more and more products that help us with our training. One such product is the heart rate monitor. The heart rate monitor allows us to track our heart rate as we exercise and thus control the intensity of the workout and optimise its effectiveness. The subject of this report is to answer the questions: if heart rate monitors using sonified feedback rather than graphical interfaces is a better solution and if we can suggest a better sonification solution than the ones existing today. The conclusion is that it depends on what form of exercise each individual is performing and that sonified feedback is better in some instances. The sonification solution presented in this report is also found as superior to the solutions of other products found today.

**Statement of collaboration**

Background research was divided with Henrik covering heart rate training and Mårten covering sonification. Both cooperated in designing the algorithm for the application and later on implemening the application. Both designed the tests to be performed and Henrik researched existing solutions. The writing of the report was divided equally between the two as Henrik covered the sections on heart rate training and Mårten covered the sections on sonification. The introduction as well as the Approach was written together. The tests were performed together as much as possible and the results were summarized together as well.

Henrik took responsibility for the pictures and graphs included in the report and Mårten wrote the Results section of the report. The conclusion was then written together and afterwards Henrik finished of the finishing touches on the layout while Mårten wrote the abstract and statement of collaboration.

# Contents

# 1 Introduction

Daily, physical exercise is performed by humans around the world for different purposes. Some people are exercising to increase physical properties such as aerobic endurance, anaerobic threshold, others to burn calories and lose weight, and others only doing it as an activity without goals and objectives. If you are looking for a way to monitor, evaluate and improve your training - heart rate training may be an eligible activity to try out. Heart rate training refers to the use of a heart rate monitor during a workout, giving the performer information of his/her heart rate. This information can be used to control the intensity of your workout, monitor your development, and measure the amount of calories burned etc.

A popular form of running exercise is heart rate zone training. This refers to a runner trying to stay in a specific heart rate interval, e.g in a 60% - 75% (of maximum heart rate) interval, for a certain amount of time.

Classical heart rate monitors use a graphical display to inform the user of his or hers heart beats per minute in real time. This forces the user to continually check the monitor for updates on her heart rate in relation to the target zone. Modern heart rate training devices utilize sound in the form of signals or recorded voices to alert the user to her heart rate in relation to the target zone rather than a graphical interface.

Sonification is the practise of visualizing physical data with non-speech sound [1]. Human hearing can pick up more differentiated information than its sight. This is very practical when exercising since this means that the runner will not have to break his concentration to receive feedback from the device and can keep his eyes on the road [2].

The aim of this study is to answer the following questions: Can heart rate zone training be improved by using sonification to alert the user of her heart rate in relation to the target zone, rather than using a graphical display? Can we provide a better sonification solution than the ones existing today?

# 2 Background

## 2.1 Physical exercise

There are different goals to running exercise. Some of these could be to enhance endurance, remain healthy [3] or to prepare oneself to participate in a race [4]. There are numerous running exercise programs to be found in different forums, such as the Internet. Some of the programs states for how long a workout shall last, the level of the pace of a workout shall be and also how long a rest interval should be, e.g. run 20 minutes at an easy pace - walk (rest) 1 minute [5]. The main problem with most exercise programs is that they are not based on an individual's body shape and current fitness level. They are likely generic programs based on basic exercise physiology and thus not adapted to individual needs [3].

There are two ways of determining the intensity level a human body is working at which gives individuals the opportunity to adapt the intensity of their training to their physical fitness level. Two readings which indicates the intensity level is:

- the amount of oxygen consumed ($VO_2$)
- cardiovascular system

Measuring the oxygen uptake, $VO_2$, and comparing it to the greatest amount of oxygen a individual can consume indicates the level of intensity the body is working at (when $VO_2$ is at the same or very close to the the greatest amount of oxygen which can be consumed - the body is working at maximum intensity)[3]. To measure and monitor this value, special equipment is required which is usually not found outside a laboratory environment [6].

A simple way to measure how hard the cardiovascular system is working is by monitoring the heart rate. The cardiovascular system of a human is the organ system consisting of the heart, the blood and the blood vessels. Its task, in short terms, is to transport nutrients, wastes and gases to and from cells [7]. During exercise, the heart rate increases as a result of the cells increasing need for oxygen and other substances [8]. Heart rate monitors is a cheaper and easier alternative for a runner to analyze the intensity of her exercise, compared to $VO_2$ readings.

## 2.2 Heart rate training

Benson and Connolly divide the physical fitness into four components (figure 1) - endurance, stamina, economy, and speed. These are developed in phases at different intensity which can be determined using the maximum heart rate as a measuring instrument. Exercising above or below the intensity range while training a specific component, e.g endurance, may result in an increased risk of injury, premature peaking or staleness from overtraining [3]. The different components are:

- *Endurance* - is the ability to go from point A to point B no matter how much a runner needs to slow down.
- *Stamina* - is the ability to go from point A to point B without slowing down.
- *Economy* - is the ability to go at race pace while using the least amount of oxygen and energy.
- *Speed* - is the ability to go to top speeds for short periods of time and stay relaxed while tolerating increasing levels of lactic acid in the muscle tissue.

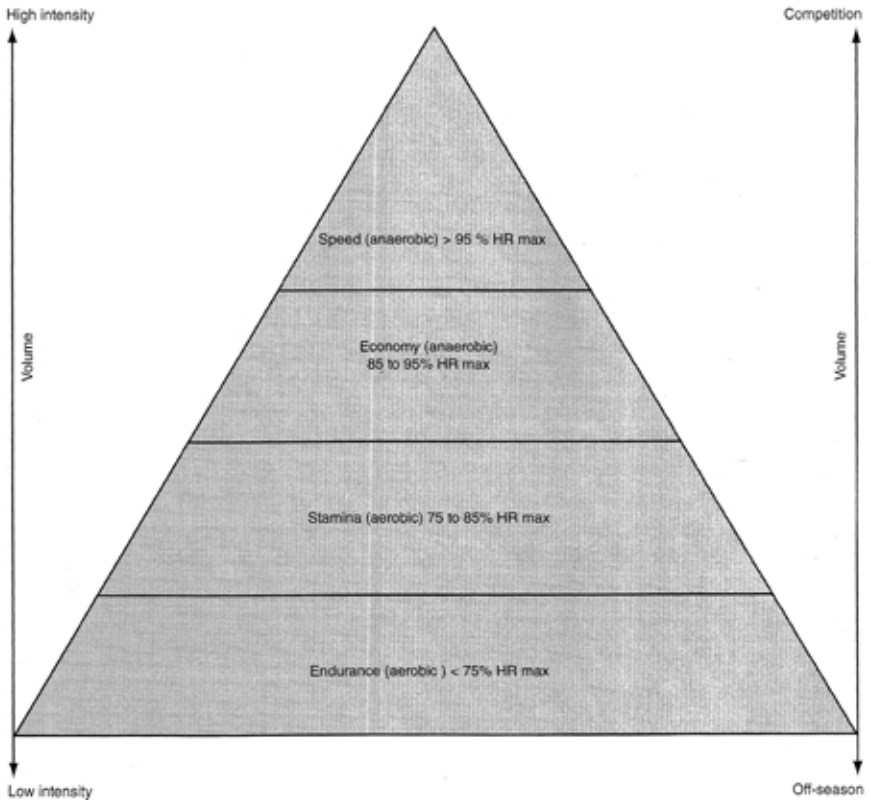


Figure 1: Basic model for training [3]

## 2.3 Existing heart rate training devices

The products presented below were chosen because they are all compatible with the Garmin Ant+ heart rate sensor. The Garmin Ant+ and the Zephyr HxM were the heart rate monitors available for this study, but no heart rate training applications were found that were compatible with the Zephyr HxM.

### 2.3.1 iRunner

iRunner version 5.31 [9] is an application for iPhone (requires iOS 4.3 or later) by iTMP Technology, INc. The full version of the application, which costs 1.99 $ (2012-04-12), includes features such as compatibility with Ant+ devices [10]. The user can set up several customized heart rate zones. Customized workouts can also be created, including intervals with heart rate zones and time length. The feedback during a heart rate zone workout is a male or female voice, alerting the user, only once, when she enters a new zone (below, in, or above target zone). The application logs the results from a workout, presenting it to the user with tables, graphs and statistics.

### 2.3.2 Garmin Fit

Garmin Fit version 1.1 [11] is an application by Garmin, available for the Android and the iOS platform. It costs 0.99 $ (2012-04-12, AppStore[12]). It is compatible with Ant+ devices, allowing the user to e.g. connect a heart rate sensor. The application records data, such as average heart rate beats per minute, during a workout. There are no capabilities concerning creating customized workouts of specific intervals with heart rate zones. There are no features such as sonification or voice feedback to alert the user when exercise in a certain heart rate zone.

### 2.3.3 Garmin ForeRunner 410

Garmin ForeRunner 410 [13] is a sports watch compatible with Ant+ devices. Suggested retail price is 229.99 £. The device offers the possibility to create customized heart rate zones, as well as customized workouts of specific intervals with heart rate zones and time length. During a heart rate zone workout, e.g. run 20 minutes in a 75%-85% of MHR zone, the device alerts the user with sounds signals. If the user is below the target zone, a specific sound is played every 11th seconds as longs as the user stays below the target zone. The same design is applied when the user is above the target zone, but using a different sound. When the user enters the target zone, a distinct sound is played once. When staying in the target zone, no alert will occur until the user strays below or above the target zone.

## 2.4 Sonification

### 2.4.1 What is sonification

Sonification is the practice of visualizing data with the use of non speech sound. To be more precise, sonification is the transformation of raw data into audio streams to facilitate interpretation or communication [1].

J.Keller defined in 2003 that sonification can be used in three different ways [14]:

- **Iconic sonification** - this type of sonification is when data is mapped to a sound that represents a certain phenomena. If, for example, someone were to gather weather data such as air humidity and air pressure to calculate the weather, using the sound of rain would be an iconic sonification of the risk of rain. So basically iconic sonification is using the iconic sound of a phenomena to represent it.
- **Direct conversion sonification** - This form of sonification is converting raw data directly into sound to be able to listen for patterns or changes in the data. For example, space scientists map electromagnetic waves directly into sound waves. This can be done as simply as creating sound waves with frequencies matching the frequencies of the electromagnetic waves. This is of course only viable if the waves are of such frequencies that we can hear them. Earth's whistler wave is an electromagnetic wave that space scientists have been sonifying for 30 years.
- **Musical sonification** - Is the practise of mapping data to sound in a musical way. For example, Keller had created a program that converted data on superfast particles that came from the sun and were picked up by either of the two Helios satellites (Helios 1 and Helios 2) to bell like sounds. Musical sonification of space data have been used to create quartets or orchestra music pieces.

### 2.4.2 What is sonification used for

The first use of sonification as we understand it today was by Pollack and Ficks. They wrote a paper on the use of auditory variables to convey large amounts of information in 1954 [15]. They experimented with combining different sound dimensions such as frequency and timing and discovered that they could get test subjects to notice changes in multiple dimensions at once [16].

Today instruments that use sonification is a part of everyday life even if people may not realise it. One of the most common ones are the proximity detectors found in modern cars used as parking and reversing aids [17]. These exist in various forms but the most common one measures the distance to an obstacle in relation to the car and alerts the driver with a series of increasingly frequent signals. Another well known application of sonification is in geiger counters, devices that are used to detect radiation. They utilize an ionization chamber to catch radiation particles and emit a "click" for every caught particle [18]. This produces an iconic sound that, when a lot of particles are caught in a short span of time, sound almost like radio static. Other studies into the use of sonification includes studies in sonifying physical data in athletics to help athletes optimise their performance and training [2]. Sonification is also finding a place in the field of computer science. One such example is a project where they are investigating whether sonification can be used to enhance program comprehension. The program code is sonified into distinct patterns depending on the function of segments of code. This helps programmers find segments of code that perform the same tasks but use different syntax, thus making it easier to understand programs and syntax they are not familiar with [19].

# 3 Approach

## 3.1 Subjects

The test subjects were four adults in the age range of 22 - 24 years old, one female and three male. All exercise regularly but are in various states of physical fitness. All the subjects were physically healthy at the time of the tests. Before the tests each subject were queried upon their well being and earlier experience using heart rate monitors.

**Subject 1:** Male, 24 years old. No experience with HR monitors.
**Subject 2:** Male, 23 years old. Limited experience with HR monitors.
**Subject 3:** Male, 24 years old. No experience with HR monitors.
**Subject 4:** Female, 22 years old. No experience with HR monitors.

For more information on the subjects, see Appendix A.

## 3.2 Test design

The tests took place between the 30 march 2012 and 10th April 2012. The tests were comprised of three 20 min runs at 75-85% of maximum heart rate by each of the test subjects using a different heart rate monitor device each time.

The three different heart rate monitor devices used were; the Android application we had designed ourselves, iRunner from App store and one using the graphical interface of the Garmin FR 410 HRM. The sonified alert capabilites of the Garmin FR 410 were disabled during the tests. The reason to this was that we wanted to evaluate the use only of the graphical interface. The reason for not evaluatingthe sonfied feedback of the Garmin FR 410 is that it is very similar to feedback found in iRunner. See section 2.3 for information on iRunner and the Garmin FR 410 HRM.

Each of the test subjects tried the different heart rate monitors in different order to compensate for the fact that you learn which pace you have to keep to stay in the target heart rate zone. During the tests, the heart rate of the test subjects were recorded into a graph for every run and analyzed to discover how well the subject had stayed in the target zone with the different devices. The tests were preceded and followed by a questionnaire.

## 3.3 Application design

The application was designed for the Android platform using a Zephyr HxM bluetooth heart rate monitor. The HxM monitor was chosen since it works well with and provides an easy to use API for Android.

The application is designed to retrieve the heart rate from the HxM bluetooth device and alert the user every ten seconds to where her heart rate is in relation to the target zone. In our algorithm design we have three zones; below target zone, target zone and above target zone. We also have five distinct states as shown in figure 2:

This is to give the user continuous feedback and allow her to adjust her pace as she goes without actually having to exit the target zone to realise she is starting to running too quickly or too slowly. Whenever the user changes zone she will be alerted with the appropriate sound. The application will however never play a sound more frequently than every five seconds. If the user spends more than 30 seconds outside the target zone, alerts will be sent with a five second interval instead of ten seconds.

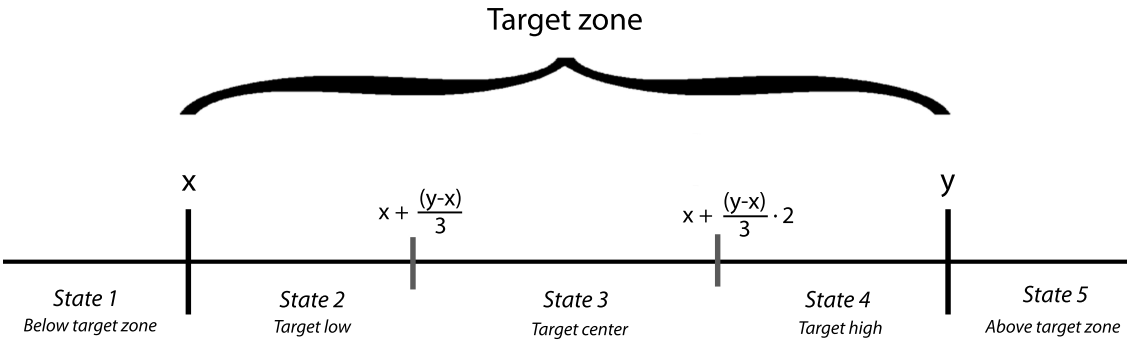


Figure 2: Zone design

### 3.3.1 Pseudo code

This is the pseudo code for the algorithm used to handle the sonification (which sound should be played when):

```
/*** PER RUN ***/
previousState = the zone we were in at the last time we played a sound
currentState = the zone we are in at the time of the check
timePassed = the time since we last played any sound

onHeartRateChange(heartRate)
if timePassed < 5 seconds then
   return
end if
if currentState == previousState then
   fromSameStateToSameState(heartRate, currentState)
else
   fromOneStateToAnotherState(heartRate, currentState)
end if
previousState ← currentState
return

/** Each time a playSound function is called, the timePassed variable is updated */

fromSameStateToSameState(heartRate, currentState)
if currentState ≠ targetState then
   if time spent in wrong zone > 30 seconds then
      playSound(currentState)
   else if timePassed > 10 then
      playSound(currentState)
   end if
```

```
else
  if timePassed > 10 then
    playTargetSound(heartRate)
  end if
end if

fromOneStateToAontherState(heartRate, currentState)
if currentState ≠ targetState then
  playSound(currentState)
else
  playTargetSound(heartRate)
end if

playTargetSound(heartRate)
if heartRate is in the lower third of targetZone then
  playTargetLowSound
else if heartRate is in the upper third of targetZone then
  playTargetHighSound
else
  playTargetCenterSound
end if
```

## 3.4 Sonification design

The sonification is designed using five distinct sounds for the five different states. When the users heart rate is too high or too low a sound with three beeps will be played. When the heart rate is too low the beeps will go from a higher to a lower pitch with each beep, signaling the user that she is currently having a lower heart rate. Appropriately the three beeps will go from a lower to a higher pitch when the users heart rate is higher than the target zone. When in the target zone only a single beep will be played ranging from a low pitch for the lower target zone to a high pitch for the upper target zone so the user gets feedback on where she is located in the target zone. This is to let the user know when she approaches the edge of the target zone so she can adjust her pace accordingly.

# 4 Results

All results are derived from the tables, graphs and questionnaires found in Appendix A.

## 4.1 Raw data

### 4.1.1 Staying in target zone

Two out of four of the test subjects performed better for every test and spent an increasingly longer period of time in the target zone. One performed similar the whole time and one performed with varying results every time. Out of the three products the Garmin FR 410 and our Android Application were tied in first place, both having two test subjects performing best with them.

### 4.1.2 Garmin FR 410

Three out of four of the test subjects never went over the target zone during the whole test session. The same three never went under either except one of them who once came under for a few seconds.

All of the test subjects kept their lowest average heart beat rate with the Garmin FR 410 but this did not noticeably affect the distance they covered during the test.

### 4.1.3 iRunner

None of the test subjects went below the target zone after reaching it the first time. However all of the test subjects went over the target zone several times except for one who only went above once. Three out of four of the test subjects spent the highest amount of time above the target zone using iRunner compared to the other products.

Three out of four also kept their highest average heart beat rate but did not run noticeably further during their test run for that.

### 4.1.4 Our Android application

Except one, none of the test subjects went below the target zone after reaching it the first time. When it comes to not straying above the target zone the Android application never performed better than the Garmin FR 410, but better than iRunner in all but one case.

Two of test subjects kept their median average heart rate when using the Android application but covered the longest distance out of their three test runs. One test subject kept his highest average heart rate but covered the shortest distance and one kept his median average heart rate and covered the shortest distance out of their three test runs.

## 4.2 Summary of the questionnaire

### 4.2.1 Garmin FR 410

All of the subjects answered that since they could get feedback whenever they wanted to by just looking at the watch staying in the target zone was easy. The test subjects all had to check the watch frequently to get enough feedback to stay in the target

zone. This irritated them all to some degree but only one answered that it actually distracted her attention from her running.

### 4.2.2 iRunner

Three out of four of the test subjects found it easy to stay in the target zone while one answered that it was easy after she had found her pace. All of the test subjects found the lack of continuous feedback irritating and three out of four test subjects forgot in which zone they were in one or more times because of it.

All of the test subjects answered differently concerning how much attention they put on the zone feedback.

### 4.2.3 Our Android application

All of the test subjects found it easy to stay in the target zone. Three of them appreciated the continuous feedback while in the target zone since it allowed them to adjust their speed to stay in the target zone. All of the test subjects agreed that it was hard to hear the difference between the target center and target high sounds. One also thought that it was difficult to hear the difference between the below target zone and above target zone sounds but all agreed that after the initial learning curve the sonification became more intuitive and they could concentrate more on the running.

### 4.2.4 Final question

Three of the test subjects preferred the Garmin FR 410 for this particular workout since it gave them on demand and precise feedback. However one of them answered that he would have chosen the Android application if the sonification had been a bit more polished. Another one answered that if the test had not been on a flat running track devoid of distractions he would have chosen the Android app since it allows him to keep his eyes on where he is going. The last test subject answered that she prefered the Android application but that it needs a bit more polishing.

# 5 Conclusions

Graphical heart rate monitors such as the Garmin FR 410 provide on-demand feedback during exercise. All the heart rate training devices, that we know of that, that give feedback with sound rather than showing it graphically only provide feedback when a new zone is entered and not when one stays in the target zone. Since constant feedback facilitates staying in the target zone and sound can convey information without the recipient having to break their concentration on whatever they are doing, we designed our sonification with this in mind.

If one looks to the raw data both the Garmin FR 410 (using a graphical interface) and our Android application perform equally well. According to the final question though, asking which product they preferred, three out of four answered that they would choose the Garmin FR 410. Interestingly, one test subject whose worst performance was with our application also chose it as her favored product since she prefered the sonified feedback to having to check the watch constantly. However this person performed better with each test and tested our application first - which could be an explanation to her bad results.

According to one subject, if the sonification was reworked, he would have chosen our application over the Garmin FR 410. As it was, the sonification was a bit unclear and that was what made him prefer the Garmin FR 410, since its feedback was as clear as it can be. Another subject said that if there had been more distractions (e.g. terrain) during the test he would have prefered our application since it allowed him to keep his attention on what he was doing.

Since the graphical interface of the Garmin FR 410 provides real time feedback with precise data it was the prefered choice for this workout. This workout however was on a flat and smooth running track devoid of any distractions or obstacles. This provides the Garmin FR 410 with its optimal environment where nothing distracts the user from checking their heart rate whenever they want. If however the exercise was to be performed in, for example, more rugged terrain or in an environment with more distractions, sonified input would be preferable since it does not distract from the running. While iRunner provided very clear feedback our application was still prefered since it provided continuous feedback. It provided them with feedback on how quickly or slowly they were running even while in the target zone. This allowed them to adjust their pace to stay in the target zone. Even though it did not always provide better results, it gave the runners information on how they were performing which the testers found useful and pleasant.

All of our results and conclusions are limited by the amount of time and resources at our disposal. The test has been made with few test subjects and is very one-sided.

Finally, we can say that if exercising on a flat, dry track with no distractions, a graphical heart rate monitor is still the best choice. If, however, you are in a situation where you need to put more attention on your running, sonified feedback is preferable.

If our sonification was reworked, if the signals were made more differentiated - our sonification solution would be better as a heart rate training tool than currently (to our knowledge) existing solutions. We base this conclusion on the fact that our test subjects prefered the constant feedback from our application over the feedback design of iRunner.

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# A Appendix

**The Appendix**
This appendix contains all the data gathered from our tests as well as information on our test subjects. It contains tables containing specific information about each test, graphs depicting the heart beat rate throughout the tests and the original answers to the questionnaire for each test.

**About the tests**
The subjects did a 20 minutes running performance on a running track (400 m), three times using a different product at each test. The objective of each test was to exercise in the heart rate zone 75% to 85% (which is referred to as the target zone) while using the product as a tool to achieve this. The subject answered questions before and after each test (see Questions).

**The results**
The results are represented in three sections: statistics, graphs and questionnaires. Statistics are calculated for the total distance covered and the percentage of time spent in, below, and above target zone. The percentages are drawn from the log functions found in their respective apps except in the case of the Garmin FR 410 which was used in conjunction with iRunner to get the results. The graphs were generated by iRunner for the iRunner and Garmin tests and by using Google Documents spreadsheets and the results from the log function for the Android application.

# Subject 1

## *Information*

Age: 23

Gender: Male

Maximum heart rate (MHR): **197 bpm**

75% of MHR: **147 bpm**

85% of MHR: **167 bpm**

# *Statistics*

| **Test number:** | **1** | **2** | **3** |
|---|---|---|---|
| **Product:** | Garmin FR 410 | iRunner iOS application | Our Android application with Zephyr HxM |
| **Weather:** | 4 °C, cloudy | 7 °C, cloudy | 5 °C, rain |
| **Date:** | 4/4 2012, 19.10 | 9/4 2012, 12.10 | 10/4 2012, 12.10 |
| **Total distance:** | ~4200 m | ~4200 m | ~4600 m |
| **In target zone (percentage):** | 94% | 93% | 93% |
| **Below target zone:** | 6% | 5% | 7% |
| **Above target zone:** | 0% | 1% | 0% |
| **Average BPM:** | 151 | 159 | 155 |

Table A.1

# *Graphs*

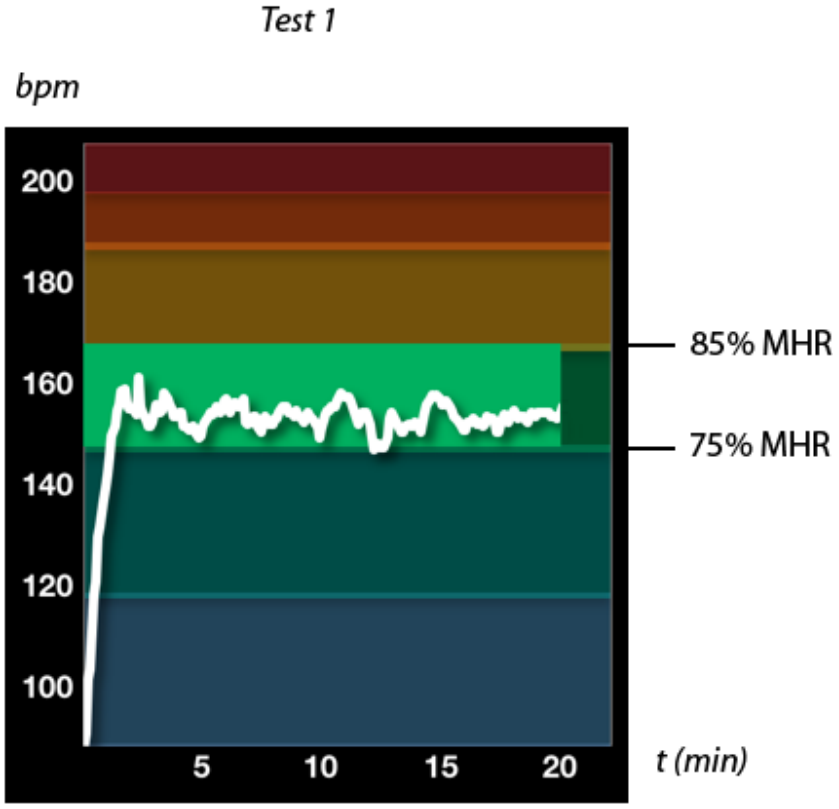


Figure A.1.1

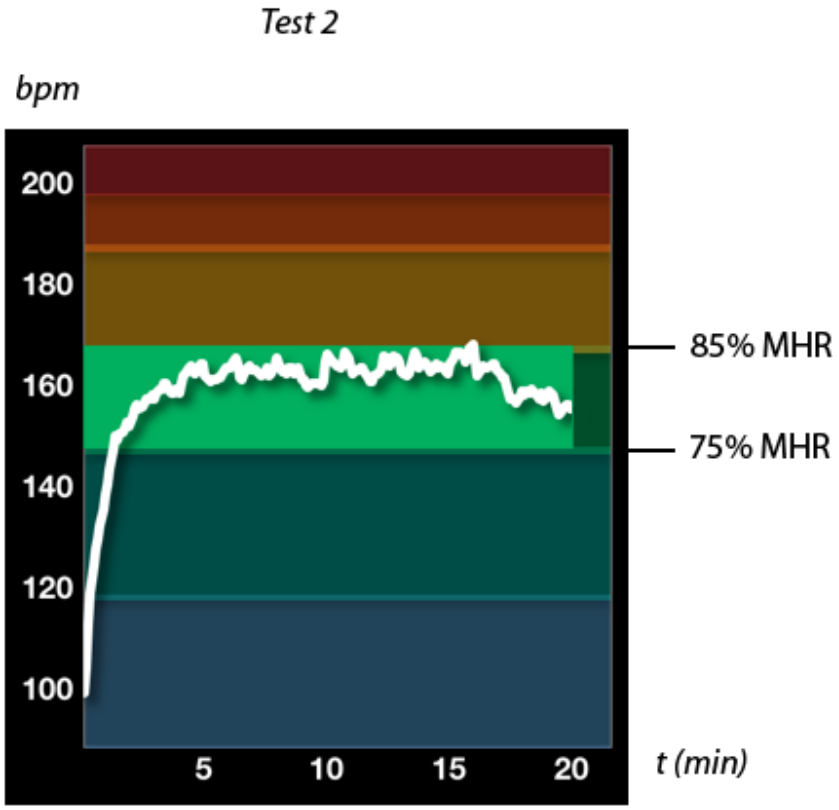


Figure A.1.2

*Test 3*

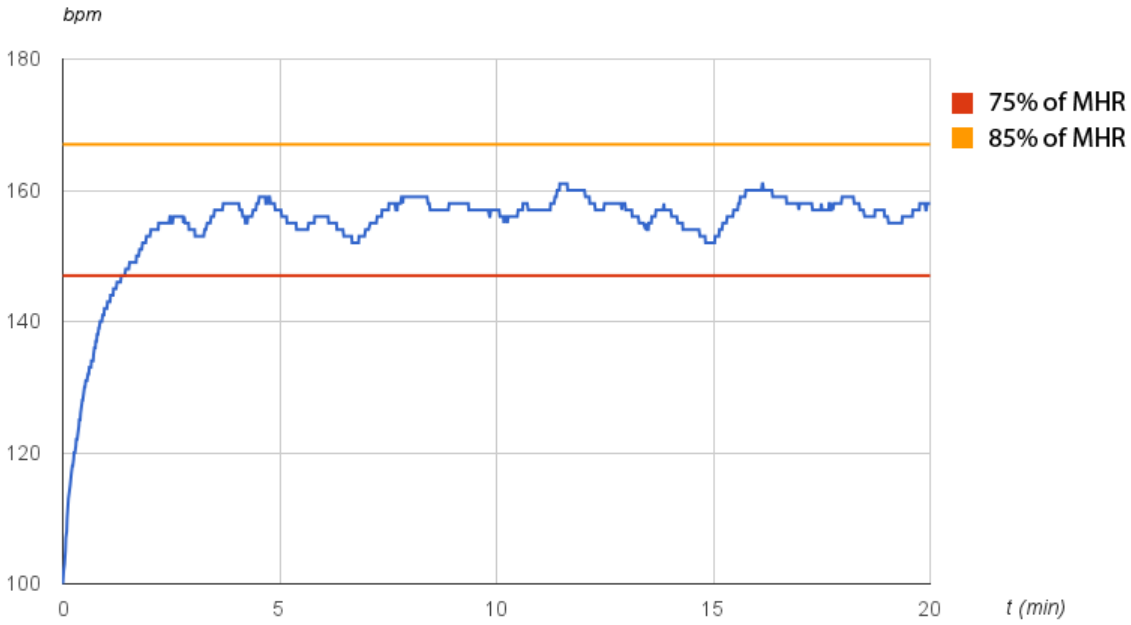


Figure A.1.3

# *Questionnaires*

## Test 1

## Before the test

1. How do you feel today? (On a scale 1-5, where 1 is very tired and 5 is fully rested)
A: 3
2. Earlier experience of using heart rate monitor?
A: None.

### After the test

2. How tough was it? (on a scale 1-10 where 10 is extremely hard)
A: 6

3. Free description, how (easy, difficult) was it to stay put/train in the target zone?
Easy, might get irritating after a while that you have to keep checking the watch but it depends on what kind of running you are doing.

5. How much attention did you put on the “zone-feedback”? (on a scale 1-5, where 1 is “didn’t think of it at all”)
A: 3, didn’t really have to think about it that much but I had to check the watch frequently so that I stayed in the target zone.

---

## Test 2

## Before the test

1. How do you feel today? (On a scale 1-5, where 1 is very tired and 5 is fully rested)
A: 4

### After the test

2. How tough was it? (on a scale 1-10 where 10 is extremely hard)
A: 6

3. Free description, how (easy, difficult) was it to stay put/train in the target zone?
A: Easy, the feedback was clear and easy to understand.

4. How did you experience the “zone-feedback”?

A: Since it only alerts you when you enter a zone and never else you sometimes forget where you are, this is irritating.

5. How much attention did you put on the “zone-feedback”? (on a scale 1-5, where 1 is “didn’t think of it at all”)
A: 3

6. Would this product help you with heart rate training? Why/why not?
A:Yes, it would make it easier to stay in the right heart rate zone when running.

---

# Test 3

# Before the test

1. How do you feel today? (On a scale 1-5, where 1 is very tired and 5 is fully rested)
A:4

2. How tough was it? (on a scale 1-10 where 10 is extremely hard)
A: 6

3. Free description, how (easy, difficult) was it to stay put/train in the target zone?
A: Easy, I could “parry” before my heart rate went outside the target zone.

4. How did you experience the “zone-feedback”?
A: Clear except for target center and target high.

5. How much attention did you put on the “zone-feedback”? (on a scale 1-5, where 1 is “didn’t think of it at all”)
A: 3, got used to it after a while then I didn’t think about it so much. Mostly because the target high and target center sounds were so similar.

6. Would this product help you with heart rate training? Why/why not?
A: YesBefore the test

7. Do you see potential in this product? Why/why not?
A: Yes

Final question: Which product did you prefer for this specific workout session?
A: The Garmin watch or your app. Probably the Garmin watch since it gives me complete constant one-the-second feedback of my heart rate.

# Subject 2

## *Information*

Age: 23
Gender: Male
Maximum heart rate (MHR): **177 bpm**
75% of MHR: **132 bpm**
85% of MHR: **150 bpm**

# *Statistics*

| **Test number:** | **1** | **2** | **3** |
|---|---|---|---|
| **Product:** | iRunner iOS application | Garmin FR 410 | Our Android application with Zephyr HxM |
| **Date:** | 30/3 2012, 12.15 | 3/4 2012, 18.00 | 5/4 2012, 12.00 |
| **Weather:** | 6 °C, sunny | 4 °C, cloudy | 4 °C, cloudy |
| **Total distance:** | ~3300 m | ~3300 m | ~3400 m |
| **In target zone (percentage):** | 90% | 95% | 96% |
| **Below target zone:** | 2% | 5% | 3% |
| **Above target zone:** | 8% | 0% | 1% |
| **Average BPM:** | 145 | 139 | 142 |

Table A.2

# *Graphs*

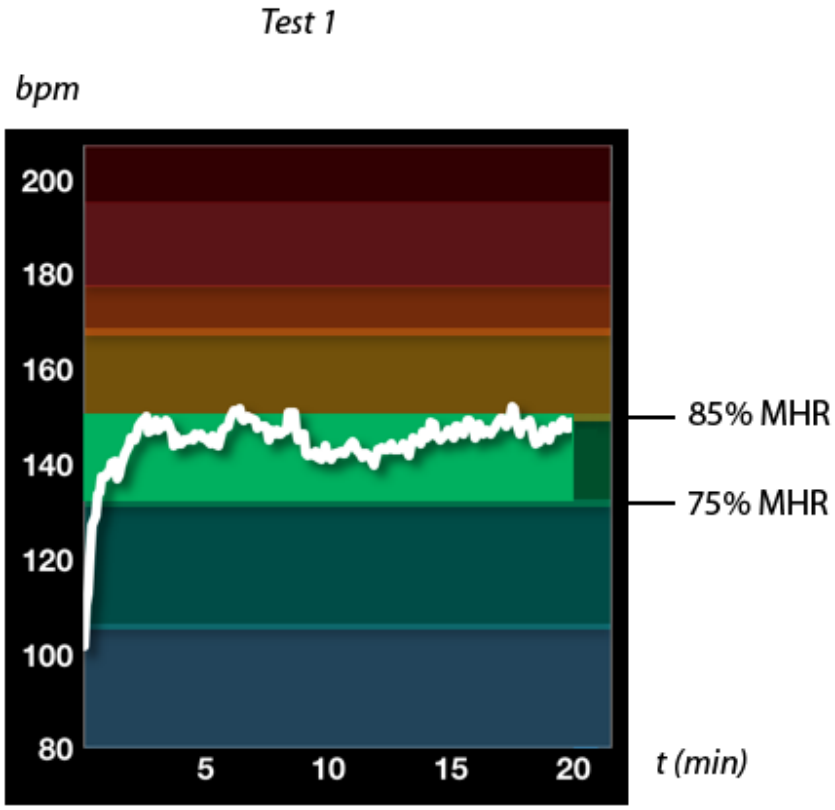


Figure A.2.1

*Test 2*

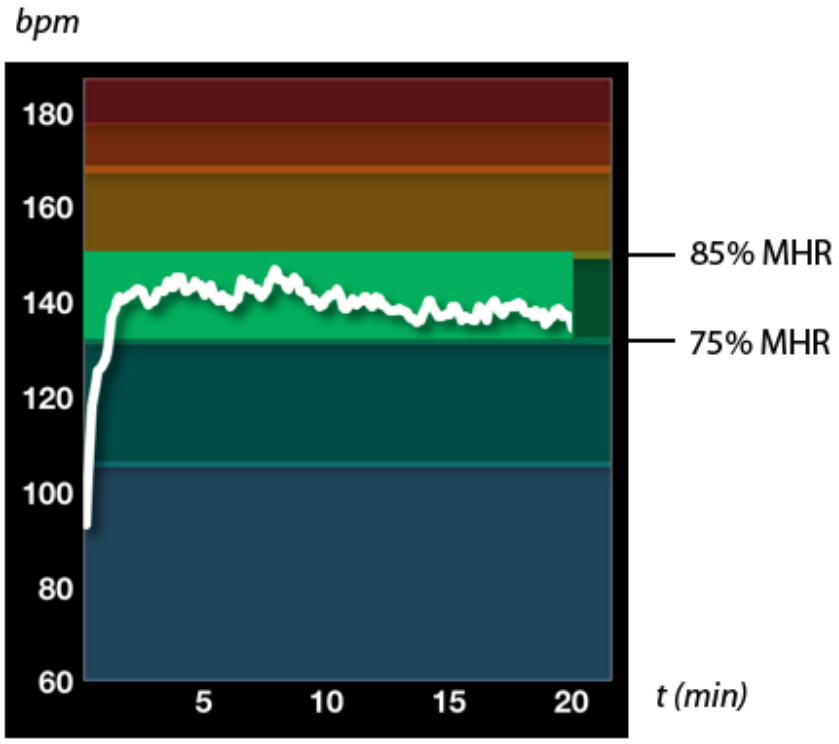


Figure A.2.2

*Test 3*

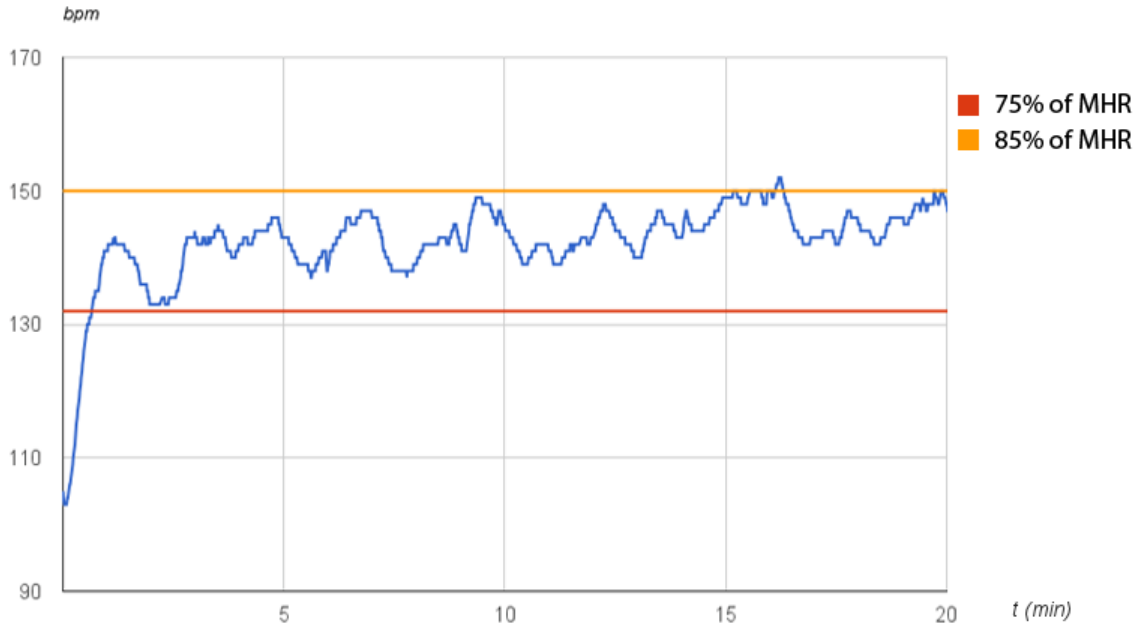


Figure A.2.3

# *Questionnaires*

## Test 1

## Before the test

1. How do you feel today? (On a scale 1-5, where 1 is very tired and 5 is fully rested)
A: 4
2. Earlier experience of using heart rate monitor?
A: Some

### After the test

2. How tough was it? (on a scale 1-10 where 10 is extremely hard)
A: 5

3. Free description, how (easy, difficult) was it to stay put/train in the target zone?
A: It was pretty easy

4. How did you experience the “zone-feedback”?
A: It was easy to understand the feedback. I didn’t like the lack of continuous feedback, at at least one occasion I forgot in which zone I was in.

5. How much attention did you put on the “zone-feedback”? (on a scale 1-5, where 1 is “didn’t think of it at all”)
A: 4. All the time I had my attention on upcoming feedback.

6. Would this product help you with heart rate training? Why/why not?
A: Yes, the product fulfills its purpose informing me about heart rate zones.

---

# Test 2

# Before the test

1. How do you feel today? (On a scale 1-5, where 1 is very tired and 5 is fully rested)
A: 4

## After the test

2. How tough was it? (on a scale 1-10 where 10 is extremely hard)
A: 4

3. Free description, how (easy, difficult) was it to stay put/train in the target zone?
A: Very easy I would say. Each time I was unsure about my heart rate I looked at the watch and received the feedback I wanted. The hard part was to remember the zone boundaries, which was not too hard.

4. How much attention did you put on the “zone-feedback”? (on a scale 1-5, where 1 is “didn’t think of it at all”)
A: 3. I looked at the watch several times but in between I could put my focus on the running.

---

# Test 3

# Before the test

1. How do you feel today? (On a scale 1-5, where 1 is very tired and 5 is fully rested)
A: 3

## After the test

2. How tough was it? (on a scale 1-10 where 10 is extremely hard)

A: 6

3. Free description, how (easy, difficult) was it to stay put/train in the target zone?
A: It was easy to control the pace thanks to the constant feedback given while I was in the target zone. That made it easy to stay put in the zone since I got early indications if I was increasing or decreasing my heart rate.

4. How did you experience the “zone-feedback”?
A: It was difficult to separate the “target center” from the “target high” sound. Other than that it the zone feedback was useful.

5. How much attention did you put on the “zone-feedback”? (on a scale 1-5, where 1 is “didn’t think of it at all”)
A: At the beginning, a 4. I was paying attention to what sound I just heard and I had to think about what it meant. But by the time, when the zone feedback became more and more familiar and therefore intuitive, I could concentrate more and more on the running.

6. Would this product help you with heart rate training? Why/why not?
A: Yes it would. It gave me control on how to adjust my pace according to the heart rate workout.

7. Do you see potential in this product? Why/why not?
A: Yes, since the amount of control it gave me, compared to the iRunner application for example, was greater. Though hard to say if I really need that control.

Final question: Which product did you prefer for this specific workout session?
A: For this particular workout I would prefer your Android application to the iRunner application as the continuous feedback helped me adjust the pace before getting above or below target zone. But at the end I would prefer the Garmin FR 410, since I had total control over the flow of the feedback and it gave me the most precise feedback (on the number) compared to the others. If the target center + target high sounds would have been more differentiated I would have chosen the Android application.

# Subject 3

## *Information*

Age: 23

Gender: Male

Maximum heart rate (MHR): **188 bpm**

75% of MHR: **141 bpm**

85% of MHR: **159 bpm**

# *Statistics*

| **Test number:** | **1** | **2** | **3** |
|---|---|---|---|
| **Product:** | Our Android application with Zephyr HxM | iRunner iOS application | Garmin FR 410 |
| **Date:** | 30/3 2012, 12.15 | 4/4 2012, 11.30 | 5/4 2012, 11.30 |
| **Weather:** | 6 °C, sunny | 6 °C, cloudy | 4 °C, cloudy |
| **Total distance:** | ~2900 m | ~2900 m | ~3000 m |
| **In target zone (percentage):** | 94% | 91% | 92% |
| **Below target zone:** | 2% | 4% | 5% |
| **Above target zone:** | 4% | 5% | 3% |
| **Average BPM:** | 154 | 152 | 151 |

Table A.3

# *Graphs*

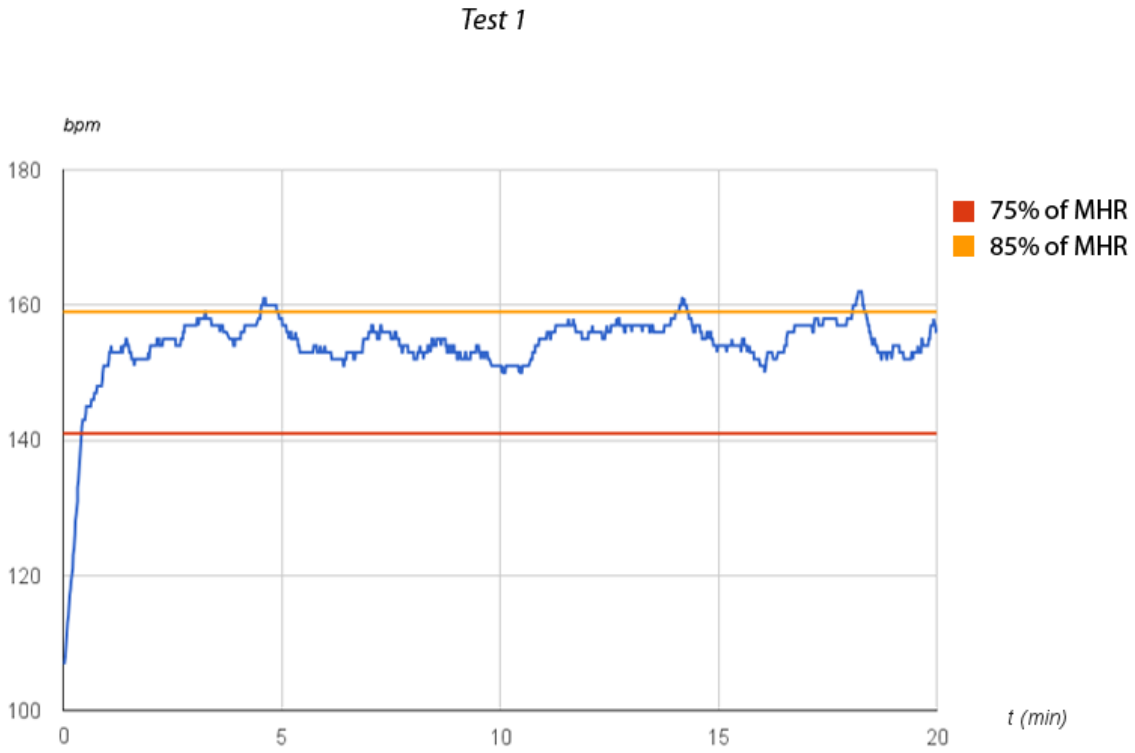


Figure A.3.1

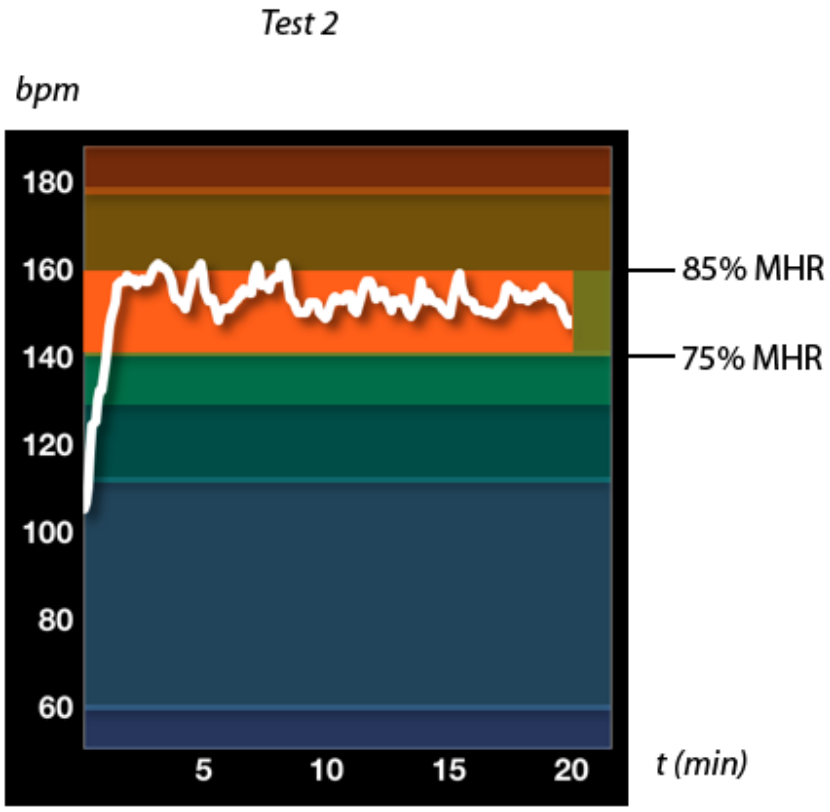


Figure A.3.2

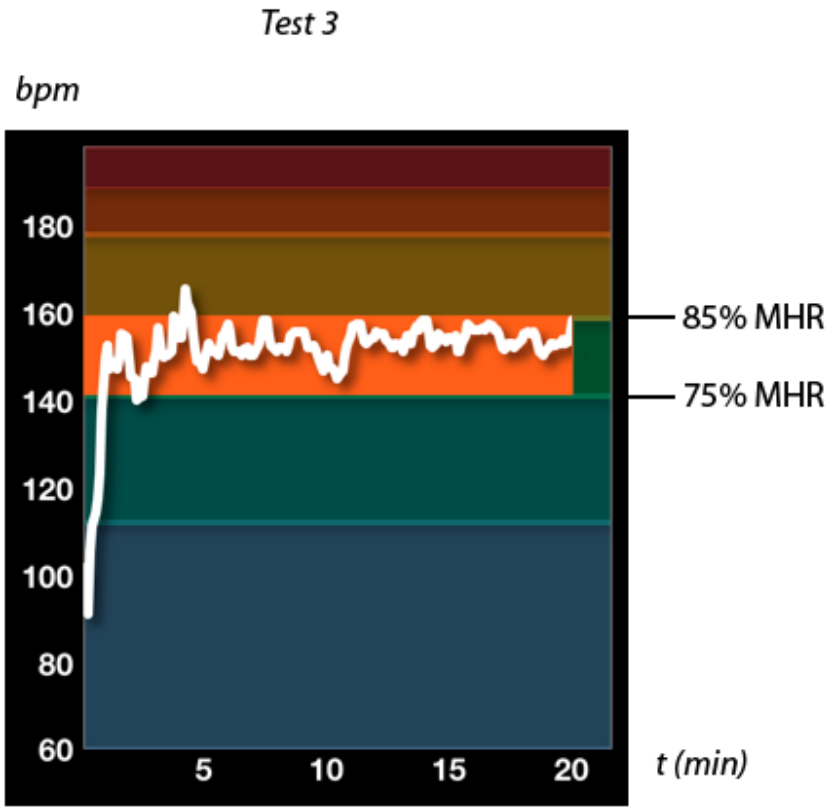


Figure A.3.3

# *Questionnaires*

## Test 1

### Before the test

1. How do you feel today? (On a scale 1-5, where 1 is very tired and 5 is fully rested)
A: 4
2. Earlier experience of using heart rate monitor?
A: none

### After the test

2. How tough was it? (on a scale 1-10 where 10 is extremely hard)
A: 6

3. Free description, how (easy, difficult) was it to stay put/train in the target zone?
A: Very easy, I got good feedback from the app. The division of the target zone helped me modify my pace when I was started running too slowly or too quickly.

4. How did you experience the “zone-feedback”?
A: It was hard to hear the difference between the target center and target high sound during the first 2 minutes, but then I got used to it.

5. How much attention did you put on the “zone-feedback”? (on a scale 1-5, where 1 is “didn’t think of it at all”)
A: 4, I concentrated a lot on the feedback but that was partly because I knew this was a test and I really tried hard to stay in the target zone. After a while I got used to it and stopped thinking about it so much.

6. Would this product help you with heart rate training? Why/why not?
A: Yes it would, I’ve never used heart rate monitors before but it could help me find the pace I should be running at and thus make my training more effective.

7. Do you see potential in this product? Why/why not?
A: Yes, it gives good and constant feedback which is good for helping beginners find their pace. It requires a bit of polishing however.

---

# Test 2

# Before the test

1. How do you feel today? (On a scale 1-5, where 1 is very tired and 5 is fully rested)
A: 4

## After the test

2. How tough was it? (on a scale 1-10 where 10 is extremely hard)
A: 5

3. Free description, how (easy, difficult) was it to stay put/train in the target zone?
A: When I found my pace it was easy. Comparison: It was harder to find my pace than with the first app. It was hard to gauge where you were since you got no continuous feedback, forgot if I was in the target zone or not a few times.

4. How did you experience the “zone-feedback”?
A: Very clear when it was there. Irritating that I got no continuous feedback while I was in the target zone.

5. How much attention did you put on the “zone-feedback”? (on a scale 1-5, where 1 is “didn’t think of it at all”)
A: 2, but I had to put a lot of attention on my running since I didn’t get any feedback on how I was doing when I was actually in the target zone.

6. Would this product help you with heart rate training? Why/why not?
A: Yes, because it helps me stay in the right pulse zone.

---

# Test 3

# Before the test

1. How do you feel today? (On a scale 1-5, where 1 is very tired and 5 is fully rested)
A: 3

## After the test

2. How tough was it? (on a scale 1-10 where 10 is extremely hard)
A: 5

3. Free description, how (easy, difficult) was it to stay put/train in the target zone?
A: Easy, because I had exact control on the second where my pulse was. Since I kept my focus on staying in the correct zone it was easy.

5. How much attention did you put on the “zone-feedback”? (on a scale 1-5, where 1 is “didn’t think of it at all”)
A: 4. A lot, since I had to check the heart rate monitor every time I wanted to know where I was I did it very often.

# Subject 4

## *Information*

Age: 22
Gender: Female
Maximum heart rate (MHR): **208 bpm**
75% of MHR: **156 bpm**
85% of MHR: **177 bpm**

# *Statistics*

| **Test number:** | **1** | **2** | **3** |
|---|---|---|---|
| **Product:** | Our Android application with Zephyr HxM | iRunner iOS application | Garmin FR 410 |
| **Date:** | 4/4 2012, 10.45 | 5/4 2012, 11.00 | 8/4 2012, 13.45 |
| **Weather:** | 6 °C, cloudy | 4 °C, cloudy | 5 °C, cloudy |
| **Total distance:** | ~3500 m | ~3600 m | ~3700 m |
| **In target zone (percentage):** | 81% | 88% | 90% |
| **Below target zone:** | 6% | 6% | 10% |
| **Above target zone:** | 13% | 6% | 0% |
| **Average BPM:** | 169 | 170 | 167 |

Table A.4

# *Graphs*

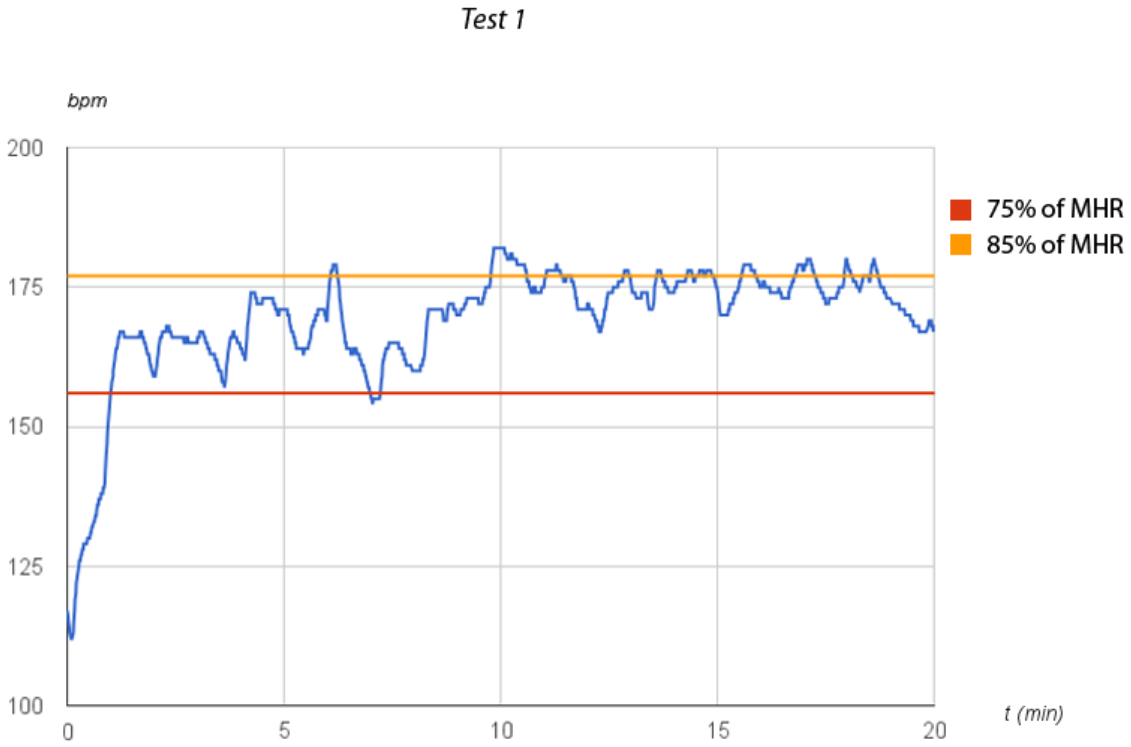


Figure A.4.1

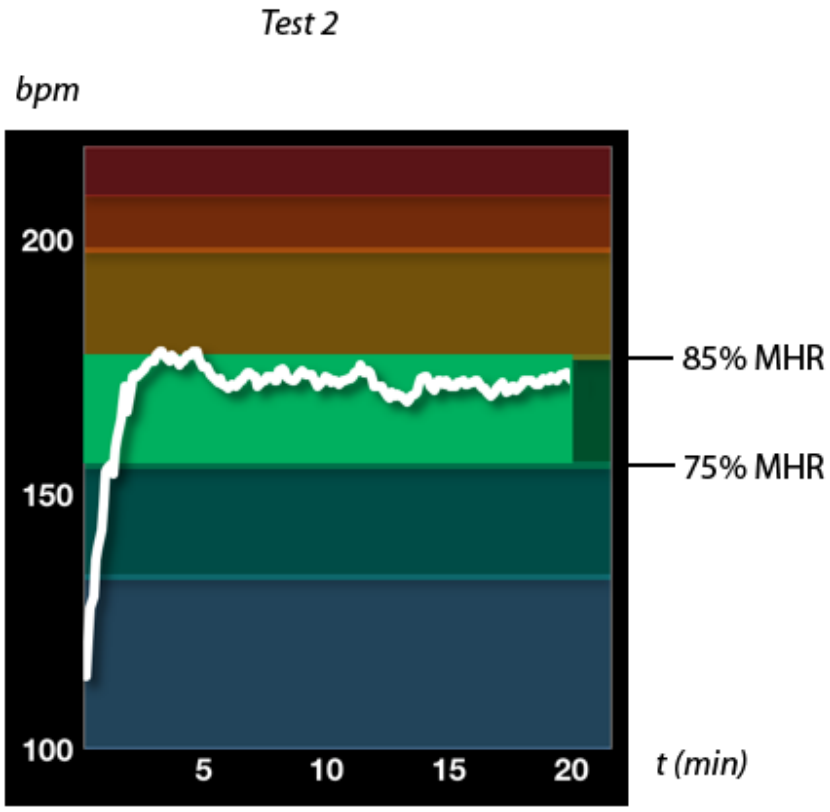


Figure A.4.2

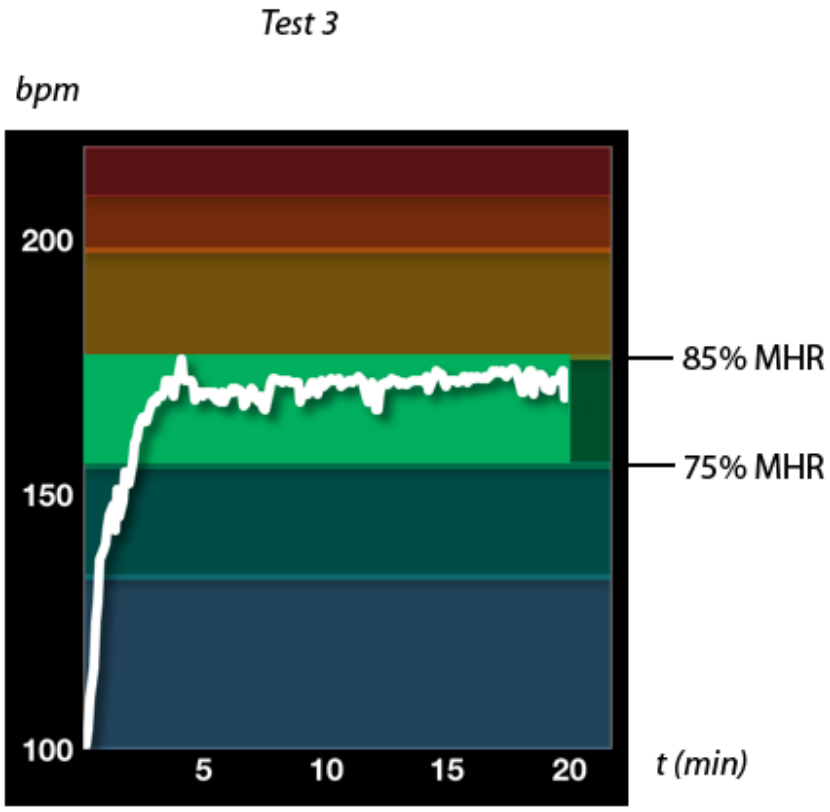


Figure A.4.3

# *Questionnaires*

## Test 1

## Before the test

1. How do you feel today? (On a scale 1-5, where 1 is very tired and 5 is fully rested)
A: 4

2. Earlier experience of using heart rate monitor?
A: none

### After the test

2. How tough was it? (on a scale 1-10 where 10 is extremely hard)
A: 4

3. Free description, how (easy, difficult) was it to stay put/train in the target zone?
A: Pretty easy, it was difficult to lower my heart rate.

4. How did you experience the “zone-feedback”?
A: Difficult to hear the difference between the below target and above target sounds. But the “on target” sounds were good, except target center and target high.

5. How much attention did you put on the “zone-feedback”? (on a scale 1-5, where 1 is “didn’t think of it at all”)
A: 3, it was easy to find my pace so could stay in the target zone. I had to pay more attention to the feedback in the beginning but I got used to it quickly.

6. Would this product help you with heart rate training? Why/why not?
A: Yes, it would give me more control over my training.

7. Do you see potential in this product? Why/why not?
A: Yes if it was polished a bit. The signals could be made clearer.

---

# Test 2

# Before the test

1. How do you feel today? (On a scale 1-5, where 1 is very tired and 5 is fully rested)
A: 4

## After the test

2. How tough was it? (on a scale 1-10 where 10 is extremely hard)
A: 3

3. Free description, how (easy, difficult) was it to stay put/train in the target zone?
A: Easy, I think it was as easy as it was because I found my pace when trying out the last app.

4. How did you experience the “zone-feedback”?
A: The feedback was too infrequent, easier to understand than your app.

5. How much attention did you put on the “zone-feedback”? (on a scale 1-5, where 1 is “didn’t think of it at all”)
A: 1, none.

6. Would this product help you with heart rate training? Why/why not?
A: Yes, but I’d rather use yours. Depends on what kind of exercise you’re going for. This product fits better for long distance running while yours fits better for more intense exercise.

---

# Test 3

# Before the test

1. How do you feel today? (On a scale 1-5, where 1 is very tired and 5 is fully rested)
A: 3

## After the test

2. How tough was it? (on a scale 1-10 where 10 is extremely hard)
A: 5

3. Free description, how (easy, difficult) was it to stay put/train in the target zone?
A: Extremely easy, on one hand it was easy to know exactly what my heart rate was but on the other hand I had to keep checking to know where I was.

5. How much attention did you put on the “zone-feedback”? (on a scale 1-5, where 1 is “didn’t think of it at all”)
A: 4, almost all of it to stay in the target zone. Irritating to have to change my focus the whole time from running to looking at the watch. The arm movement to bring the watch into view also disturbed my rhythm.

Final question: Which product did you prefer for this specific workout session?
A: Yours, but change the below target and above target sounds to make them more different. After that the Garmin watch since I have complete control the whole time. Lastly iRunner, since there is no feedback when you are actually in or outside the right zone only when you enter or leave it you could theoretically miss the warning by some mischance and spend the entire workout session in the wrong zone.