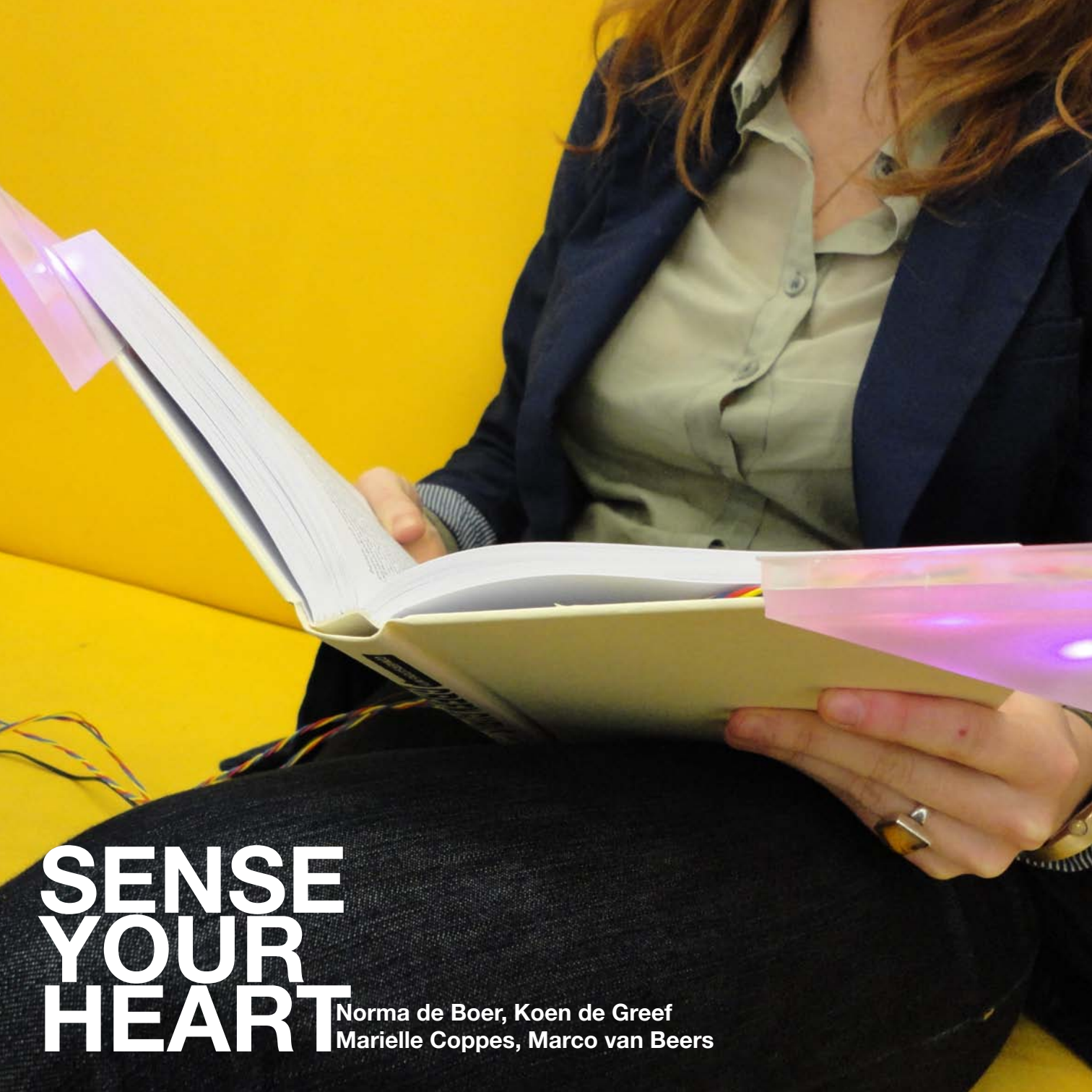
SENSE YOUR HEART

Norma de Boer, Koen de Greef, Marielle Coppes, Marco van Beers

2011

TU/e Technische Universiteit Eindhoven University of Technology



SENSE YOUR HEART

Norma de Boer, Koen de Greef
Marielle Coppes, Marco van Beers

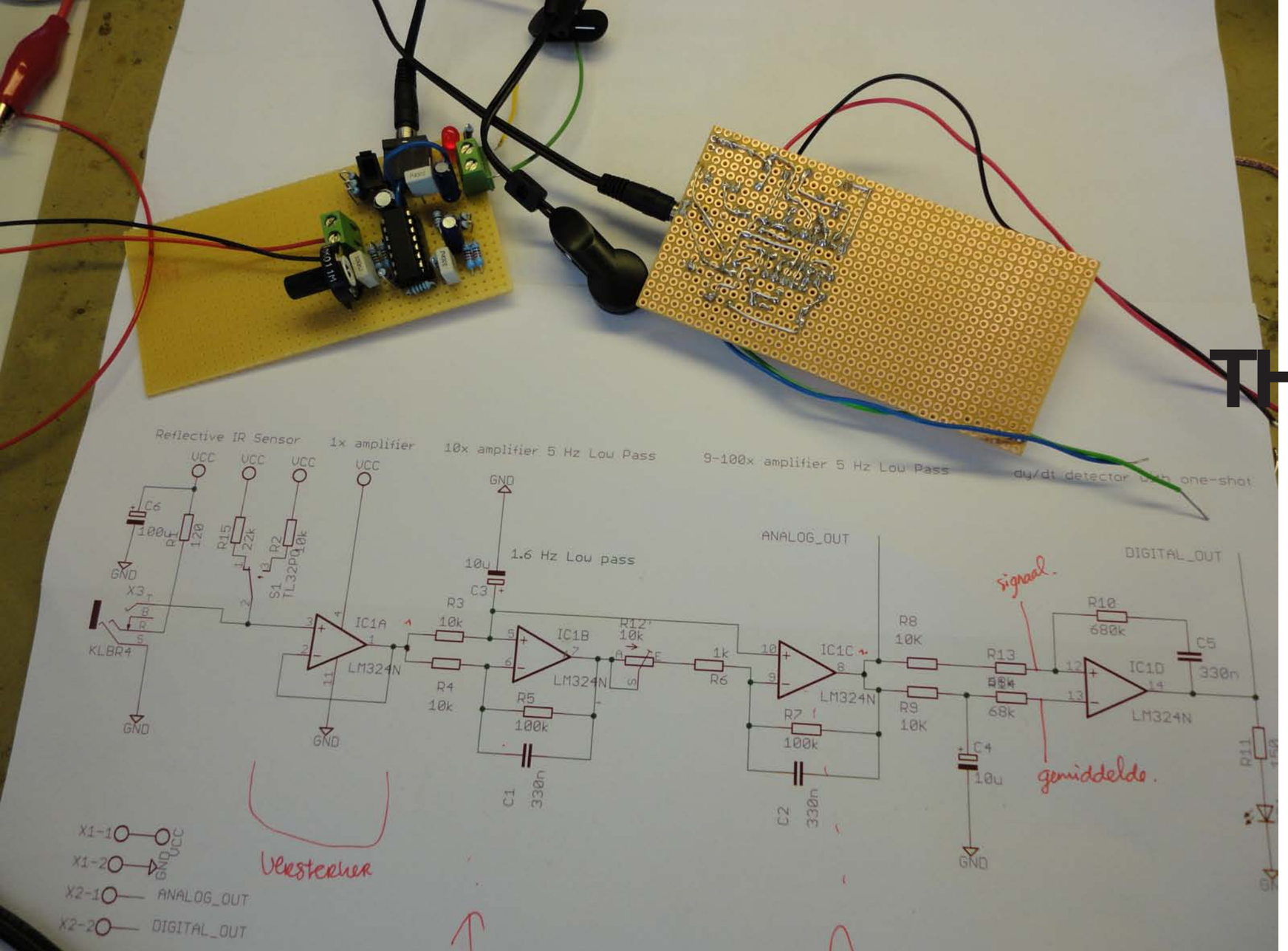
INDEX

INTRODUCTION

The heart is one of our most important organs as it pumps blood through our veins. This pumping can be measured in multiple ways like ECG or PPG, this could give us information on health, physical activity, stress and much more.

Reading, as an activity, could also influence the heart rate. The heart rate could decrease when one is focused and reading a relaxing book. Interesting would be if this information on how the person is experiencing the book, according to his or her heart rate, is used as ambient feedback to the user and his environment.

We designed an application that can be used while reading, it gives ambient feedback on how the person is experiencing the book, according to his/her heartbeat, to the reader and the environment.



MEASURING THE HEARTBEAT

Photoplethysmography (PPG)
Each time the heart beats there is a small volume change because the veins become a bit wider. This volume change in the veins can be measured by the use of Photoplethysmography (PPG). PPG measures this volume change by the use of infrared light and an infrared light receiver. When the volume increases, the transmittance of the light through the veins decreases. PPG can be used to measure the heart beat.

CONCEPT

courtesy of gettyimages.com

Reading is very much an individual activity and experience, whereas watching a TV show is a more public experience which could be shared by more than one person. A book, just like a TV show or movie, could have different story lines and multiple climaxes. Interesting would be if the experience of the engagement with the book and the climax moments could be visualized in a more public manner. Reading a book could not only have an influence on the reader's mental state of mind, but perhaps have a physiological effect as well.

The average heartbeat per minute could give information about a person's physiological state and reading experience: how intrigued a person is by the story, if it is boring or if there are a series of exciting events unfolding. In order to measure the average heartbeat per minute PPG is used.

The design entails a heart measuring system and book corners that emit light. The book corners display information of the reader's heartbeat to the reader and to his or her environment by pulsating and changing the hue of the light according to the beats per minute the user has. Therefore it enables one to subtly share the experience of reading a book in an unobtrusive way. It shares no concrete information about the story line or the subjective emotional state of mind; however it does give some information about the physiological state of the reader. This information could work as a social actor between the reader and people around him or as an ambient experience enhancer. Perhaps people are more hesitant to disturb the reader, or more likely to ask what the last part was about.

APPLICATION AREAS

Many kinds of data could be extracted from measuring a person's heart rate (variability). It is useful to know what information could be extracted from these measurements within the given context of reading. This way variations of the same concept could open new possibilities for application areas of the design. Here some examples of information one could attain are listed:

- Time it takes a person to read an entire book/reading speed
- In how many fragments does a user read a book (over a longer period of time)
- Concentration level
- Relaxation level
- The number of disturbances during reading process
- Bio-feedback on the storyline

There are many options for using this information for design applications in the context of reading. Here a few examples will be given.

The design could be used as a tool in the education domain. Teachers might be interested in the reading development of children. The time it takes a child to read a book and the level of concentration needed. Such information could help teachers monitor the reading process of each individual child, without the need to physically observe each child.

Another possibility could be integrating the design into a library system.
Each member of the library could get an individual set of book corners to apply when reading. This way huge amounts of data could be measured, stored and compared, giving information on the read books. There are already online systems that work with customer ratings, reader's comments and system suggestions to help one find interesting reading material. Also there are categorizations on genre in the library to assist readers in chosing books of their personal interest. All these systems work in the center of a user's attention. Next to these tools, the proposed design adds bio-feedback which is a more unconscious way to give information on the reading span of a specific book. It could be an added input for comparing books on a more personal and emotional level.

Gathering data from many people who have read the same book can be a way to give authors feedback as well on their storyline and even work as an assisting tool in that sense.

Another option is expanding the existing concept from just book corners to an ambient display. Perhaps a person's reading experience could be enhanced with light effects in the periphery of the reader's attention. The environment could change its lightning according to the reading experience of a specific moment in time.

EXPERIMENT

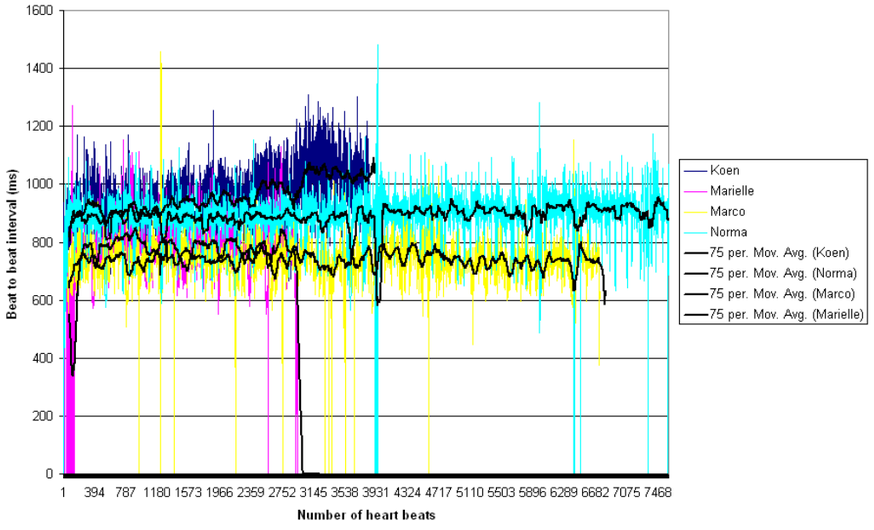
Aim
A small experiment was done in order to find possible effects of reading a book on the heart rate. The aim was to find similarities in the reading span of individual team members and to stumble upon new insights or implications for the design area.

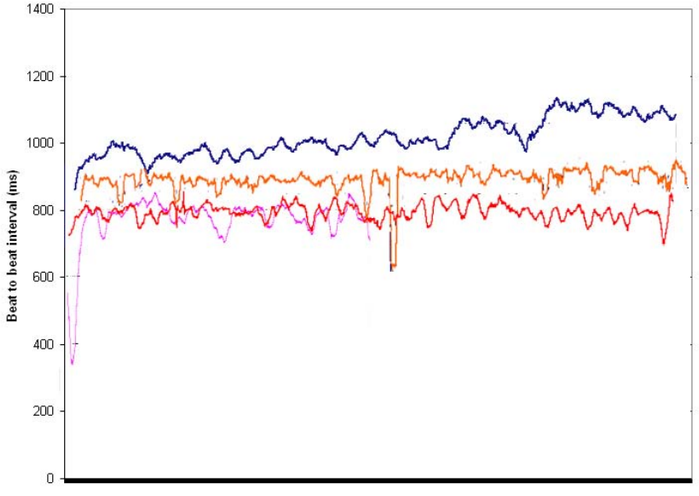
Set up
Each team member was given the same book: 'het boekenweekgeschenk' (the book week gift) by Kader Abdolah named 'De Kraai'. Team members read the book at home while their beat-to-beat intervals were measured and stored. One team member made a video of the reading process in order to compare peaks or irregularities in the measured data with the page of the correlating moment.

Results
The graphs below show the beat-to-beat intervals of individual team members during the reading experience. The black line indicates an average. Note that an increase in the line correlates with a decrease in heart rate and vice versa.
The reading time varied between half an hour and one and a half hour and varied between reading the first half of the book and all of it.

Since everyone read in a different speed and one person did not finish the book, it is hard to compare the gathered data. Therefore the data was combined in a new graph, showing the relative reading process. It is not an exact page-to-page mapping, but it makes it possible to better compare the data.

Conclusion
Some peaks could to be explained. For example one peak in heart rate was afterwards be explained by a sudden telephone call during that moment which interrupted the reading process. Another one was caused by sensor problems. Interesting is that in two graphs a more general decline (increase in heart rate) and incline (decrease in heart rate) can be seen towards the end. A decrease in heart rate here is caused by a more relaxed state. If this is caused by the reading itself, simply sitting still for a longer time or other causes like fatigue is still a point of speculation. The other one, the gradual increase in heart rate was explained by the team member as being happy that the story was almost finished.





One could argue that there can be found some similarities between parallel peaks in the graph, but more extensive research is needed to be able to conclude whether these assumptions are correct. Although surrounding stimuli were brought to a minimum during the test, there is no denying that for an implementation of the design there are many factors that influence the heart beat other than the book itself. However this does not have to be a problem. In fact, it might give a richer experience. Since the output is in real time, people noticing the output might be aware of shared external stimuli or otherwise have extra indications for the internal processes of the person reading, even if it is not merely caused by the reading itself.

Discussion

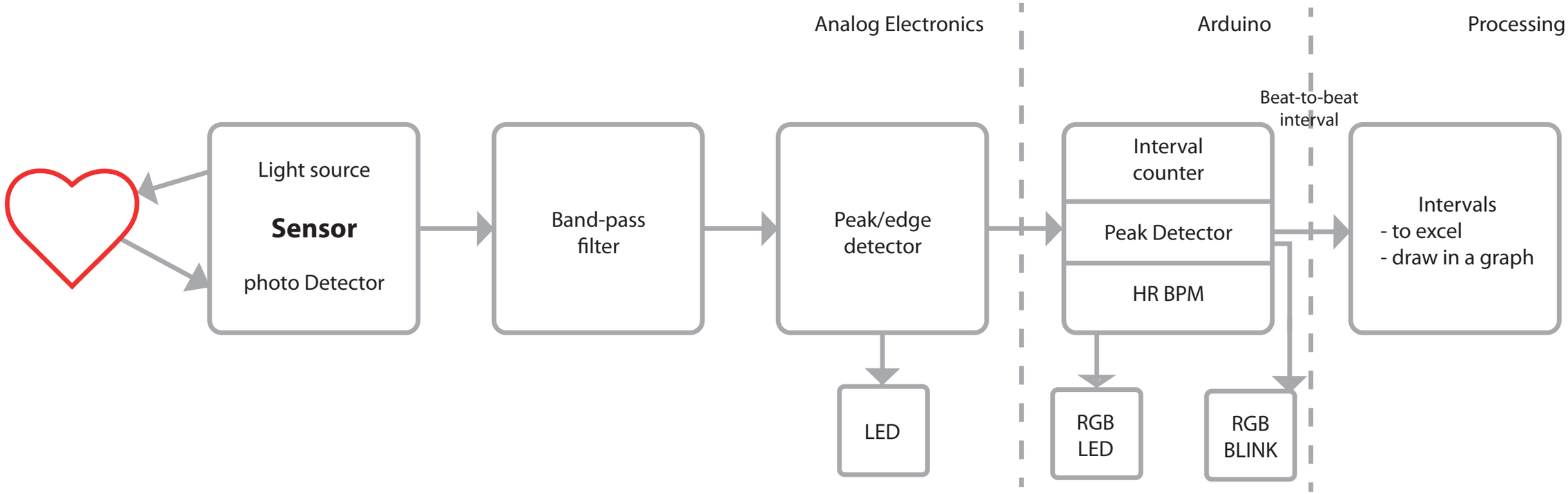
No hard conclusions can be drawn from the conducted test. No control test was performed, not enough people were tested, the people who were tested were the same people who initiated the test, being aware that your heartbeat is measured could influence the heart rate directly and the heart rate could be influenced by many factors.Also the chosen story could have been more exciting and varying over time. Of course such a story could have been selected but then it would have been necessary to know the story on forehand and that would have influenced the reading process as well. Besides these improvement points the test did help to explore the design, which shows promising opportunities.

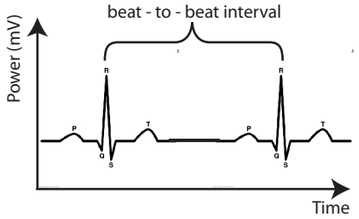
EXECUTION

In order to measure the heartbeat in our concept we used the amplification and filtering circuit to which a PPG sensor can be connected, and the code for reading and processing the heart beat signal, designed by Dr. Ir. G.R. Langereis. This system was used as the basis of our concept.

We extended, the already existing platform with some simple hardware: 4 SMD RGB LEDs integrated in 2 Perspex book corners. These two bookcorners will visualize and communicate the reading experience of the user. As you can see in the picture.

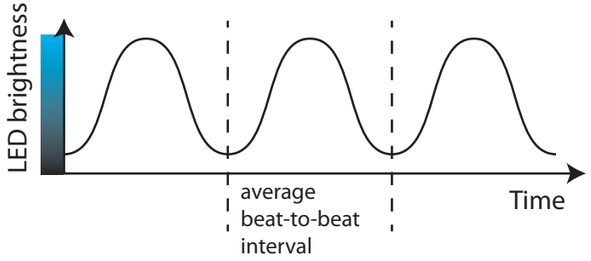
The following graphs explain how the system works and the data is processed. In the appendix the code can be viewed with comments.


Analog Electronics
Arduino
Processing
Light source
Sensor
photo Detector
Band-pass filter
Peak/edge detector
Interval counter
Peak Detector
HR BPM
Beat-to-beat interval
Intervals
- to excel
- draw in a graph
LED
RGB LED
RGB BLINK

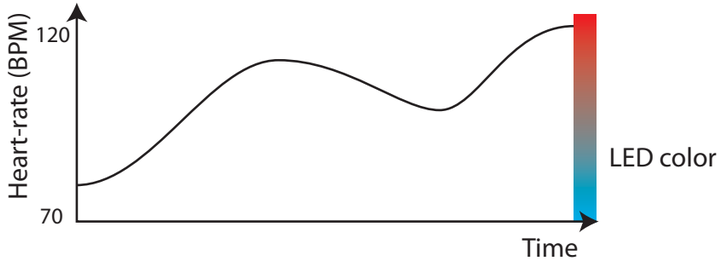


We count the beat-to-beat intervals.
To create a calm system we've smoothed out the peaks of the beat-to-beat intervals, we've taken the average of 30 beat-to-beat interavals, to try and decrease the influence of short physical movements and things happening in the environment.

Average beat-to-beat interval = 30 beat-to-beat intervals / 30
The average beat-to-beat interval is used as the time cycle for fading the LED's on - dimmed - on



The average heart-rate in beats per minute = 1 minute / average beat-to-beat interval
The average heart-rate determines the color of the LED's



APPENDIX
FINAL CODE

```
int Baudrate = 19200;                  //baudrate for the serial connection
int Digital_Input_Pin = 2;             //the sensors digital output to the arduino
int ledPinArray[] = {3,5,6,9,10,11};   //array to store the led output pins

int nrOfAvg = 30;                      //nr of hrv intervals to take for averaging
unsigned long intervalArray[30];       //array to store intervals for average calculation

int lowBPM = 70;                       //BPM range to change color on, take extremes that are
int highBPM = 115;                     //within an average range for the most dramatic effect

//other vars needed in the program
int hueVal = 150;
int BPM, redVal, blueVal, ledValue, index, hueBufVal;
unsigned long lastTime, newTime, avgInterval, total, newMillis, prevMillis;
float valueStep;
boolean ledVUp = true;
boolean processingConn = false;

void setup(){
 //ini serial connection and send ">", processing can answer with "I" to establish a connection
 Serial.begin(Baudrate);
 Serial.print(">");
 if (Serial.read()=='I'){
  processingConn = true;
 }

 //ini input and output pins for sensor and leds and set leds to off (high signal)
 pinMode(Digital_Input_Pin, INPUT);
 for(int j=0; j<5; j++){
  pinMode(ledPinArray[j], OUTPUT);
  analogWrite(ledPinArray[j], 255);
 }

 //create an interupt function for a rising signal on the input  pin
 attachInterrupt(0,Send_Interval, RISING);
}
```

```
void loop(){
  calcValue();
  pulseLED();
}

void Send_Interval(){
  //calc the difference between the last time this func was called and now
  newTime = millis();
  unsigned long hrInterval = newTime - lastTime;
  lastTime = newTime;

  //if connected to processing, send out the HEX value of the interval
  if(processingConn == true){
    Serial.println(hrInterval, HEX);
  }

  calcBPM(hrInterval);
  calcHue();
}

void calcBPM(unsigned long newInterval){
  //replace the oldest interval in the average array with the last interval
  total -= intervalArray[index];
  intervalArray[index] = newInterval;
  total += intervalArray[index];
  index ++;
  if (index >= nrOfAvg){
    index = 0;
  }

  //calc the avg interval by dividing the sum of intervals in the array with the nrOfAvg
  avgInterval = total/nrOfAvg;
  //calc the BPM by dividing nr of ms in a minute by the avgInterval
  BPM = 60000/avgInterval;
  //if not connected to processing, print out the BPM
  if(processingConn == false){
    Serial.print("BPM = ");
    Serial.println(BPM);
  }
}

void calcHue(){
  //constrain the BPM between lowBPM and highBPM
  int cBPM = constrain(BPM, lowBPM, highBPM);
  //map the constrained BPM to a hue value between 240 and 0 (blue to red), a buffer value is used for a
    smoother color transition
  hueBufVal = map(cBPM, lowBPM, highBPM, 240, 0);
}

void calcValue(){
  //calculate how much ms it will take to make the leds 1 value more or less intense
  //the inverse of the range of intensity(255-25=230)/the average interval(1.5, this number controls the
    link between the speed of pulses and the actual heartrate)
  valueStep = 1.0/(230.0/(float)avgInterval*1.5);
}

void pulseLED(){
  //if the difference between the previous time and now is bigger than a valueStep, in-/decrease value
  newMillis = millis();
  if(newMillis - prevMillis >= valueStep){
    if(ledVUp == true){
      ledValue ++;
    }else if(ledVUp == false){
      ledValue --;
    }
    //switch direction of value
    if(ledValue <= 25){
      ledVUp = true;
    }else if(ledValue >= 255){
      ledVUp = false;
```

```
  }
  prevMillis = newMillis;

  //make the actual hue value go towards the hueBufValue
  if(hueVal < hueBufVal){
   hueVal ++;
  }else if(hueVal > hueBufVal){
   hueVal --;
  }

  //calculate the RGB value from HSV
  HSV2RGB1(hueVal, 230, ledValue);
  //compensate for our eyes sensivity to red
  redVal -= redVal/10;

  //send the red and blue values to the corresponding leds
  analogWrite(5, (255-redVal));
  analogWrite(6, (255-redVal));
  analogWrite(9, (255-blueVal));
  analogWrite(10, (255-blueVal));
 }
}

// Inspired by code from: http://www.kasperkamperman.com/
void HSV2RGB1(int hue, int sat, int val) {
 //calculate the corresponding RGB values of HSV values
 int r, g, b, base;

  base = ((255 - sat) * val)>>8;

  switch(hue/60) {
  case 0:
     r = val;
     g = (((val-base)*hue)/60)+base;
     b = base;
  break;
  case 1:
     r = (((val-base)*(60-(hue%60)))/60)+base;
     g = val;
     b = base;
  break;
  case 2:
     r = base;
     g = val;
     b = (((val-base)*(hue%60))/60)+base;
  break;
  case 3:
     r = base;
     g = (((val-base)*(60-(hue%60)))/60)+base;
     b = val;
  break;
  case 4:
     r = (((val-base)*(hue%60))/60)+base;
     g = base;
     b = val;
  break;
  case 5:
     r = val;
     g = base;
     b = (((val-base)*(60-(hue%60)))/60)+base;
  break;
  }

  redVal = r;
  //greenVal = g;  //no green needed
  blueVal = b;
}
```


TU/e
Technische Universiteit
Eindhoven
University of Technology