# The relation between humidity, temperature, air quality and the heartrate during sleep

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## ABSTRACT

Every person needs to get enough sleep to function properly. However, there are issues with students' sleep quality, which could potentially be caused by influencing and external factors. This study focuses on how the students' heart rates during (deep) sleep are affected by temperature, humidity, and air quality. The connectivity of temperature and humidity are researched, as well as several external factors that possibly affect temperature, humidity, and air quality.

The results showed a relationship between temperature and humidity. The relationship between heart rate during sleep and humidity is negligible. Besides, there is no relationship between air quality and heartrate during night nor between the percentage of deep sleep and average air quality per night. The influencing factors can, however, be used in further research to find interesting relations.

### Author Keywords
Air quality, temperature, humidity, heartrate, deep sleep.

## INTRODUCTION

Sleep is an essential component of an individual's wellbeing. Its timing, duration and quality are critical determinants of health [9]. Sleep plays an important role in metabolic regulation, emotion regulation, performance, memory consolidation, brain recuperation processes and learning [29]. However, the present performance-oriented society causes certain contemporary issues regarding students' sleep quality. Besides academic demands, the reasons for students sleep deprivation is dependent on a wide range of social, cultural, environmental and biological factors (e.g., personal interests, involvement with activities including technology and social media) [1].

Despite numerous ways to improve one's sleeping habits (e.g. advancing sleep hygiene, external factors including indoor environment, especially thermal conditions and indoor air quality (IAQ), can be decisive [30]. Indoor exposure to air pollutants can cause significant damage to health. Despite this, public health awareness on indoor air pollution has lagged compared to outdoor air pollution, particularly the availability of scientific literature concerning indoor air within sleeping environments is scarce [6, 7, 33]. Therefore, this paper aims to investigate the relation between humidity, temperature and air quality and the participants' heart rate during (deep) sleep, all within an indoor sleeping environment. The team has made a measuring setup by using (i) a Mi-Band 5 to collect heart rate and sleep stages and (ii) a data acquisition setup which contains (a) a DHT11 temperature and humidity sensor and (b) a MQ-135 gas sensor to measure IAQ. The MQ-135 sensor is suitable for detecting NH3, NOx, alcohol, benzene, smoke, CO2, etc. (Appendix B). The data of the participants (students) will be stored according to the FAIR principles and processed by Python. In addition, a logbook, which provides insights into the influence of external factors (e.g. room measurements and ventilation), will be conducted to explore the results in further detail. This paper aims at synthesizing available knowledge with both quantitative and qualitative research outcomes to provide a contribution to knowledge respecting: indoor sleep environments and sleep quality.

Therefore, this is the research question: "How does the air quality, humidity and temperature in a bedroom influence the heartrate during sleep?". The hypothesis: air quality, humidity and temperature do have a relation with the heartrate during night.

## RELATED WORKS

### Temperature, humidity

A reduction in core temperature happens together with the onset of sleep [12]. This core temperature is in connection with the sleep-wake rhythm that is recurring each 24 hours, a circadian rhythm [21]. Ambient temperature plays an important role on the circadian rhythm of organisms [30]. This can explain why studies show that a thermal comfortable sleeping environment is important for sleep maintenance [14].

The thermal conditions are also closely linked to humidity [5, 22]. Relative humidity is defined by the rate of water vapor in the air, or moisture [27]. Humidity is an important factor that can increase heat stress. It hinders sweat from evaporating, therefore keeping the skin wet instead of cooling the body through sweat evaporation, thus affecting thermoregulation during sleep [21, 22].

Multiple studies have investigated this relation between sleep and both temperature and humidity, resulting even in the determination of optimal conditions. Where the optimal conditions range between 17 and 28 °C and 40-60% relative humidity [5].

### Air quality

When it comes to an indoor situation such as a livestock building, not only temperature and moisture, but also toxic or noxious gases must be controlled [27]. Or in other words, air quality is one of the factors determining the quality of a building's environment, that is linked to the health of the occupants [20]. Therefore, air quality is important to consider in an indoor context.

Air quality is defined by the pollutants in the air, such as nitrogen dioxide (NO2), ozone (O3) and particulate matter [24]. Indoor air quality (IAQ) impacts health and thermal comfort of humans [18]. The fewer the exposure to these air pollutants, the better for our health [23, 33].

When it comes to good sleep, IAQ plays a main role in the influencing physical environment [30] and bad air quality has been related to poor sleep experiences [1]. Even with this, more focus has been on outdoor air pollution compared to indoor air pollution, and specifically the research on the relation between IAQ and sleep is limited [5, 6, 7, 30, 33].

### Influencing factors

For indoor air quality (IAQ), there are some factors often used to determine the concentration of particular parts in the air. Among others, the volume of the room, the number of occupants in the space and the air flow into a space, are important factors [18]. Temperature and humidity are also influenced by these factors [17, 18, 20]. Even more, research has found for example room-sharing to be a factor increasing the probability of sleep problems [16].

As these factors relate to the air and sleep situation, participants will keep a logbook of the occupants in the room, the ventilation in the room, and the size of the room.

### Heart rate over night

A typical value for resting heart rate (RHR) is between 60 and 100 beats per minute (bpm) [2]. This value varies during the day and decreases during night-time [3, 25]. During sleep a normal heart rate ranges often between 40 and 50 bpm [26]. However, these values also depend on the physical condition of each specific person [13].

When falling asleep (light sleep), the stimulation of your nervous system is reduced and many body processes slow down, leading to the body's core temperature dropping, muscles relaxing and heart rate slowing down to its resting rate [10,19]. Entering deeper sleep stages makes the heart rate drop even further by 20-30%. However, during REM sleep the heart rate increases [35].

Research has shown that there may be a relation between particles in the air and specifically deep sleep, however more research could be done in this area [5, 34].

### Research opportunity

Several factors in an indoor environment have been researched and shown to influence sleep. Also, some research showed a relation between air quality and (deep) sleep. However, indoor air quality affecting sleep has not been researched as much, even though it is a key influencing factor in the indoor environment. Therefore, a research opportunity lies in investigating air quality in relation to sleep in general, and specifically deep sleep. Furthermore, various aspects of the room, plus both temperature and humidity, have been shown to relate to sleep or air quality and could therefore be considered in this research as well.

## METHODS

### Study setup

The participants of this study were five students from Industrial Design from the Technical University of Eindhoven. This participant group existed of three men and two women. To prevent from missing data or mistakes with sensors, the study initially took approximately fourteen days to complete. Also, there were no variables the researchers change during the fourteen days.

The first thing needed for this study is the Xiaomi MiBand which can collect data, such as: sleep data, heartrate, stepcount, etc. Four of the participants had the Xiaomi

MiBand 5 and one participant had the Xiaomi MiBand 6. With this Xiaomi MiBand, the heartrate during sleep was measured. The second thing needed for this study is the gas sensor module (MQ-135) which measures the overall air quality existing of: carbon dioxide, ammonia, nitrogen oxides, benzene, alcohol and smoke (Appendix B). With this sensor the overall air quality in the room was measured. The last thing needed for this study is the YODL kit, existing of: Arduino Uno, SD card, data logging shield and the temperature and humidity sensor (DHT11). The combination of the SD card and data logging shield allowed the researchers to log all the data and save it to work with it later on in the study. As mentioned in the related works, temperature and humidity is related to sleep. Therefore, the temperature and humidity sensor is used to collect this data and later compare it to the heartrate during the night.

Temperature, humidity and air quality are all measured every ten seconds during the nights by using the DHT11 sensor and the MQ-135 sensor. The heartrate was measured every ten minutes by the Xiaomi MiBand. The electronics setup is made compact and placed in the room of the participant. An excel sheet with possible influence factors is setup (Fig. 1, Appendix C), so that the participant can fill this in every night before going to bed. The possible influence factors have to do with: whether there was any ventilation before, ventilation during, the room size and the number of extra occupants in the room. This information is based on several studies [4, 15, 28] Also, the data from the SD card is backed-up every morning, so that there is no possible data loss.

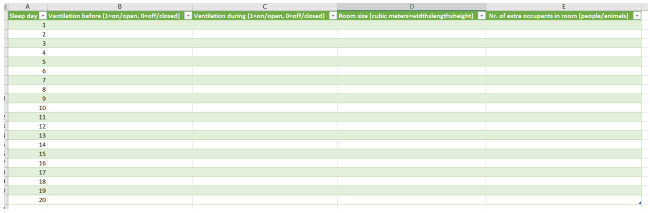


Figure 1: Empty excel sheet influencing factors

### Data analysis

First step towards analysing the data was importing the .csv files from the sensors to excel. There, the data for each participant separately were combined, cleaned and fitted to the sleep time. Then the excel tables were converted back to .csv files to be analysed using Python. There the data were interpolated to eliminate the gaps due to non-coincidental tine stamps of the YODL kit and the smart band.

Next, line plots containing all data were used to explore any possible correlation. However, this way did not offer any insights, so box plots were created. To create the box plots the data were split into days. That was not sufficient, though, as each day contains the second half of the participants' sleep and the first half of the next one. Subsequently, each sleep was assigned a number manually. Using this categorising method, the box plots were created.

To explore further and validate our decisions, aside from visual inspection linear regressions between heart rate and air quality and heart rate and humidity were made. To assess the quality of the models and the association between the values, the goodness of fit was found for both models of each participant.

## F.A.I.R. PRINCIPLES & ETHICS

### Ethics

In order to ensure that there would not be any harm inflicted on participants, the risks that could have occurred during this research were taken into consideration.

Because the research is using sensitive data collected by the participants, the collected data will only be accessible by the researchers (the participants self) through OneDrive, with the files only accessible with a password. When presenting the results, it is made sure that it is not traceable by not using the names of the participants.

It is made sure that this study did not negatively affect health of the participants. The participants were not allowed to intentionally make the air quality worse nor intentionally change their heart rate for research purposes.

The participation of the participants was completely voluntary, and they could stop whenever they wanted. Furthermore, a consent form will be filled in by the participants with above things stated.

### F.A.I.R. principles

*Findable*

*(Meta)data should be easily findable, for humans as well as computers. [11. 32]*

As there will be 2 datasets for each group member, they need to be stored under an identifier. In this situation, something like a DOI is not needed as it will not be published outside of Canvas. The files and folders do need findable names so everything is easily traceable. The datasets for heartbeat will be stored under the name of: [dataset_heartbeat_group19_lastname]. The datasets of the data acquired by the sensor, will be stored under the name of: [dataset_sensor_group19_lastname]. They will be stored in the map 'datasets' in the python notebook that will have the name: [data_group19_lastname].

With the help of a metadata editor, the metadata will be enriched. In this will be described: the devices used to capture the data, the protocol used, keywords and other details about the experiment. In this metadata, the unique name of the dataset will also be noted.

*Accessible*

Once the user finds the data, they need to know how to access it. [11, 32]

The place of upload is Canvas, which means those who need to can access it without any barriers. The data will be no-cost and is accessible when the assessor has a computer and an internet connection. The conditions under which the data is accessible will be to have access to it through the canvas page. This does mean only assessors and group members can access it, but this is simply the context of this project. It is also possible to upload the data to the internet, where it would be accessible.

As it will not be published publicly. There is also no need to sustain the metadata when the data has disappeared.

*Interoperable*

The data need to be integrated with other data and needs to interoperate with applications etc. [11, 32]

The comments in the data and the metadata will be written in English (UK) to ensure people from being able to understand or translate it. It will also be mentioned in the metadata that there will be no added datasets necessary to complete the data, but that both datasets are combined to gather useful data.

*Reusable*

Data should be well-described so they can be replicated or combined in different settings. [11, 32]

There will be metadata added that describes the context of this project and what was the intended use. The timeframe in which it was collected and whether it was processed or not is also mentioned. The variables used will have a name that makes them self-explanatory. We will also add metadata on who collected the data, how it has been processed and who to cite if they use our data.

## RESULTS

### Humidity & temperature

Firstly, the relation between heart rate and humidity was investigated with a linear regression model (Fig. 2). The results from participants 1,2 and 3 show no relation between humidity and heartrate. Additionally, it seems that the distribution is also very similar. In contrast to the results of participants 1, 2 and 3, the results of participants 4 and 5 show a small positive relationship between heart rate and humidity. However, In terms of distribution, 4 and 5 are different from each other. The temperature was also measured during this study. The boxplots (Fig. 3) indicate that there seems to be a strong negative relation between humidity and temperature. Therefore, the temperature is not further investigated in this research.

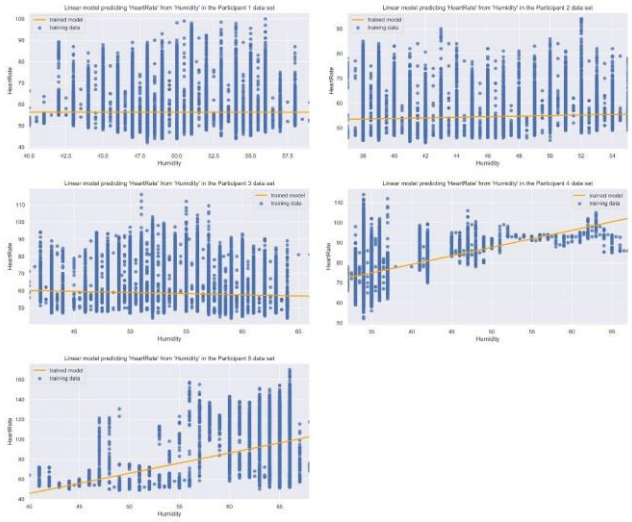

Figure 2: Linear models: Humidity and heartrate

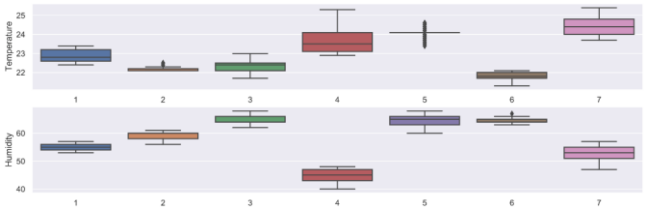

Figure 3: Box plots: Temperature and humidity

### Air quality

Secondly, the relation between heart rate during sleep and air quality was investigated. When taking into account the linear regression models (Fig. 4) that shows the relation between heartrate and air quality, it looks like the shape differs much per participant. It seems that there is no relation between the two for participants 1 and 3. For participants 2, 4 and 5 there is more than a flat line. However, it doesn't seem steep enough to say there is a positive relationship. Something that is also noticeable is that participants 1 and 3 have a similar shape. Both have two big clusters of points, while the participants 2, 4 and 5 have very distinctive shapes. The graph of participant 5 also stands out because almost all the data points are on the left side of the graph, due to some outliers.

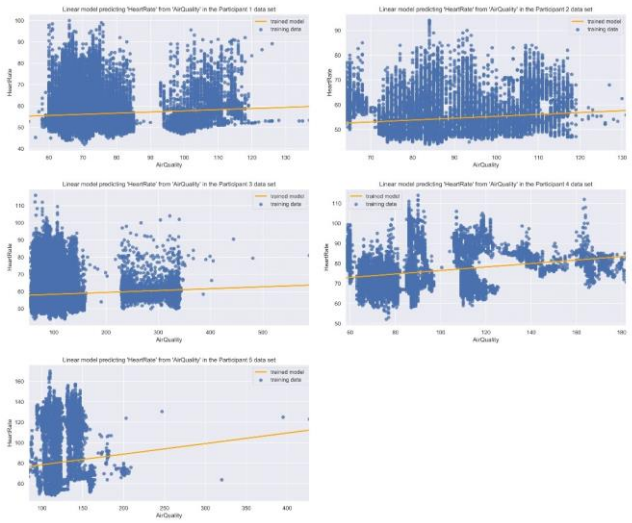

Figure 4: Linear models: Heartrate and airquality

### Coefficient of determination

In order to more accurately see if heart rate is influenced by humidity or air quality, a table (Table 1) was created with $R^2$ values. It shows that there is no correlation between heart rate and air quality for any of the participants because all the values approach zero. For participants 1, 2 and 3 the value for humidity and heart rate approaches zero and therefore there is no correlation. However, for participant 4 and 5 there is a low correlation.

| Participant | R2: Air Quality / Heart Rate | R2: Humidity / Heart Rate |
|---|---|---|
| 1 | 0.008737097222653367 | 0.000001228374505557 |
| 2 | 0.019226712312417238 | 0.007285030335387077 |
| 3 | 0.0044043519300949185 | 0.007875627885696956 |
| 4 | 0.05290745472071867 | 0.1782834416480077 |
| 5 | 0.004141023677529554 | 0.3276491807661509 |

Table 1: R2 values table

### Deep sleep

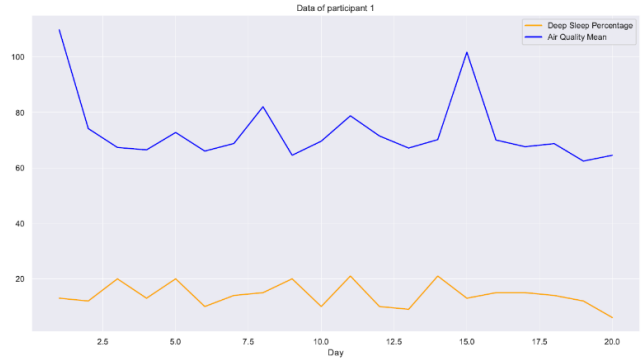


Figure 5: Line plot: Deep sleep percentage and air quality mean (P1).

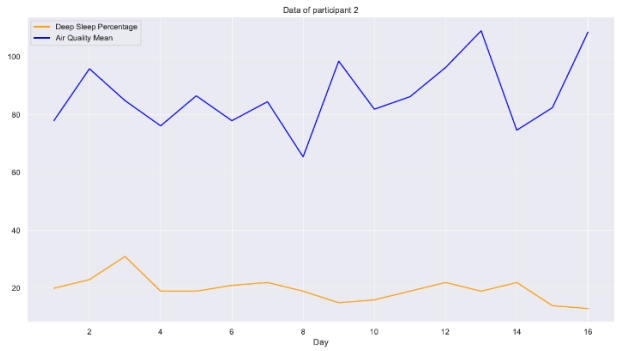


Figure 6: Line plot: Deep sleep percentage and air quality mean (P2).

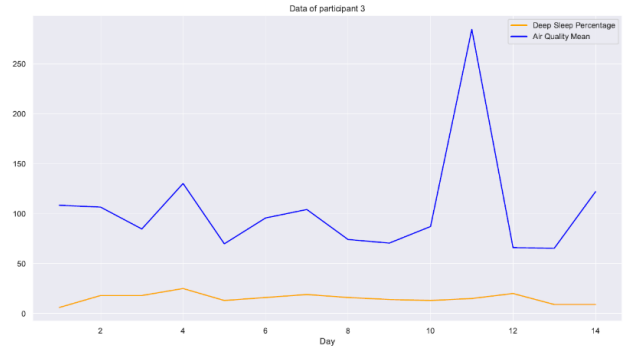


Figure 7: Line plot: Deep sleep percentage and air quality mean (P3).

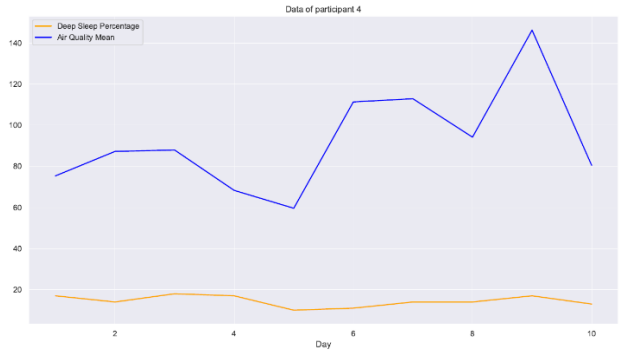


Figure 8: Line plot: Deep sleep percentage and air quality mean (P4).

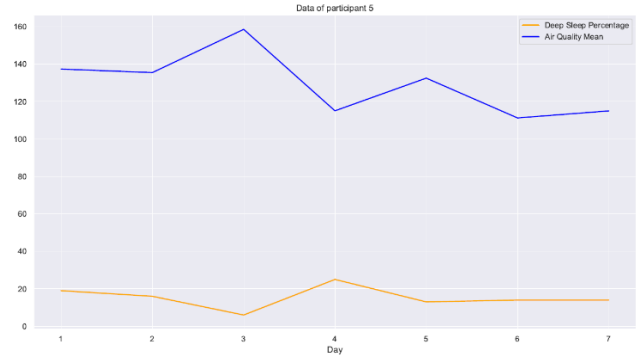


Figure 9: Line plot: Deep sleep percentage and air quality mean (P5).

The relation between the percentage of deep sleep per night and the average air quality per night is investigated (Fig. 5, 6, 7, 8, 9). There seems to be no relation between the percentage of deep sleep and air quality for participants 5 and 2. Also, the deep sleep percentage line of participants 3 and 4 is quite straight, which also shows that there is probably no relation. However, the graph of participant 1 shows the most relation, but still not enough to conclude that there is a clear relation between the percentage of deep sleep and air quality during the night.

### Influencing factors

There were some individual indications for relations in the influencing factors (Appendix A). A few examples:

- For participant 2 ventilation on (windows open) seemed related to the temperature, showing the participant's behavior.
- For participant 5 extra occupants in the room seemed to relate with higher humidity.
- The irregular high value for the air quality on day 11 for participant 3 could possibly be explained by it being the only day where the room size was 35 cubic meters.

However, altogether comparing the noted factors to box plots showing the air quality, temperature, humidity and heartrate showed no convincing correlations, or could explain outliers in general.

## DISCUSSION

### Reflect on results

The results show some differences among participants, especially when looking at the shape of the linear regression models. There seems to be no clear explanation for the two different clumps of point for participants 1 and 3 for air quality. One possibility is that it is the results of sleeping in multiple environments in the study, which can be seen in the influencing factors. Another possibility is that it is a technical issue regarding the air quality sensor.

Another part that could have been improved is the scope of this research. A lot of factors can influence sleep, such as room size, ventilation, air flow. If more factors would have been measured, more accurate results could have been produced. Or instead of only keeping track of these factors, one factor could have been changed halfway while keeping the other factors constant.

### Participant differences

During the study, a number of participants had problems with the YODL kit, especially with the data logging shield. This resulted in some participants missing days of data or having incomplete data. Also, because not everyone started on the same day and ended on the same day, the participants did not measure at the same days. This is something that has to be taken into account. This could have been prevented by not doing the pilot study for one day, but for several days. Despite this, it can never be completely prevented, something can always happen. As researchers we have learned a lot from this, to try to solve it quickly and to adapt where necessary.

### Air quality

The measurement of air quality seemed very interesting to us as researchers, especially in relation to the heart rate at night. Therefore, the MQ-135 gas sensor was chosen. However, we did not think about the need for calibration beforehand. It turned out that the settings were different for everyone, so everyone got different values. We compared all the sensors in the same environment and also found differences in the DHT11 sensor values. However, the air quality values differed significantly more per setup. Nonetheless, it was still possible to gain results with these measurements since a relationship could still be clearly seen despite the different values. Also, not having properly calibrated the sensors made it impossible to understand the exact values being measured. Although it is known that lower values relate to fewer particles in the air, better research on this sensor should have been done before starting the study.

### Data cleaning

Data cleaning is important to do before analysing the obtained data. However, this remains a point where important decisions are made. The researchers themselves decide (with the theory of data cleaning in mind) which data should be used. In this study, some data was manually cleaned, because there was simply no other way to do it. Theoretically, errors could have been made here, causing the data to be incomplete or inconsistent.

### Influencing factors

A conscious choice was made to measure 4 variables: heart rate, air quality, temperature and humidity. This is quite a lot, but in the visualisations the relationships are clearly visible. What is not clearly visible is the cause of certain changes. Because there are so many variables and external factors, it is very difficult to draw a conclusion. The numbers could have been influenced by external factors, about which you could not really conclude anything, as there are quite a few of them. However, this could be improved in the future, for example by talking to the participants in order to collect more qualitative data and get a clearer picture.

### Sleep stages

In this paper the focus was on heartrate during sleep. This might make it difficult to see correlations, as this heart rate is highly dependent on the different sleep stages. Therefore, we also focused on deep sleep specifically, since research has shown there might be a relation between the air quality and deep sleep [5, 34]. However, the deep sleep percentage was used from the ZeppLife app. This is debatable because we do not know exactly what these percentages are based on. Also, the other sleep stages were not included in the study. These sleep stages could have explained some outliers and observations of the visualizations. In new research all sleep stages should be included in research related to this research.

## CONCLUSION

### Humidity and temperature

To investigate whether humidity and temperature have an influence on the heartrate during the night, there was focused first on what the relation between humidity and temperature is. When the temperature is high, the humidity seemed low and vice versa, which resonates with the existing literature. Therefore, it was decided to only relate humidity to heartrate. The results showed differences per participant, where some graphs seem to have a slight relation. However, because the R2 values are very low, it can be concluded that the research done showed no relation between humidity (and temperature) and the heartrate during night.

### Air quality

The influence of air quality on the heartrate during night has been investigated. The graphs in this research clearly show no relation between the air quality and the heart rate during night. Although the linear regressions slightly differ per participant, the steepness of the lines is not clear enough to draw conclusions. Similarly, the R2 values being close to zero further indicate no relation between the air quality and heartrate during sleep.

### Deep sleep

The percentage of deep sleep has been compared to the average air quality values per night. Again, there are differences between participants, but no graph showed a clear relation between the percentage of deep sleep compared to the average air quality per night.

### Influencing factors

A logbook was filled in by the participants for each night, to keep track of the influencing factors. This was used to compare it with: humidity, temperature, air quality and heartrate during night. Although there seems to be differences between participants, it cannot be concluded that there is a relation between the influencing factors and the other measured values. Therefore, further research needs to be done to further investigate this relation.

## ACKNOWLEDGMENTS

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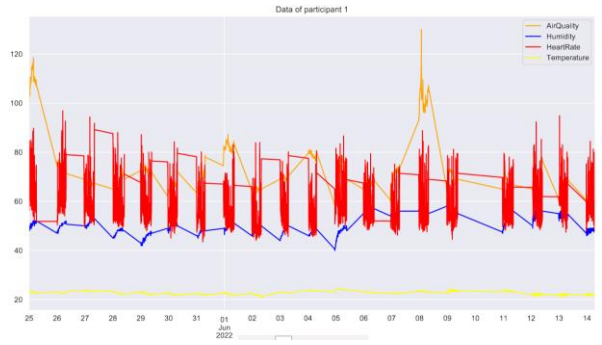
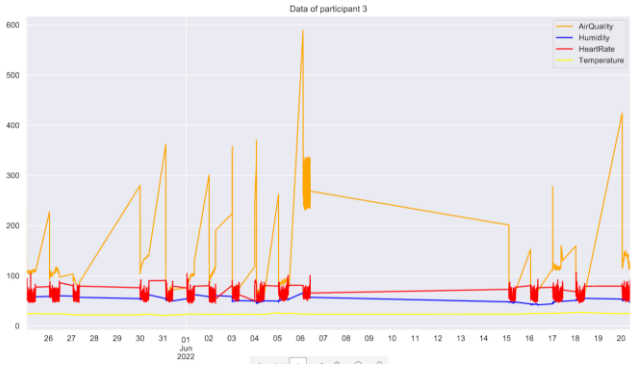
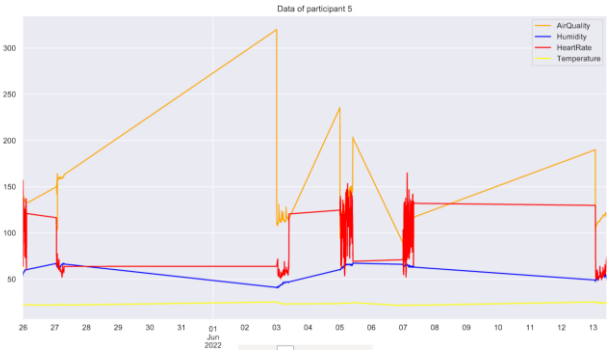
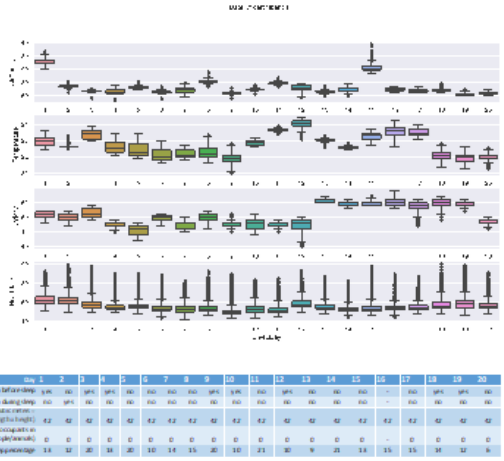
## APPENDICES

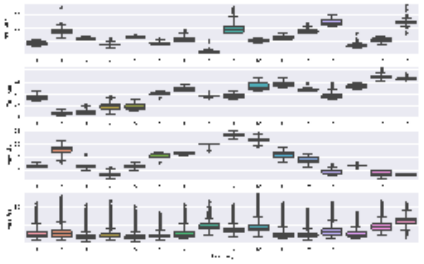
### Appendix A – Other plots

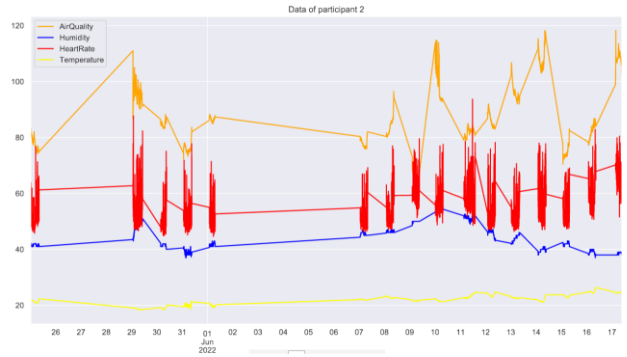


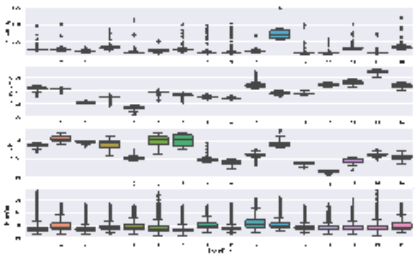



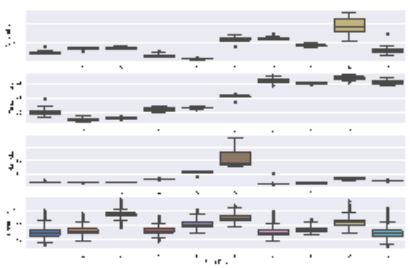



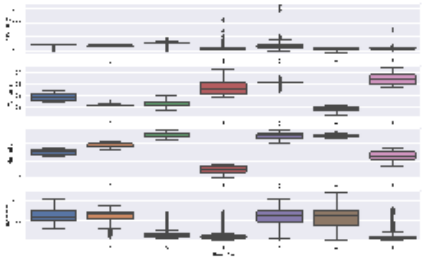




| Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ventilation on before deep | yes | no | no | no | yes | yes | yes | no | no | no | no | yes | yes | no | no | no |
| Ventilation on during deep | no | no | no | no | no | no | no | yes | no | no | no | no | yes | no | no | no |
| Room size (cubic meter - width x length x height) | 25 | 30 | 25 | 35 | 25 | 25 | 30 | 25 | 30 | 30 | 35 | 25 | 25 | 25 | 30 | 25 |
| Nr. of extra occupants in room (people/annuals) | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| Deep sleep percentage | 20 | 23 | 31 | 19 | 19 | 21 | 22 | 19 | 15 | 16 | 19 | 22 | 19 | 22 | 19 | 19 |



| Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Ventilation on before deep | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Ventilation on during deep | no | no | no | no | yes | no | no | no | no | no |
| Room size (cubic meter - width x length x height) | 48 | 48 | 48 | 32 | 48 | 48 | 32 | 48 | 48 | 32 |
| Nr. of extra occupants in room (people/annuals) | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| Deep sleep percentage | 17 | 14 | 18 | 17 | 10 | 11 | 14 | 14 | 17 | 13 |



| Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Ventilation on before deep | no | no | no | no | no | no | no |
| Ventilation on during deep | no | no | no | no | no | no | no |
| Room size (cubic meter - width x length x height) | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| Nr. of extra occupants in room (people/annuals) | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Deep sleep percentage | 19 | 16 | 6 | 25 | 13 | 14 | 14 |

## Appendix B – MQ-135 datasheet

### TECHNICAL DATA MQ-135 GAS SENSOR

**FEATURES**

Wide detecting scope — Fast response and High sensitivity
Stable and long life — Simple drive circuit

**APPLICATION**

They are used in air quality control equipments for buildings/offices, are suitable for detecting of $NH_3$,NOx, alcohol, Benzene, smoke,$CO_2$ ,etc.

**SPECIFICATIONS**

A. Standard work condition

| Symbol | Parameter name | Technical condition | Remarks |
|---|---|---|---|
| Vc | Circuit voltage | 5V±0.1 | AC OR DC |
| $V_H$ | Heating voltage | 5V±0.1 | ACOR DC |
| $R_L$ | Load resistance | can adjust | |
| $R_H$ | Heater resistance | 33Ω±5% | Room Tem |
| $P_H$ | Heating consumption | less than 800mw | |

B. Environment condition

| Symbol | Parameter name | Technical condition | Remarks |
|---|---|---|---|
| Tao | Using Tem | -10 -45 | |
| Tas | Storage Tem | -20 -70 | |
| $R_H$ | Related humidity | less than 95%Rh | |
| $O_2$ | Oxygen concentration | 21%(standard condition)Oxygen concentration can affect sensitivity | minimum value is over 2% |

C. Sensitivity characteristic

| Symbol | Parameter name | Technical parameter | Ramark 2 |
|---|---|---|---|
| Rs | Sensing Resistance | 30KΩ-200KΩ (100ppm $NH_3$ ) | Detecting concentration scope 10ppm-300ppm $NH_3$ 10ppm-1000ppm Benzene 10ppm-300ppm Alcohol |
| α (200/50) $NH_3$ | Concentration Slope rate | ≤0.65 | |
| Standard Detecting Condition | Temp: 20 ±2 Humidity: 65%±5% | Vc:5V±0.1 Vh: 5V±0.1 | |
| Preheat time | Over 24 hour | | |

D. Structure and configuration, basic measuring circuit

| | Parts | Materials |
|---|---|---|
| 1 | Gas sensing layer | $SnO_2$ |
| 2 | Electrode | Au |
| 3 | Electrode line | Pt |
| 4 | Heater coil | Ni-Cr alloy |
| 5 | Tubular ceramic | $Al_2O_3$ |
| 6 | Anti-explosion network | Stainless steel gauze (SUS316 100-mesh) |
| 7 | Clamp ring | Copper plating Ni |
| 8 | Resin base | Bakelite |
| 9 | Tube Pin | Copper plating Ni |

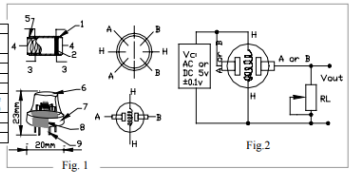
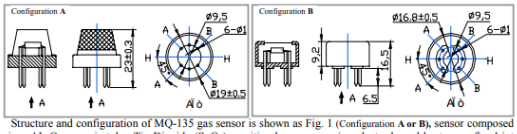



Fig.2

Fig. 1




Structure and configuration of MQ-135 gas sensor is shown as Fig. 1 (Configuration **A or B**), sensor composed by micro $AL_2O_3$ ceramic tube, Tin Dioxide ($SnO_2$) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive components. The enveloped MQ-135 have 6 pin ,4 of them are used to fetch signals, and other 2 are used for providing heating current.

Electric parameter measurement circuit is shown as Fig.2

E. Sensitivity characteristic curve

Fig.2 sensitivity characteristics of the MQ-135

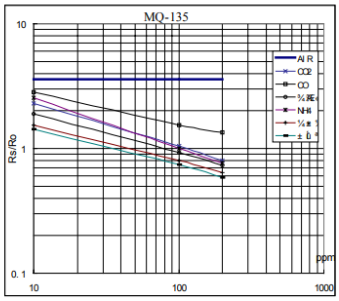



Fig.3 is shows the typical sensitivity characteristics of the MQ-135 for several gases.
in their: Temp: 20
Humidity: 65%
$O_2$ concentration 21%
RL=20kΩ
Ro: sensor resistance at 100ppm of $NH_3$ in the clean air.
Rs:sensor resistance at various concentrations of gases.

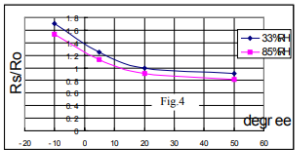
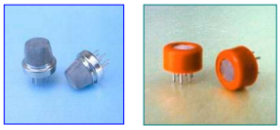



Fig.4 is shows the typical dependence of the MQ-135 on temperature and humidity.
Ro: sensor resistance at 100ppm of $NH_3$ in air at 33%RH and 20 degree.
Rs: sensor resistance at 100ppm of $NH_3$ at different temperatures and humidities.

**SENSITVITY ADJUSTMENT**

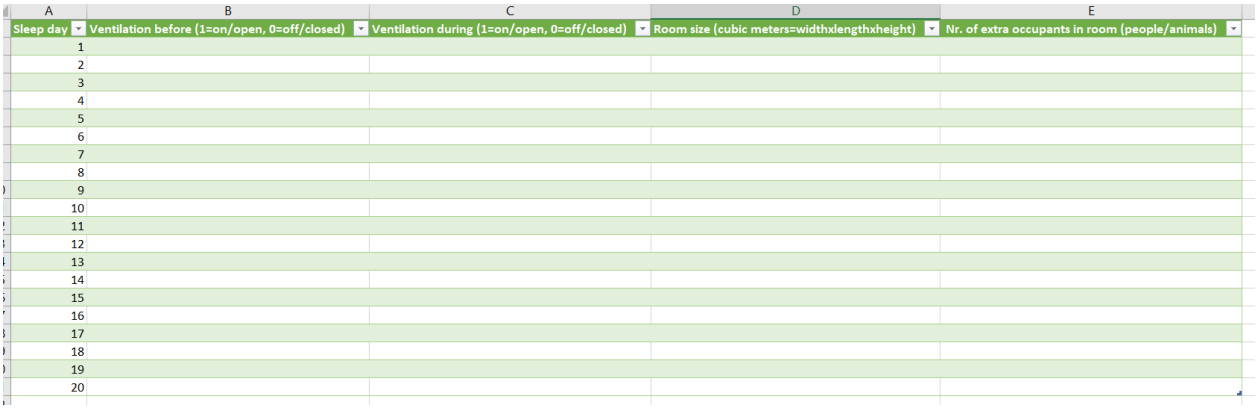
Resistance value of MQ-135 is difference to various kinds and various concentration gases. So,When using this components, sensitivity adjustment is very necessary. we recommend that you calibrate the detector for 100ppm $NH_3$ or 50ppm Alcohol concentration in air and use value of Load resistancethat( $R_L$) about 20 KΩ(10KΩ to 47 KΩ).

When accurately measuring, the proper alarm point for the gas detector should be determined after considering the temperature and humidity influence.



source: Use introduction of HS-129 type gas sensitive components (olimex.com)

## Appendix C – Empty influencing factors



| | A | B | C | D | E |
|---|---|---|---|---|---|
| | Sleep day | Ventilation before (1=on/open, 0=off/closed) | Ventilation during (1=on/open, 0=off/closed) | Room size (cubic meters=widthxlengthxheight) | Nr. of extra occupants in room (people/animals) |
| | 1 | | | | |
| | 2 | | | | |
| | 3 | | | | |
| | 4 | | | | |
| | 5 | | | | |
| | 6 | | | | |
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| | 19 | | | | |
| | 20 | | | | |