Influence of air temperature and precipitation amount on office workers' physical activity during work hours in the Netherlands

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1. INTRODUCTION

UPDATED – 26 JUNE 2018 Over the last century, physical activity has decreased immensely, while food intake has drastically increased. This results in an increase in the amount of people with obesity of 550% since 1986 [3]. Currently, 39% of all American women and 33% of all American men suffer from obesity [7]. Next to smoking, obesity is the biggest preventable cause of death [2], which means that anything designed to help people become more physically active or reduce their food intake could possibly help save someone's life.

Over the last years, wearable activity trackers have become popular to get in shape. These trackers, usually in the form of a watch, quickly show the user his or her activities, sleep patterns, heart rate and the number of burnt calories among other things. All this data is measured by the tracker to create awareness of ones activity throughout the day.

One of the biggest goals among activity tracker users is usually to become more physically active. The weather can be a factor that causes someone to either be more motivated to go for a walk or be more inclined to stay inside. Studies show that the amount of precipitation and the difference in temperature can influence the number of steps a person takes [13]. This study will focus on the influence of air temperature and precipitation on office workers' physical activity pattern during working hours in the Netherlands.

1.1 Relevance

As obesity is the second biggest preventable cause of death [2], it is important to research what the causes are and how obesity can be prevented. As mentioned previously, around 35% percent of the population has obesity in the US, and this number is even higher for office workers [7]. In order to find the cause behind this, researchers need to look beyond the obvious suspects, such as food- and drink intake. Plenty of research has been done on the field of nutrition and the consequences of poor nutrition on health are now common knowledge. However other possible influences such as weather are overlooked. There is a literature gap on this subject, not much research has been done. Therefore, this research will look at the weather and how it infuences office workers' activity pattern. It is relevant for two reasons. To start with, designers can make use of this information in future designs, and particlurary in designs which will improve office workers' physical activity. The second reason is to create more awareness of other factors which may influence physical activity. This paper aims to give new insights in the relation between weather and office workers' physical activity pattern.

1.2 Scope

The research described in this paper will focus on collecting step data of office workers during working hours and comparing it to online available weather data in the region of the subjects' office space to see whether the weather has an influence on their physical activity pattern.

Office worker

An office worker is an employee who works in an office, especially engaged in administrative or clerical work [11].

Physical activity

There are many parameters for measuring physical activity (e.g. step count, heartbeat, acceleration, sweat). However, in this paper, only step count is considered as physical activity.

Weather data

Hourly weather information from the subjects' region will be obtained from the Royal Netherlands Meteorological Institute (KNMI) online archive [12]. In particular, air temperature (in 0.1 degrees Celsius) at 1.50m altitude during observation, and the sum of precipitation (in 0.1 mm) will be obtained. Furthermore, it is important to mention that in this paper a summer day applies when air temperature is 25.0 °C or higher, which is the definition of a summer day in the Netherlands [14]. Everything below 25 °C is not considerd as a summer day.

Step count data

Step count data will be obtained using a dedicated pedometer: MiBand 2 [13]. Each participant will wear this device at all times during the trial. Step count data will be synced through dedicated mobile device apps: Google fit and Apple health.

Working hours
Working hours in the Netherlands depend on the company, but as each participant is working between 9 am and 5 pm, data will be obtained only is this time period.

2) LITERATURE RESEARCH

Many studies focus on the influence of weather on the activity pattern of office workers. For example, Japanese researchers studied the walking pattern of Japanese office workers during summer and winter. The researchers observed a significant reduction in walking during winter, compared to summer [5]. In another study, researchers studied the effect of typical and extreme Finnish weather conditions on office workers in Finland (e.g. air temperature). They discovered that office workers are more comfortable and productive in summer conditions in the office [1]. In a somewhat similar study, Indian researchers studied the effects indoor environment may have on office workers' performance, among other things. They found out that the impact of indoor room temperature on office workers' performance is almost twice as big as the effect of illumination [10].

Due to strong growth in the use of connected devices in recent years [6], more studies now use such devices to measure the influences of weather on the activity pattern of people. For example, in a longitudinal English study, researchers used pedometer self-monitoring to collect 365 days of data to explore the natural variability of physical activity of people. They found a significant seasonal difference in steps per day (summer > winter, $F = 7.57$, $p = .001$) [9]. There are also a few studies which focus on office workers. For example, in an on-going Japanese study, mobile GPS- and weather data (e.g. air temperature, precipitation amount) are used to detect the weather's effect on after-work habits of office workers in Tokyo [4].

Thus far, previous related work has mainly focused on the weather's influence on office workers, which is often related to clerical performance and productivity. However, there is little focus on the weather's effect on the physical activity pattern of office workers during work. The work described in this paper is novel, because it focuses on the influence of outdoor weather parameters on office workers' activity pattern during working hours.

3) RESEARCH QUESTION

3.1 Research question

This research focuses on the weather's effect on the physical activity pattern of office workers during work hours. It will focus on air temperature and precipitation and whether these factors influence their physical activity pattern. Regarding the physical activity pattern, the focus will be on the office workers' step count, as these are easily measured and a relatively accurate respresentation of an office worker's activity pattern.

The research question is formulated as follows:

Research Question (RQ): To what extent do air temperature and precipitation amount influence the physical activity pattern of office workers during work hours in the Netherlands?

3.2 Hypothesis

The following hypotheses were formulated:

Hypothesis (H1): Office workers' step count increases when air temperature increases.

Hypothesis (H2): Office workers' physical activity decreases when precipitation amount increases.

The hypotheses are formulated in this way for two reasons. To start with, studies showed that office workers are more active in summer days. They have a higher step count, they perform better, and are more comfortable [1,5,10]. Secondly, some studies used connected devices, such as sport bands and mobile phones, to measure the influences of weather on the activity pattern of humans [4,9]. These studies showed activity increase in summer days. Considering the previous related work, the formulated hypotheses (H1,2) are considered true.

4) METHODOLOGY

4.1Data collection

Step count data is collected using 5 identical Xiaomi MiBands 2, which are synchronized to a smartphone. All data is collected using Google Fit and Apple Health. 3 researchers will use Apple Health and 2 researchers will use Google Fit. Raw data from the Mi band 2 refreshes every fifteen minutes in the Google Fit app and every 10-30 minutes in Apple's Health app. However, data points are taken every second on both apps. All functions of phone sensors are disabled and only the data gathered by the MiBand 2 is collected, as, contrary to the MiBand 2, the participants do not carry their phone everywhere.

Hourly weather information from the subjects' region is obtained from the Royal Netherlands Meteorological Institute (KNMI) online archive [11], and in particular air temperature (in 0.1 degrees Celsius) at 1.50m altitude during observation, and the sum of precipitation (in 0.1 mm).

4.2 FAIR principles

This research is conducted through the FAIR principals, FAIR stands for *Findable, Accesible, Interoperable and Re-useable*. The data is findable and accesible due to the way that it is clearly structured and presented in this paper. The data is retrievable with a communications protocol. The protocol is open, free and implementable. The metadata is accessible, also when the data is not available.

The data is interoperable and reusable because it is converted to hourly intervals, therefore it can be compared with any other data that is also measured on hourly intervals. A formal and accessible language is used to represent knowledge. The vocabulary follows FAIR principles. Other researchers are able to establish the validity of the data and use the data for future research.

Before starting the research, no opinions on the correlation between the physical activity of office workers and the weather were discussed with the participants to avoid being biased. No opinions were shared with the participants to avoid influencing their data. Any form of feedback, criticism or compliments have been received well and have been processed in the final paper.

All particpants have been made anonymous to protect their privacy and all participants have signed an informed consent form to prove they were willing to participate. The participant did not partake in any harmful activities concerning our research. The research was done according to the TU/e code of conduct and the FAIR principles.

4.3 Data preprocessing

Raw data from Google Fit and Apple Health has been transferred to a workable worksheet using Microsoft Excel. This yielded a data base containing 25 unique records of office workers' step count during working hours.

4.4 Descriptive statistics

All visualisations are made by importing the workable worksheet in Tableau. The step count data of the office workers is compared to KNMI wheather data. This is plotted against eachother by using linear graphics for activity and a floating line for temperature and precipitation.

All the data of the office workers will be plotted in graphs;

Precipitation(bar)/Activity(bar)(y-axis) - Time(x-axis)
and
Temperature(line)/Activity(bar)(y-axis) - Time(x-axis).

After that an avarge graph can be derived from the data;

Activity(y-axis) – Temperature(x-axis) and Activity(y-axis) – Precipitation(x-axis).

These averages show at what temperature/precipitation the activity is highest. See appendix.

5. RESULTS

5.1 OVERVIEW

After the research was conducted with the office workers, all the data (from participants A-E) was analyzed and visualized using Tableau. All the raw data can be found in the appendix.

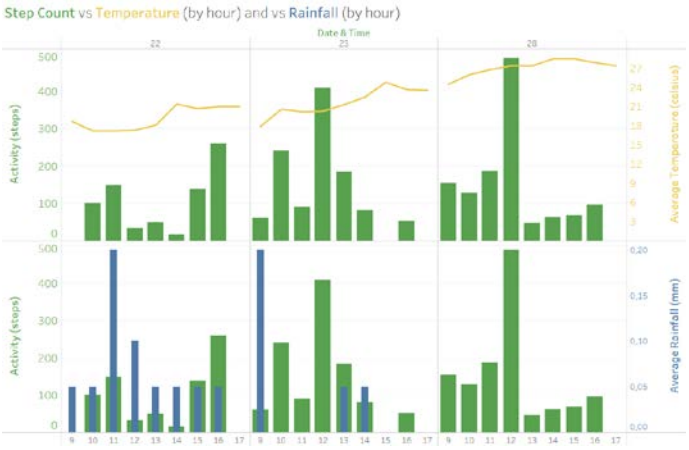

Figure 1 : Data participant A. At the top graphs the step count per hour is compared to temperature (Celsius), at the bottom graphs the step count per hour is compared to rainfall (mm).

This is the activity of one office worker during working hours, as you can see its activity between 12 and 13 increased a lot.

5.2 TEMPERATURE

KNMI provides temperature data in 0.1 degrees Celsius therefore this was converted to degrees Celsius using the following formula in a calculated field:

Temperature filtered = T / 10

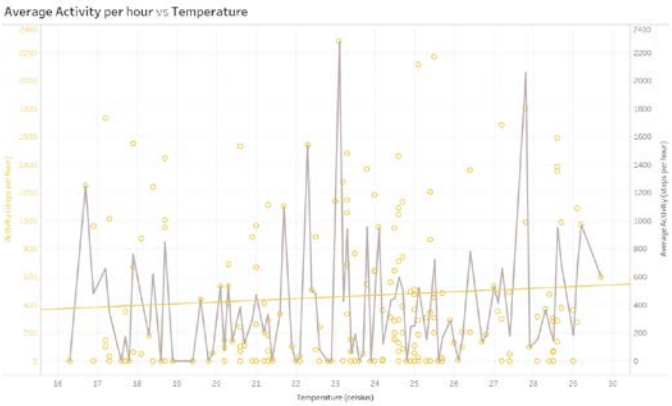

Figure 2: Step count per hour for all measured temperatures (Celsius).
Step count = 12.2689 * Temperature filtered + 173.6
R-Squared: 0.0054359
P-Value: 0.299977

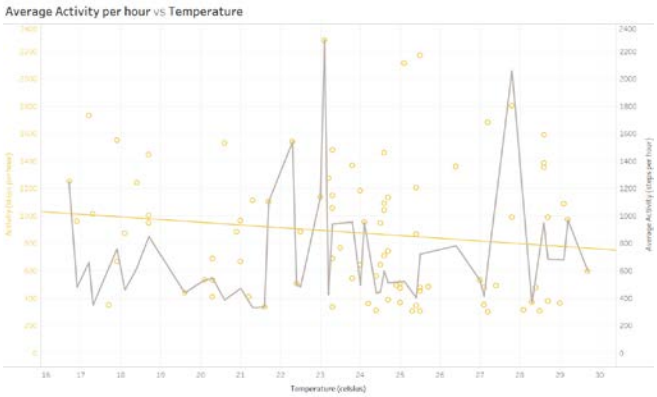

Figure 3: S**tep count per hour (minimal 300) for all measured temperatures.**

Step count = -9.79586 * Temperature filtered + 1138.37

R-Squared: 0.0036869

P-Value: 0.0563148

5.3 RAINFALL

KNMI provides rainfall data in 0.1 mm therefore we filtered this to mm using the following formula in a calculated field:

Rain_divided_by_10 = Rain / 10

KNMI uses -1 to indicate rainfall below 0.05 mm therefore this was filtered using the following calculated field:

IIF([Rain_divided_by_10] < 0, 0.05, [Rain_divided_by_10])

This if statement checks whether a value is negative and turns it into 0.05 mm rainfall

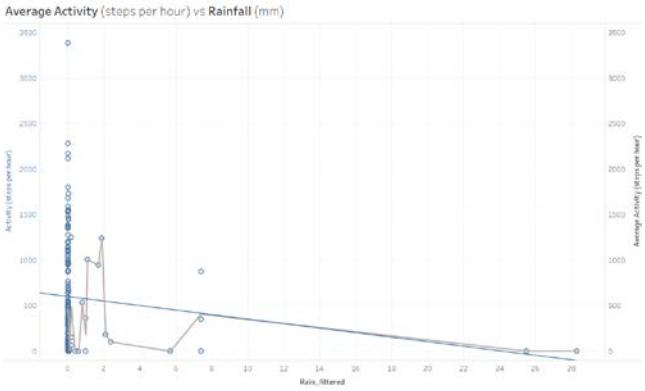

Figure 4: Step count per hour for all measured rainfall (mm) decreases when more rain falls.

Step count = -24.8518 * Rainfall filtered + 599.055

R-Squared: 0.0192699

P-Value: 0.0870301

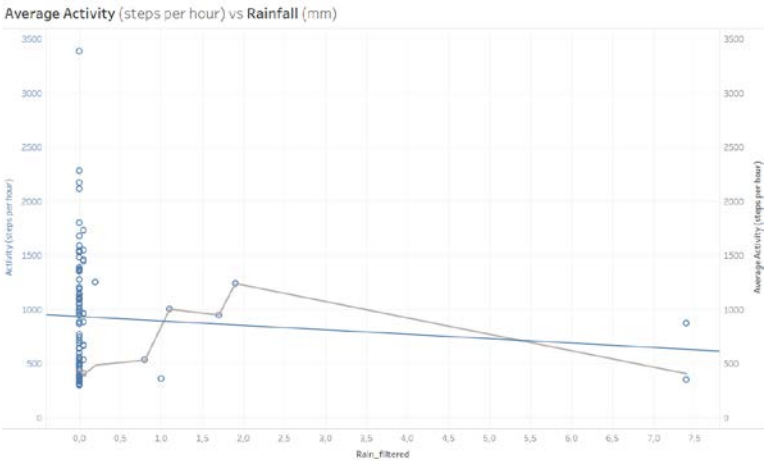

Figure 5: Step count per hour (minimal 300) for all measured rainfall (mm) decreases when more rain falls.

Step count = -40.8719 * Temperature filtered + 933.272

R-Squared: 0.0071762

P-Value: 0.429938

These graphs are scattered plots of the activity on every measured temperature/precipitation, the grey line is the average activity at every measured temperature/ precipitation and the yellow/blue line is the trend line of all the measured activities.

The unfiltered graphs (figure 2 and figure 4) are the average activity per hour for each measured temperature or precipitation, the filtered graph (figure 3 and figure 5) is the average activity per hour for each measured temperature or rainfall however the values bellow 300 are filtered out. This for the reason to analyze only the bigger activities, the graphs filtered out all the small walks for example getting coffee etc.

Figure 2 shows an upward trendline which shows that the average activity per hour increases when the temperature increases. Figure 3 shows that the average activity per hour decreases when the temperature increases, this could be for the reason that when people are going home for example they do the bigger activities anyways, no matter the temperature or precipitation. Figure 4 and figure 5 both show a downward trend which shows that the average activity per hour decreases when the rainfall increases.

6. CONCLUSION

Summary results

From the gathered data it can be concluded that air temperature has a positive correlation (H1) and rainfall has a negative correlation (H2) with the physical activity of office workers. Both hypotheses have been confirmed.

Although both hypothesis have been confirmed, all measurements were done during one season. Amounts of sunlight and difference in temperature of the average temperature of the month should also be taken into account in the future.

The trendline of the office workers is based on the average off all data collected on the office workers. It's a representation off the whole group. Differences can occur on individual scale. This was taken into account, but since the research is based on the average office worker, the behavior trendline is seen as representative.

Qualitative data is needed to analyze the exact impact of the temperature, the researchers can now only make assumptions on the type of activity of the office worker. Drawing a conclusion can thus be difficult, since some activities like biking to work or walking will always be done, even if the temperature stays the same, because the workers always have the need to change workspaces or work in certain areas. With qualitative data, the researchers could have analyzed if the workers took walks because it was needed or because they wanted to.

To come back to the research question; from the results it was calculated that the average step count per hour is 415 when temperature is below 25 degrees Celsius and that the average step count per hour is 467 when temperature is above 25 degrees Celsius.

Limitations

The first limitation is that only 5 persons were tested during the user study. Testing more participants would have yielded better and more grounded results. The second limitation is that the Mi Band 2 did not work properly at all times. The researchers noted that some sport bands did not record data for several hours during the course of the user study due to an inexplicable reason. However, this only happened a few times and therefore it is negligible compared to the useful collected data. The third limitation is that the precipitation amount during the user study was small. More precipitation amount over a longer period of time during the user study would have helped to analyze its implications on physical activity better. The fourth limitation is that most of the tested office workers work part time. Therefore, less data has been collected during a trail period. More data would have yielded better and more grounded results.

Future work

The authors found a literature gap with regards to the weather's influence on office workers' physical activity during work hours. Therefore, this papers presented a method for collecting data about step count and comparing it with weather data to examine the influence of the latter on activity. The obtained findings confirmed the hypotheses which shows that outside weather factors actually influence activity in office workers.

The scientific contribution of this paper is thus a method for examining the influence of different weather factors on office worker's physical activity. Although this method was successful to some extent, there are still some areas where the authors see potential for further deepening. To start with, user data was collected during a very short period of time with little or no precipitation. Therefore, the conclusion with regards to H2: '*office workers' physical activity decreases when precipitation amount increases'* is not reliable, since it is based on very little data points. For this reason, future work should focus on collecting step count data over a longer period of time, and preferably throughout the year. In this way the effects of precipitation amount on physical activity can be measured to a larger extent. In addition, collecting step count data over a longer period of time will reveal the effects of temperature difference between seasons on office workers' physical activity, which will improve the conclusion with regards to H1: '*Office workers' step count increases when air temperature increases.'*

Future work should also focus on collecting data about more weather factors and in particular: humidity, duration of sunshine, and wind speed. These factors are mentioned in previous related work about physical activity as influential, and therefore may have a significant effect on office worker's physical activity.

Finally, the researchers collected user data from five young and fit office workers (around 20-25 years old) consisting only of step count, ignoring important physical factors (e.g. age, fitness level). Therefore, the conclusions in this paper do not say much about the physical activity pattern of the average office worker in the Netherlands. For this reason, future work should focus on testing a large variety of office workers with divergent age and fitness level.

Managerial implications

The obtained results and method described in this paper can be implemented in current- and future applications. Think of digital coaching software such as CtrlWork (pronounced as Control Work), which stimulates office workers at Eindhoven University of Technology to regularly take brakes during data entry work, and make it possible to optimize their work and workload in a more efficient and healthy manner based on their computer behavior [8]. Combining physical activity and weather factors will help CtrlWork to monitor office workers better, also outside the office. In this way, office workers' work and workload can be optimized even better. Another example for future use of the method described in this paper is to implement it in mobile sport- and healthcare applications. Current apps such as Google Fit and Apple Health are 'dumb': they collect sensor data, but do not translate it to outside factors. Taking weather data into account will help such apps to monitor physical activity better, and personalize it even more.

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8. REFERENCES

1. Mia Ala-Juusela and Masanori Shukuya. 2014. Human body exergy consumption and thermal comfort of an office worker in typical and extreme weather conditions in Finland. *Energy and Buildings* 76: 249–257. https://doi.org/10.1016/J.ENBUILD.2014.02.067

2. Mathieu Bélanger, Katherine Gray-Donald, Jennifer O'loughlin, Gilles Paradis, and James Hanley. 2009. Influence of Weather Conditions and Season on Physical Activity in Adolescents. *Annals of Epidemiology* 19, 3: 180–186. https://doi.org/10.1016/j.annepidem.2008.12.008

3. Centralohiobariatrics.com. Obesity in America — Central Ohio Bariatrics. Retrieved May 25, 2018 from http://www.centralohiobariatrics.com/obesity-in-america/

4. Karlvin David C Cuaresma, Teerayut Horanont, and Ryosuke Shibasaki. 2013. Usage of Large Scale Mobile GPS Data : Detection of Weather Effect to After Work Habits of Office Workers in Tokyo. 7. Retrieved May 19, 2018 from http://a-a-r-s.org/acrs/administrator/components/com_jresearch/files/publications/SC03-0885.pdf

5. Takahiro Mitsui, Tomoko Barajima, Michihiko Kanachi, and Kiyoshi Shimaoka. 2010. Daily walking activity among male office workers in a rural town in northern Japan. *Journal of physiological anthropology* 29, 1: 43–6. Retrieved May 19, 2018 from http://www.ncbi.nlm.nih.gov/pubmed/20453433

6. Shilpa Phadnis. 2016. Households have 10 connected devices now, will rise to 50 by 2020, IT News, ET CIO. *ETCIO.com*. Retrieved May 12, 2018 from https://cio.economictimes.indiatimes.com/news/internet-of-things/households-have-10-connected-devices-now-will-rise-to-50-by-2020/53765773

7. Stateofobesity.org. Obesity Rates & Trends Overview. Retrieved May 6, 2018 from https://stateofobesity.org/obesity-rates-trends-overview/

8. TU/e. CtrlWork. Retrieved June 18, 2018 from https://intranet.tue.nl/en/university/services/information-management-services/ict-services/help-and-support/software-tue-device/ctrlwork/

9. Catrine Tudor-Locke, David R. Bassett, Ann M. Swartz, Scott J. Strath, Brian B. Parr, Jared P. Reis, Katrina D. DuBose, and Barbara E. Ainsworth. 2004. A preliminary study of one year of pedometer self-monitoring. *Annals of Behavioral Medicine* 28, 3: 158–162. https://doi.org/10.1207/s15324796abm2803_3

10. Komalanathan Vimalanathan and Thangavelu Ramesh Babu. 2014. The effect of indoor office environment on the work performance, health and well-being of office workers. *Journal of environmental health science & engineering* 12: 113. https://doi.org/10.1186/s40201-014-0113-7

11. Office worker | Definition of office worker in English by Oxford Dictionaries. Retrieved May 20, 2018 from https://en.oxforddictionaries.com/definition/office_worker

12. KNMI - Uurgegevens van het weer in Nederland - Download. Retrieved May 20, 2018 from https://projects.knmi.nl/klimatologie/uurgegevens/selectie.cgi

13. Mi Band 2 - Mi Global Home. Retrieved May 20, 2018 from http://www.mi.com/en/miband2/

14. 2018. KNMI - Zomerse dagen. Retrieved June 17, 2018 from https://www.knmi.nl/kennis-en-datacentrum/uitleg/zomerse-dagen