Measuring Eating Speed with the Sensory Interactive Table

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ABSTRACT

Over the past few decades, more research is done on eating behavior of humans. Tools like diets and exercise programs exist to help people live healthier. Other, less conventional tools, are being developed to give humans yet another tool to help them living a healthier lifestyle. One of these tools is the Sensory Interactive Table (SIT), developed in 2019. This table uses weight sensors en LED lights to register eating behavior and give appropriate feedback. Since the SIT has been developed recently, not much research had been done on the table as of yet. The goal of this research will be to register data from a real-life dining setting with human interference, analyse the data and suggest how eating speed can be deducted from the data-set.

Keywords

SIT, Sensory Interactive Table, Eating speed, Data analysis

1. INTRODUCTION

1.1 Introduction

Eating behavior has become a popular topic of research in the past decade. More people have eating disorders or health issues, like obesity, then ever. James et al. [4] mentioned in their 2001 study that obesity is on the rise in most parts in the world. In the 21st century, this problem has most likely only gotten worse and therefore new technologies to encourage healthy eating need to be thought of.

One possible new technology was developed at the University of Twente in 2019. The Sensory Interactive Table (SIT) (as seen in figure 1) was developed by Haarman et al. [2] with the goal of being a tool in giving users insight into their eating behaviors. This can be done by dividing the table into parts and installing sensors into all of these parts. The SIT is divided into 199 hexagon-shaped modules that form a circular grid. Each module is equipped with a load cell and 42 LED lights.

Since the SIT is a relatively new technology, there is not a lot of research done on the table as of yet. At the time of writing, the hardware is fully functioning. The individual load cells can measure up to five kilograms with one gram precision, as seen in Haarman [2]. However, no research has been done on the analyzing of the data produced by the SIT. Therefore we will make first steps into looking into analyzing the data and suggestion what next steps in the research may be to further implement the table.

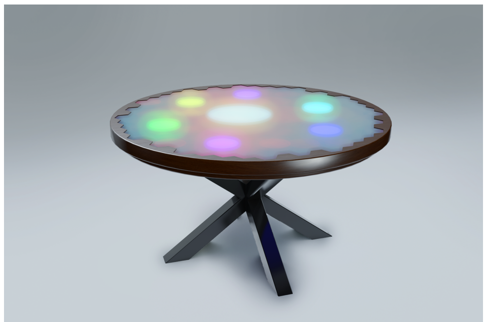

Figure 1: The Sensory Interactive Table

This research will answer the following research question:

Main research question: How can eating speed be extracted from the Sensory Interactive Table with human interference?

To determine the eating speed in a real life setting, multiple factors need to be taken into account. First, it needs to be determined how a base measurement will look. A base measurement is considered to be a plate with food at a known location that will encounter as close to no interference as possible. Second, there is the behaviour of people. During dinner, people can interact with a table in different ways, for example leaning onto the table. This will create extra noise in the sensor readings which need to be filtered. This adds two sub-questions that help answer the main research question:

Sub-question one: How can eating speed be extracted in a base measurement without human interference?

Sub-question two: What influence does human interference have on the data of the SIT?

This research will measure the eating speed in different dining scenarios, ranging from basic measurements to measurements with high human interference. Human interference in this study is seen as the pressure a human puts on the table while eating. The specific topic has been chosen since, according to Robinson [5], a high eating speed can be linked to more food consumed. Therefore, researching the extraction of eating speed can lead to the intended result of SIT, helping people achieve a healthier lifestyle. And since obesity is increasing according to James [4], the SIT will be a tool for people to avoid health issues as obe-

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sity.

In section 2 related work will be discussed. Section 3 will discuss the Methods used in the experiment. Section 4 will show the results. Section 5 will look at discussion points, section 6 will present suggestions for further research. Finally, section 7 will discuss the conclusions that can be drawn form the collected data.

2. RELATED WORK

This research will focus on recognizing eating behavior from both a controlled and dynamic environment. Ugurlu [6] researched whether the load cells could classify different actions on the Sensory Interactive Table. Ugurlu determined that classifiers for different eating actions could be up to 90 percent accurate in a controlled environment. Further research needs to determine whether this also applies to a dynamic environment.

De Boer [7] and Robinson et al. [5] researched if there is a relationship between the speed at which humans eat and the amount of food that they consume over te course of a meal. Both concluded that a high eating rate is directly linked to higher long term energy intake and higher BMI. Therefore, the measuring of the eating speed is a first step in reaching the final goal of the SIT: Assisting humans in living a healthier lifestyle.

De Vries et al. [1] and Higgs et al. [3] showed insights into the social eating behavior. When eating together with others, it is common to adapt to each others eating behavior. This is called the norm, according to Higgs [3]. The SIT can assist here by reducing the norm. This can be done by giving users individual feedback about their eating behavior.

3. METHODOLOGY AND APPROACH

3.1 Creating a data set

Since there is no existing data yet of a dining setting at the SIT, data collection is an important first step. This data will be collected in two different stages:

1. Base measurement
2. Interference measurement

All measurements are done in a static environment. According to Haarman [2], the load cells can achieve high accuracy. Therefore, the assumption is made that all parts of the table will show the same data since the weight of the plate is always the same. By using a fixed part of the table, the data extraction is made easier since it is known in advance which load cells need to be analyzed.

3.1.1 Base measurement

In the first stage, a plate was placed on the table at the predetermined position. During the measurements, bites will be taken in regular intervals. In later stages, this can be extended to changing intervals but since there is no data yet on this subject, it was decided to limit this research to fixed intervals. The bite size is also going to be fixed, this is for the same reason. Recognizing the bites is a first step, and making the bite size equal and of a known weight helps this process. And finally, since this is the base measurement, there is as little interference with the plate as possible. Hands will attempt to avoid touching the plate as much as possible when removing the food. All factors together will allow for the easiest recognition of the eating speed. This sets a base scenario for the eating speed that can be compared to later measurements.

3.1.2 Interference measurement

When the base scenario has been measured, interference can be added to the measurements. This will cause the load cells to register weight from the human pressure together with all the plates and food on the table. A real-life dining setting will also have users interfere with the table. So, this will simulate a dynamic environment, comparable to a real dining setting. However, this can cause a distorted measurement and might even make it impossible for the eating speed to be measured.

3.2 Experiments

The above mentioned steps will all be combined in two experiments. Both experiments will be done at eating rates between 5 and 30 bites per minute (BPM) with intervals of 5 BPM between the measurements. All measurements are done at least two times giving a minimum of twelve measurements per experiment. The two experiments are:

1. Placement of a plate at a known fixed position combined without human interference.
2. Placement of a plate at a known fixed position combined with human interference

A picture of the setup can be seen in figure 2. This picture was taken during an interference measurement (experiment 2). The setup for the base measurement (experiment 1) is the same as seen in figure 2, but instead of leaning onto the table, the table is not touched at all.

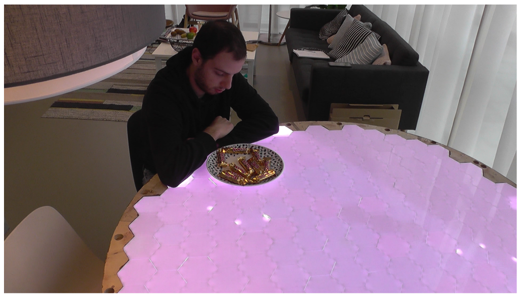

Figure 2: The measurement setup with the added interference

To ensure there is a fixed weight for each bite, the choice was made to use small chocolate bars, of a popular brand, of twenty gram each. This removes the variation in bite size making the recognition of bites easier because the jump in weight for each bite during the experiments is expected to be constant.

In experiment 1, the plate was put onto the table, as seen in figure 3. The index numbers of the load cells where the plate was standing on was noted and the experiment was done twelve times (at the mentioned BPM).

In the next step, the data is extracted, the unused load cells are removed (there are 199 total load cells total) and the results will be analyzed. Since this is the first type of experiment that is looking at the weight of a plate over the course of a meal, it is uncertain how the data will turn out and how it needs to be processed in order to make the data usable in later research. This will be the second part of the research, processing the data and making it usable for later research.

In experiment 2, an extra step will be added in comparison to experiment 1. Human interference will be added to the

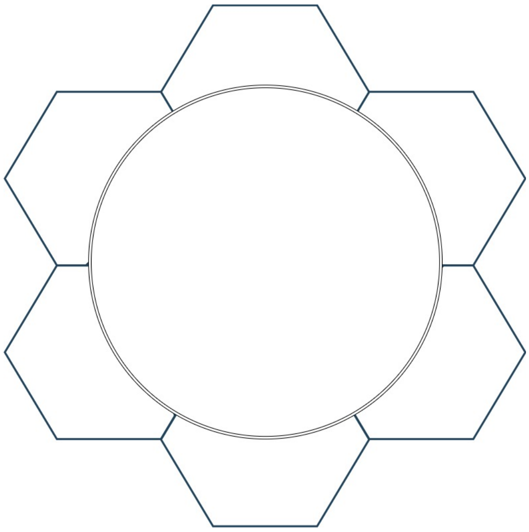

Figure 3: A schematic view of the setup of the plate on the SIT. The location of the base of the plate on top of the table is shown.

measurement by leaning onto the table in the area of the plate, as seen in figure 2. This is done because, in a real-life dining setting, humans also tend to have some interaction with the table. The most common form of interference is the use of elbows on the table. This is the interference that is also applied during the measurements in this part of the research.

The combination of the two experiments will lead to insight of the eating speed in both a basic and real-life setting. Since the quality of the data is unknown as of yet, the result of the measurements is hard to predict. The experiment will deliver an insight into this type of data so it can be used in later research or development.

4. RESULTS

4.1 Prepossessing data

After collecting the data, it needs to be processed before it can be analyzed. This happens in two stages. First, the unused load cells are removed. Second, a low-pass filter is applied.

4.1.1 Removing and adding the load cells

The raw data contains the data from all 199 load cells and as saved is a .txt file where there is one column for every load cell, 199 columns in total. This file needs to be opened and the irrelevant load cells will be removed. In this context, irrelevant load cells are all the load cells that are not in contact with the plate. The plate was placed on the table as seen in figure 3, where the base of the plate was touching six hexagon load cells. The load cell in the middle of the plate was untouched by the base. All load cells, not being part of these six are removed from the data, and the remaining have the load cell values added together. These six load cells are analyzed together instead of one at the time. In theory, the weight of the plate is distributed over all six load cells. Figure 4 shows what the data from the individual load cells looks like. As can be seen in figure 4, there are irregular time gaps between the bites seen. While the time difference is expected to be constant. However, when adding the six load cells together, regular loss of weight is noticed. The raw data can be seen in figure 5. As can be seen, the data is still a very messy. The raw data does allow for the human eye to detect the bites since there is weight loss at constant intervals. However, due to the noise level, a next step is needed in the processing of the data. A low-pass filter needs to be applied to remove the inaccuracies seen in the data.

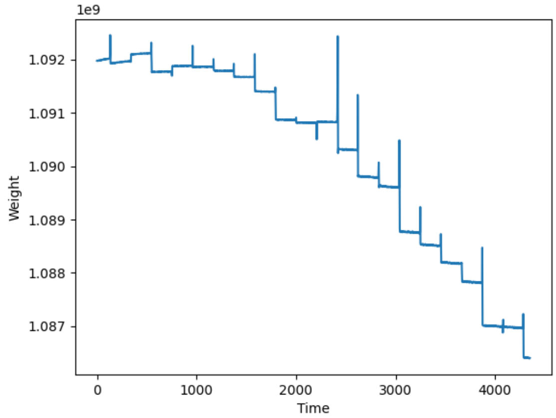

Figure 4: Raw data of one load cell

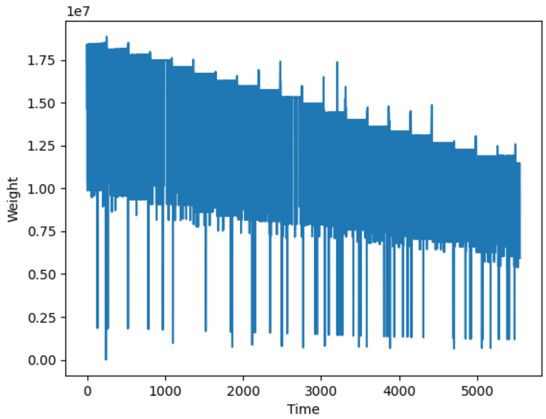

Figure 5: Raw data (at 5 BPM) from the base measurement

4.1.2 Low-Pass filter

To remove the noise from the raw data, a low-pass filter is applied. The reason why a low-pass filter needs to be applied here can be seen when enlarging the data from figure 5. This is seen in figure 6. It can be seen that across the whole measurement, high frequency spikes are present that will show inaccurate measurements. The low-pass filter will remove these high frequency spikes and will leave the other data. To use a low-pass filter, a cut-off frequency needs to be determined. The frequency set will determine which frequencies will be filtered out and which will stay in the data. All data with a lower frequency then the cut-off will remain, but the frequency above cut-off frequency will be removed. As a result, the inconsistencies in the data, as seen with the high frequency spikes, will be removed with the correct cut-off frequency and the requested data will remain.

The cut-off frequency used for the collected data was chosen by a trail method. If the cut-off frequency in chosen too low, then all data being below the chosen frequency will be passed through the filter, including the noise that is trying to be filtered out. A too high frequency chosen, will

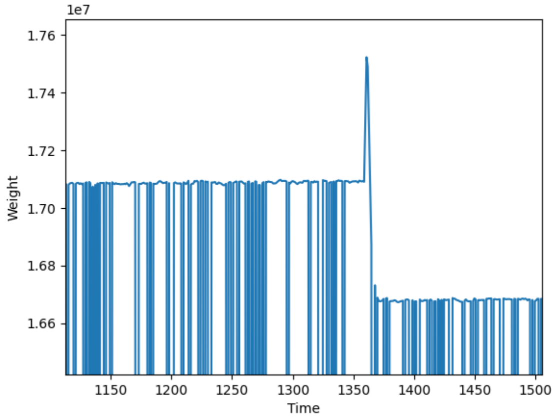

Figure 6: Enlarged raw data, 5BPM base measurement

result in all data being filtered out, leaving a straight line downward without any spikes or inconsistencies. Therefore, after some testing, a cut-off frequency of 0.025Hz was determined to be a suitable frequency for the data of the SIT. This allowed for a clear insight into the times a bite was taken.

4.2 Base measurement

After the experiment was done at the mentioned eating rates, the data was processed and analyzed. The raw data can be seen in figure 5 and the data after applying the low-pass filter is shown in 7. When looking at the results, it can be seen that the raw data does show a clear trend. The data shows a constant decrease in weight at the expected interval. There are upward spikes at the moments a bite is taken. This can be explained by the pressure that is put on the plate when grabbing a bite.

Looking at the data after applying the low-pass filter gives a clearer picture. While there is constant weight loss instead of the intervals where weight is lost. he removal of noise is a great asset to the data. The bites can still be determined because they can be linked to the upward spikes in figure 7. These spikes are the pressure added from taking a bite from the plate.

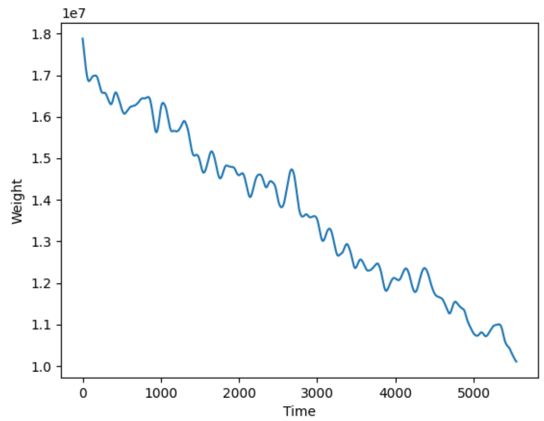

Figure 7: The data from figure 5 after applying the low-pass filter

4.3 Interference measurement

Next, the measurement was repeated with added human interference on the table next to and onto the plate. The expected result was that the bites would not be very visible with the naked eye without filtering the data. However, when looking at the unfiltered data, as seen in figure 8, it can be concluded that the bites can still be determined with the naked eye. Although, there is clearly more noise in the base data in figure 5, than in figure 8. As seen in figure 9, the processed data will show a general downward trend with spikes when a bite is taken. Although the data is more irregular, interference does still allow for the eating speed to be determined.

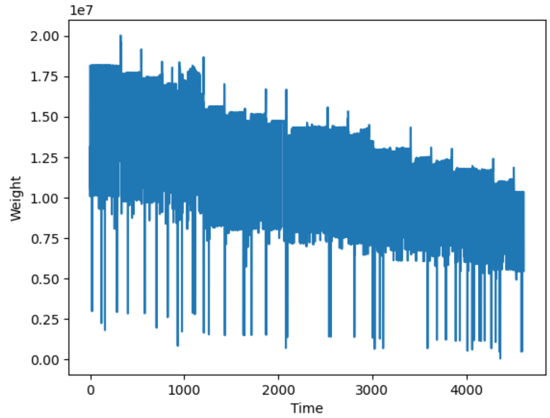

Figure 8: Raw data at 5BPM, with addition of interference with the plate

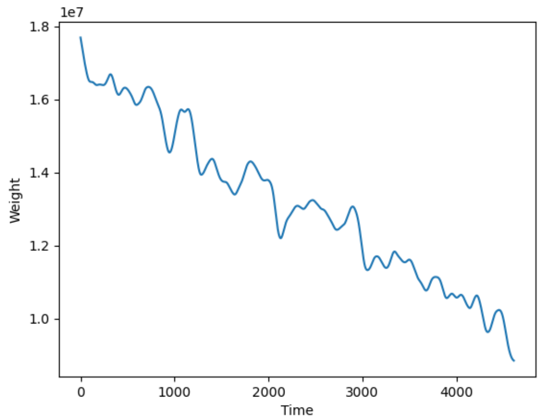

Figure 9: A low-pass filter applied to figure 8

5. DISCUSSION

5.1 Sensory Interactive Table

During the extraction of the data, it became clear that the table had a lot of noise in the measurements. This can have multiple causes. One possible cause may be friction between the load cells. On the SIT, all load cells are touching their neighbour load cells, and this adds the possibility that friction is also measured. The load cells are proved to be very precise so even a little friction might cause a lot of noise.

Next, the issue might also lay in the load cells themselves. Although precise, during the measurements it happened occasionally that the table would completely crash if too many load cells detected weight at the same time. This could mean that there is an error in the registering of the load cell data and that the load cells measure more data than the SIT can handle.

5.2 Plate dimensions

One of the goals of the research was to get an insight into the data when human interference is added. The idea was that the human would touch the same load cell as the one the plate is standing on. But due to the dimensions of the plate used this idea soon looked hard to pull off. The edge of a plate is wider than the base where the plate is standing on. This led to the situation where the plate was standing on one load cell, but the edge was over another load cell. Therefore human interference on the same load cell as the plate was impossible to accomplish. This was tried to overcome by not only leaning on the load cells next to the plate but also onto the edge of the plate. With the goal of registering the weight of the human arms. This added some interference but not as much as expected. When smaller plates are chosen such that interference on the same load cell is possible, this might show a different result.

5.3 Interference level

During the measurements, two different types of interference have been measured. No interference and maximum interference. There was no in between measurement. For example, leaning on the table with one arm, only leaning when taking a bite or leaning at random intervals could have been possible alternatives to the interference. By changing the types of human interference, for example by making the interference random, the weight can increase at random times. This can lead to the upward spikes not being related to a bite at times and this can potentially make the eating speed recognition harder. So, for a better insight in the data, different types of interference could have been used.

5.4 Plate positioning

For this research, the position of the plate was fixed at all times. However, for a realistic eating environment, it might have been better for the plate to change positions at unknown times. The fixed position was chosen to make the data extraction easier. However, when adding movement, it would add another difficulty to the data analysis. It could influence what load cells need to be measured. This feature would allow for a more realistic dining environment.

6. FUTURE WORK

6.1 Use of cutlery

During this research, cutlery of any form was not used. The food was taken from a plate with hands taking a bite, as if it was a plate of snacks on the table at a party. The pressure fingers put onto a plate might be different than cutlery will most likely have. Therefore, getting insight into how the data looks when bites are taken with cutlery might give different insights into the eating speed. Ugurlu [6] made a start in the classification of cutlery on the table but this was only done in a static environment, not a moving environment.

6.2 Measure different types of food

This research has focused on one specific aspect in a regular dining setting, consuming food off a plate. However, during a meal, different kinds of food can be served. A bowl of soup for example, is far less dense than solid food, making detection possibly harder since the weight reduction per bite is smaller. Therefore, a next research could focus on the effects of low density foods when detecting the eating speed with added human interference.

6.3 Different dining settings

This research has focused on one specific aspect in a dining setting. Future research of the table can possibly look into yet another aspect of dining. A second plate, a glass of water or a pan from which food is put on the plate can be added as well. Especially adding a second serving of food on a plate can be interesting. During a real dining setting it is common for a person to get a second serving when hungry. This will probably result in a big increase of detected weight at some point during the dinner. If this is properly recognized, this can be a big step in registering the total amount of food eaten by a user.

7. CONCLUSION

The results, as seen in section 4, show the results of the eating speed measurements in both a static and interference measurement. Here, it can be seen that human interference does influence the data. However, after conducting the experiments, it can be concluded that this interference is not high enough to corrupt the data. This means that the main research question can be answered the same for both the base and interference measurement.

To extract the eating speed from the Sensory Interactive Table, the data needs to be filtered with the use of a low-pass filter. Afterwards, when the correct cut-off frequency is chosen, the leftover data will show a clear downward trend with upward spikes at moments that bites are taken. With added interference, the upward spikes can vary in size. However, they can still be used to determine the eating speed. This is because, bites can be directly linked to the pressure onto the plate when taking a bite. Therefore it can be concluded that these upward spikes can be used to determine the eating speed on the Sensory Interactive Table.

8. ACKNOWLEDGEMENTS

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