Automatizing the measurement of Quality of Life in senior citizens with early-stage dementia using smart technology

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Abstract

This study investigates the monitoring of the Quality of Life (QoL) of senior citizens using a teddybear with built in sensors. Utilizing an accelerometer, a motion sensor and a sound sensor, we attempt to employ anomaly detection methods to track the activities of a senior citizen and estimate their QoL. The goal is to keep family members and caregivers updated with the QoL status and let them know if their support is required. In this work, a prototype of the teddybear was kept by a senior citizen for a week while keeping a diary of daily activities. Results show that the collected data can be correlated to daily activities relevant to measuring QoL levels.

1. Introduction

Dementia is a progressive declining illness which mostly affects senior citizens [1]. Notably, dementia is one of the most common and serious disorders in later life. It causes an irreversible decline in cognitive capacity, physical mobility, and has a personal, social, and health impact on those with dementia and their caregivers [2]. Besides that, due to the aging society trend in Europe, the percentage of citizens suffering from dementia is constantly rising. As dementia starts to set in, the patients face increasing risks which inevitably result in them moving to a nursing home. This project aims at developing solutions that will help patients remain living independently in their own homes. One possible way to cope with this is by utilizing new technologies to support the well being of senior citizens. One example of such solutions is “Paro” [3], a robotic seal toy designed to give seniors companionship. The toy proved quite successful and opened the potential for more interventions using toys as a deployment medium.

Here we explore the possibilities of monitoring the Quality of Life (QoL) of senior citizens by using anomaly detection methods [4] implemented in a smart teddybear. This automated monitoring the the QoL levels can guide caregivers in regulating their interventions to when it is most useful. The smart teddy aims to be an automated feedback system for caregivers informing them about the improvement or deterioration of the QoL of a senior citizen with early-stage dementia.

2. Methodology

2.1. Longitudinal observation

To research how measuring the QoL can be automated through smart technology, the smart teddy is be used. This smart teddy contains an accelerometer-gyroscpe configured to act as a tap sensor that can register how many times the smart teddybear has been petted, touched or carried. There is also a sound sensor measure the sound levels inside the room and a motion sensor to detect the amount of movement around the smart teddy. Great care has been put into choosing sensors that do not intrude on the privacy of the person being monitored to reduce the barrier to entry due to privacy concerns.

The smart teddybear is installed inside the participant’s living room. The smart teddybear collects data from the three sensors mentioned above and logs this every day. All the data collected is saved locally.

2.2. Daily Diary questionnaire

This work uses the Daily Diary Methodology, where a set of assessment methods allow researchers to study individuals’ experiences, behavior, and circumstances. This is done in natural settings, in or close to real time, and on repeated measurement occasions over a defined period. [5].

The diary allows the participants to note down their activities throughout the day. The aim is to find patterns in the sensor data that can be correlated to some of these activities. The participants also have to answer questions based on the

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DEMQOL questionnaire [2]. Only 19 questions of the 28 from the original DEMQOL questionnaire were included. Questions which are not possible to automate by the smart teddybear were left out of the questionnaire (e.g. quality of memory).

2.3. Participants

The target group of this study is senior citizens with early-stage dementia. In other words, those who are above the age of 60 and score 20 or more points on the MMSE (Mini-Mental State Examination) [6]. Besides that, we also constructed a set of additional requirements for our participants which must be met, which are:

- The participant needs to be living alone; sensor data will be collected from one individual inside their house. Multiple habitants would result in several different data sources and will interfere with the measurement of QoL of one individual.
- The participant needs to own a small apartment, preferably with the least amount of rooms possible.
- The participant should behave normally as in typical daily life; it is not expected of participants that they will be performing activities that they normally would not do if there wasn't a research setup.

In this preliminary study, only one participant was used who fit the age criteria. The participant did not suffer from dementia.

3. Results & Analysis

For the duration of the experiment, the participant had a stable DEMQOL score between 62-64 (the DEMQOL score can range between 19-76 with higher numbers indicating a better QoL). Table 1 shows that if motion activity of the participant increases and if many small clusters of motion are present, then for that day a higher DEMQOL score was calculated from the DEMQOL questionnaire. In addition, a decrease in motion activity accompanied with the absence of large motion clusters resulted in a lower DEMQOL score for that day. However, due to the lack of provided information of the participant with regard to his activities for those days, no explanation could be found.

Table 1. Patterns in motion activity

Motion detection	DEMQOL score	Explanation
Motion activity increases – many small clusters of motion	HIGHER	NONE
Motion activity decreases – absence of large motion clusters	LOWER	NONE

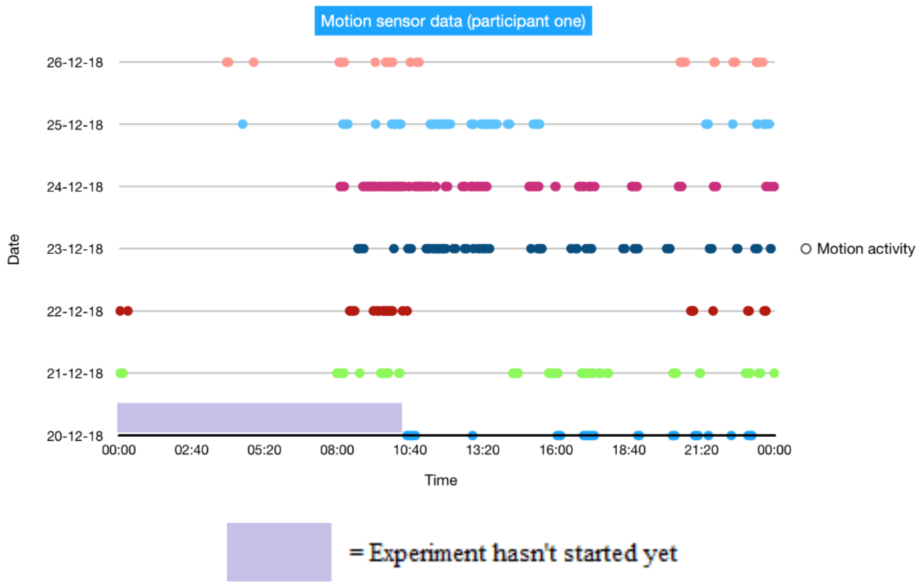

Figure 1. Motion activity of participant one for a week.

Figures 1 and 2 show the motion activity of the participant and the interactions with the smart teddy. The motion activity shows a regularity except for the dates 26-12-18, 25-12-18 and 22-12-18 for which the participant answered in the digital questionnaire that he was not at home for a full day. This regularity can be correlated with the DEMQOL score of this participant which had minor fluctuations.

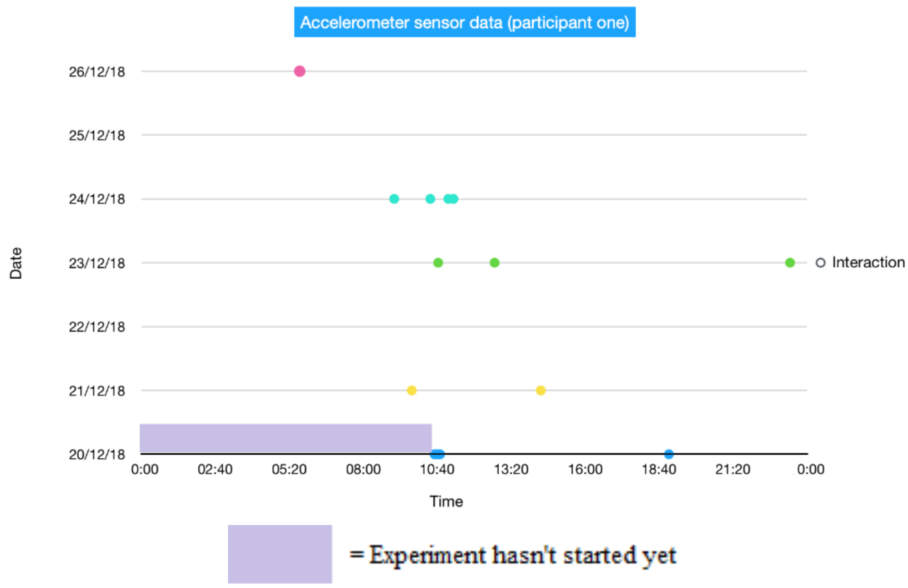

Figure 2. Interactivity with the smart teddybear of participant one for a week.

3.3. Estimation of DEMQOL score

On the graph below (see Figure 3) all the sensor data is combined from one (full) day. It shows the sound levels, motion activity and the interactivity with the smart teddybear. Additionally, based on the provided activities and their timespan in the Daily Diary, the graph is segmented in various color marked areas.

Furthermore, for the estimation of the DEMQOL score, the following elements were taken in consideration:

- Total number of interactions with the smart teddybear (more interactions indicate a lower QoL score).
- The variety of activities (more activities indicate a higher QoL score).
- Does the graph contain social-oriented activities (chatting) (more social activities indicate a higher QoL score).
- Is there a consistent sleep pattern without interruptions present (interruptions lead to a lower QoL score).

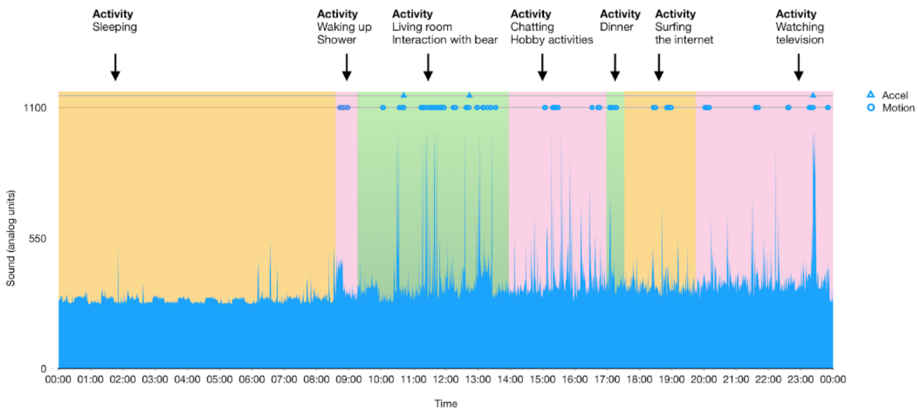

Figure 3. Interactivity with the smart teddybear for a day

The participant scored a DEMQOL score of 63 calculated from the given answers on this specific day. However, when strictly examining the sensor data of this graph in combination with the questions from the online questionnaire an assumption can be made that our participant should score a DEMQOL score of 67.

4. Conclusion & Discussion

According to Figure 1 and taking the DEMQOL score in consideration, one can hypothesis that more activity leads to a higher DEMQOL score. This of course needs to be confirmed with more data points. Interestingly, the participant evaluated his own QoL lower when the DEMQOL score was higher and his own QoL higher when the DEMQOL score was lower. This in itself is a noteworthy anomaly.

The results show potential to finding patterns in the sensor data. The sound sensor for example clearly shows the lack of activity during sleeping. Figure 3 clearly shows that sound measurements increase as soon as the participant wakes up as indicated by the participant in the diary and by the readings of the motion sensor. Since quality of sleep is an important indicator of QoL, this alone is quite a promising result. Still, it was witnessed that the absence of motion for a short period of time does not need to signify that the participant is sleeping or left the house. It can also mean that the participant is still inside the house and engaging in activities that do not require any movement. Therefore an increase in motion detection for the second participant did not lead to a higher QoL scoring and this can be explained by activities that do not involve movement inside or outside the house that have a positive effect on the QoL.

The sound sensor values and the motion sensor values also significantly increase on the days where there is a visitor. This may be a way to identify the amount of face to face social contact the senior is having. As another important indicator of QoL, this is another useful find. More work is needed however to identify the type of contact and avoid false positives. It may also be the case that the threshold of the sound level while being alone and while someone else is visiting is different for different people. Therefore some user tailored calibration may always be needed.

The high peaks in sound sensor values detected (see Figure 3) which always reach between 900 and 1000 analog units are anomalies which are difficult to explain. It would be interesting to find out what the source of these sound levels are. With the help of more hardware components (e.g. a microphone), it may be possible to find explanations for occurrences in each sensor individually.

The main conclusion can be summarized by stating that the smart teddybear has the potential to provide insight in the QoL for senior citizens. While working with a limited set of sensors carefully chosen so not to intrude on the privacy of the user, it is still possible to identify patterns indicating activities with a close connection to someone’s QoL. With further refinement of the pattern recognition models, it may be possible to identify more activities with a larger certainty.

However, during this research, we had to make a lot of assumptions based on the collected sensor data on whether patterns could be detected. These assumptions signify that the DEMQOL score from the self-assessment in the digital questionnaire does not differ much with our assumptions. Nevertheless, additional research with more participants is needed in order to confirm these assumptions. Thus, this article should only be used as a stepping-stone for further research.

It would be interesting to do follow-up research using, for example, an accelerometer programmed in such a way that can determine if the smart teddybear is picked up (instead of only when touched as it was here) to find other anomalies that can explain a significant increase or decrease in the QoL. Sensor data that can gather health information may answer other questions of the DEMQOL questionnaire that were left out of this research.

Another possible idea for measuring the memory of the participant is by designing an interactive game where users can reach a higher score the better their memory functions. Such creative solutions and workarounds can help in tracking more of the parameters relevant for estimating the QoL.

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