

# Diagnosing Dementia Using Smart Chair, Wearable Device, and Testing Apps

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**Early and reliable diagnosis of dementia can help patients and their caretakers to take timely actions, in terms of treatments and effective future planning. Sedentary positions can reveal a lot about patients' bodily movements, and so we use a smart chair installed with force sensitive resistors that record pressure points of a patient while taking a screening test. We expect that using combination of a smart chair, a wrist device, and screening test on an iPad, it is possible to diagnose most kinds of dementia earlier than the current methods with reliability.**

## I. Introduction

**D**EMENTIA is an umbrella term for the diseases that result in cognitive decline, symptoms of which can include memory loss or ability to perform usual activities [1]. This paper discusses dementia and its symptoms, how it affects an individual diagnosed with it, ways to treat or avoid it, and better, possibly quicker, and more effective approaches to diagnose than the current methods. Our focus is the combination of using a smart chair, a wearable device, and a Saint Louis University Mental Status (SLUMS) examination score, which yields signs of dementia.

Dementia has multiple forms, Alzheimer's disease being the most common [1], and its prevalence includes multiple stages. These stages begin with an asymptomatic phase when there are no apparent signs of dementia present, then they transition into a phase where the symptoms are not severe enough to be considered dementia, however, there are some cognitive changes such as forgetfulness, lack of focus, and behavioral inconsistency leading towards the diagnosis of Mild Cognitive Impairment (MCI) [2]. Final stage is when the symptoms of dementia are severely apparent and there is a drastic decline in the life quality of a patient.

Our objective is to develop and use an operational smart chair and a wrist device that records patients movements and pressure points during the clinical session when they take the screening test.

## II. Related Works

Multiple studies are available on smart chairs that record bodily movements through sensors, on tests that are used as screening test to diagnose dementia, and on wearable devices that measure an individual's cardiovascular conditions. However, the amalgamation of the three to diagnose dementia and its forms, to the best of our knowledge, has not yet been thoroughly explored. We are currently looking at the ground truth data (see the Data Analysis section below) available for patients that either have dementia or MCI and analyzing their measurements recorded using the smart chair and wearable device, and complementing their sensed data with the scores from the SLUMS test. First, we are going to explain the available work on why early diagnoses of dementia is helpful and desired. Second, we are going to compare the test available that help diagnose dementia and justify our choice of using SLUMS. Lastly, we are going to look at research done on using chairs to improve quality of life and describe how our initiative of using a smart chair for dementia patients can help in conducting reliable diagnoses.

### A. Desirability of Early Diagnoses

Symptoms are not present when dementia is developing, due to which the diagnoses can be easily missed [2]. On early diagnoses, the patients, as well as the care takers of the patients, can gain sufficient amount of time to prepare for the necessities required for the treatment. During this asymptomatic stage, there may be precursor biological and neurological changes occurring, which might lead to early symptomatic stage [2], where the patient starts to suffer with symptoms like minor memory loss or mild cognitive impairment (MCI).

So, what does it mean to be diagnosed early? According to the Cambridge Dictionary, "early," means "near the beginning of (a period of time), or before the usual, expected, or planned time." While "near the beginning of time,"

suggests the diagnoses when there is no evidence of benefit or harm [3], “before the usual, expected, or expected,” suggests premature revelation, which indicates possibility of harm. Therefore, “early” is good enough if it allows early treatment, as well as the ability to plan future effectively such that access care and support that can be made available or possible by advanced decision making [3].

Our goal is to develop screening tools and diagnostic approaches that have high sensitivity and specificity: where sensitivity measures the correct identification of patients with dementia, while specificity measures the correct identification of people without dementia [4]. In other words, our goals include conducting a session with a smart chair, wearable device, and the SLUMS score such that the percentage of people correctly identified and correctly reject is high. Our major goal is to be able to identify symptoms of dementia at comparatively earlier stages such that the severe consequences can be avoided or timely treated. However, currently, there are no treatments available for dementia that slow down or prevent its prevalence [3].

## **B. Why SLUMS?**

There are several screening tests that are used to diagnose dementia, including Mini-Mental State Exam or Folstein Test [5] and Montreal Cognitive Assessment [6]. Tariq et al. [7] conducted a comparison between SLUMS and Mini-Mental State Examination for detecting dementia and MCI. In their study, they revealed that although both SLUMS and MMSE are able to identify dementia with high sensitivity and specificity, MMSE doesn't perform as well as SLUMS for MCI [7].

SLUMS examination is a screening method for kinds of dementia [8], which consists of 11 items that measure a patients' memory, attention, orientation, and executive functioning such as planning, organizing, sequencing, and abstracting [7, 8]. Following from the comparison between MMSE and SLUMS from above, it has also been found out that SLUMS is a more difficult than MMSE. Total of 30 points is possible in both tests, however, SLUMS score is observed to be approximately five points lower than that of MMSE, which is why likely to be more sensitive to MCI [8].

## **C. What does a chair tell us?**

Simple pressure sensors installed in a chair can yield results about users' activity by recording information on different postures, hand movements, and head movements [9]. The body, which is the main physical entity between the user and the chair, produces numerous amount of information about the physiological parameters, body motions, as well as cognitive processes [10]. Arnrich et al. [9] describes work-related stress as a potential cause of hindrance faced in body functions. Back, neck, shoulder, arm-wrist-hand problems are a few examples that can result from abnormal stress levels. Our smart chair has pressure sensors on the backrest. The force sensitive resistors on the backrest sense body movements of the patient and wirelessly collects and stores this data in the receiver for stable and fast outcomes.

Sedentary positions can reveal a great amount of information about our stress levels. Either at work or home the we sit or relax can if our stress level is normal or not. Breathing, sitting position, body movements, can reveal about the pressure points. Lewy body dementia (LBD), a kind of dementia, resembles Parkinson's Disease and causes involuntary bodily movements in patients [11]. Recording such movements and observing the delays in response to a SLUMS score can direct clinicians' attention towards dementia, especially when there's no prior diagnosis available.

## **III. Data Analysis**

The variety of data recorded includes SLUMS score for each of the questions, pressure sensor data for all the 9 sensors, the data from the wearable device for 296 patients. Out of these, there is a ground-truth data available for 21 patients. Ground-truth data contains clinical diagnosis identifying patients with dementia, MCI, or normal (non-dementia and non-MCI) conditions.

Before conducting any analysis, a lot of data cleaning and organizing was necessary.

### **A. Cleaning**

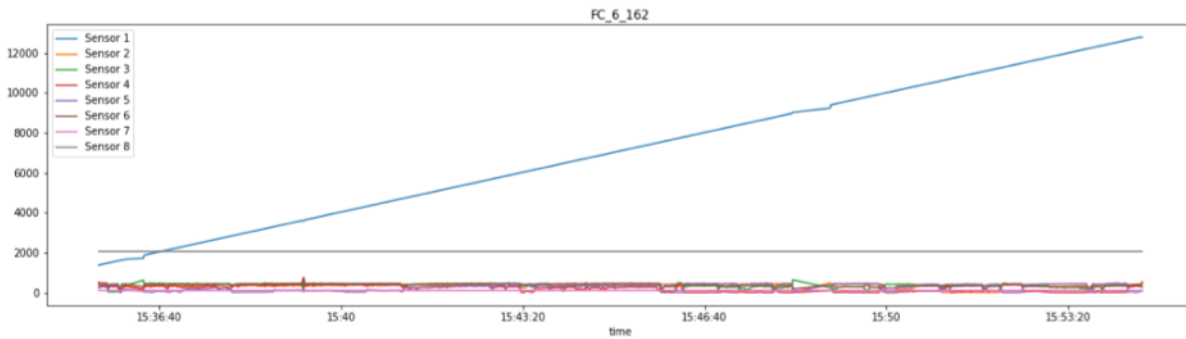
Given the volume of the data, the preliminary preparation to structure the data required:

- 1) manually assigning headers, which were initially included as repeated values in columns corresponding to their data value
- 2) importing new files, using Python, into Jupyter Notebook for analysis to make sense of the data
- 3) plotting to compare and find meaningful implications

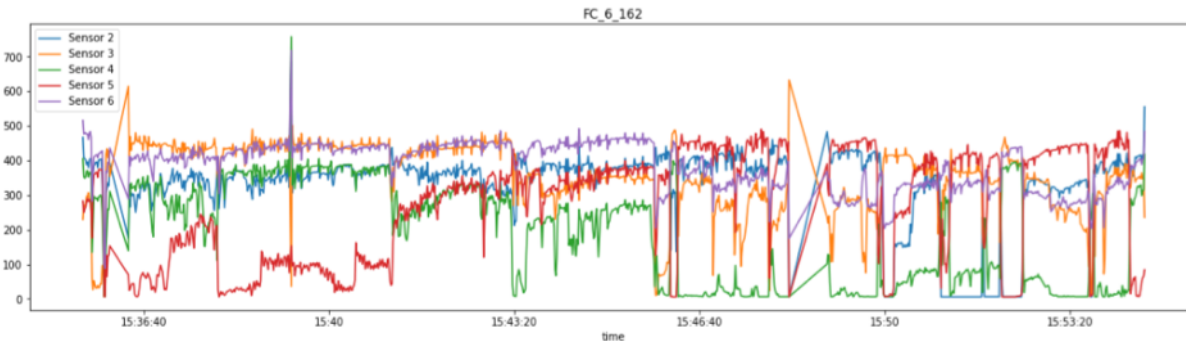
## B. Organization

The 21 patients for which we have the ground-truth data available, we separated the pressure sensor data, wearable device data, and the SLUMS score for each patient. Reading folders in Python for each patient, we stripped the columns with recorded time to convert it to `date_time()` to be able to conduct time-wise analysis. Some data files were separated using commas, while some were separated with whitespaces, making it difficult to read them altogether.

## C. Analysis



**Fig. 1 Plot of all 8 sensors for a single patient.**



**Fig. 2 Plot of sensors that recording appropriate values for a single patient.**

Figure 1 shows the plot of the pressure sensors for a session of a single patient. As it can be observed, there are total 8 sensors, with a few of them producing bad values such that it is hard to see any meaningful activity. Deleting these sensors, in figure 2, the pattern can be observed recorded from the pressure sensors installed on the chair.

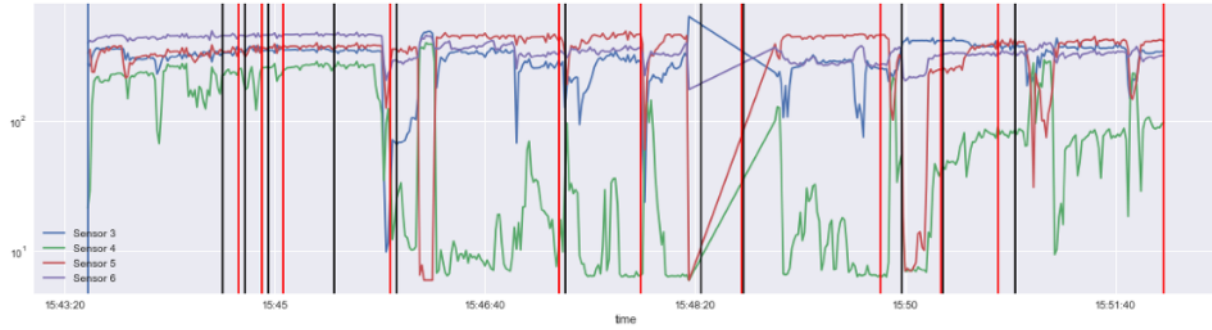
Notice that these pressure sensors are installed on different positions, so the variations depict the pressure points of different movements. The slot between 15:46 and 15:50, there is some missing data (the straight lines), which tells patient might have possibly leaned away from the backrest, disallowing any values to get recorded for a brief period.

In figure 3, using the starting time, we manually added the time, converting it to seconds, to visualize how much time the patient took to answer each of the 12 questions. The first blue vertical line is the starting time, possibly of when the patient was done being set up with the devices. Black vertical lines show the starting time for each question, while red lines show the ending time. It can be observed from the figure that some questions, like questions 5, 8, and 12, took longer than other questions for this patient.

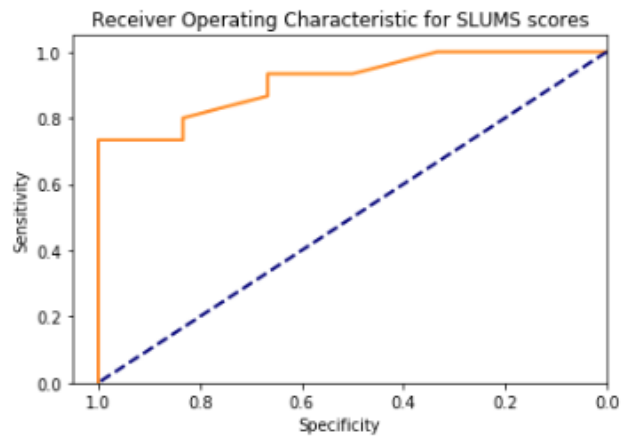
Note these figures are for a single patient only, who does not have dementia.

## IV. Expected Results and Discussion

Plotting these for all the 21 patients, we expect to see a pattern such that patients with dementia share some common traits observed in the analysis. Similarly, the patients with MCI, and those without any signs of MCI, are expected



**Fig. 3** Vertical lines on Fig. 2 representing starting and ending times for SLUMS questions



**Fig. 4** Receiver Operating Characteristics for SLUMS Score with 91.1% accuracy

to show some similar behavior as other patients with the similar diagnosis. On success, we would like to look at the Receiver Operator Curves for sensitivity vs. specificity and compare them to the ground truth data. The analysis and results of which will enable us to look at other patients, for which we don't have the ground-truth data available, and yield results for those to identify if they have any signs of dementia.

Moreover, given the current structure of the data, we also plan to find ways to automate plotting and converting of start/end time of questions from SLUMS, to find any patterns and difference in the data according to each response between patients who have dementia and those who do not. We would also like to find out the which sensor records which plot to better understand the different curves in a single figure.

In conclusion, we have the ample amount of data to conduct analysis and investigate if we can identify signs of dementia in patients who have taken the screening tests using our smart chair and wearable device. So far, we have the preliminary analysis for the 21 patients for which we have the true diagnosis available. Plan is to conduct careful analysis to see if the pressure data shows any difference between the patients with dementia and the patients with not.

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