Kumas: An Application that Quantifies Qualitative Data from Patient Monitoring at Home

With a Focus on Patients with Brain Deterioration/Dementia

< TEAM 108 >

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I. ABSTRACT

In the senior population, dementia is an internationally leading cause of disability and dependency[1]. Dementia is a condition where a person's cognitive capabilities progressively worsen over time. Our application, Kumas, acts as a platform to quantitatively collect and record qualitative data from the patient while they are in a non-clinical environment (i.e. home) through a variety of tests that measure cognitive impairment. Physicians can rely on and analyze the data for trend lines.

II. INTRODUCTION

Primary Objective

The vision behind the project is to create an application that quantifies data of the patient's cognitive assessments.

Background & Significance

Dementia is a condition associated with impairments of memory, communication and cognition abilities. It is caused as a result of damage to brain cells. Current statistics predict that at least one in three seniors will die as a result of Alzheimer's disease or some other form of dementia.

Memory loss, communication problems, mood swings and difficulty completing familiar tasks are usual symptoms. As dementia is caused by brain cell death, there is no cure for degenerative dementia. However, there are treatments to alleviate and improve the symptoms associated with the condition. The physicians have to rely on the caregivers or the patients to understand and assess the patient's condition, as there is no current method to obtain the information at the time of the episode. Oftentimes, by the time the patient meets the physician, the symptoms of dementia has subsided, which makes it difficult for doctors to measure the severity of the syndrome.

Kumas aims to bridge the gap between the doctor patient interaction by obtaining quantitative data from the patient through a series of games and questions.

Areas of focus include:

- Healthy Aging and Healthcare
- Value-based care
- Focus on keeping patients healthy

[1] "Dementia." *World Health Organization*. World Health Organization, Apr. 2016. Web. 05 Mar. 2017.

Target Setting / Patient Population

Around the world, there are 47.5 million people with dementia, and every year, there are 7.7 million more cases being added. Dementia most commonly afflicts the elderly and overwhelmingly affects the lives of patients and their loved ones. Its emotional, physical, and economic impact makes it a crucial problem to address.

Physicians frequently struggle to measure the severity of a patient's syndrome because they often rely on others' observations (qualitative). We developed Kumas as a way to quantify that information for doctors.

III. PROJECT DESIGN

Overview

The patient suffering from dementia is asked to play games and answer questions regularly on Kumas. The results are compiled over time to generate a trend of the patient's performance in the tests. Doctors can use the data to determine whether the patient's condition is improving, stable, or deteriorating. The results can also be used to determine whether the treatment should be continued or altered. We have implemented an Android application for this and a website alternative for non-Android users.

- **Website:** http://jigar-p.github.io/Kumas/
- **Android Application:** https://github.com/jwickes/healthhack

Design

Kumas can be approached in two ways, either by the caregiver or by the patient as a self assessment. The two different approaches are designed to cater to the patient's emotional state and his/her ability to participate in the tasks. In both the cases the webcam is enabled in order to record the patient's reactions, eye movements and expressions in order to create a visual archive for the physician. The Android application has self-coded games of both Corsi Block-tapping Test and the Eriksen Flanker Test.

Features of the website and Android application include:

- *Self Approach.* Two games that assist in diagnosing and measuring the severity of dementia.
- *Caregiver Approach.* The caregiver is given a set of questions to ask the patient.
- *Uploads.* Caregiver can upload a clock drawing, as a part of the Clock Drawing Test, or a video of the patient.

Self Approach (Play Games)

In this approach the patient directly interacts with the program by participating in various games that will be used to assess the patient's cognitive abilities. This approach has two games:

1. *Corsi Block Tapping Test*[2]

This game is used to test assess the patient's visuo-spatial short term working memory. In this test, the patient has to mimic the computer by tapping blocks in the same sequence as shown by the computer. The patient is given three lives and once the patient misses three sequences, the game comes to an end. The results of this test are used to track whether the patient's short-term memory is deteriorating. If the patient's score is consistently lower that his/her previous score, it can be concluded that the patient's memory is deteriorating and the dementia is getting severe.

2. *Eriksen Flanker Test*[3]

This test is used to assess the patient's response time, which correlates with the patient's ability to process information and generate an action to the stimulus. In the test, the computer generates an arrow pointing either in the left or right direction. The patient has to respond by pressing the arrow keys that points in the same direct and the response time is recorded. The task is made tougher by the presence of non-target stimuli that may be congruent or incongruent to the target stimulus. This not only helps in assessing the patient's response time but also helps in assessing the patient's ability to focus and can be used to determine the patient's condition over time. If the patient's average response time is increasing, it can be concluded that the patient's cognitive abilities are deteriorating.

The Corsi Block-tapping Test and the Eriksen Flanker Test have been used in the past to monitor cognitive growth in children. However, these tests have not been used for patients suffering with dementia. We decided to use these tests to assess the patient's abilities to determine the severity and progress of their condition as the tests have proven to work in the case of the children. The only difference is that in case of the children, it is used to measure cognitive growth, however, in case of the patients it is used to monitor consistency or deterioration.

Caregiver Approach (Questionnaire, CDT)

In this approach, the caregiver asks the patients a couple of questions and gives him or her some tasks and records whether the questions were correctly answered. This approach was designed as an alternative to the self-approach in cases when the patient is going through an episode of dementia and is unable to take the test. The questions used were adapted from the

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[2] Kessels, Roy P.C., et al. "The Corsi Block-Tapping Task: Standardization and Normative Data." *Applied Neuropsychology.* 7.4 (2000): 252-258

[3] Davelaar E.J. "When the ignored gets bound: sequential effects in the flanker task." *Front. Psychology.* 3 (2013): 552.

Self-Administered Gerocognitive Exam (SAGE test)[4] and are designed to detect signs of cognitive, memory or thinking impairments. It helps physicians in evaluating how well the patient's brain is working by analyzing patient's ability to answer questions and reason.

We also use the Clock Drawing Test (CDT), which is an insightful, commonly used tool that screens for cognitive defects, particularly in the frontal and temperoparietal functions[5]. The simple test requires a patient to draw a clock on a large sheet of paper. The drawing is scored by the given rubric – points are subtracted for inaccurate numbering and the severity of visuospatial disorganization. Higher scores represent an accurate clock, while lower scores correlate to a greater impairment. Studies involving CDT prove its usability and reliability for accurately testing older populations for neurological disorders[6].

Data Uploads

Each of these tests produces data that will be uploaded into the EPIC health system. In order to prevent data-overloading, general trend lines will be generated for each of the individual tests, allowing doctors to quickly see the current status of the patient. The doctor can then check a couple of the videos in order to see a more intimate viewpoint of the symptoms if it seems necessary. These trend lines can also be made for the caregiver questionnaire - allowing doctors to go into individual reports and see how the patient is responding to the questions. For the clock-drawing test, if signs of deterioration are shown in other tests, a doctor can open up their clock drawings to confirm the other results.

Data Interpretation

Acquired data from the graphs can be interpreted for trend lines:

1. A relatively horizontal trend line with little to no slope indicates that the patient is staying around the same condition.
2. A decreasing trend line indicates that the condition is gradually worsening.
3. A graph without a trend indicates that the results are inconsistent, scattered, and without correlation.
4. An increasing trend line indicates that the condition is improving, though this is uncommon as there currently is no treatment for dementia.

Examples of the aforementioned trend lines (#1-4) are shown below from left to right:

[4] "SAGE: A Test to Detect Signs of Alzheimer's and Dementia." *Ohio State Memory Disorders*. The Ohio State University Wexner Medical Center, n.d. Web. 05 Mar. 2017.
[5] Critchley, M. *(*1953, *reprinted 1966)* The Parietal Lobes. *Hafner*, New York.
[6] Brodaty, H, et al. "The Clock Drawing Test for Dementia of the Alzheimer's Type: A Comparison of Three Scoring Methods in a Memory Disorders Clinic." *Int. J. Geriat. Psychiatry.* 12 (1997): 619-627.

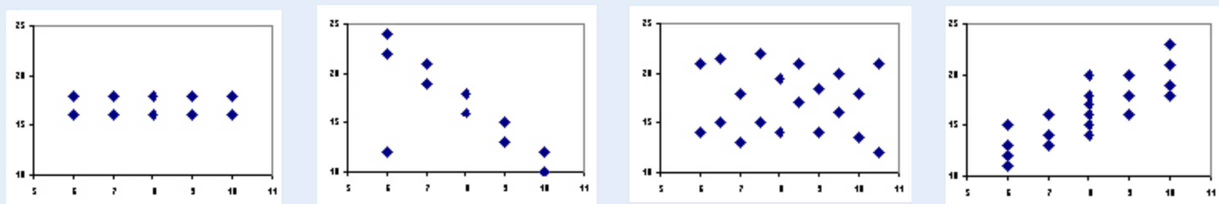

Figure 1. Examples of possible trend lines are shown from left to right: 1) no change, 2) patient is worsening, 3) no trend, and 4) patient is improving.

Logistical Complications

Making this application, we ran into a few issues regarding the overall development cycle. In terms of the Android application, there is no easy way to connect the data stream to the EPIC system - making it on an iOS device would have been easier to connect. In addition better methods have to be made in how the application runs - since our current application is merely a framework to build on. This includes making the camera run while taking these tests. In addition, one of the most important aspects of our test is the ability to make it easy to play and appealing, which will be improved upon in future iterations as only the core gameplay is shown currently.

The website functionality works a bit different than our Android application. For the website, we do not have a functionality to record the patient while the questions are being asked. Due to lack of portability of desktop or laptop when compared to mobile/tablet, there is no simple way to record the patient's answer directly. Our alternative method for this complication was to have the caregiver/family member to upload the video of their answer. This way there is still some quantitative data that will help physicians have a better understanding of their responses.

Financial Logistics

Our product is a free, open-source application built from publicly available resources. No money is needed to fund for the current application prototype. However, if we produce an iPhone app, an Apple Developer's Kit is required, which costs $100.

IV. FUTURE ENDEAVORS & APPLICATIONS

This application helps bridge the gap between doctor and patient and allows key data recording to occur at a patient's home when it is needed - not just at the hospital. Fully integrating this with EPIC would allow for a stream of information to flow from the patient's everyday life to their clinical visit, with doctors being fully informed of their current state – allowing them to make better judgments on the medications and treatments that each individual patient receives.

In terms of this specific application, it can easily be repurposed to help chart the cognitive growth of young children, with parents administering the tests. Even making slight adjustments could allow doctors to predict if a child has a cognitive disability, allowing both them and the parents to react sooner.

Developing applications that allow patients to communicate their symptoms more easily to the doctor is the next step in preventative medicine. This can be applied to not just cognitive development but also to many other physical and mental ailments. Newer ways to quantify data and administer tests remotely removes unnecessary doctor's visits. This could be seen as making medicine less personalized, however running these tests at home is actually makes visits much more meaningful and personable. Doctors can know exactly what is happening at all times and will have some idea of the issue before a patient even comes in for a visit, and there will be less time that the patient's waste going in for these small tests.

V. SUPPLEMENTARY INFORMATION

Secondary Objective

We use Principle Component Analysis (PCA), a technique that detects correlations between multiple variables, as an application to integrate circadian biology concepts into our project. PCA can be used to analyze acquired data for variability in results between different times of the day.

Background & Significance of PCA

PCA analysis is a popular statistical technique used to reduce the dimensionality of graphs. It finds the two directions with the greatest variance and reorganizes the data in a way that allows the analytic to identify patterns within large datasets with multiple dimensions. Its applications are impactful and are used to predict the stock market and analyze gene expression among its many uses.

Background & Significance Circadian Biology

Biological clocks are ubiquitous and applicable to many interdisciplinary fields. Many studies have concluded that the timing of medicine intake for a patient greatly impacts the quality of the treatment. Studies have shown that the frequency and timing of food intake is correlated with obesity[7] and suggests that a person's tolerability to anticancer drugs vary with their circadian timing[8].

Early studies have concluded that the average healthy human circadian rhythm ranges from about 24 hours and 11 minutes to 24 hours and 16 minutes[9]. Among patients of Alzheimer's disease, evidence has suggested a correlation between sleep disturbances and lower cognitive scores[10]. It suggests that functional changes to the biological clock, which regulate circadian rhythms, may be correlated to physiological changes expressed through mentally ill patients.

These studies suggest that it would be highly advantageous for doctors to receive data that indicates whether or not lapses that are warning flags for dementia occur more often during specific times of the day. Information indicating a correlation between dementia lapses and the timing of the day could improve the timing of medicine consumption. Although there is no successful treatment for Alzheimer's dementia, it is valuable information to collect that tells us whether the timing of drug intake could prevent further brain deterioration.

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[7] Arble, Deanna, et al. "Circadian Timing of Food Intake Contributes to Weight Gain." *Obesity (Silver Spring)*. 17 (2009): 2100-2102.
[8] Lévi, F, et al. "Circadian timing in cancer treatments." Annu. Rev. Pharmacol. Toxicol. 50 (2010): 377-421
[9] Czeisler, Charles A, et al. "Stability, Precision, and Near-24-Hour Period of the Human Circadian Pacemaker." *Science*. 284 (1999): 2177-2181.
[10] Lamont, Elaine W, et al. "The Role of Circadian Clock Genes in Mental Disorders." *Dialogues in Clinical Neuroscience* 9.3 (2007): 333-342.

Applying PCA

PCA is used to analyze for variability between samples with multiple dimensions. In our project, we have three dimensions represented by the results of the three tests we use: 1) Corsi block-tapping test, 2) Eriksen flanker test, and 3) the Clock Drawing Test (CDT). Separating these the results by categories of time, we want to condense the dimensions through PCA and answer the question: is there a difference in test results at different times? Is there variability in the results at different time points? Does dementia lapses occur during a specific time of the day, or is it sporadically scattered throughout the day?

Using arbitrary numbers that represent a healthy individual and a mentally ill individual, we ran three sets of pseudo-results separated by time, in order to provide an example of how to analyze real data.

1. Data that suggests that dementia lapses occur during the night.
2. Data that suggests that dementia lapses are random – no correlation with the time of day.
3. Data that suggests that dementia lapses during a specific time of the day.

Pseudo-Dataset for PCA #1

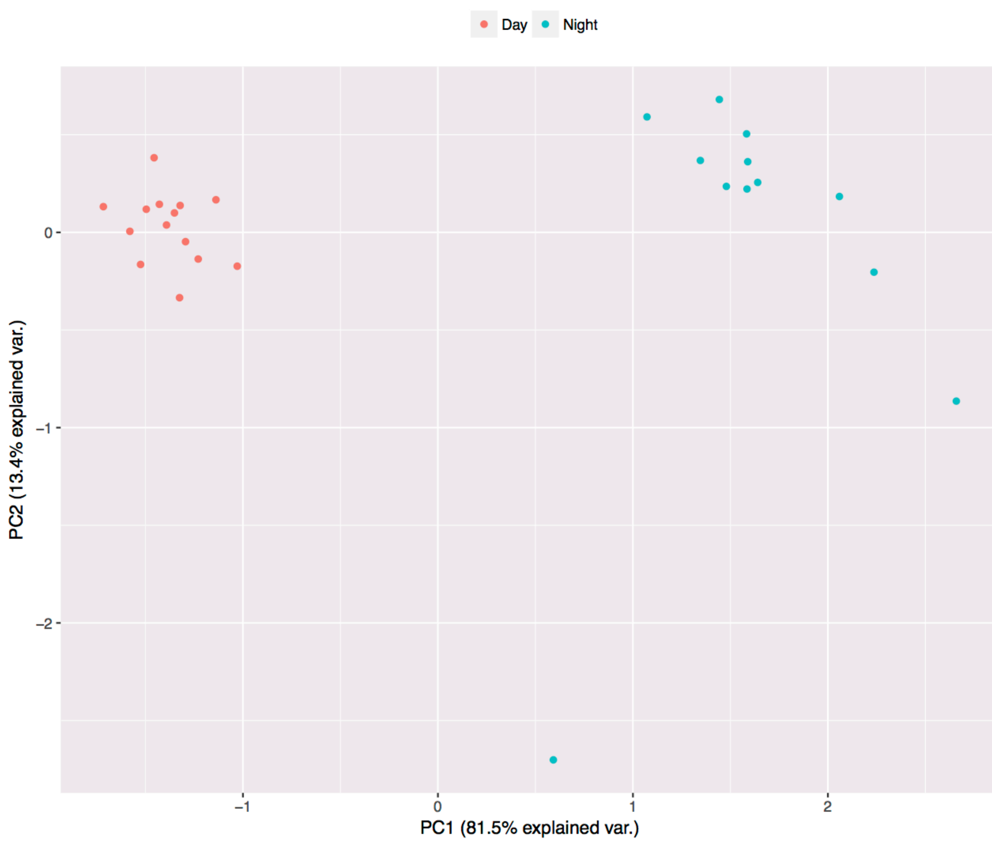


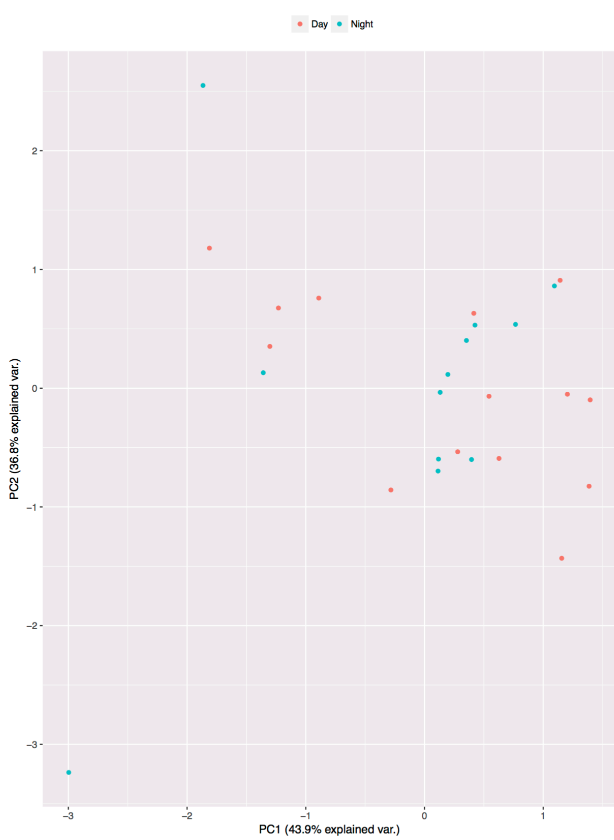
Figure 2. The PCA graph above was generated from the following dataset below, which suggests that dementia lapses are more prominent at night.

Day (D)	D	D	D	D	D	D	D	D	D	D	D	D	D
Score	15	17	18	20	15	15	15	14	16.6	17.4	17.5	18	19.1
Reaction Time (RT)	400	444	500	540	467	576	476	493	490	543	419	589	462
CDT	5	4.9	4.6	4	4.2	4.5	5	3.9	4.1	4.3	3.5	5	5

Night (N)	N	N	N	N	N	N	N	N	N	N	N	N	N
Score	15	7	5	5	5	6	8	6.6	5.9	8.5	7.7	7.9	5.8
Reaction Time (RT)	502	1578	1698	198	1932	1587	1734	1982	1983	1752	1853	1931	1641
CDT	5	0	1	1	1.5	2	1.7	1.9	2.6	2.2	1.3	1.4	1.9

Table 1. The dataset of which we ran the PCA graph in Fig. 2 on.

For values representing data collected during the day, we assigned high scores for the Corsi block-tapping test, fast reaction times for the Eriksen flanker test, and high scores for the Clock Drawing Test. For the values recorded at night, we assigned the opposite values. Data like this would suggest an obvious indication that dementia lapses occur at night. Running a PCA on our pseudo dataset, we get two blatant clusters, each for data collected during the daytime and nighttime. This indicates that there is variability between results recorded during the day and night, which suggests a correlation between dementia lapse and the time of the day.



Pseudo-Dataset for PCA #2

Figure 3. The PCA graph above was generated from the following dataset below, which represents a relatively healthy person and suggests that the performance of cognitive tests have no correlation to the time of day.

For this pseudo-dataset, we chose data values representing generally good scores both during the day and the night. This dataset represents a collection of data points where there is NO correlation between the patient's cognitive function during the day and their cognition during the night. Running the PCA on this dataset, it is clear that there is no obvious cluster because no variability exists between results obtained during the day and those gotten during the night.

Day (D)	D	D	D	D	D	D	D	D	D	D	D	D	D
Score	15	17	18	20	15	15	15	14	16.6	17.4	17.5	18	19.1
Reaction Time (RT)	400	444	500	540	467	576	476	493	490	543	419	589	462
CDT	5	5	4.6	5	4.8	4.2	4.2	3.9	4.8	4.9	5	4.5	5

Night (N)	N	N	N	N	N	N	N	N	N	N	N	N	N
Score	15	16	18.4	17.5	18.3	10	18.4	16.3	14.4	15	15	14.9	14.9
Reaction Time (RT)	502	504	485	576	498	600	1734	523	534	476	409	523	634
CDT	4.1	4.7	4.6	4.7	4.5	4.4	4.3	4	5	5	5	4.9	5

Table 2. The dataset of which we ran the PCA graph in Fig. 3 on.

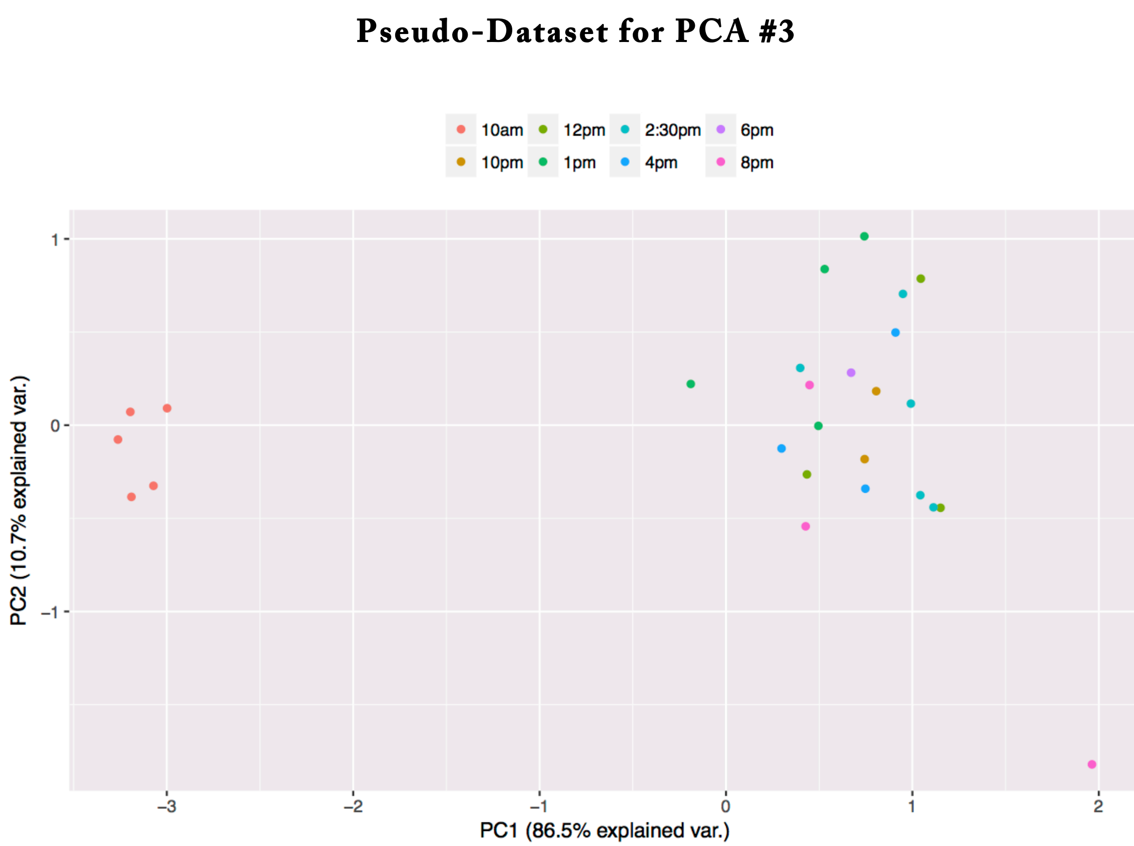


Figure 4. The PCA graph above was generated from the following data below, which suggests that dementia lapses during a specific time of the day – in the case of our example, 10am.

Time	10a	10a	10a	10a	10a	12p	12p	12p	1p	1p	1p	1p	2:30p
Score	15	17	18	20	15	5	7	8	7.5	9	5.5	4.5	5.3
Reaction Time (RT)	400	444	500	540	467	1932	1954	1589	1698	1578	1586	1467	1899
CDT	5	5	4.4	4.6	4.9	2	1	1.5	1.7	2.5	2.4	2.3	2

Time	2:30p	2:30p	2:30p	2:30p	4p	4p	4p	6p	8p	8p	8p	10p	10p
Score	6.8	6.4	6.9	6.3	8	7	5.5	7	7	7.6	8.7	6.6	6.8
Reaction Time (RT)	1567	1985	1857	1564	1543	1531	1764	1985	1764	1875	1587	1498	1984
CDT	2	1.5	1	1	1.7	1.2	1.8	1.9	0	2	1.3	1.3	1.7

Table 3. The dataset of which we ran the PCA graph in Fig. 4 on.

The first two pseudo-datasets split the results into two categories:

1. Results obtained during the day
2. Results obtained during the night

For this third pseudo-dataset, we wanted to show a more complicated application of our idea. It is possible to split the results by hours, as shown below. If dementia lapses occur at all times except in the morning, perhaps at 10am as we chose to represent in our dataset, then the following PCA graph would show a cluster of 10am results. That indicates that there is variability between the results taken at 10am and those of the other times.