Improved Healthcare Decisions with Timely Data

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Mechanical & Industrial Engineering
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Interactive MediaLab

Data Driven Clinical Decision Support Apps

- Assess requirements and opportunities for innovative decision support
- Create novel data sets relevant to the decision context
- Build clinical decision support applications that utilize those data sets
- Key Ideas
  - Continuous Data Collection
  - Data Fusion
  - Targeted Application Development
  - User-Centred Interface Design

Timely Health Data Projects

- Game-Based Cognitive Assessment (Tiffany Tong)
  - Delirium Risk Assessment
  - Neuro-Rehab Evaluation
  - Detection of Cognitive Impairment in Long-Term Care
- Ambulatory Gait Analysis (Phil Lam)
  - Falls Risk Detection
  - Mobility Assessment
- Summarized Patient Types from Healthcare Data (Mahsa Rouzbahman)
  - Clinical Decision Support in the Emergency Department
  - Clinical Decision Support in the ICU

Game-Based Cognitive Assessment: Motivation

- Rising prevalence of cognitive disorders such as dementia and delirium and many cases are undiagnosed
- Existing tools tend to have low sensitivity when administered by under-trained staff and they are expensive to administer with trained staff
- In order to prevent under-diagnosis, and to provide more timely data, a new assessment approach is needed

Classic Cognitive Assessments

Gold Standards

- Mini-Mental State Examination (MMSE)
- Montreal Cognitive Assessment (MoCA ©)
- Confusion Assessment Method (CAM)

Disadvantages

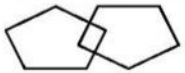
- Costly
- Time-consuming
- Requires trained staff
- Subjective based on test administrator

Mini-Mental State Examination (MMSE)

Mini-Mental State Examination (MMSE)

Patient's Name: _____ Date: _____

Instructions: Score one point for each correct response within each question or activity.

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day? Month?"
5		"Where are we now? State? County? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then the instructor asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible.
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, …) Alternative: "Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.) 
30		TOTAL

Confusion Assessment Method (CAM)

- The diagnosis of delirium requires the presence of features 1 and 2, plus either of 3 or 4.

1. Acute Onset and Fluctuating Course
2. Inattention
3. Disorganized Thinking
4. Altered Level of Consciousness

Why Gamify?

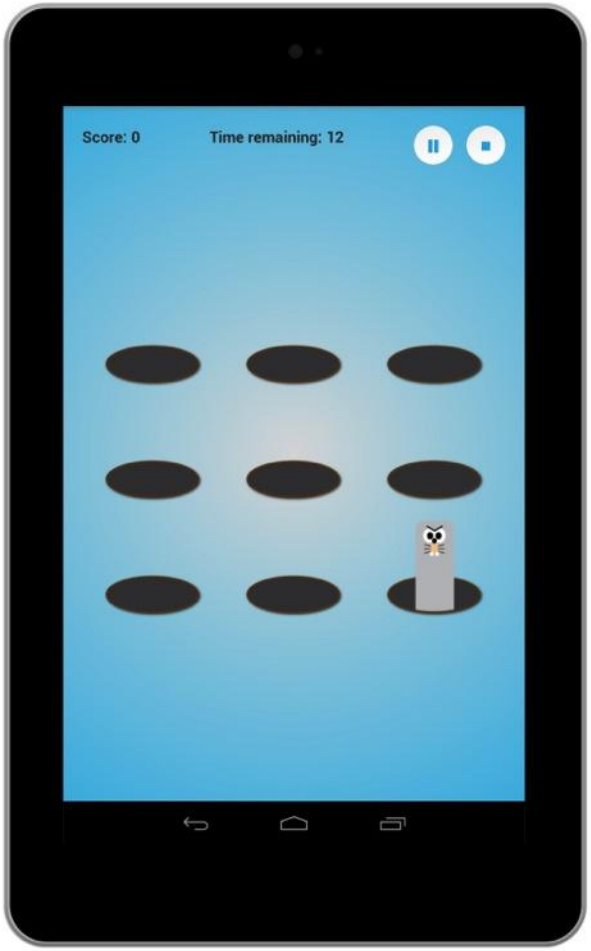
- Motivate patients to stay cognitively active
- Alleviate boredom in the waiting room and long-term care facilities
- Not one test form, but many (continuous testing)
- Test can be patient self-administered
- Games/tests can be adaptive, can have different levels and can test a number of different abilities
- Test results can be exported in real-time to data repositories
  - Reduction in data transcription errors
  - Fast and timely summarization/presentation of results

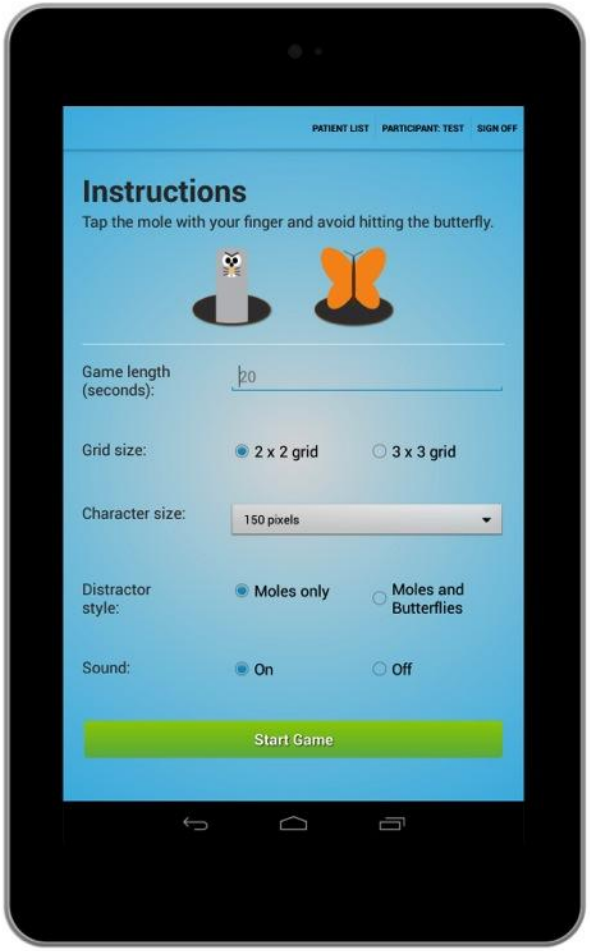
Why Use Tablets?

- Record accuracy and response speed with high sensitivity
- Potential cost savings
- Reduced load on clinicians
- Other Advantages for tablets
  - easily sanitized for multiple patient use
  - Adjustable screen magnification reduces visual impairment issues
  - Appropriately designed apps can require similar skills needed to complete standard pencil and paper tests .

Prototypes


Whack-A-Mole
To begin, please sign in using your provided ID.
Please enter your participant ID
Login
Register


Score: 0
Time remaining: 12


PATIENT LIST
PARTICIPANT: TEST
SIGN OFF
Instructions
Tap the mole with your finger and avoid hitting the butterfly.
Game length (seconds):
20
Grid size:
2 x 2 grid
3 x 3 grid
Character size:
150 pixels
Distractor style:
Moles only
Moles and Butterflies
Sound:
On
Off
Start Game

Usability Study

Methodology

- Demographic and technology-use questionnaire
- Computer-based study
- Tablet-based study and exit questionnaire

Sample Population

- 24 participants
- 7 females, and 17 males
- Age range: 21 to 51 years

Predicting Cognitive Ability/Executive Functioning

	Inhibition	Shifting	Updating
-Z(accuracy)	.008	- .116	.216
Z(time)	.257	.136	.275
-Z(accuracy)-Z(time)	- .602**	- .400*	- .355*

*$p < .001$, *$p < .05$

Future Cognitive Assessment Work

- Clinical study with post-operative elderly adults
- Clinical study with elderly adults in emergency departments
- Clinical study with neuro-rehabilitation patients

Sunnybrook HEALTH SCIENCES CENTRE

BRIDGEPOINT active healthcare

Summarizing Patients to Support Case-Based Reasoning

Mahsa Rouzbahman

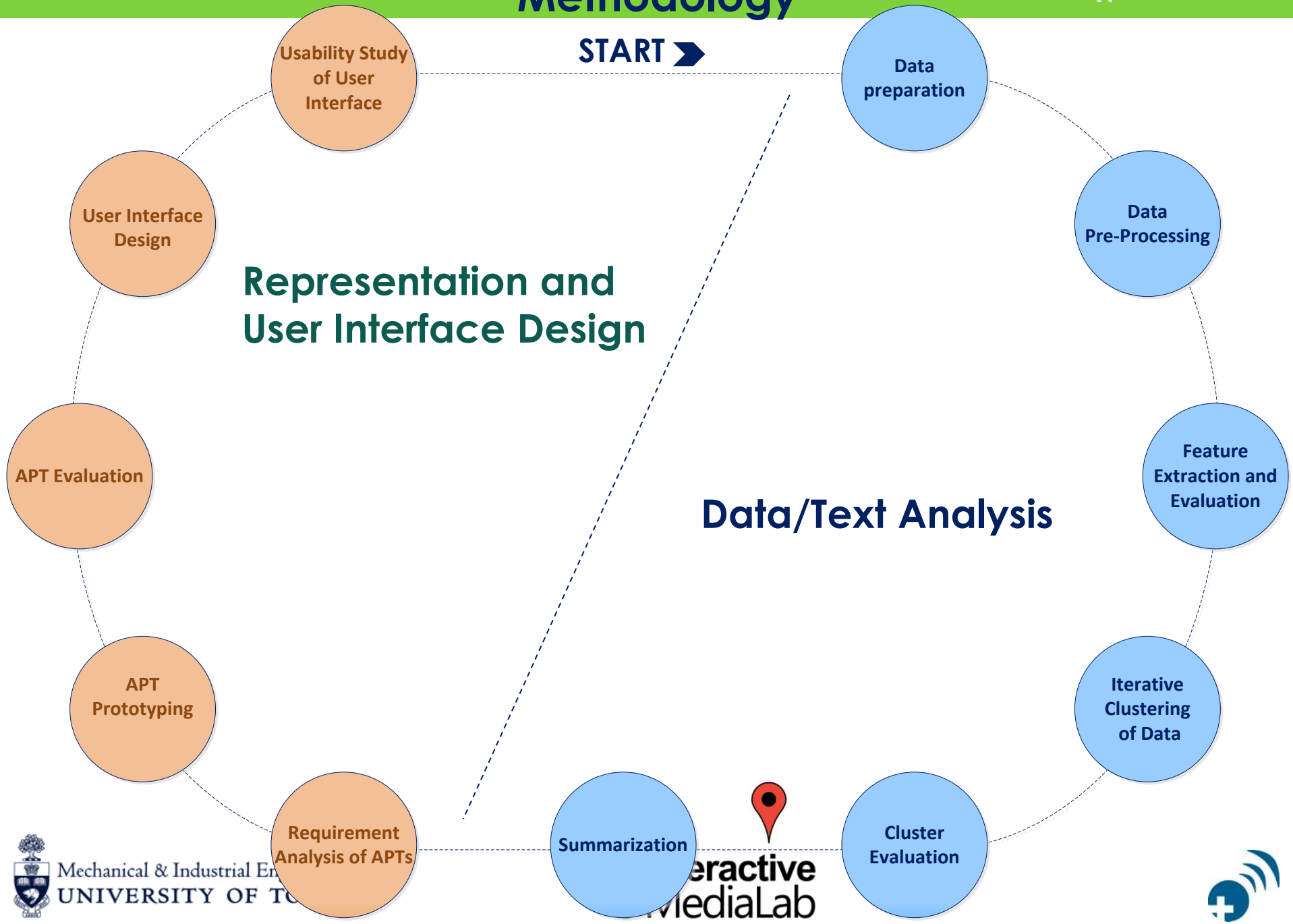
Introduction:
Decision Making based on Similar Patients

- Physicians' decision making can be affected by previous cases they had experienced (Choudhry et al., 2005).
- Providing similar patients' information can prevent additional cognitive effort from the physician (Ebadollahi et al., 2010).
- Physicians often use case based reasoning, so it seems natural to develop clinical decision support tools based on patients who are similar to the current patient (Chan, 2010).
- Ideally, health repositories could be mined to identify patients who are similar to each other.

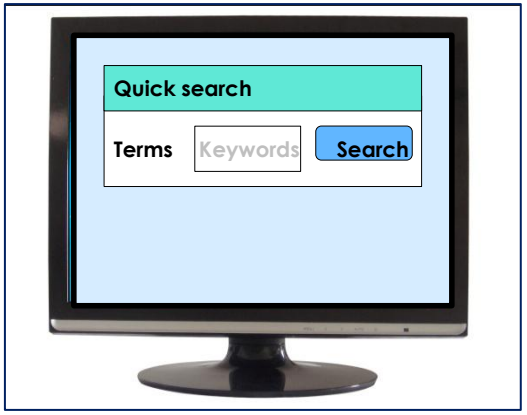
Main Research Questions:

- How to develop decision support tools for physicians so as to provide overall view of similar patients and their relationships rather than showing individual patient records?
- How to extract the important knowledge in large confidential data sets, so as to support physicians without violating the privacy of the people whose data is being utilized?
- What types of user interface would be useful for physicians trying to diagnose patients by reviewing patient types that are similar to them?

Methodology

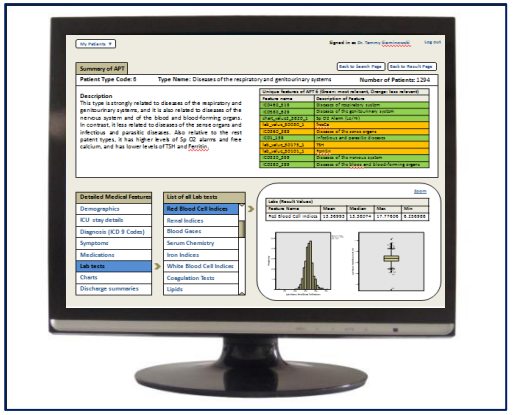


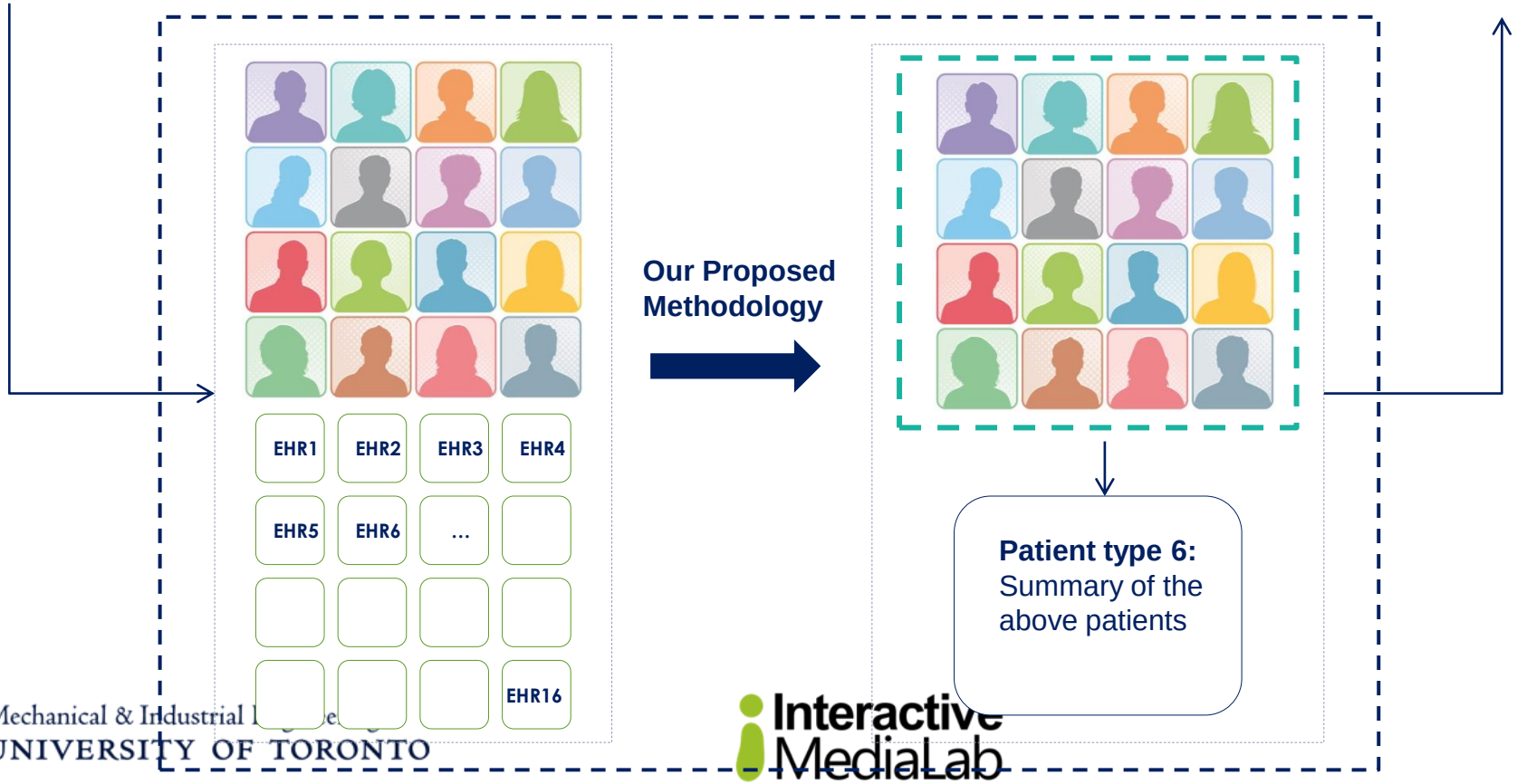
Search Engine



A decision support tool for presenting overall view of similar patients

Search Results



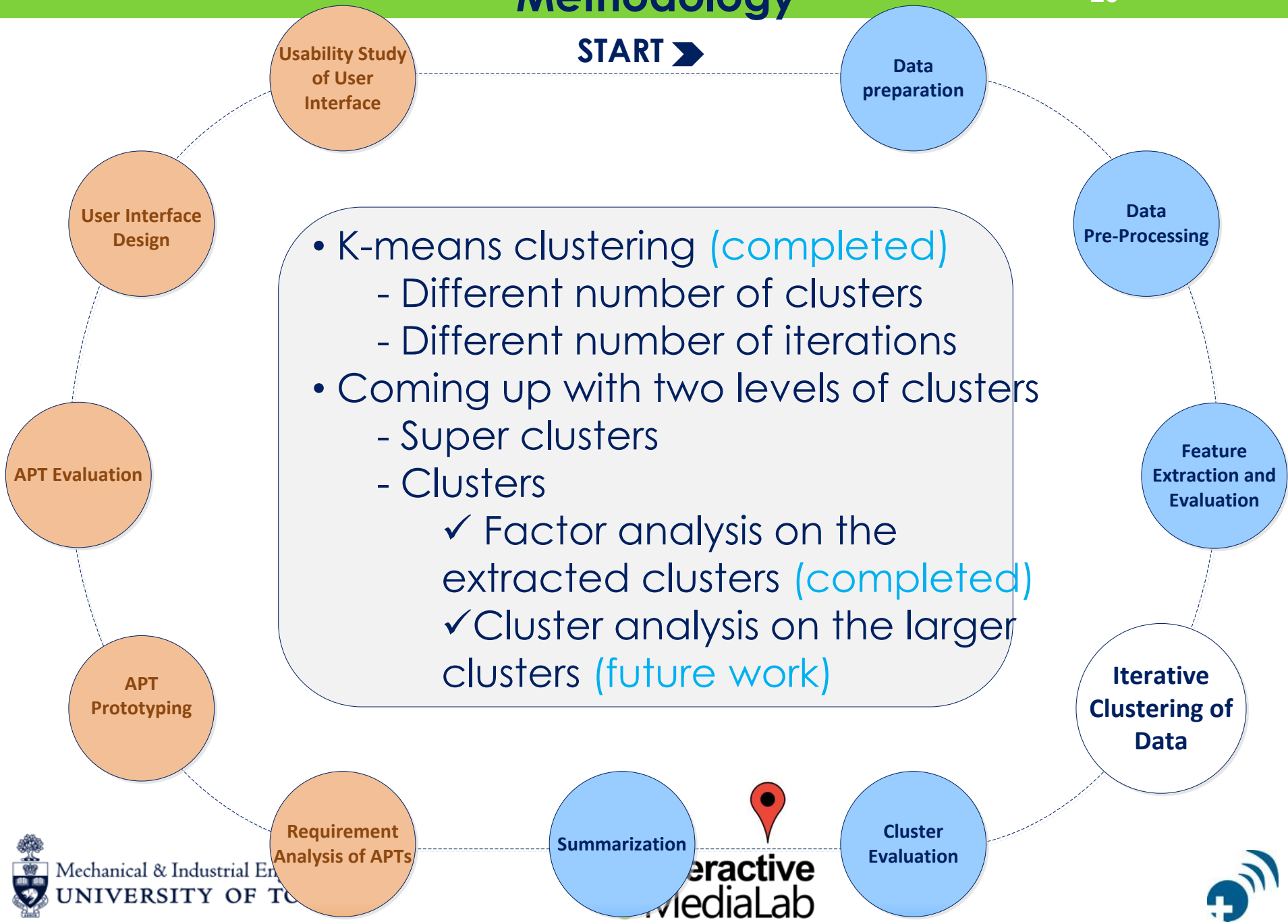


MIMIC II Database (An Intensive Care Unit database)

- **The clinical database:** 38 different tables (33000 patients)
  - Patient demographics
  - Medications
  - Results of lab tests
  - Notes (nursing notes and discharge summaries),
  - Charts
  - Diagnoses and ICD codes, etc

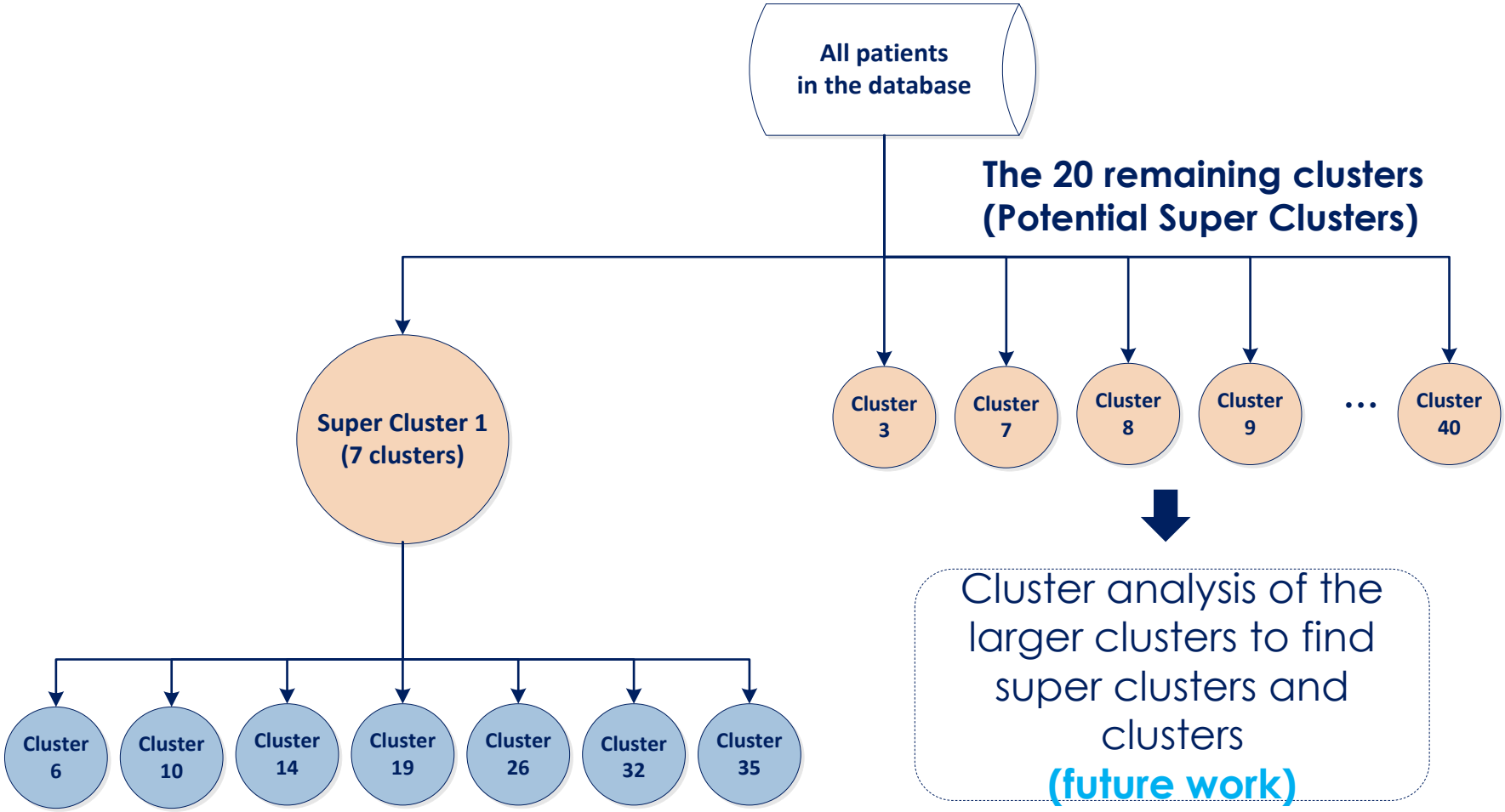
- In MIMIC II database, each patient has multiple rows of data. As a result, database tables have more than millions of rows.

Methodology

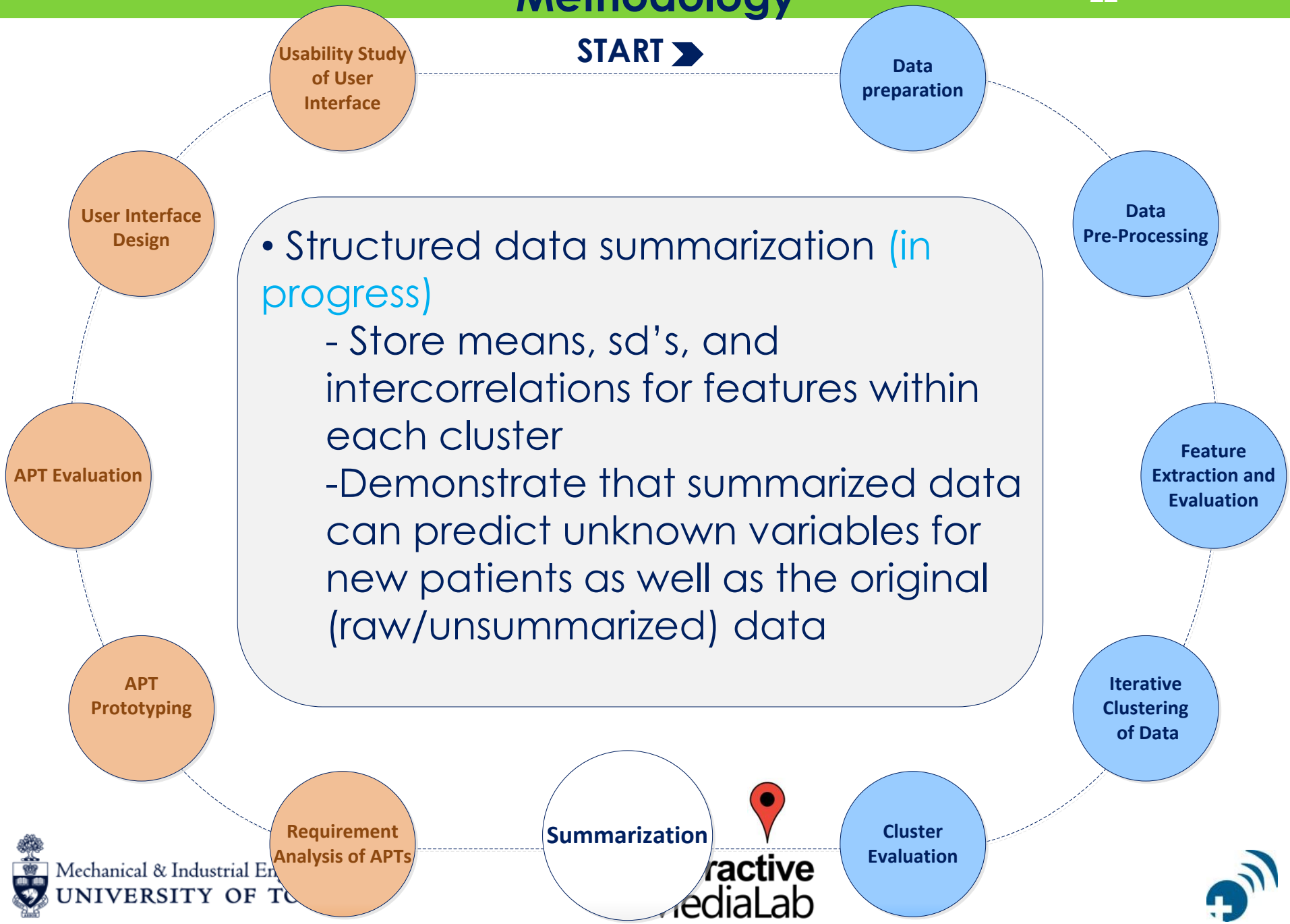


- K-means clustering (completed)
  - Different number of clusters
  - Different number of iterations
- Coming up with two levels of clusters
  - Super clusters
  - Clusters
    - ✓ Factor analysis on the extracted clusters (completed)
    - ✓Cluster analysis on the larger clusters (future work)

Super Clusters and Sub-clusters



Methodology



- Structured data summarization (in progress)
  - Store means, sd's, and intercorrelations for features within each cluster
  - Demonstrate that summarized data can predict unknown variables for new patients as well as the original (raw/unsummarized) data

Predicting Death in ICU – Case Study

- Death rates varied between the clusters we generated (unexpected)
- Prediction with Summarized Patient Types
  - 1. Match the new case to a cluster
  - 2. Do a regression analysis within the cluster using the target/unknown variable as the criterion
  - 3. Use the resulting regression equation to predict the unknown target variable value for the new patient.

- Results
  - Predicting death rate (regression analysis) with summarized data was as good as, or better than predicting death with the original raw data
  - Regression analyses with summarized data were just as predictive as discriminant analysis and logistic regression on the original (raw) data

The Magic of Summarization

Cluster 22	**Correlation with Actual Dead**	**Accuracy**
Regression analysis on summarized data	0.447	
linear regression analysis on the raw data	0.447	
Logistic regression on the raw data	0.481	78.9
Discriminant analysis on raw data	0.365	78.4
All Clusters	**Correlation with Actual Dead**	**Accuracy %**
Regression analysis on summarized data	0.543	
linear regression analysis on the raw data	0.543	
Logistic regression on the raw data	0.473	77.2

Preliminary Results

- Predictions of Death Outcomes based on Summarized data are just as good (if not better) than predictions based on Raw (confidential) data.

- Next Step: How to make this prediction capability useful to Emergency Physicians?

EARLY PROTOTYPE

My Patients

Signed in as Dr. Tammy Sieminowski

Log out

Back to Search Page

Search Results

Patient Type	Patient Type	Number of	Last Update Date
36	Diabetes and hearth disorders	1159	11/Dec/2009
Open Preview | Related Patient Types			
61	Nervous system and mental disorders	598	01/May/2009
Open Preview | Related Patient Types			
6	Diseases of the respiratory and genitourinary systems	1294	30/Oct/2008
Open Preview | Related Patient Types			

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6	Diseases of the respiratory and genitourinary systems	1294	30/Oct/2008

▲ Close Preview | Related Patient Types

Demographics and Details

Variable	Mean	Median	Max	Min
Length of stay in hospital (Minutes)	16327.61	11520	96480	1440
Number of ICU admissions	1.119232	1	5.285714	1
Age	66.67467	68.29113	101.2927	18.67627
Length of stay in ICU (Minutes)	169.8061	169.7833	203	166
Height	169.5087	169.8053	198.12	124.46
Weight	82.47562	83.6	230	36.6

Description

This type is strongly related to diseases of the respiratory and genitourinary systems, and it is also related to diseases of the nervous system and of the blood and blood-forming organs. In contrast, it less related to diseases of the sense organs and infectious and parasitic diseases. Also relative to the rest patent types, it has higher levels of Sp O2 alarms and free calcium, and has lower levels of TSH and Ferritin.

Detailed Abstract Patient Type

Summary of APT 6

Back to Search Page

Back to Result Page

Patient Type Code: 6

Type Name: Diseases of the respiratory and genitourinary systems

Description

This type is strongly related to diseases of the respiratory and genitourinary systems, and it is also related to diseases of the nervous system and of the blood and blood-forming organs. In contrast, it less related to diseases of the sense organs. Also relative to the rest patent types, it has higher levels of Sp O2 alarms and free calcium, and has lower levels of TSH and Ferritin.

Unique features of APT 6 (Green: most relevant, Orange: less relevant)

Feature name	Description of Feature
ICD460_519	Diseases of respiratory system
ICD580_629	Diseases of the genitourinary system
chart_value2_5820_1	Sp O2 Alarm (Lo/Hi)
lab_value_50030_1	freeCa
ICD360_389	Diseases of the sense organs
ICD1_139	Infectious and parasitic diseases
lab_value_50175_1	TSH
lab_value_50101_1	Ferritin
ICD320_359	Diseases of the nervous system
ICD280_289	Diseases of the bloos and blood-forming organs

Detailed Medical

Demographics

ICU stay details

Diagnosis (ICD 9 Codes)

Symptoms

Medications

Lab tests

Charts

Discharge summaries

Summary of APT 6

Back to Search Page

Back to Result Page

Patient Type Code: 6 **Type Name:** Diseases of the respiratory and genitourinary systems **Number of Patients:** 1294

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Detailed Medical

- Demographics
- ICU stay details
- Diagnosis (ICD 9 Codes)
- Symptoms
- Medications
- **Lab tests**
- Charts
- Discharge summaries

List of all Lab tests

- **Red Blood Cell Indices**
- Renal Indices
- Blood Gases
- Serum Chemistry
- Iron Indices
- White Blood Cell Indices
- Coagulation Tests
- Lipids

Summary of APT

Back to Search Page

Back to Result Page

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Description

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Detailed Medical

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List of all Lab tests

- **Red Blood Cell Indices**
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- Serum Chemistry
- Iron Indices
- White Blood Cell Indices
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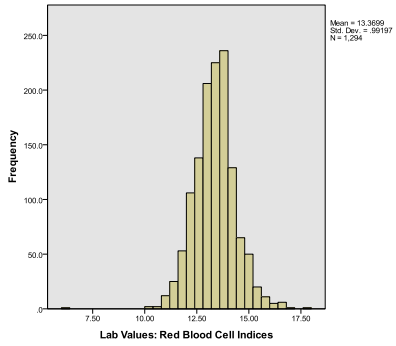
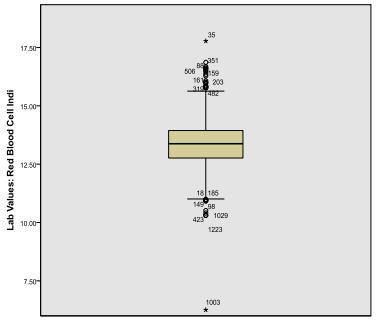
- Lipids

Zoom

Labs (Result Values)

Feature Name	Mean	Median	Max	Min
Red Blood Cell Indices	13.36993	13.38074	17.77606	6.256986





First Publication

Nonconfidential Patient Types in Emergency Clinical Decision Support

Mark Chignell, Mahsa Rouzbahman, Ryan Kealey, and Reza Samavi | University of Toronto
Erin Yu | Canadian Imperial Bank of Commerce
Tammy Sieminowski | Bridgepoint Hospital in Toronto

Tools that show similar patients' diagnoses and treatment trajectories might provide useful clinical decision support for emergency physicians who use a case-based reasoning approach. However, privacy concerns that arise with indirect use of electronic health records must be addressed.

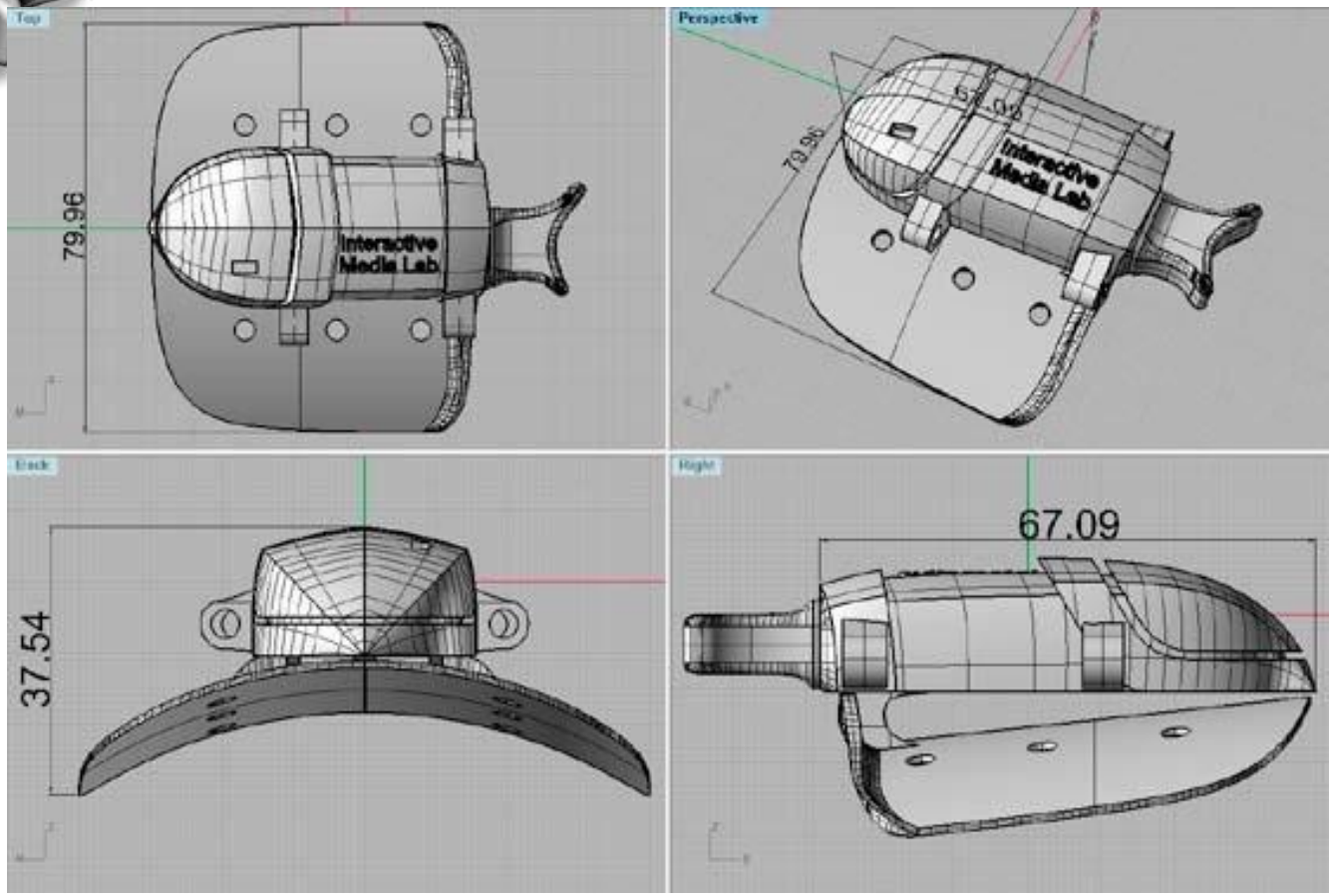
1. Chignell, M., Rouzbahman, M., Kealey, M.R., Yu, E., Samavi, R. and Sieminowski, T. Development of Non-Confidential Patient Types for Use in Emergency Medicine Clinical Decision Support. (2013). IEEE Security & Privacy (to appear in the November issue).

Contributions

- A method for discovering, and presenting sets of patient types that are comparable to a presenting patient.
- A method of summarizing data records (and removing privacy concerns from healthcare data)
- A demonstration that summarized data can predict values of unknown variables just as well as original (raw) data
- Development of novel interface designs for searching among APTs and presenting the relevant ones to a physician.

Ambulatory Gait Analysis – MIT 2002

SENSOR PACKAGE: FOR LACE-UP SHOE

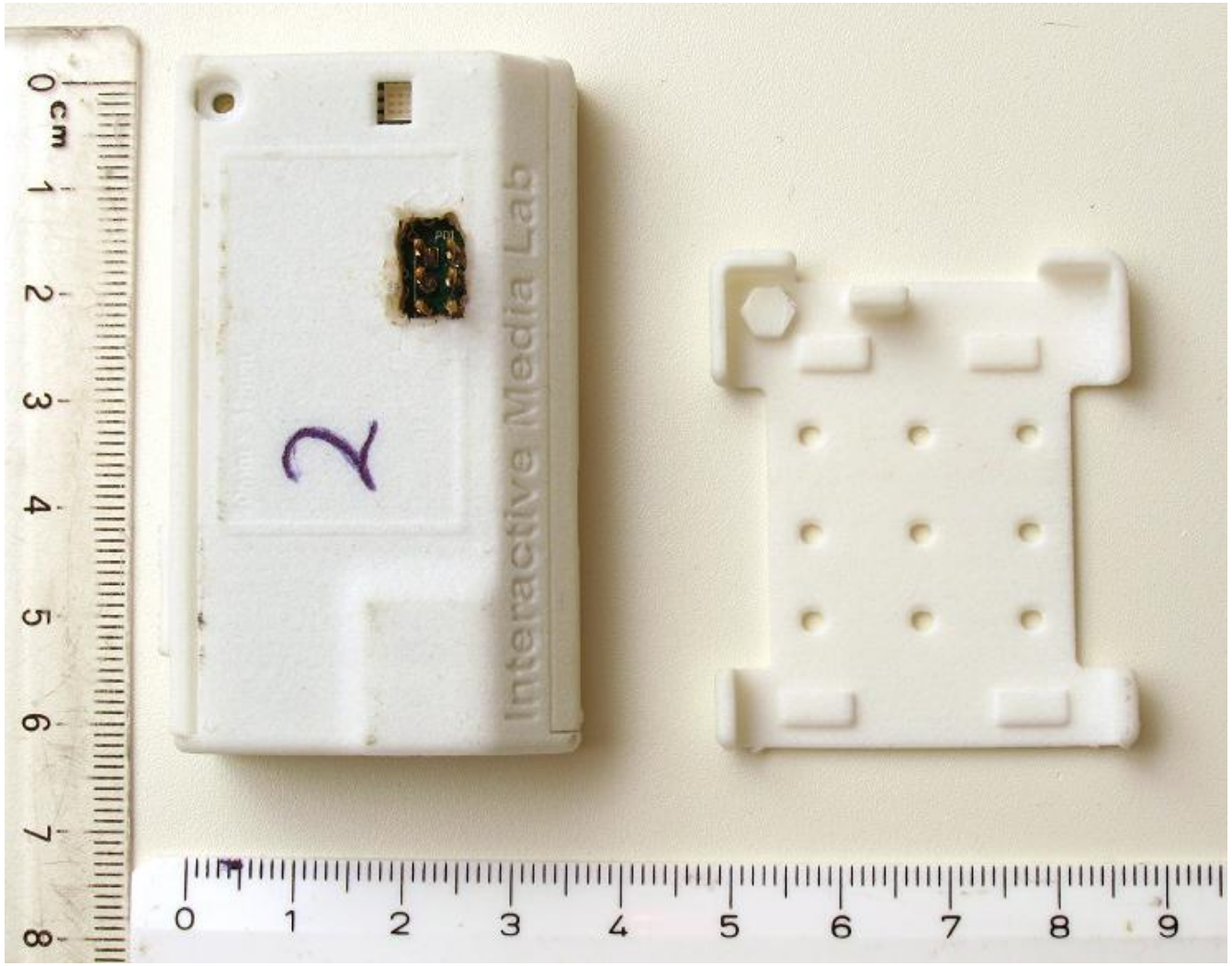


User Testing: What Older People actually Wore

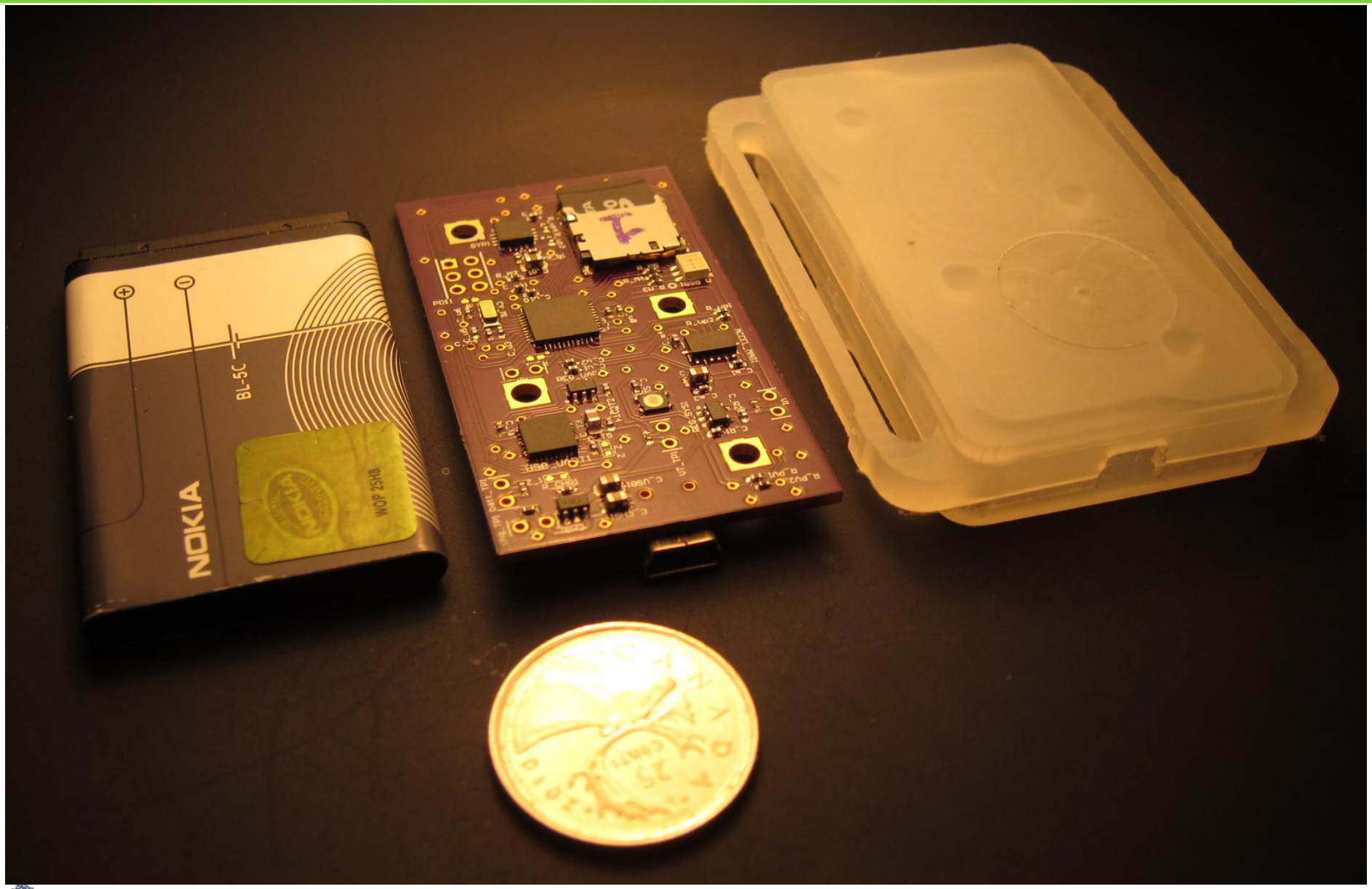





Previous Prototype



Wearing the prototype (not dependent on footwear)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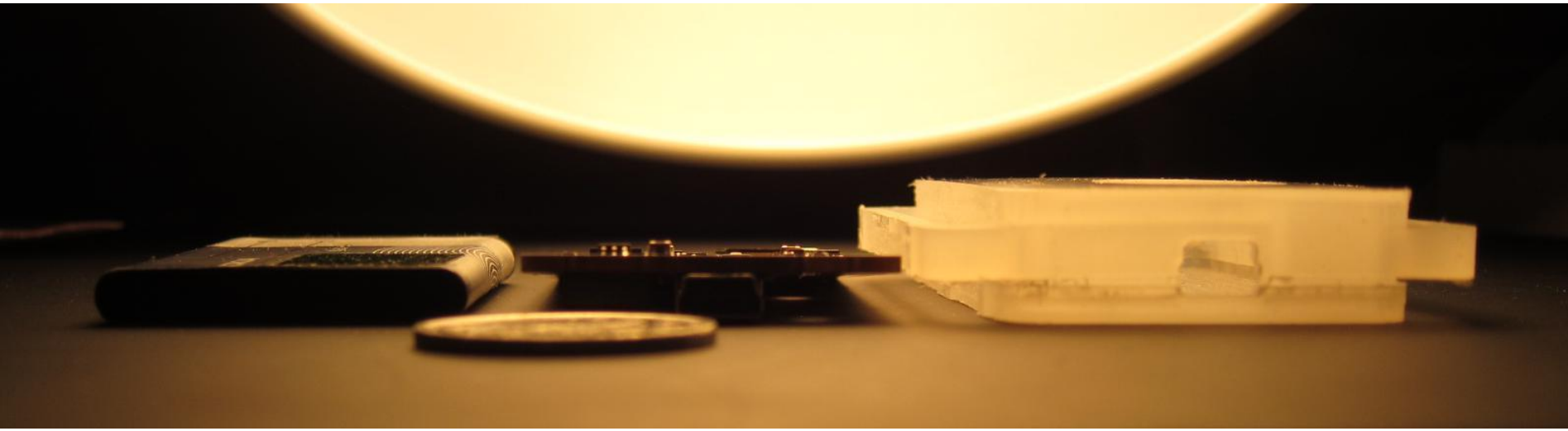
Ultra-thin!



Future Plans

- Sensor packages available for $50-$100
- We are developing step counting and trajectory modeling software
- Open source model for
  - clinical gait analysis software
  - Exercise monitoring software
  - Orthotics evaluation software
  - Cognitive impairment evaluation software
  - Etc.

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C. J. Dean, N. Alexander, and A. Kuo, "The e↵ect of lateral stabilization on walking in young and old adults," IEEE Transactions on Biomedical Engineering, vol. 54, no. 11, pp. 1919–1926, November 2007. A. J. Blake, K. Morgan, M. J. Bendall, H. Dallosso, S. B. J. Ebrahim, T. H. D. Arie, P. H. Fentem, and E. J. Bassey, "Falls by elderly people at home: Prevalence and associated factors," Age and Ageing, vol. 17, no. 6, pp. 365–372, 1988.

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