BEHAVIORAL INFORMATICS APPROACHES TO DELIVERING SAFETY, HEALTH, AND ACTIVITY SELF-MANAGEMENT INTERVENTIONS

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LiveWell

RERC *for* ICT ACCESS

Framework for Safety, Health, and Activity Treatment Planning in the Home and Community

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DISCLOSURE STATEMENT

Ronald T. Seel, PhD, FACRM

- O. Wayne Rollins Director of Acquired Brain Injury Research at Shepherd Center and receives a salary
- Receives grant funding from:
  - National Institute for Disability, Independent Living, and Rehabilitation Research
  - Shepherd Center Foundation
  - Craig H. Nielsen Foundation
- Chairs grant review panels or reviews grant applications for the U.S. Department of Defense and receives a consultation fee
- Co-author of the Neurobehavioral Functioning Inventory and receives royalties from the Psychological Corporation

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- Research Coordinators: Kimether Barlow, MPH; Nicole Thompson, MPH
- Stats: Kathleen Berger, PhD; CAT/Website: Shankar Manamalkav, MS
- ***Persons who sustained TBI and their families***

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Sara Kirkpatrick, PhD, Restore Neurobehavioral Center

LEARNING OBJECTIVES

At the conclusion of this activity, the participant will be able to:

1. Identify person with TBI and caregiver reported concerns related to safety and independent living in the home an community
2. Explain how modern test theory approaches can be used to yield measures that provide diagnostic levels, prognosis, and next steps in treatment plans
3. Use risk and protective factors for patient unsafe events in the home and community for treatment planning
4. Describe the use of technology to enhance person-centered assessment and care.

CHALLENGES IN HOME AND COMMUNITY TRANSITION FOLLOWING SEVERE TBI

- Inter- and intra-variability in ability/disability and motivation
- Awareness / denial of impairments
- Secondary medical conditions
- Coping and self-efficacy
- Psychological health
- Inter-variability in all of the above pre-injury
- Need for assistance / supervision / supports
- Caregiver knowledge / ability / motivation / coping / self-efficacy
- Financial and social resources; service access
- Generalizability of in-center rehabilitation gains to the home
- Changing conditions / next steps / problem-solving
- Increasing need to return to activity / get life back
- Unintentional injury and harm

UNINTENTIONAL HARM FOLLOWING TBI

- 32% of 504 TBI participants had 228 ER visits/ hospitalizations due to unintentional injuries at 3-months to several years following discharge (Carlson, 2012)
- Four TBI registry studies (Selassie, 2005; Harrison-Felix 2006; McMillan 2007; Ventura 2010)
  - Standardized mortality rate 3-36 times > general pop.
  - Unintentional injury (18-20%) leading cause of death
- Unintentional injuries often result from falls; improper use of electrical equipment; fire and burns; being struck by or against an object; poisoning; and firearm-related incidents.
- Additional risks include victimization, loss of money or valuables, property damage, medication errors, inappropriate response to emergency situations, and errors managing medical conditions

PERSONS WITH TBI INPUT ON PROGRAM

- Don't like being supervised
- Focus on strengths
- Independence in activities they like to do is primary goal; willing to tolerate substantial risk to do activities
- Safety is generally far less important to them but…
- They do fear setbacks that will make them less independent
- Prevention education would have been helpful
- Don't provide too much information or text in a report
- Using tables, figures and graphs are helpful
- A "roadmap" that would tell them what they can do and what to work on would be helpful
- Self-selected goals and working on activities highly desired
- In-home visits and training; 4-10 sessions, 1-2 hours each

FAMILY CAREGIVER INPUT ON PROGRAM

- Safety and reducing risk of injury is their primary concern
- Fear drives behavior
- Concede focus is on impairment, often because person with TBI is not aware of their impairments
- Overwhelmed by amount of information at discharge
- Targeted prevention education would have been helpful
- Information on when to stop supervising would be helpful
- Education on how best to talk to the person with TBI about their behavior without making them angry would be helpful
- Provide just enough information when you need it
- A “roadmap” that would tell them what the patient can do, what they can’t do, and the next set of achievable steps they could work on with the person with TBI
- In-home visits and training would be very helpful

OPPORTUNITIES IN DELIVERING HOME AND COMMUNITY TRANSITION SERVICES

- Individualized / person-centered assessment and intervention
- Bundled payment systems offer the potential to be creative with funds and services including prevention and in-home services
- Translating measures developed with state-of-the-science methods, i.e., item response theory, to generate on-going, just-in-time assessments of ability, prognosis and next steps
- Improving technologies to provide assessment if intra-variability in everyday performance over time
- Improving evidence of effective behavioral interventions; knowledge translation into usable in home protocols
- Leveraging technologies and interventions developed for older persons with early cognitive decline
- Predicting / providing feedback on momentary capacity and risk

PATIENT-CENTERED CARE
PERSONALIZED MEDICINE PRINCIPLES

- Stratify prognosis (severity) using observed behavioral "markers" that inform the selection of the most appropriate activities to target for treatment and the optimal level of family involvement
- Safety Assessment Measure (SAM):

  (a) provides empirical data on "behavior" as primary risk "marker"

  (b) stratifies people into prognostic groups, and

  (c) identifies specific activities most appropriate for treatment
- User-friendly Safe@Home Report helps survivors and family to:

  - anticipate a broader range of activities that create risk

  - target specific environmental changes

  - make decisions on family involvement in survivors' activities

  - build on individuals' strengths

  - identify progressive, achievable goals to reduce unsafe events and increase self-managed activities

RESEARCH OVERVIEW

Phase I

- Describe development and validation of the Safety Assessment Measure (SAM)
- Identify the number and types of unsafe events at 30-day follow-up and evaluate predictors

Phase II

- Use personalized medicine principles to develop an in-home harm prevention and activity training program
- Translate SAM and Independent Living Survey into a usable, web-based test that generates individualized roadmap for home and community transition

Phase III

- Use bioinformatics from performance-based measures and remote coaches to improve safety and independence

SAFETY ASSESSMENT MEASURE
QUALITATIVE/QUANTITATIVE DEVELOPMENT PROCESS

1. Conceptual Development
   - Target Population: **aged 16+ who sustained mild complicated, moderate, or severe TBI**
   - Theoretical Framework: **Social Cognitive Theory**
   - Operational Definitions: **safety, risk and scale constructs**
2. Item Pool and Rating Categories Development
   - Item generation and expert review; modifications
   - Target user focus groups and interviews; modifications
3. Field Test Item Pool – Development Sample
   - Collect items, demographics, potential associated factors
   - Collect prognostic validity data (1-month follow-up)
   - IRT / Rasch psychometric analysis of scales and items

Velozo, Seel 2012; DeVellis 2003; Bond and Fox 2007

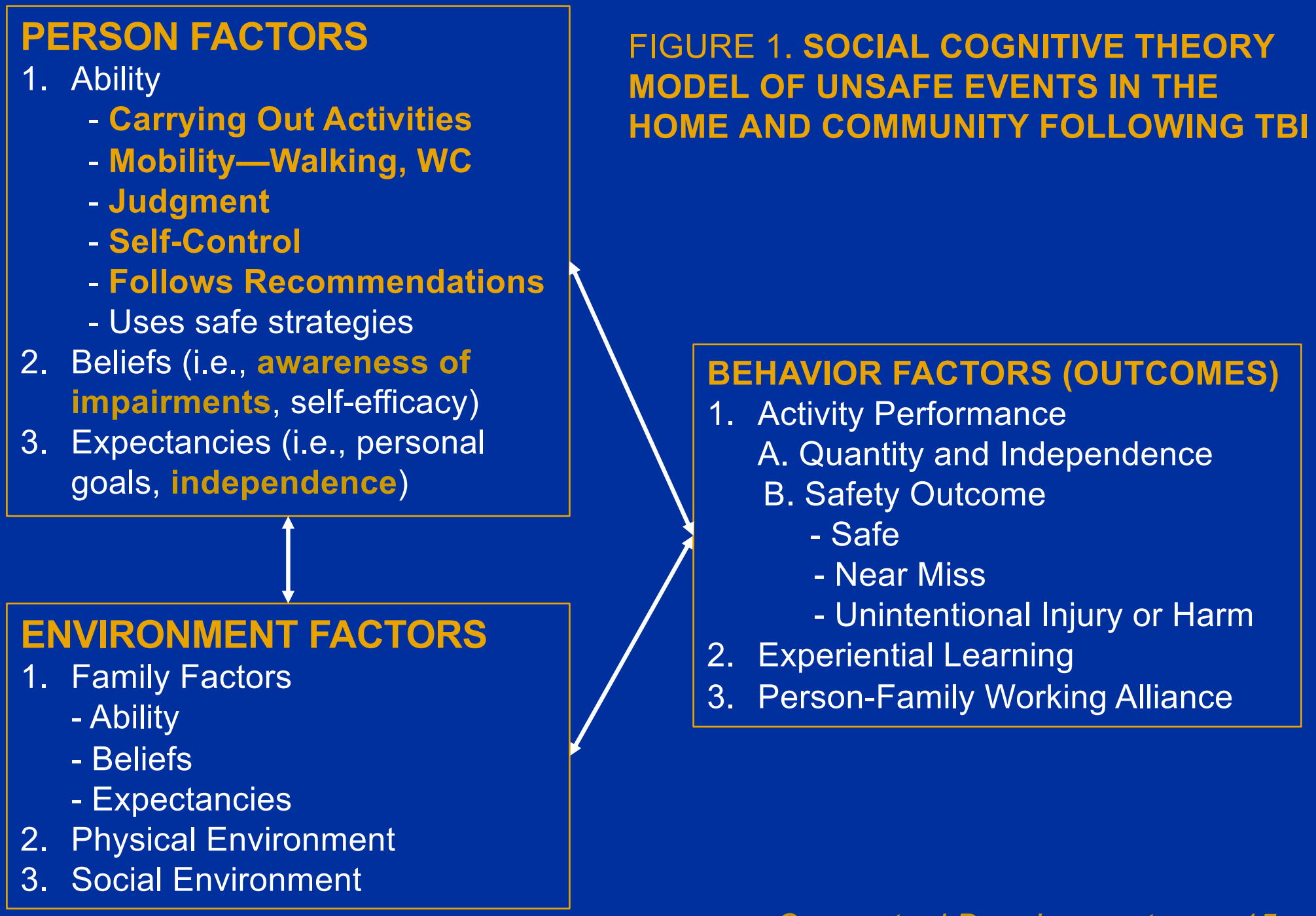


FIGURE 1. **SOCIAL COGNITIVE THEORY MODEL OF UNSAFE EVENTS IN THE HOME AND COMMUNITY FOLLOWING TBI**

PERSON FACTORS

1. Ability
   - **Carrying Out Activities**
   - **Mobility—Walking, WC**
   - **Judgment**
   - **Self-Control**
   - **Follows Recommendations**
   - Uses safe strategies
2. Beliefs (i.e., **awareness of impairments**, self-efficacy)
3. Expectancies (i.e., personal goals, **independence**)

ENVIRONMENT FACTORS

1. Family Factors
   - Ability
   - Beliefs
   - Expectancies
2. Physical Environment
3. Social Environment

BEHAVIOR FACTORS (OUTCOMES)

1. Activity Performance
   A. Quantity and Independence
   B. Safety Outcome
      - Safe
      - Near Miss
      - Unintentional Injury or Harm
2. Experiential Learning
3. Person-Family Working Alliance

SAFETY ASSESSMENT MEASURE ITEM BANK
OF ITEMS PER CDC TRACKED ACTIVITIES

CDC-NCIPC, A Report to Congress, 1999

- Transportation (23)
- Falls (17)
- Aggressive and violent behavior (13)
- Identification, avoidance and response to persons and animals who intend harm (11)
- Use of electric devices and equipment (8)
- Recreation (contact sports, water activities) (7)
- Medication management (5)
- Use of firearms (2)
- Use of sharp objects/devices (2)
- Use of fire (2)
- Alcohol and substance use (1)

SAFETY ASSESSMENT MEASURE ITEM BANK
OF ITEMS GENERATED, NON-CDC ACTIVITIES

NON-CDC Risk Activities

- Emergency Identification and Response (17)
- Ambulating, transfers (8)
- Sexuality (4)
- Money management (3)
- Eating (2)

CARRYING OUT ACTIVITIES

Cognitive impairments increase risk of unsafe events:

- "unsuccessful chain of behaviors" creates unsafe events
- forgetfulness, inattention, slowed processing speed, lack of initiation, and difficulty understanding information

Example Items	Rating
Crosses street inappropriately (e.g., does not look, misinterprets signs, misjudges traffic)	3.94
Forgets to take prescribed medication (e.g. seizure, diabetes…)	3.88
Leaves flammable items too close to fire (e.g. paper bag near burner)	3.76
Does not respond to emergency alarms (e.g. smoke, carbon monoxide…)	3.76
Forgets to turn off appliances (e.g. stove, iron, space heater)	3.71
Unable to find way if lost in the community	3.59

MOBILITY—WALKING

Mobility impairments increase risk of unsafe events:

- "Unsuccessful" behavior creates specific unsafe events
- Strength, coordination, balance, dexterity, and vision

Example Items	Rating
Loses balance when walking up or down stairs	3.85
Loses balance getting in or out of tub	3.74
Loses balance when walking on flat surfaces	3.59
Loses balance when attempting to stand from a sitting position	3.56
Loses balance when carrying objects	3.52
Trips when walking in low lit areas	3.41

JUDGMENT

Impaired ability to perceive potential harm associated with behavior or activities…

- Naiveté, limited awareness of impairments, difficulty anticipating harmful situations or consequences, acts without using common precautions

Example Items	Rating
Stands on unstable objects (e.g. chair with wheels, top step of ladder, cardboard box)	3.85
Rides in a motor vehicle driven by someone who has been drinking or doing drugs	3.77
Inappropriately reveals personal information (e.g. bank account #...)	3.73
Does not follow precautions when using electrical equipment (e.g. power tools, kitchen appliances)	3.73
Invites strangers into home	3.67
Easily influenced to do risky behaviors	3.63

SELF-CONTROL

Impaired ability to self-regulate behavior…

- Impulsivity, disinhibition, aggression, inappropriate sexual behavior, and wandering

Example Items	Rating
Physically abusive to family members or caregivers	3.81
Easily provoked into physical fight	3.78
Makes unwelcome physical contact with others	3.73
Keeps doing activities after being told to stop	3.62
Verbally abusive to others	3.52
Wanders	3.48
Sends abusive or obscene messages	3.31

FOLLOWS RECOMMENDATIONS

Does not comply with health-related recommendations…

- Ignores medical recommendations
- Does not follow activity and participation limitation recommendations

Example Items	Rating
Refuses to take important medications (e.g. seizure, diabetes…	3.96
Drives motor vehicle against recommendations	3.89
Uses firearms against recommendations	3.78
Does not wear a helmet when recommended (e.g. bicycle, scooter…	3.77
Climbs against recommendations (e.g., stool, ladder, stairs)	3.62
Ignores advice to seek medical care	3.48

SAFETY ASSESSMENT MEASURE
OTHER SCALES, CONSTRUCTS

SAM scales

- Mobility—Wheelchair

Supporting Questionnaire Based on IOM Home Health Recommendations

- Caregiver and Person with TBI sociodemographics
- Person with TBI…
  - Abilities and secondary medical conditions
  - Psychiatric hx; alcohol and substance use
  - Environmental factors

ITEM RATING CATEGORIES

- Items rated using four responses:

  4—Highly likely to occur

  3—Somewhat likely to occur

  2—Somewhat unlikely to occur

  1—Highly unlikely to occur

- NA—“ Not applicable, <reason>”

  (*example.* “Does not properly store weapons. “Not applicable, does not possess weapons”

RASCH AND ITEM RESPONSE THEORY (IRT)

- Traditional scales add all item ratings
  [Total score = Functioning level]
- IRT focuses on the items of the scale
  item difficulty and person ability
- Items reflect different levels of difficulty/risk on a hierarchical continuum
- Persons who can do more difficult items should be successful with easier items
- Basis for improved efficiency and precision
- *Can generate just in time, risk management assessment and identify treatment "next steps"*

RATING SCALE ANALYSIS
UNIDIMENSIONALITY

- Unidimensionality assessed with Confirmatory Factor Analysis (CFI >.90 good; >.95 excellent):

  Carrying Out Activities = .987

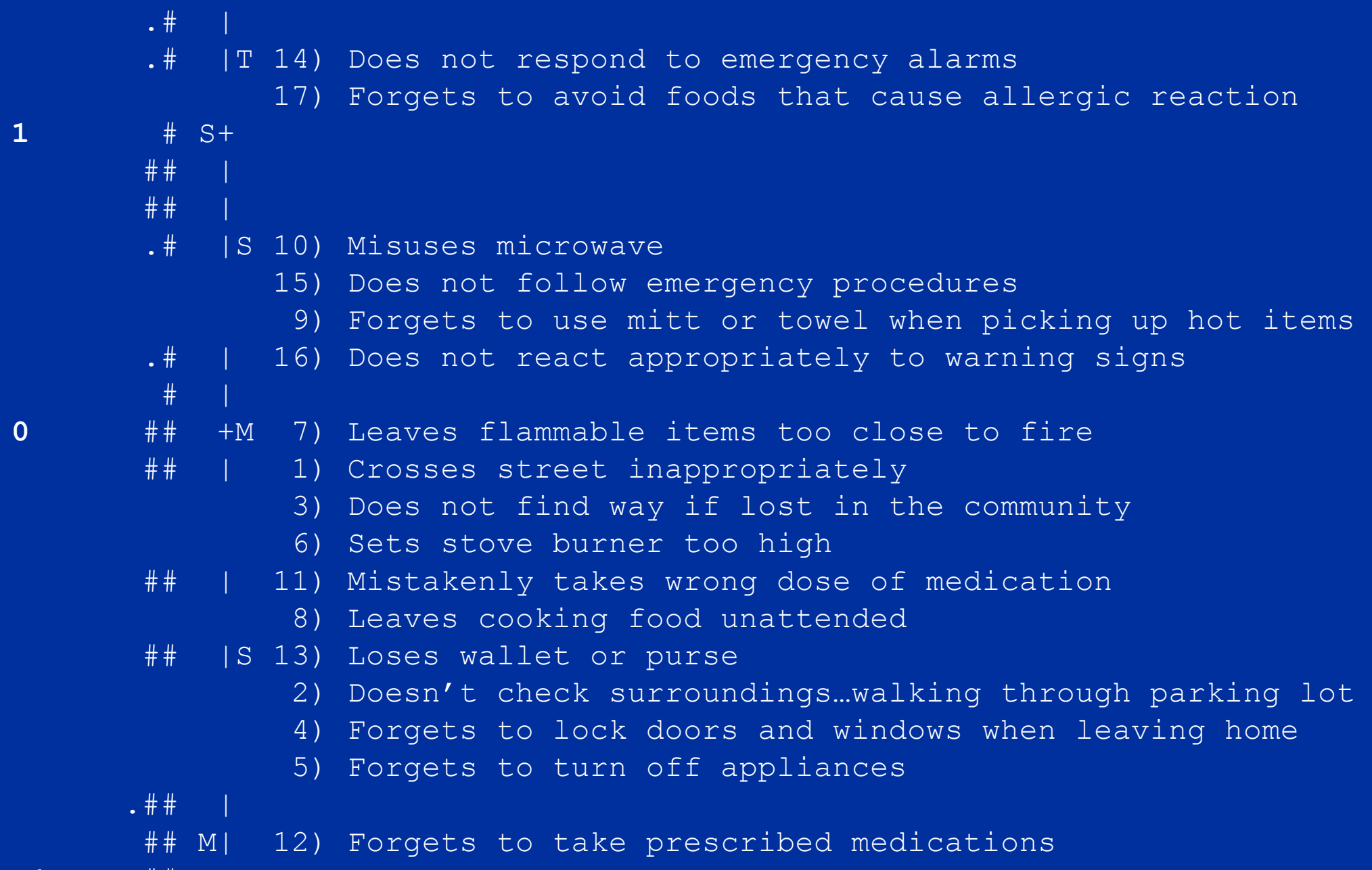
  Mobility—Walking = .990

  Judgment = .977

  Follows Recommendations = .972

  Self-Control = .987

ITEM MAP – CARRYING OUT ACTIVITIES



SAM—RASCH ANALYSIS

CONSTRUCTS	Carrying Out Activ.	Mobility—Walking	Judgment	Self-Control	Follows Recs
Item Count	17	13	23	13	14
Model Fit to Data					
# Items Misfitting	2	1	3	2	2
# Items Overfitting	0	2	1	1	0
MnSQ Outfit <2	Y	Y	Y	Y	Y
Precision					
Person Separation	3.42	3.62	2.80	1.77	1.94
Person Strata	4.89	5.16	4.07	2.69	2.92
Reliability					
Person Sep. Reliability	.92	.93	.89	.76	.79
Cronbach's Alpha	.96	.97	.96	.92	.92
Person Ability					
Mean logit score	-.82	-1.02	-1.45	-1.19	-1.79
(SD)	(1.86)	(2.30)	(1.50)	(1.17)	(1.37)
Measured (n)	138	113	131	121	101
Not applicable (n)	0	17	0	0	0
at ceiling (n)	1	3	1	1	0
at floor (n)	25	31	32	42	63

DEFINITION—UNSAFE EVENT

- Unsafe event—observable and poses a real, significant, and imminent risk of harm including death, physical injury, financial loss, damage to property, or incarceration
- Near miss—injury or harm is imminent but averted due to: (a) the intervening behavior of self or others or (b) random physical distance between the persons and the danger
- Harmed individual may be person with TBI, other persons, animals, and self/others' personal property
- Includes victimization/exposure to violent acts
- Excluded Unsafe Events:
  - Intentional Injuries to Self
  - Pre-meditated violence or victimizing of others
  - Pre-meditated damaging of property

RESULTS—UNSAFE EVENTS AT 30-DAYS

- 38% of 154 patients had 117 unsafe events
- 32 had injuries or harm; 85 near misses
- 81% of unsafe events related to 7 activities (see table below)
- No single activity > 27% of events
- Overall, 75% of unsafe events occurred at home

Activity	Incidence	At Home
Ambulating, standing or transferring, i.e., falls	27%	92%
Identify/respond to harmful persons or situations	12%	33%
Using equipment, appliances, fire, or sharps	10%	94%
Inappropriate, angry, or violent behavior	10%	56%
Losing money or valuables	9%	42%
Managing medication or medical conditions	8%	100%
Transportation	5%	20%

RESULTS—PREDICTING UNSAFE EVENTS
5-FACTOR LOGISTIC REGRESSION MODEL

Logistic regression (N =149), Pseudo R^2= 0.268

Factors	OR	SE	P	95% CI
F-T Supervision	.11	.06	0.00	.04, .30
Carrying Out Activities	1.52	.24	0.01	1.12, 2.07
F-T Supv. x COA	.64	.14	0.04	.42, .97
Mobility (Walk/WC)	1.14	.09	0.12	.97, 1.34
Impaired Awareness				
Mild-Moderate	2.55	1.21	0.05	1.01, 6.45
Severe	7.86	6.57	0.01	1.53, 40.45
Constant	1.51	.66	0.35	.64, 3.56

ROC curve = **0.819**
Sensitivity (64.3%), Specificity (87.1%)
+ predictive value (75.0%), - predictive value (80.2%)

SAFE@HOME PROGRAM

- Develop a **home-based injury prevention / activity independence program**
- Transition coach delivers treatment including:

  a. personalized assessment including the SAM,

  b. person-family education and goal-setting (2 visits),

  c. select/receive training on 2 of 5 activity modules (8 visits)
- Conduct clinical trial→ primary outcomes:
  a. reduced # of unsafe events
  b. increased self-directed activities
- Safety Assessment Measure scale scores:
  a. stratify people into prognostic treatment groups
  b. identify activities most appropriate for treatment based on activity difficulty and person ability

SAFE@HOME PROGRAM

ACTIVITY MODULES

Activity Modules	Unsafe Events Addressed in Module
Improving mobility, balance and strength	Falls or collisions while ambulating, standing or transferring
Independence in the community	Identifying and responding to potentially harmful persons or situations; losing money or valuables; transportation
Managing health and wellness	Managing medications and medical conditions; managing stress, frustration, and inappropriate behavior; knowing own limits in activities
Independence in the home	Using appliances, fire, and sharp objects; identifying and responding to potentially harmful persons or situations; pet care
Maintaining the home	Using equipment, chemicals, and utilities

WEB-BASED SAM ASSESSMENT

Home Admin About Contact Login

Safe@Home

Welcome! The goal of this project is to give you (and your family/caregiver) a customized "roadmap" that will help you to successfully adapt to the effects of TBI (Traumatic Brain Injury). This roadmap can be used to:

- ✔ highlight your current strengths and things you can do on your own
- ✔ identify your current risks and how to lower them
- ✔ set short-term goals on activities you would like to work on
- ✔ choose strategies and make a plan to reach your goals

You will be presented with a series of questions that assess the current ability level of the person with TBI. Thereafter, you will be able to generate your personalized report

Thank you for your participation. Please click on the button below to get started:

Start!

NEXT STEPS IN HOME AND COMMUNITY TRANSITION RESEARCH

- Version 3.0 of Safe@Home automated safety and independent living assessment and roadmap to include decision support system for home health providers
- Modifying existing technologies to provide assessment of intra-variability in everyday performance over time
- Translating knowledge from Safe@Home clinical trial to the automated assessment and treatment planning platform
- Leveraging technologies, processes, and interventions developed for older persons with early cognitive decline
- Predicting / providing feedback on momentary capacity and risk

Technology for Scalable Approaches to Just-in-time Health Coaching

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DISCLOSURE STATEMENT

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  - TEKES (Finland Government)
  - Halmstad University, Sweden

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- Halmstad University: Ingela Skärsäter, Kristina Ziegert, Anita Sant'Anna, Nicholas Wickström

LEARNING OBJECTIVES

At the conclusion of this activity, the participant will be able to:

1. Define behavioral informatics and identify related technologies
2. Identify approaches and benefits for using home physical activity technologies
3. Recognize relevant sensors for self-management interventions.

Technology and Bioinformatics for Independent Living (Life) Coaching

Amplifying the scalability and effectiveness of independent living and safety interventions

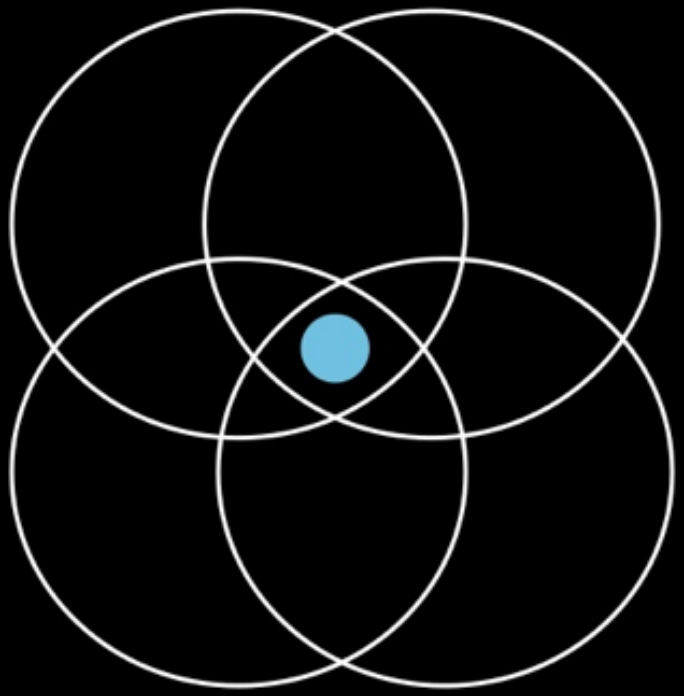
- Use of sensor data, inferential algorithms, and feedback dissemination
- Tailoring of health coaching messages to the person
- Timeliness of objective data to corroborate observed behavior and provide more specific diagnostic data
- Automated responses for identified person-specific risks
- Evaluate effects of pharmaceutical and behavioral interventions in real time compared to pre-treatment performance
- Extend the reach of a health coach

HealthStartup Europe

The #1 lesson: Look for the sweet spot as four tech domains converge to transform physical therapy and rehabilitation

Devices that integrate multiple sensors and interfaces

Software for changing behaviour (games and digital coaching)



Communication networks & tools

Analytics & Big Data

Interactive Video Exercise Use in Clinics

- VirtualRehab (virtualrehab.info)

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- VirtualRehab (virtualrehab.info)

- YouRehab (yourehab.com)
  - YouGrabber
  - YouKicker

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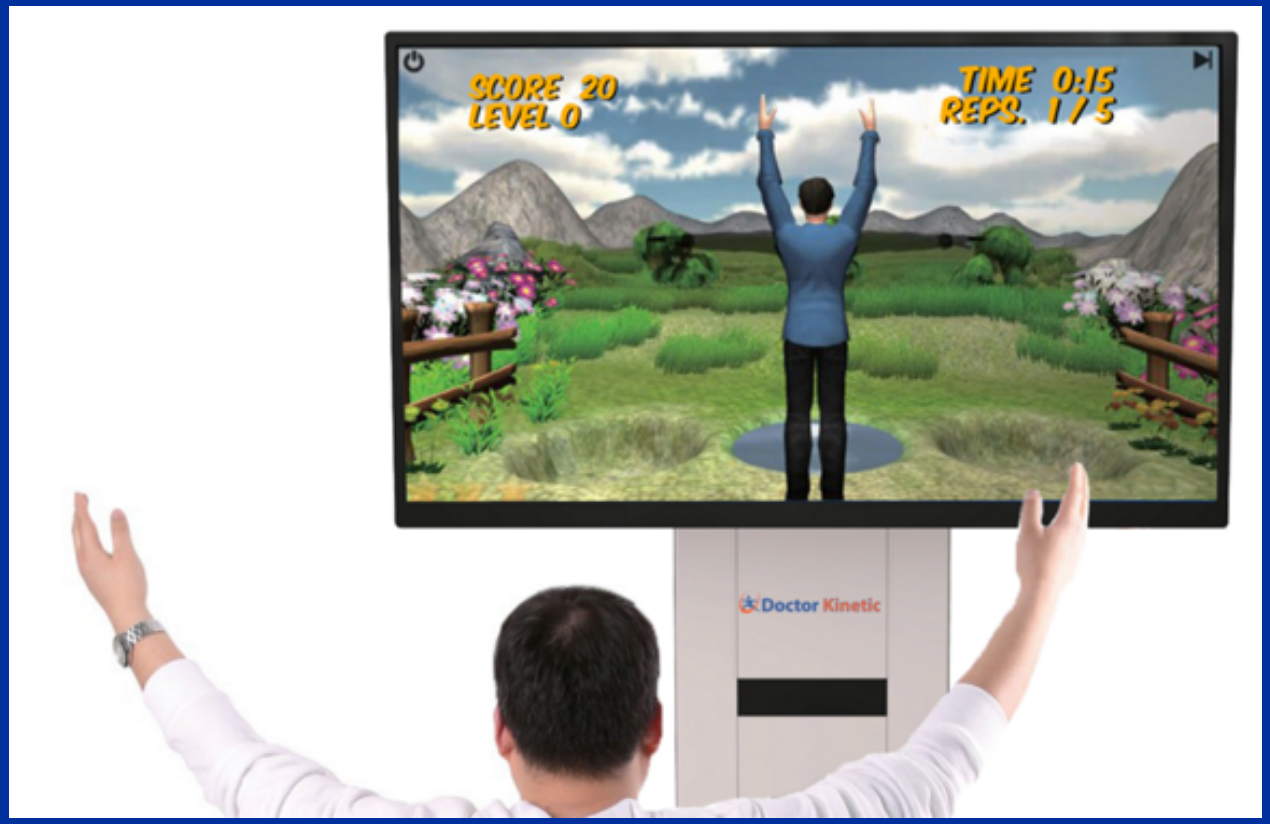
Interactive Video Exercise Use in Clinics



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  - YouGrabber
  - YouKicker
- Jintronix (jintronix.com)
- DrKinetic (drkinetic.com)

Home Physical Exercise

Approaches

- Video conferencing with therapist
- Specialty cameras to track body parts provide feedback & monitoring
- Use of interactive video games

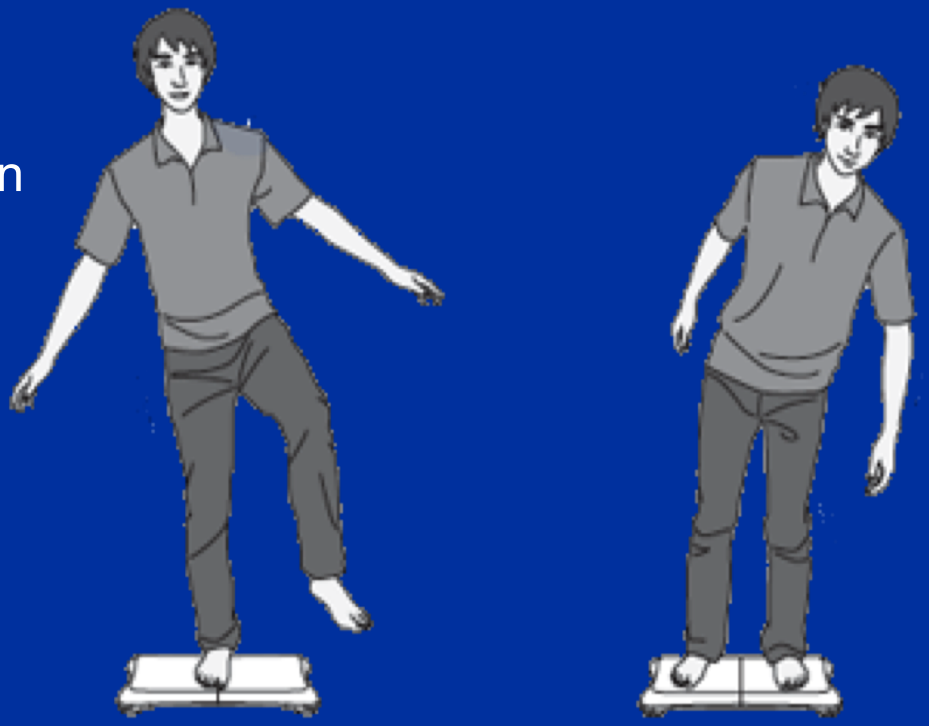
Benefits

- Access
- More frequent use
- Automate exercise guidance
- Monitor progress

Interactive Video Exercise

Nintendo Wii

- Element of competiveness
- Idea of sport / game -> more fun
- Encourages repetition
- Social support
  - family plays as well



Example: Wii Fit

- Can address balance (e.g., TBI or stroke)
- Range of motion
- Gross motor coordination

Preliminary Evidence

- Wii golf has helped speed up recovery times for stroke patients at Kaiser Permanente in Redwood City, CA.
  - http://www.nytimes.com/2012/09/09/health/physical-therapists-use-wii-golf-to-treat-patients.html

- TBI patients with 5 to 6 wks of video game exercise improved balance, gait, functional reach, coordination, dynamic stability, and precision (P<0.05 for all), but saw no significant change in ataxia scores.
  - *Ustinova K, Perkins J "Virtual reality game-based therapy for restoring postural and coordination abnormalities in patients with TBI" World Congress of Neurology 2013*

- Parkinson's patients with 12 wks of video game exercise
  - 65% had longer strides
    55% had increased gait velocity
    55% reported improved balance
  - https://www.michaeljfox.org/foundation/news-detail.php?are-video-games-a-potential-therapy-for-parkinsons-disease

Automated Coaching for Physical Exercise

- Real-time feedback based on image interpretation from Kinect skeleton representation
- Monitoring of balance, flexibility, strength, endurance

Additional Home Rehabilitation Opportunities

- Monitoring opportunities
  - Location, activity level, medications, sleep mat, voice affect (phone), cognitive games, walking speed,
- Inferences
  - Activities of daily living, socialization, sleep quality, cognitive function, stress, mood, context
- Early detection
- Holistic intervention opportunities
  - Sleep management, cognitive health, stress management, socialization, safety

Scalable Approach to Delivering Interventions to the Home

- Cognitive exercise, physical exercise, sleep management, etc. are a lifestyle interventions
- Remote, just-in-time, continuous care
- Incorporate principles of health behavior change
- Optimal use of lower cost personnel
- Integrate family & informal caregivers into the health care team (untapped resource)
- Platform for testing sustained cognitive interventions in the home

“Monitoring” Care

Training

Coaching

Chronic Care

Social Networks

Health Information

Performance

Prediction

Early Detection

Decision Support

Population
Statistics
Epidemiology
Evidence

Inference

Data mining

M Pavel, H Watclar, CISE, NSF

Other Examples of Sensors

- Nike FuelBand measures physical activity (time, calories, steps, model of total activity
- Fitbit has an accelerometer and an altimeter to track distance and stairs, infer sleep quality
- Apple watch
  - Heart rate
  - 3D accelerometer
  - Activity inference

Other Examples of Sensors

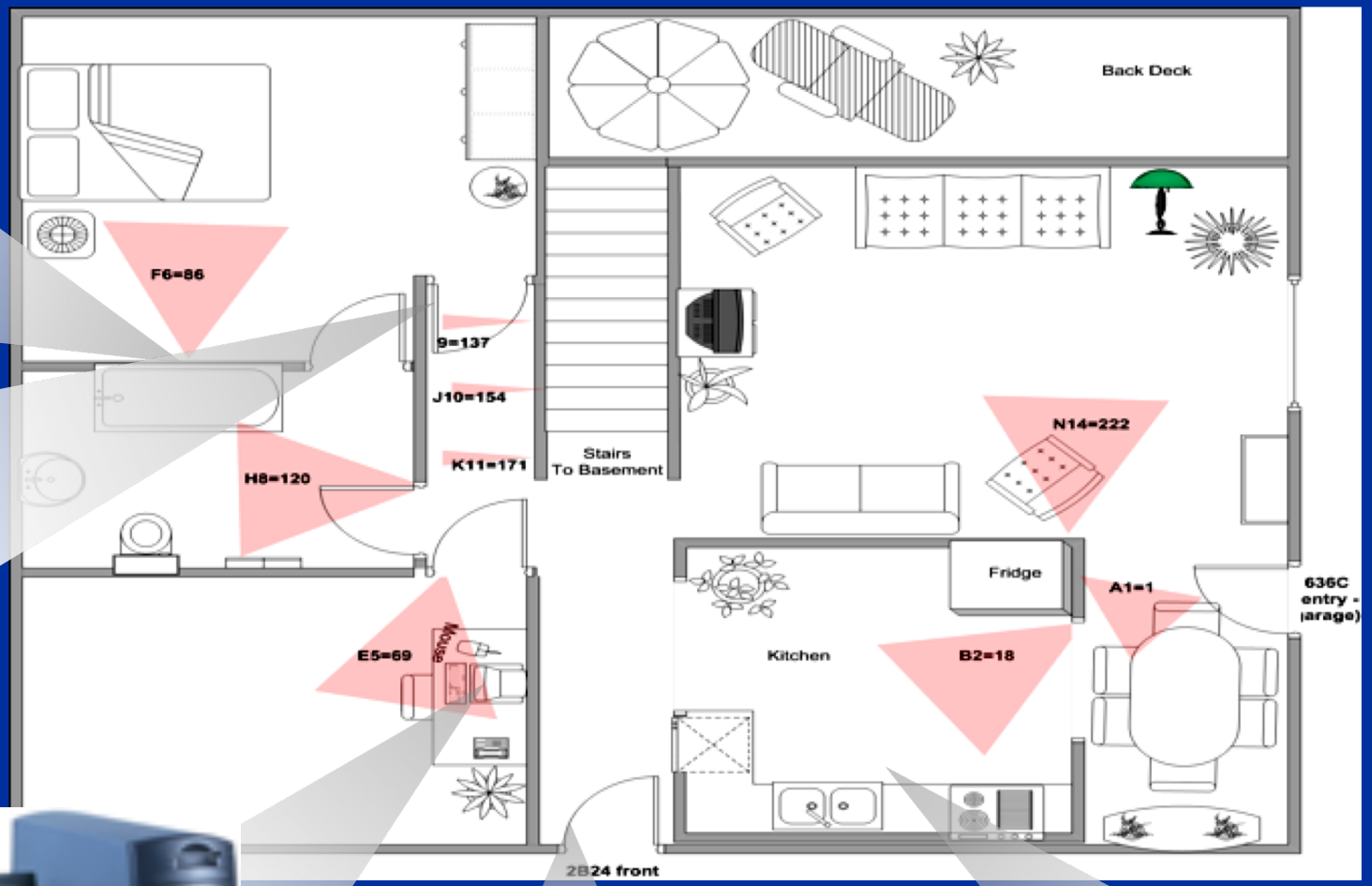
- Basis B1 Watch
  - Heart rate
  - Respiratory rate
  - 3D accelerometer
  - Body temperature
  - Ambient temperature
  - Galvanic skin response
- BodyMedia Link Armband
  - Steps, calories
  - Heat flux, skin temperature, and galvanic skin response

Other Examples of Sensors

- Moticon wireless sensor insole
- Weight distribution
- Motion

http://www.informationweek.com/mobile/10-wearable-health-tech-devices-to-watch/d/d-id/1107148?page_number=8

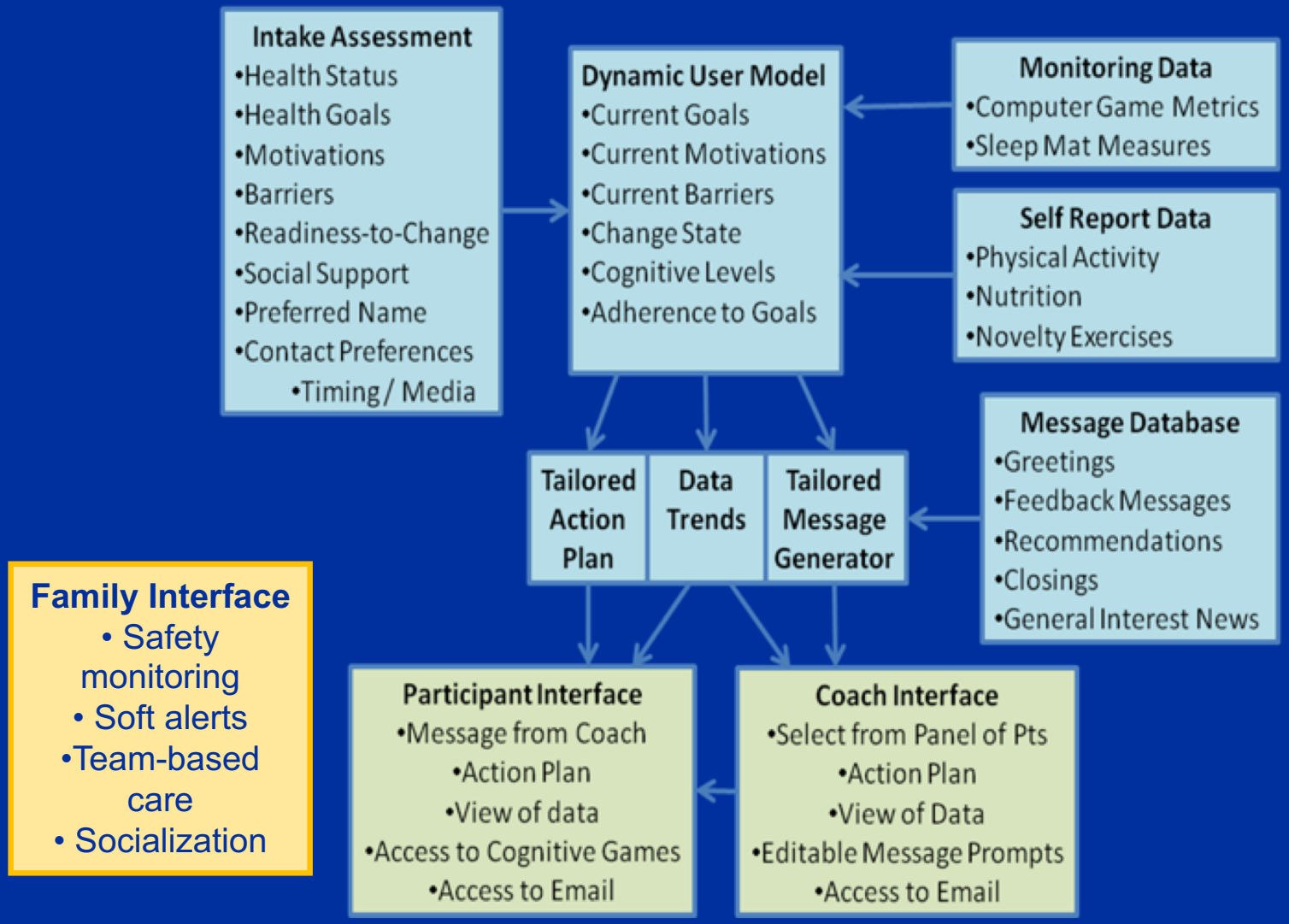
Inference of Patient Activities Based on Sensor Data



Technology Approaches to Facilitating Health Coaching

- Effective use of resources
  - Wise use of face-to-face, Skype, phone interactions (build rapport, careful assessment)
  - Supplemented by automated or semi-automated messages
- Dynamic user model
  - Behavior change variables
  - Activity / context / health state estimates from sensor data

Dynamic User Model to Support Tailored Messaging



Semi-Automated Messaging

Study of coaching efficiency with/without assisted messaging

- Coaches (n=6) completed 4 coaching sessions for a panel of 10 (simulated) patients, half using automated system, half using manual system. Coaches were crossed over to alternate system after each session.
- **Efficiency** improved with semi-automated system (mean time to clear patient manual 4:26 min vs 2:39 min ($p<.04$)
- **Quality** of message judged equivalent on average by both patients and other coaches.

Michael Shapiro, MS Thesis, Oregon Health & Science University

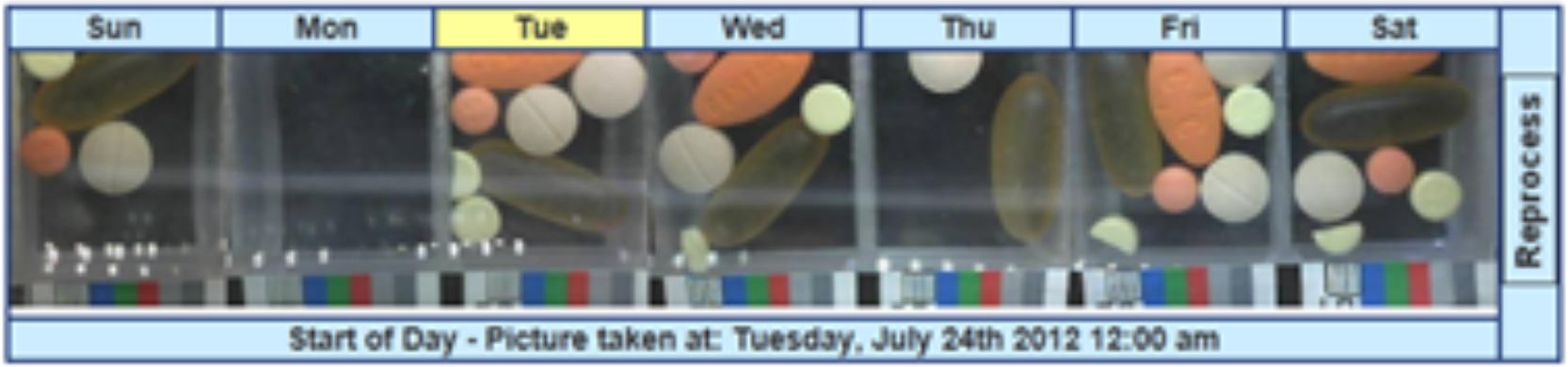
Participant Home Page

- Messages from coach
- Featured story
- Weekly goals
  - Activities
  - Surveys
- Access modules
  - Physical Activity
  - Sleep
  - Socialization
  - Novelty Exercises

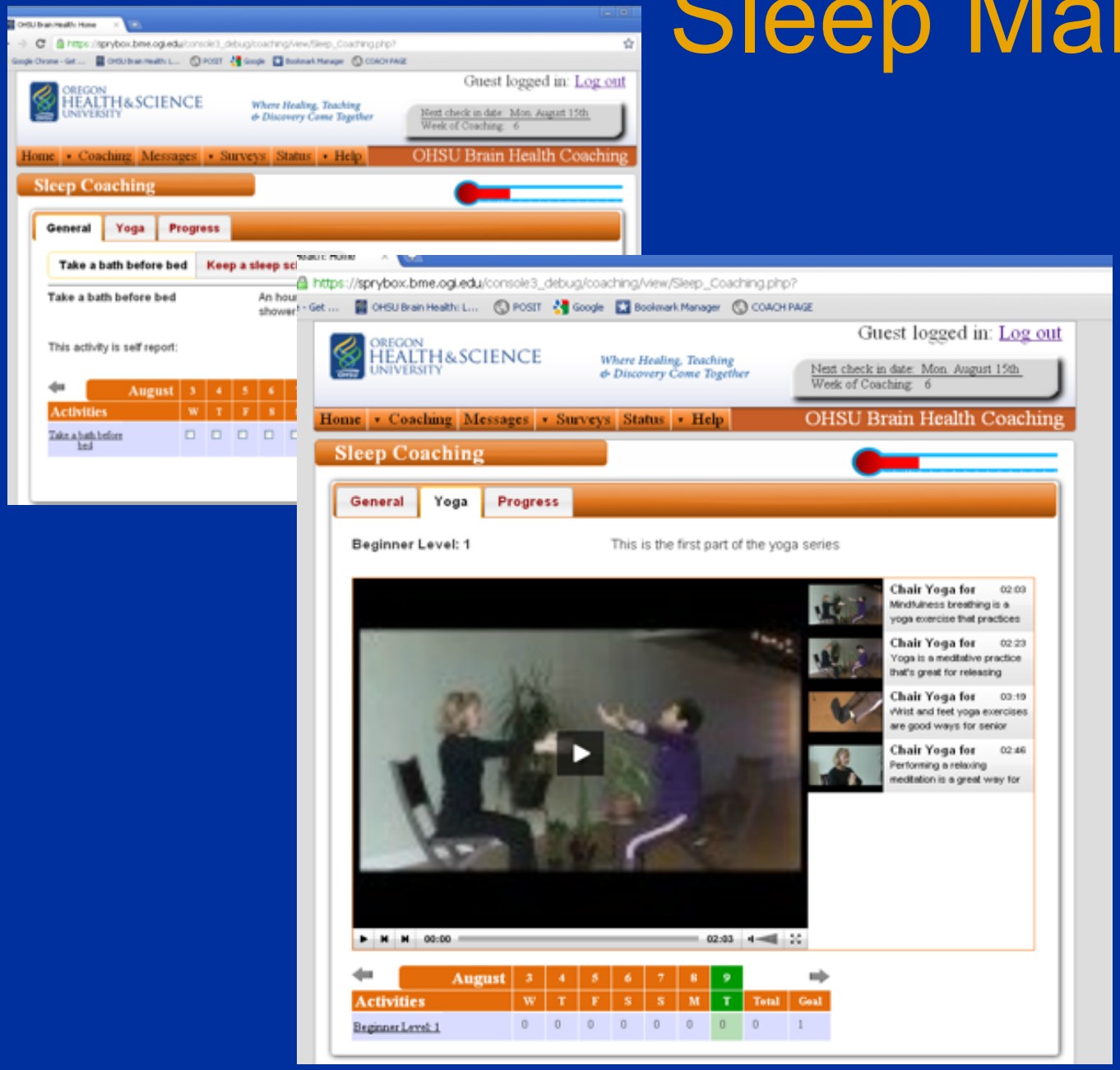
Medication Management

Bluetooth enabled dispenser

Web cam view underneath
Available to coach or
remote family member



Sleep Management



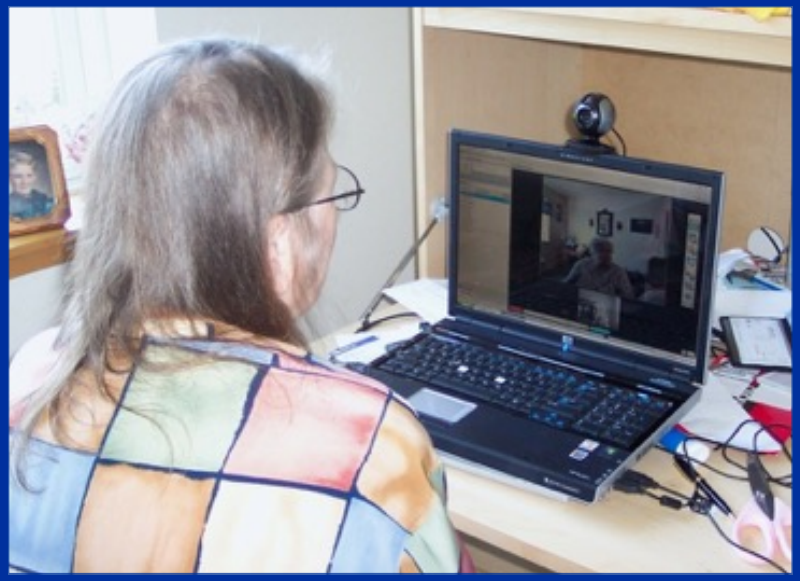
Assessment

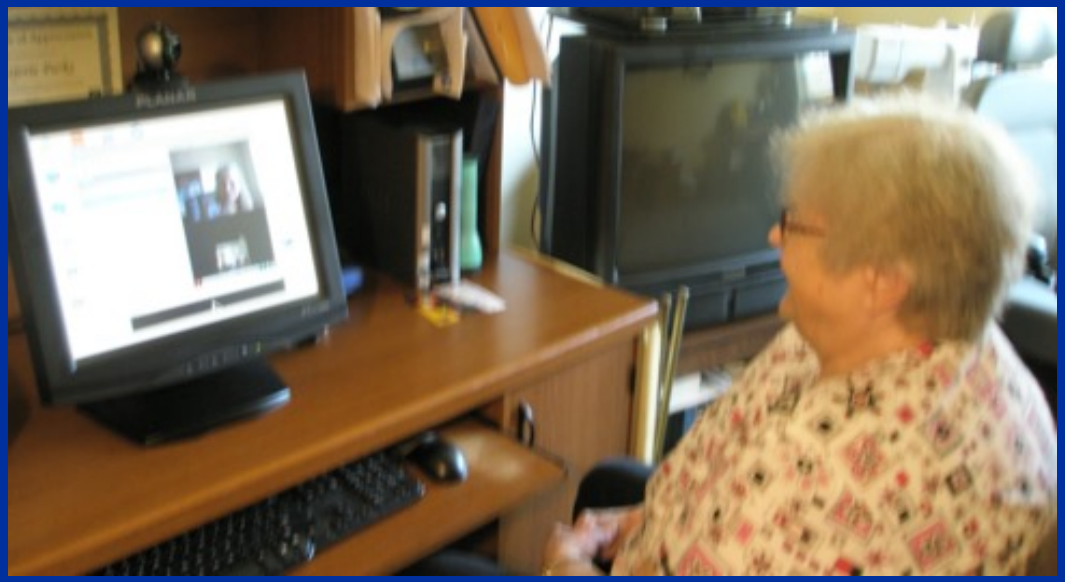
- Sleep Hygiene
- Anxiety
- Circadian Rhythm

Tailored Intervention

Socialization Intervention

- Web cams and Skype software given to participants and their remote family partner
- Frequent spontaneous use among participants





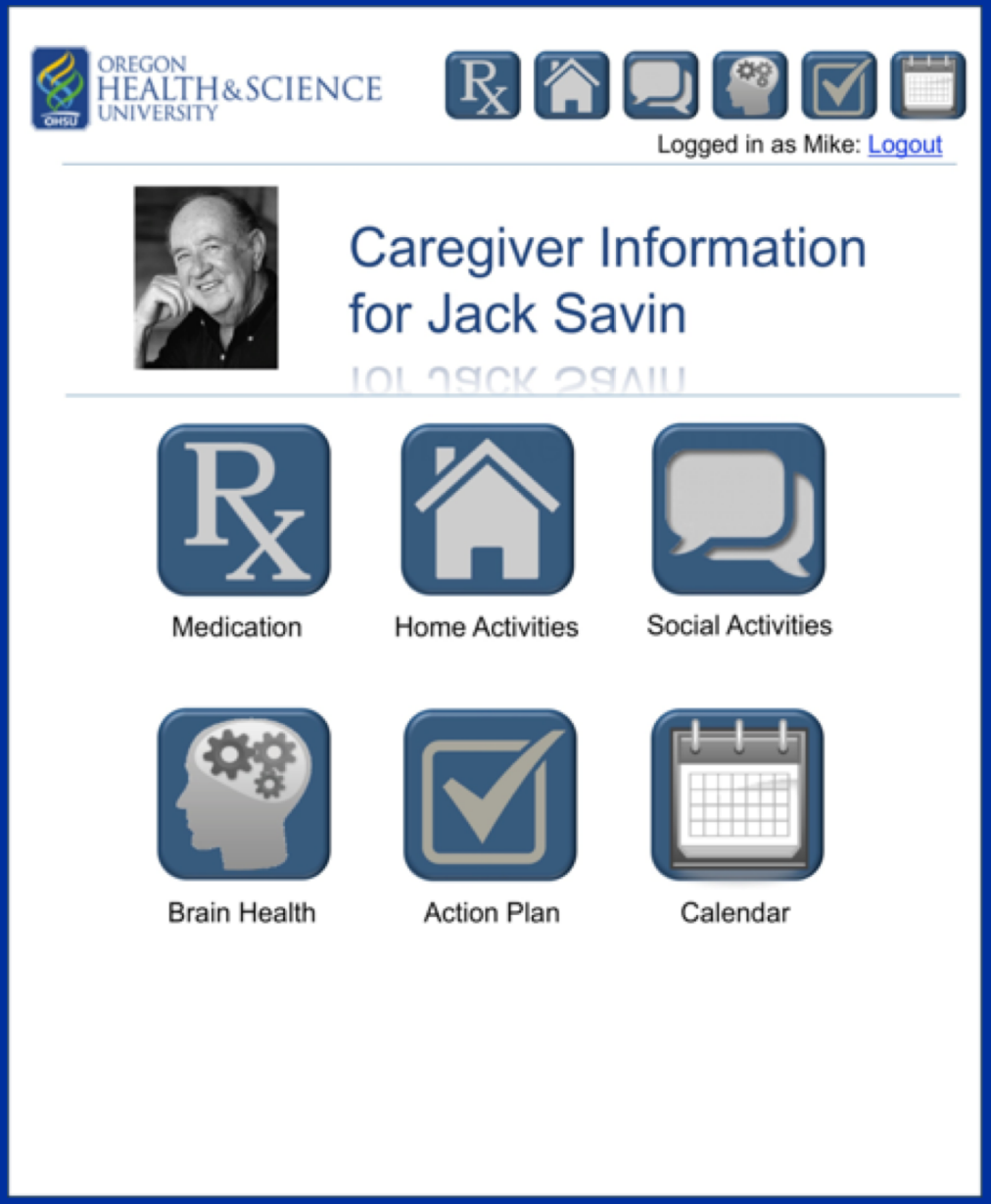
Cognitive Computer Games

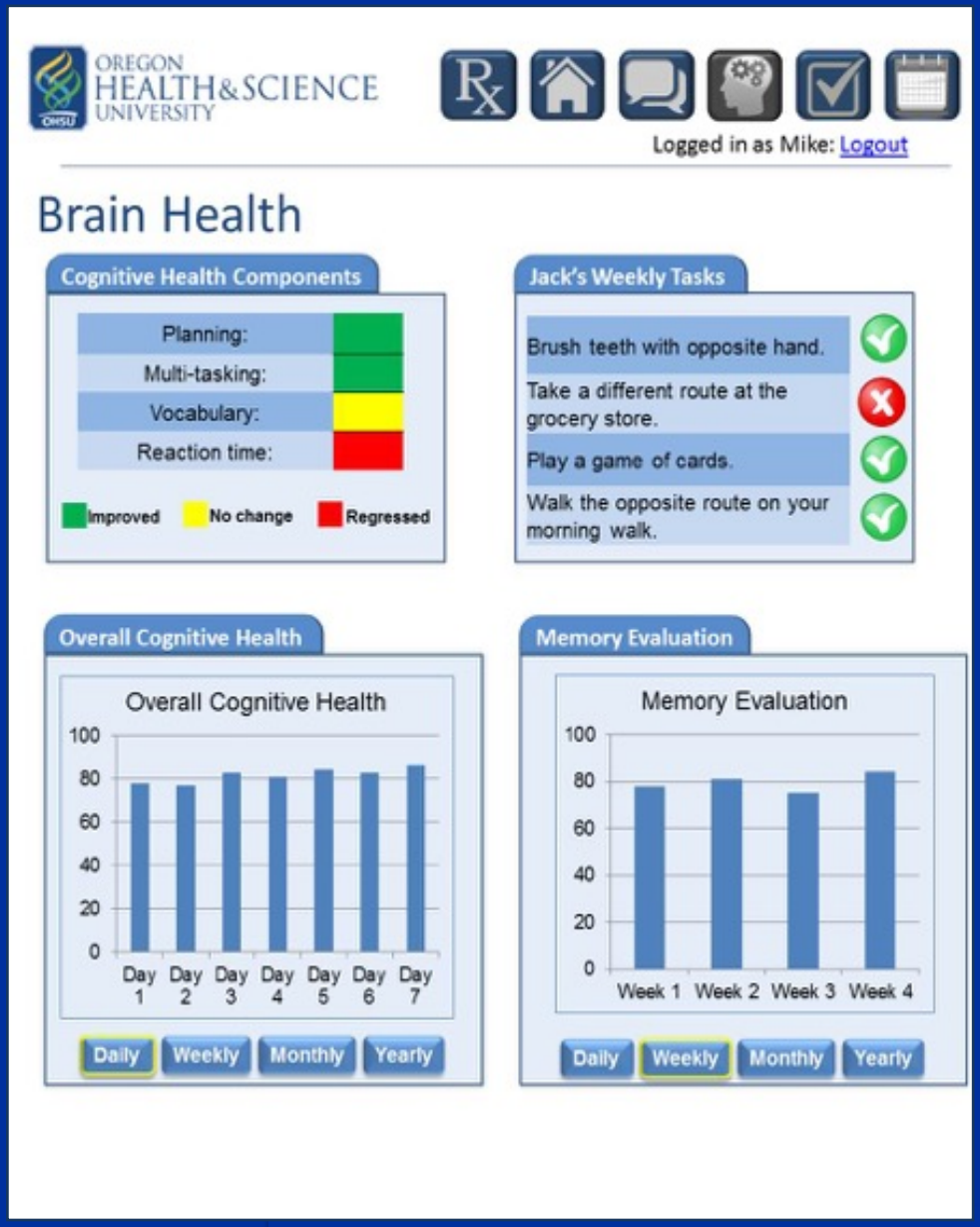
(embedded cognitive metrics)

Interface options for:

- **Older adult**
- **Remote family member**
- **Community health worker**
- **Health coach**

Steven Williamson, PhD Dissertation,
Oregon Health & Science University





Steven Williamson, PhD Dissertation, Oregon Health & Science University

Scalable Approach to Rehabilitation

- Multifaceted Approach to rehabilitation (physical exercise, cognitive exercise, sleep management, stress management, socialization, safety)
- Remote, just-in-time, continuous care
- Incorporate principles of health behavior change
- Optimal use of lower cost personnel
- Integrate family & informal caregivers into the health care team (untapped resource)
- Platform for testing sustained cognitive interventions in the home

Questions?

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h.jimison@neu.edu

Consortium on Technology for Proactive Care
Northeastern University

Computational Models for Optimizing Assessment and Intervention

Misha Pavel, PhD
Consortium on Technology for Proactive Care,
College of Computer & Information Science
Bouve College of Health Sciences
Northeastern University, Boston, MA

DISCLOSURE STATEMENT

Misha Pavel, PhD, FACMI

- Professor of Computer and Information Science at Northeastern University and receives a salary
- Receives grant funding from:
  - National Institute on Nursing Research (P20-NR015320)
  - National Science Foundation (grants 1407928 and 1111965)
  - National Institute on Aging (P30AG024978 and ASMMI0116ST)
  - Alzheimer's Association / Intel Company
  - National Institute on Standards & Technology
  - TEKES (Finland Government)
  - Halmstad University, Sweden

This continuing education activity is managed and accredited by Professional Education Services Group (PESG) in cooperation with the International Brain Injury Association (IBIA). Neither PESG, IBIA, nor any accrediting organization supports or endorses any product or service mentioned in this activity. PESG and IBIA staff has no financial interest to disclose.

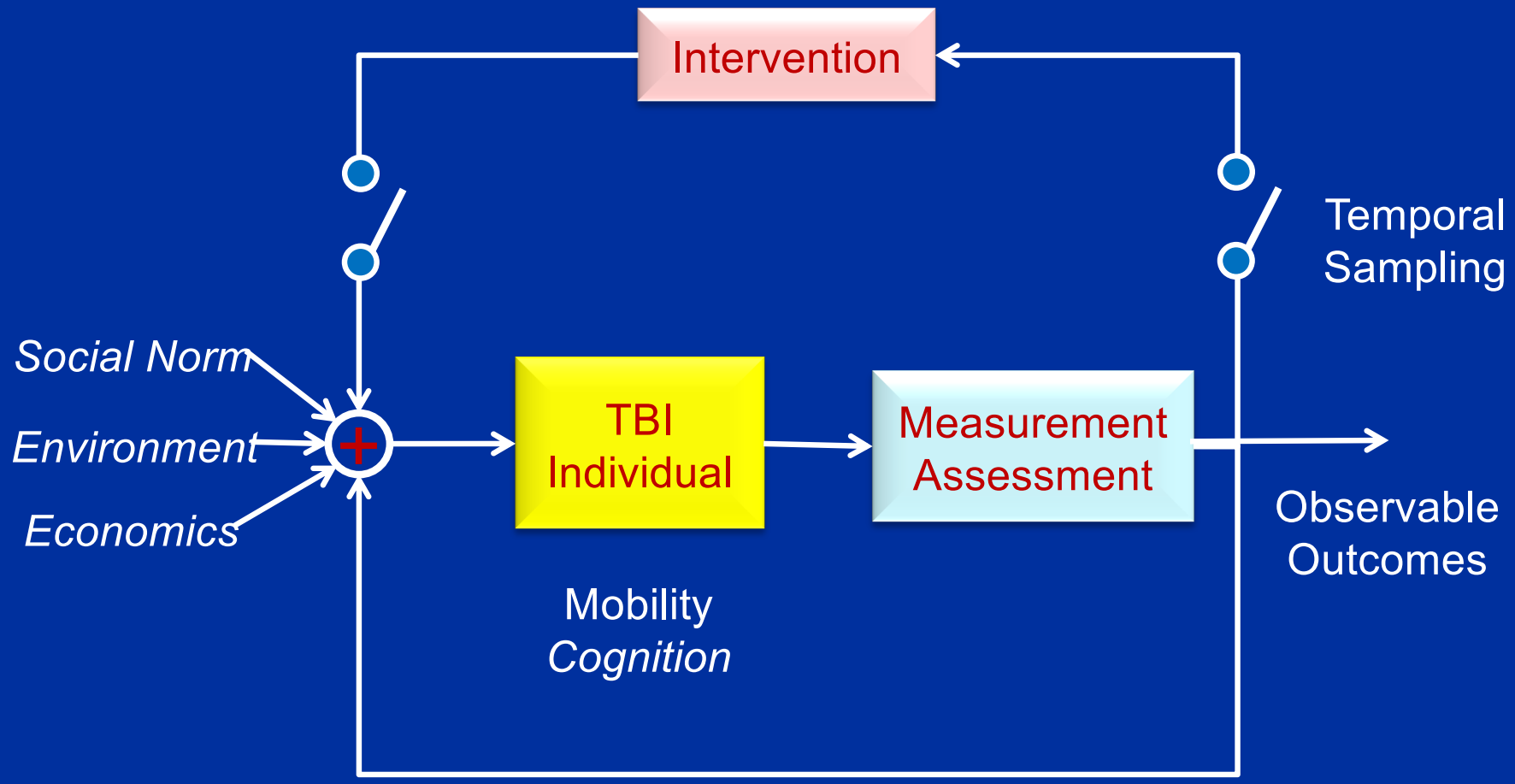
Commercial Support was not received for this activity.

LEARNING OBJECTIVES

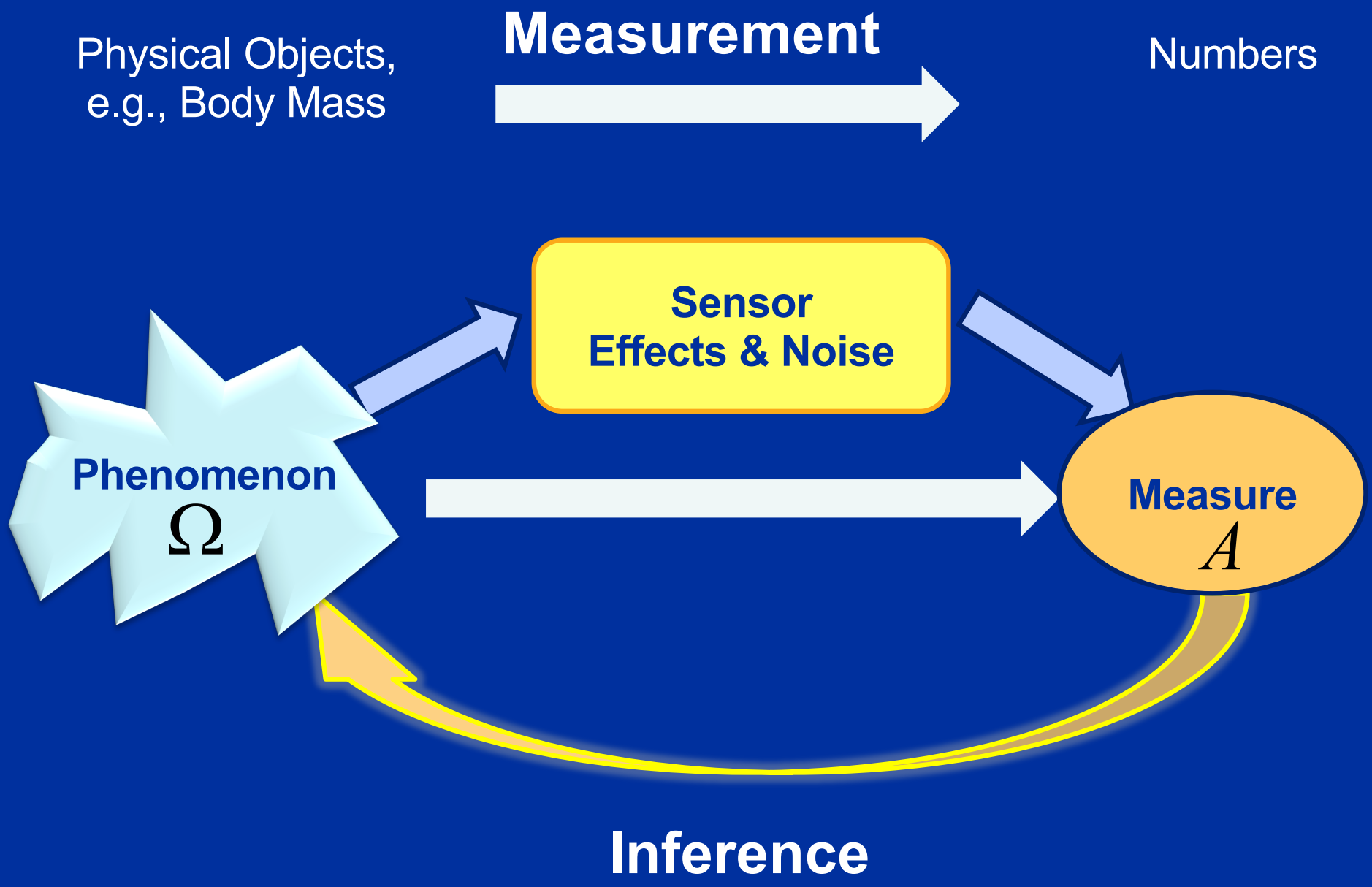
At the conclusion of this activity, the participant will be able to:

1. Explain the major issues with transforming data from unobtrusive, continuous monitoring to information useful to guide intervention
2. Understand applications of computational modeling and visualization for diagnostics and interventions
3. Identify a subset of behavioral metrics useful for diagnostics and interventions

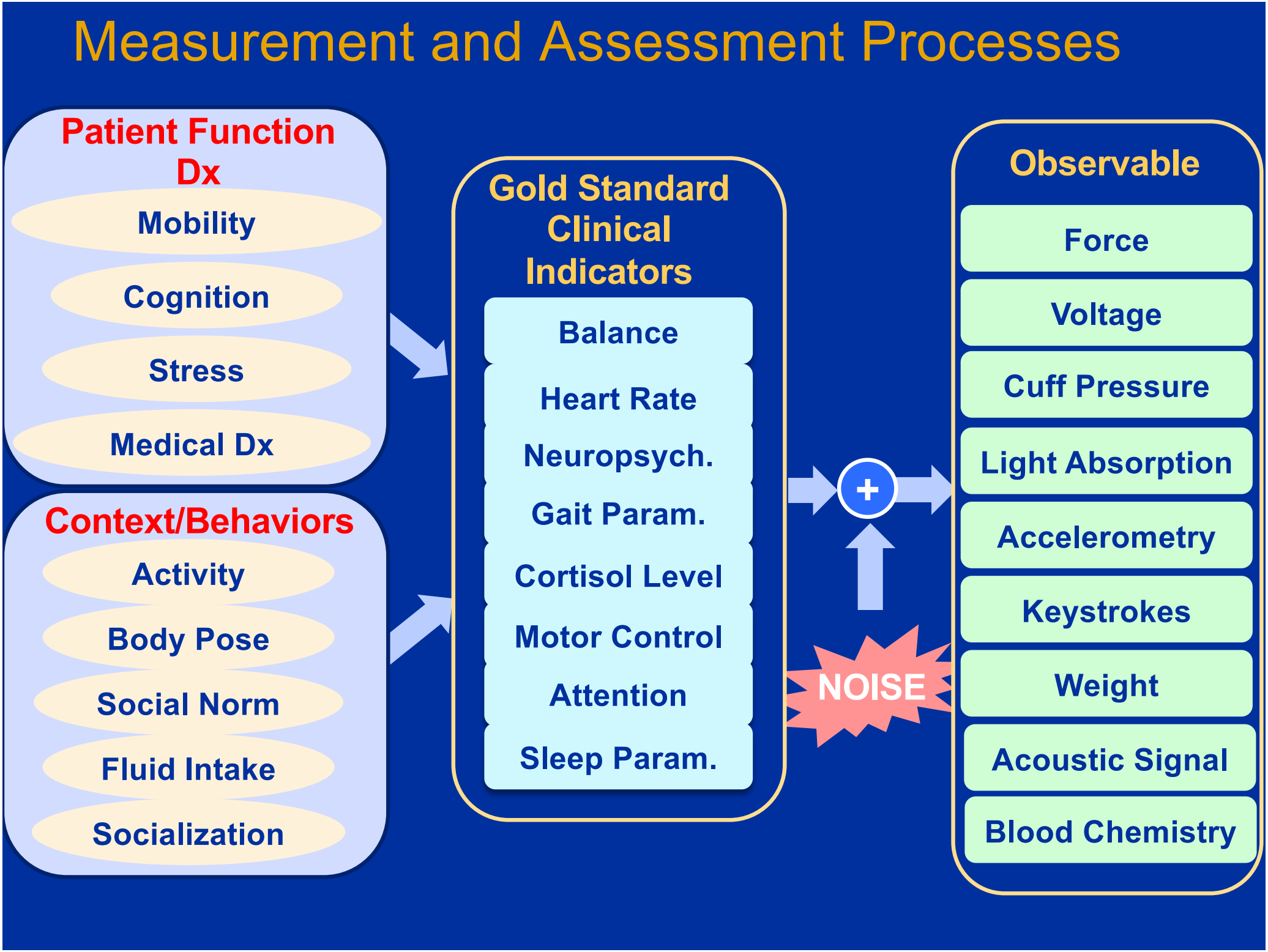
Precision TBI Care: Closing the Loop



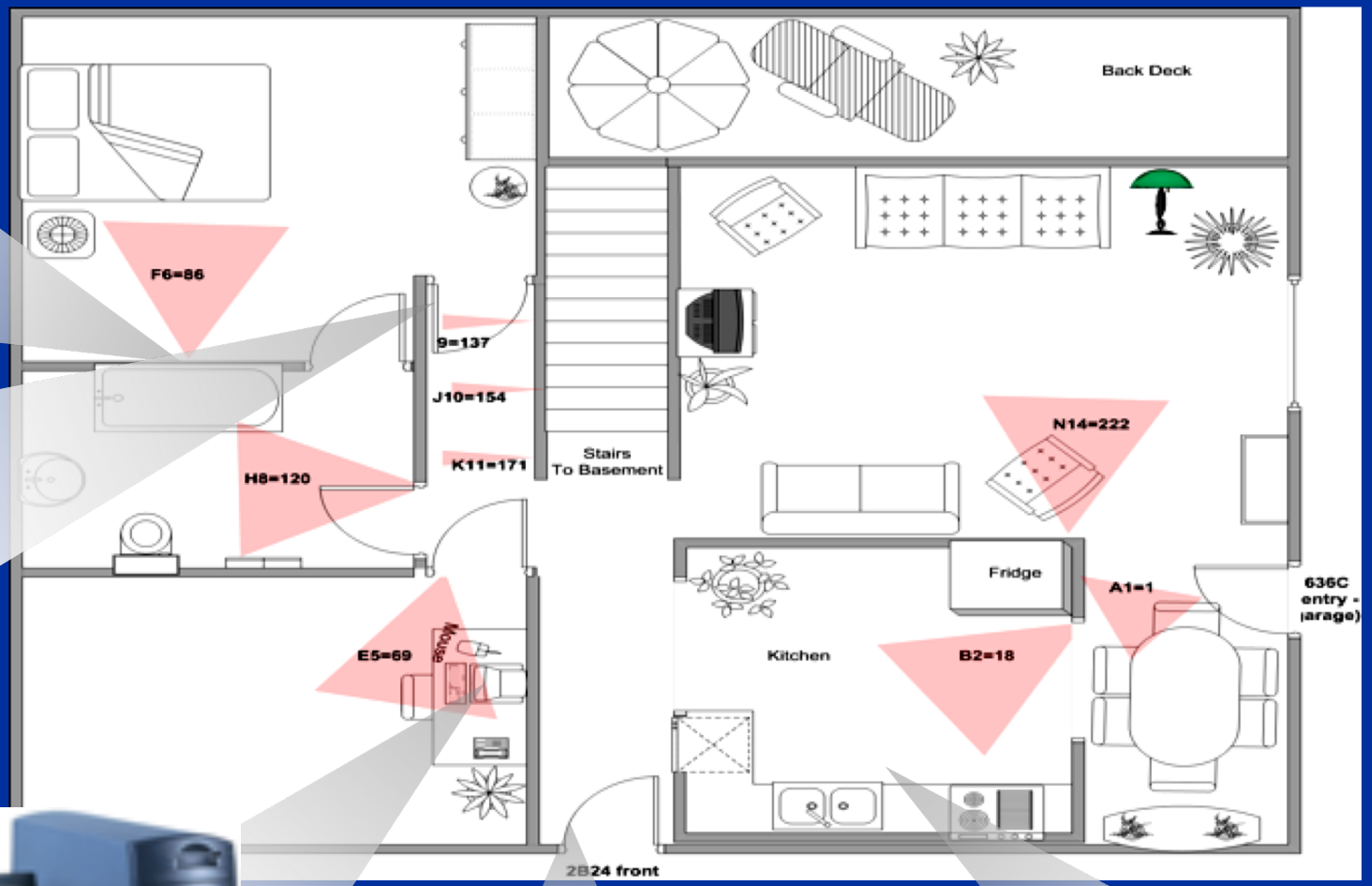
Models of Measurement and Inference



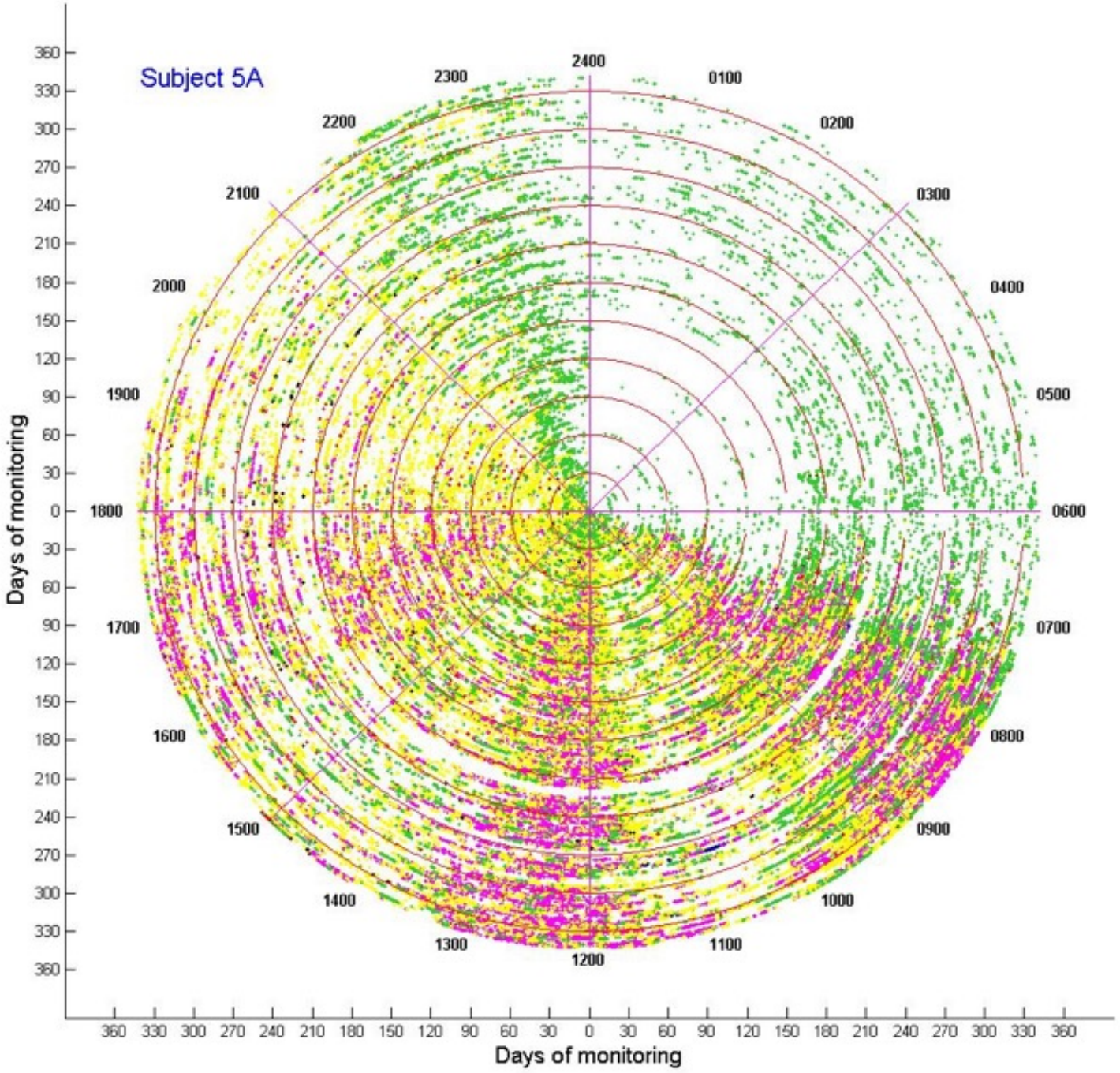
Measurement and Assessment Processes



Inference of Patient Activities Based on Sensor Data



Activity Monitoring in the Home



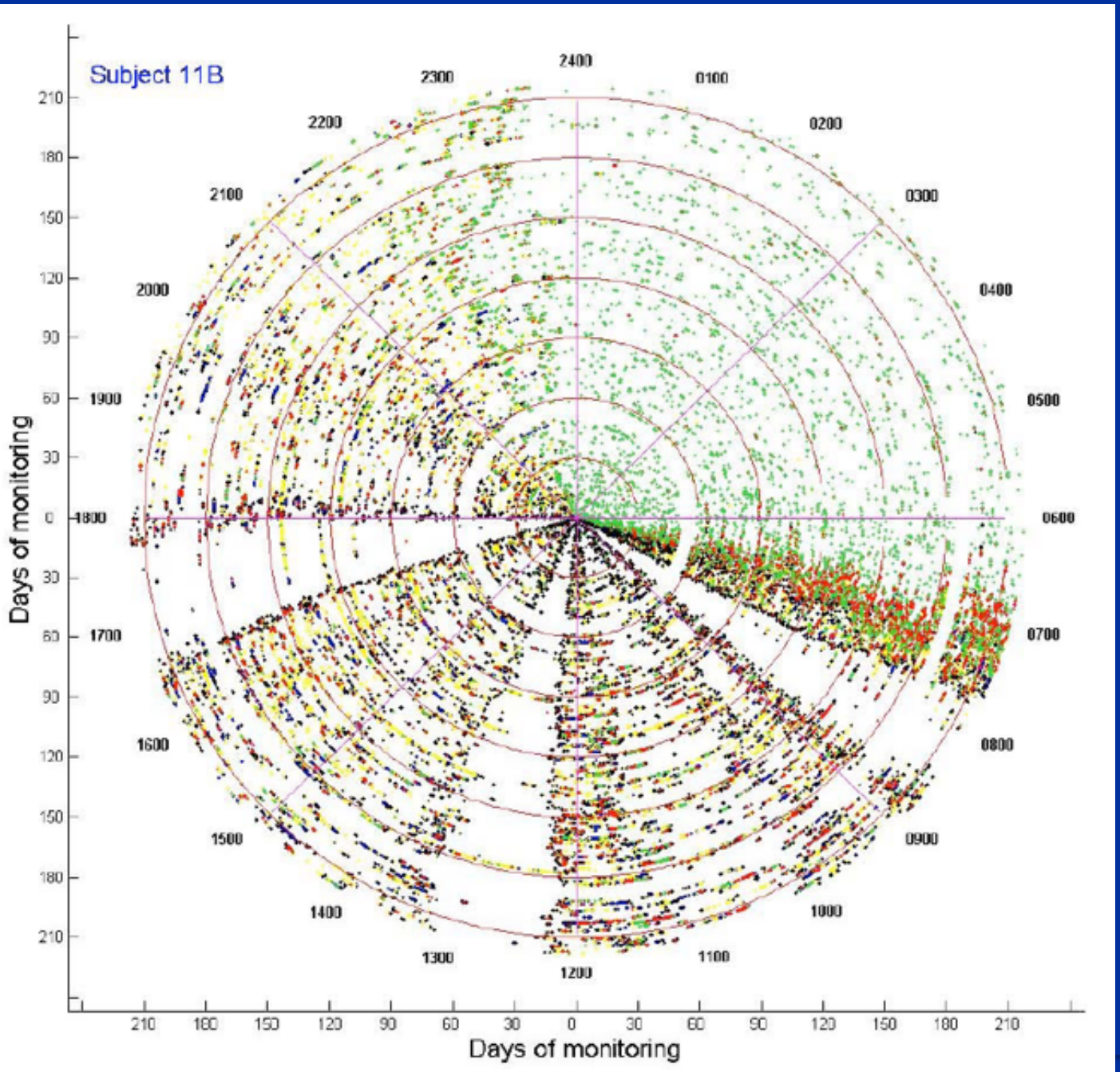
Sensor Events Private Home

- Bedroom
- Bathroom
- Living Rm
- Front Door
- Kitchen

al., www.orcatech.org

ORCATECH
SUCCESSFUL AGING WITH TECHNOLOGY

Activity Monitoring in the Home



Sensor Events Residential Facility

- Bedroom
- Bathroom
- Living Rm
- Front Door
- Kitchen

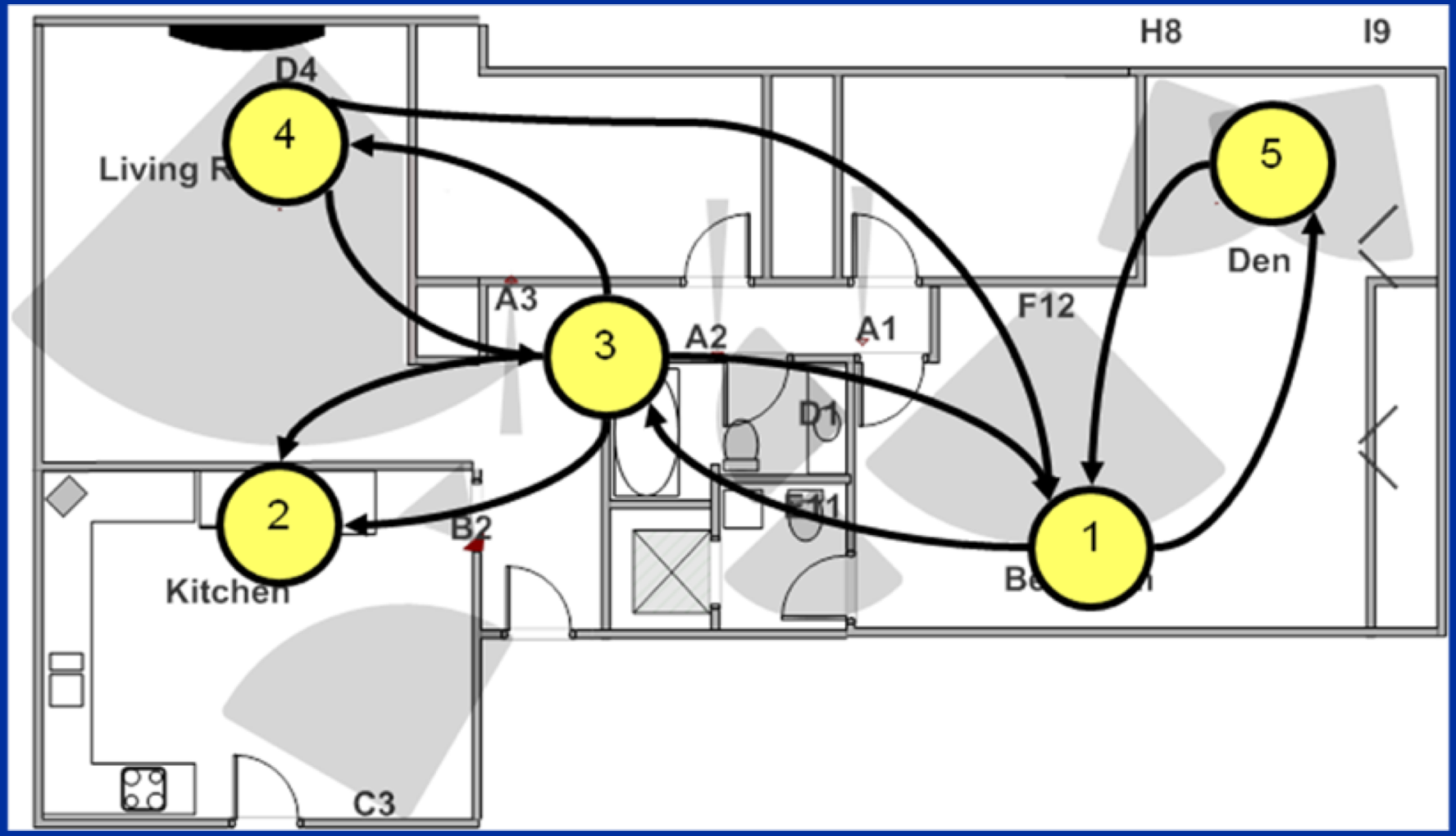
Hayes et al.,
www.orcatech.org

ORCATECH
SUCCESSFUL AGING WITH TECHNOLOGY

Hayes, ORCATECH 2007

Models to Infer Activities of Daily Living

Based on Sensor Location & Legitimate Pathways

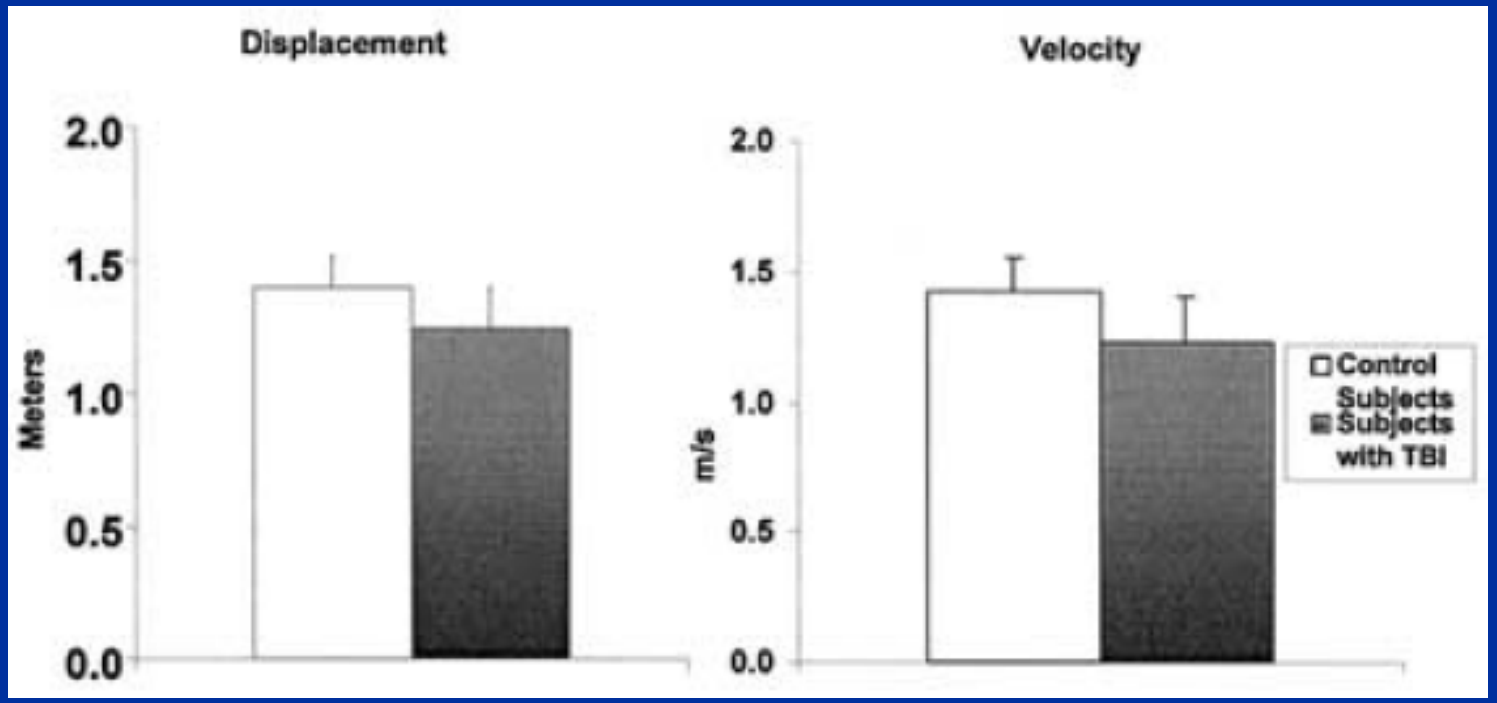


ORCATECH
SUCCESSFUL AGING WITH TECHNOLOGY

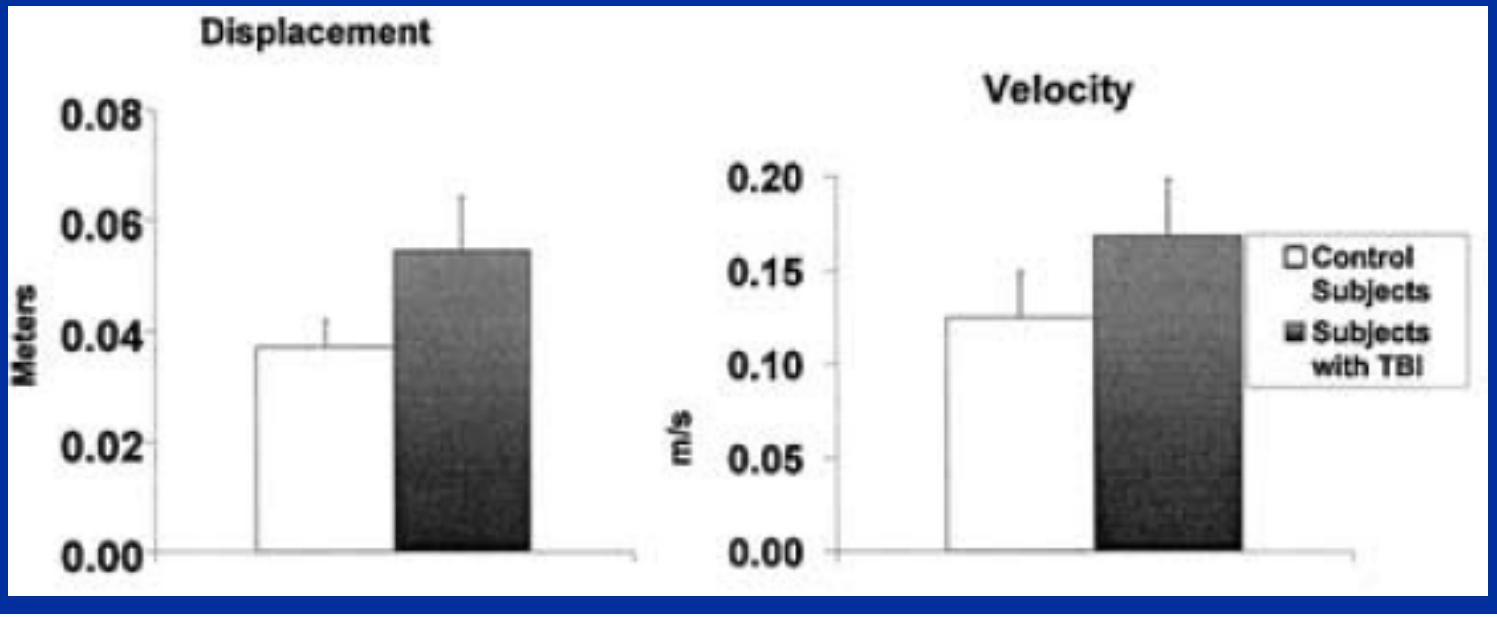
Pavel et al., The role of technology and engineering models in transforming healthcare, IEEE Reviews in Biomedical Engineering, 6:156-177, 2013.

Effect of TBI on Gait Parameters

Anterior-Posterior



Medial-Lateral



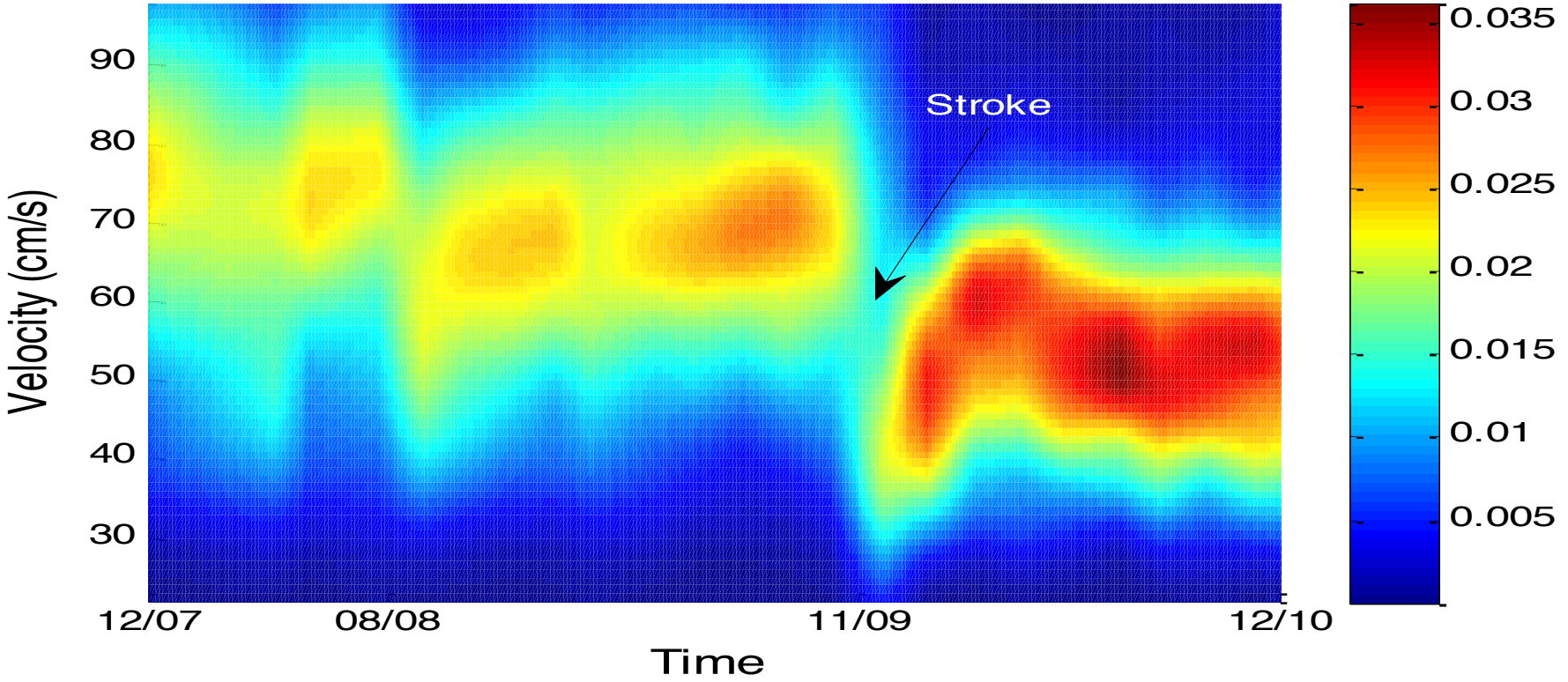
Measuring Gait in the Home

Unobtrusive gait measurement in-home with passive infrared (PIR) sensors

- Four restricted view PIR sensors
- Measure gait velocity whenever a subject passes through the "sensor-line"
- 200+ subjects monitored for > 4 years

Hagler et al., Unobtrusive and ubiquitous in-home monitoring: a methodology for continuous assessment of gait velocity in elders. IEEE Trans Biomed Eng, 57(4):813-20, *2010.*

Subject 1



Austin D et al, Unobtrusive monitoring of the longitudinal evolution of in-home gait velocity data with applications to elder care. Conf Proc IEEE Eng Med Biol Soc., 2011.

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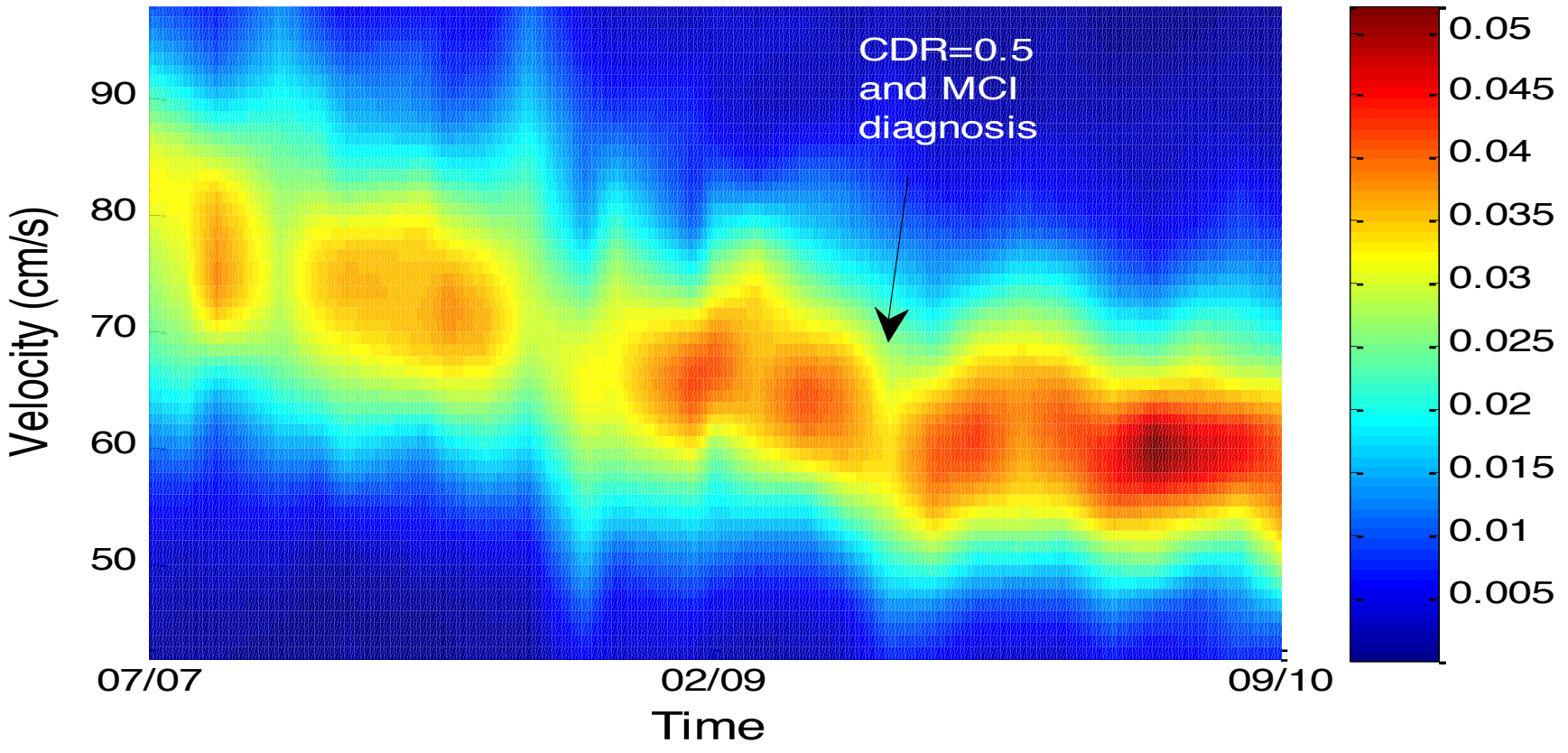
SUCCESSFUL AGING WITH TECHNOLOGY

Participant Example



Austin D et al, Unobtrusive monitoring of the longitudinal evolution of in-home gait velocity data with applications to elder care. Conf Proc IEEE Eng Med Biol Soc., 2011.

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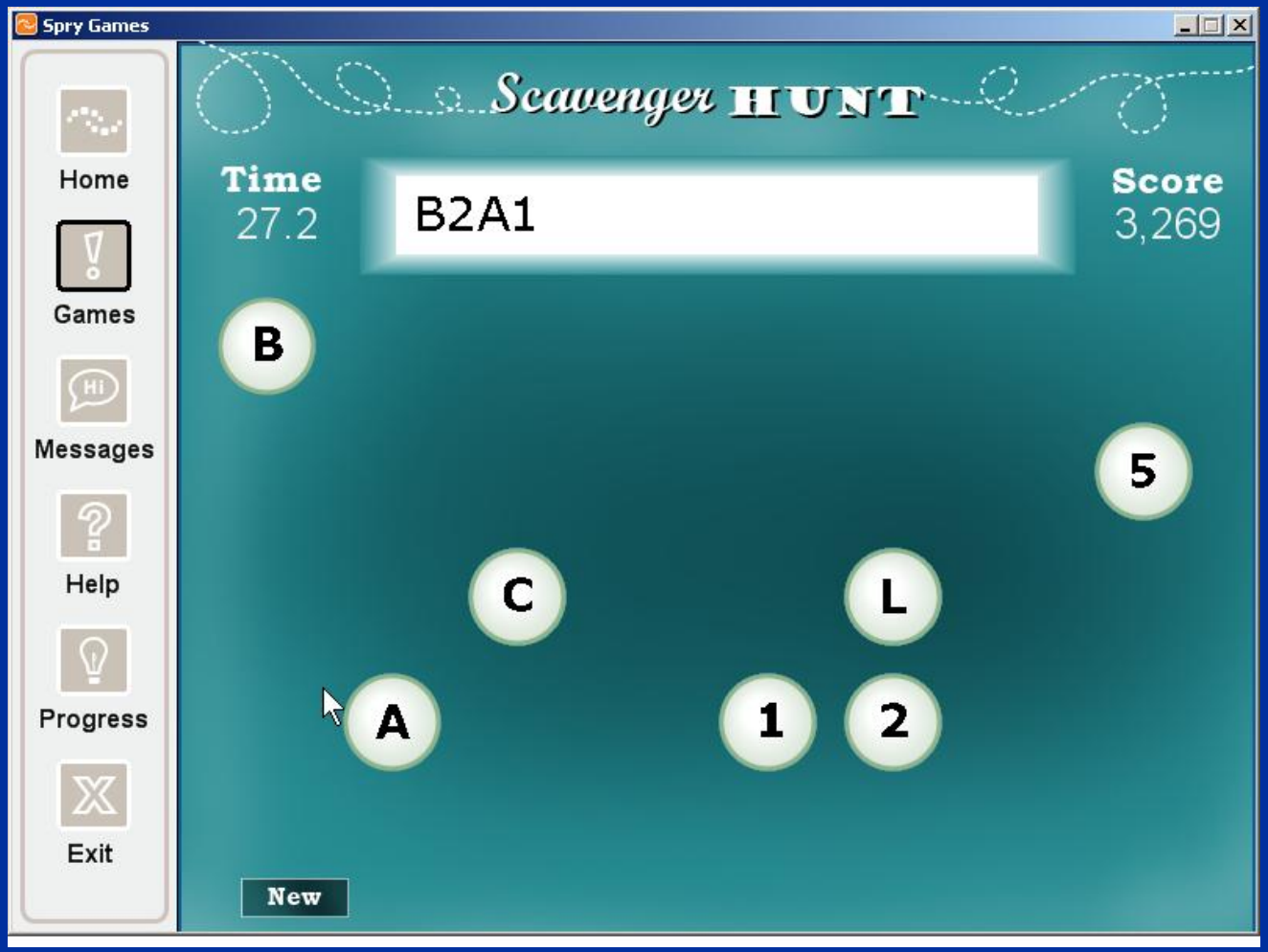
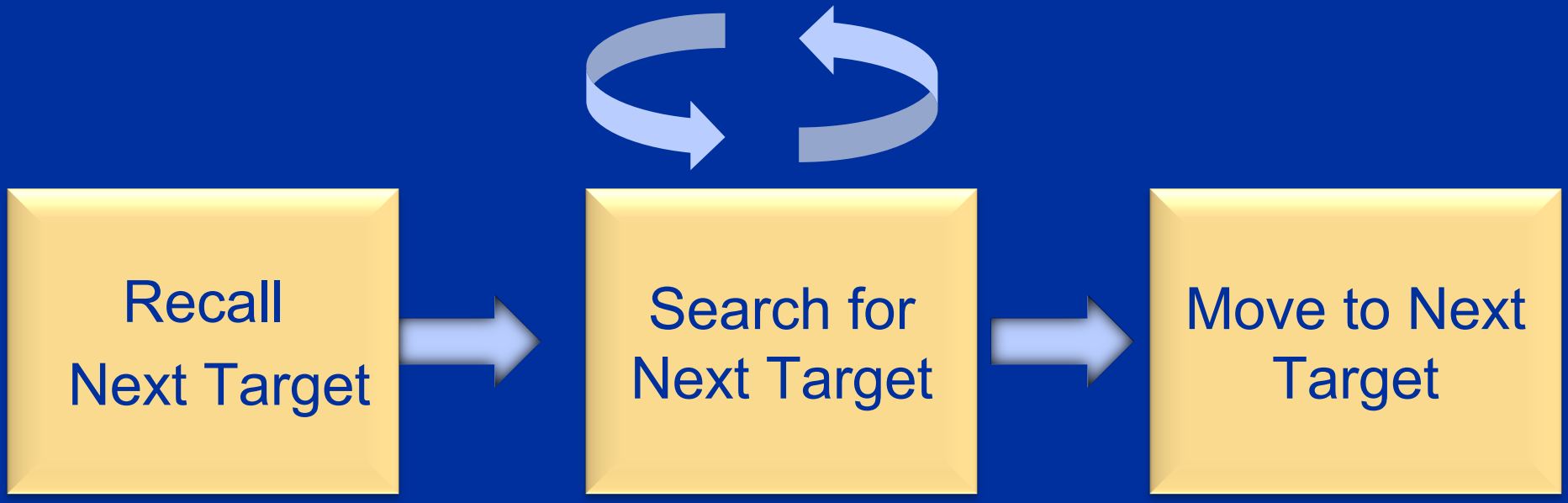
Cognitive Computer Games

(embedded cognitive metrics)

Computer Game to Measure Executive Function



Timing Model: Recall, Search, Motor Speed



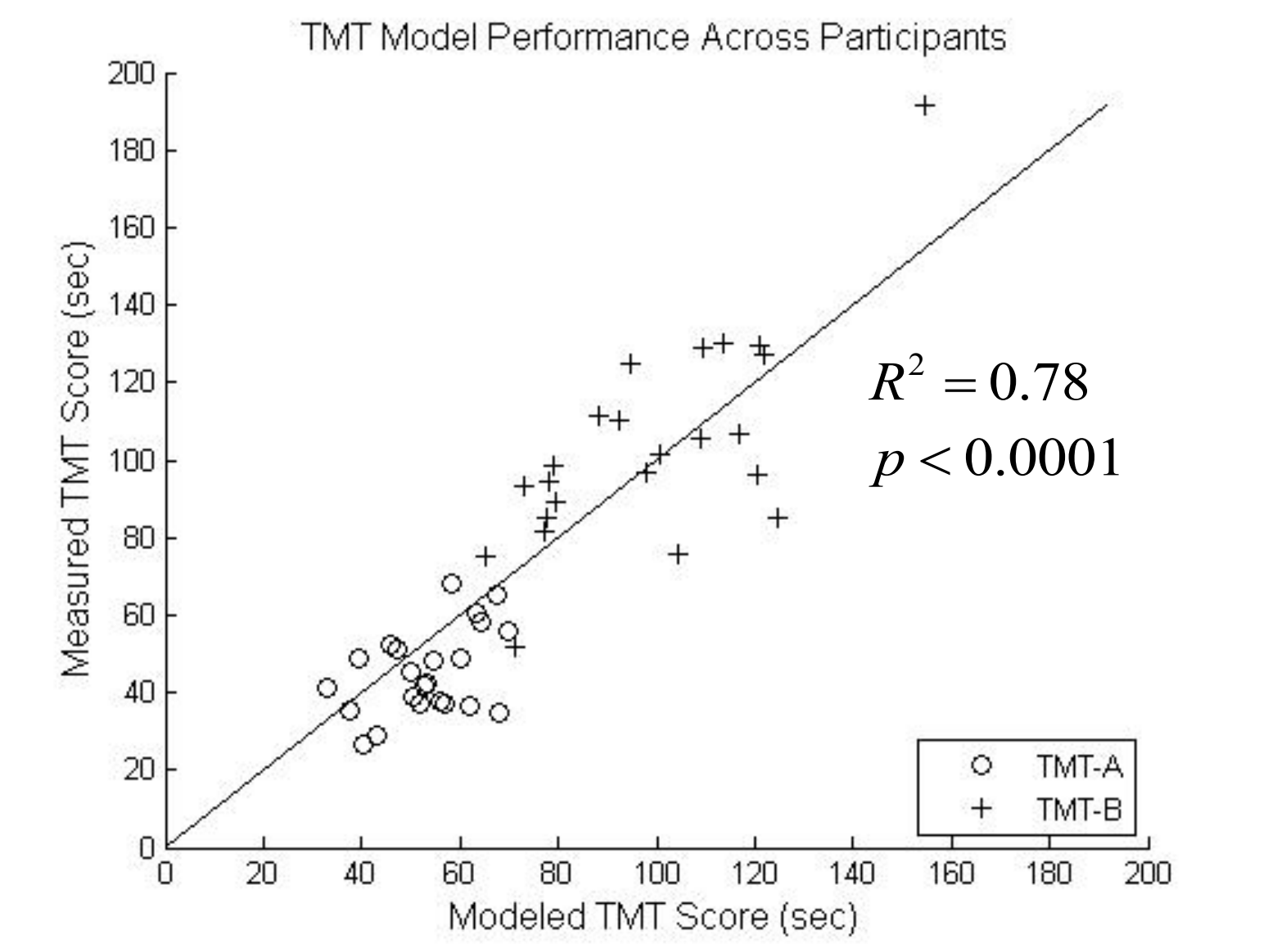
$$T_{\text{Recall}} + T_{\text{Search}}(n,d) + T_{\text{Motor}}$$

Total time to complete one trial

n – length of the sequence to find
d – *number of distractors stimuli*

S. Hagler, H. Jimison, M. Pavel, Modeling Cognitive Processes from Computer Interactions, IEEE Journal of Biomedical and Health Informatics, Vol 18, No, 4, 2014.

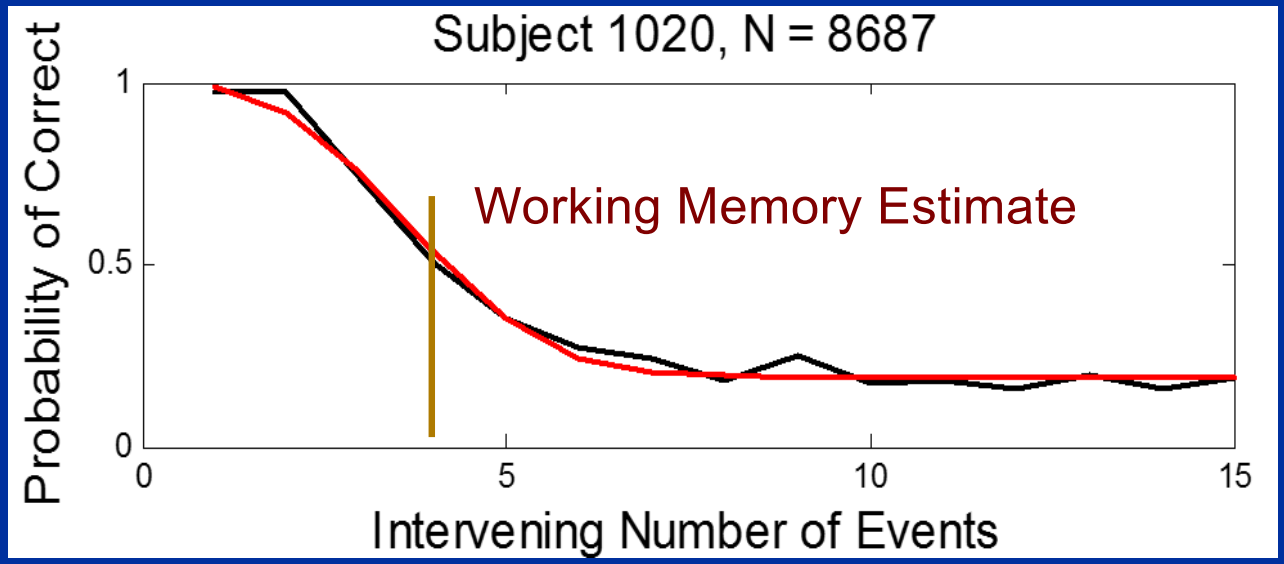
Matching Neuropsychological Test Scores



S. Hagler, H. Jimison, M. Pavel, Modeling Cognitive Processes from Computer Interactions, IEEE Journal of Biomedical and Health Informatics, Vol 18, No, 4, 2014.

Measuring Cognitive Functions

- **Example: Characterize Memory Capacity**
- Intervening number of events
- Intervening time
- Memory load
- **Simple Memory Model: Discrete Buffer**



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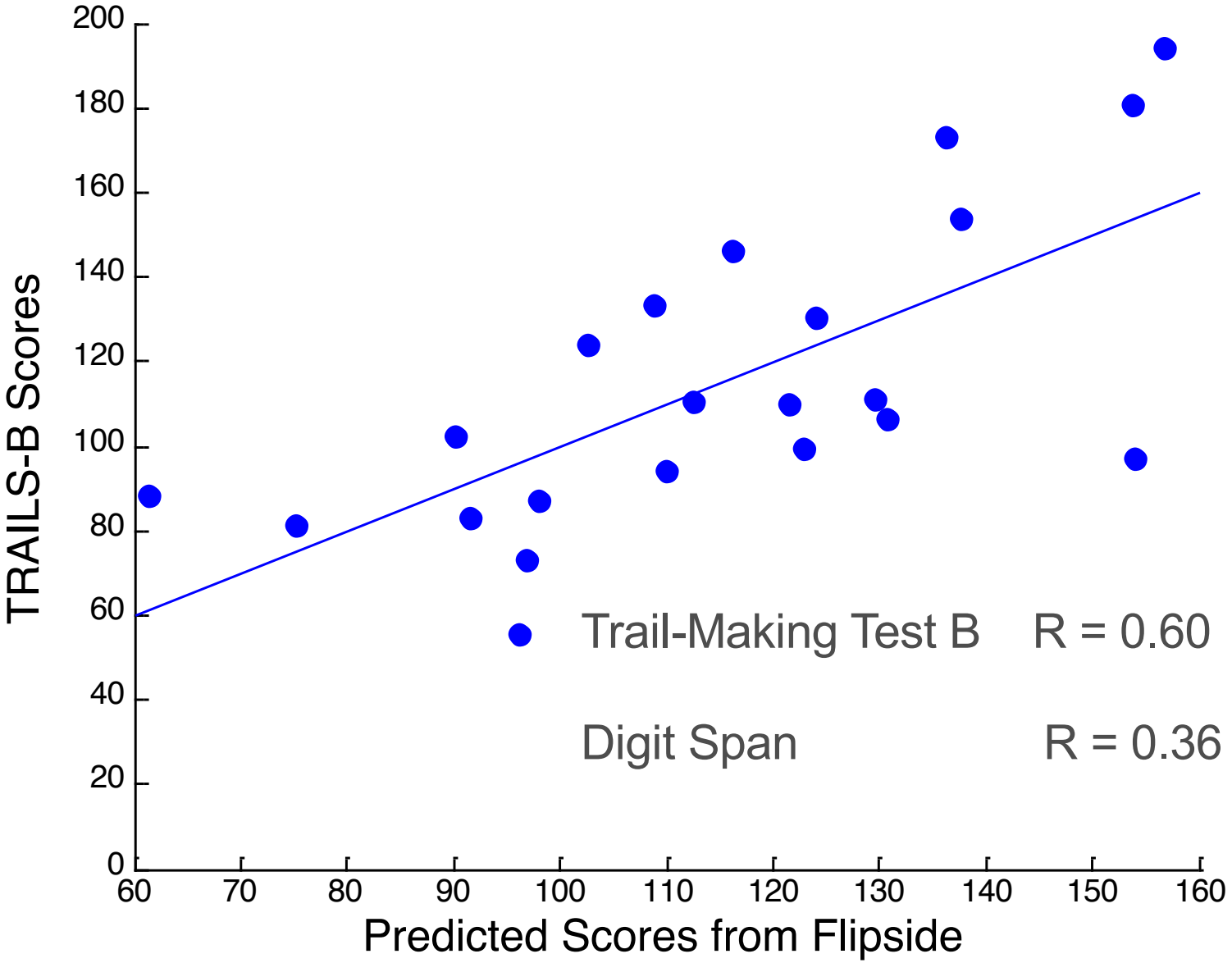
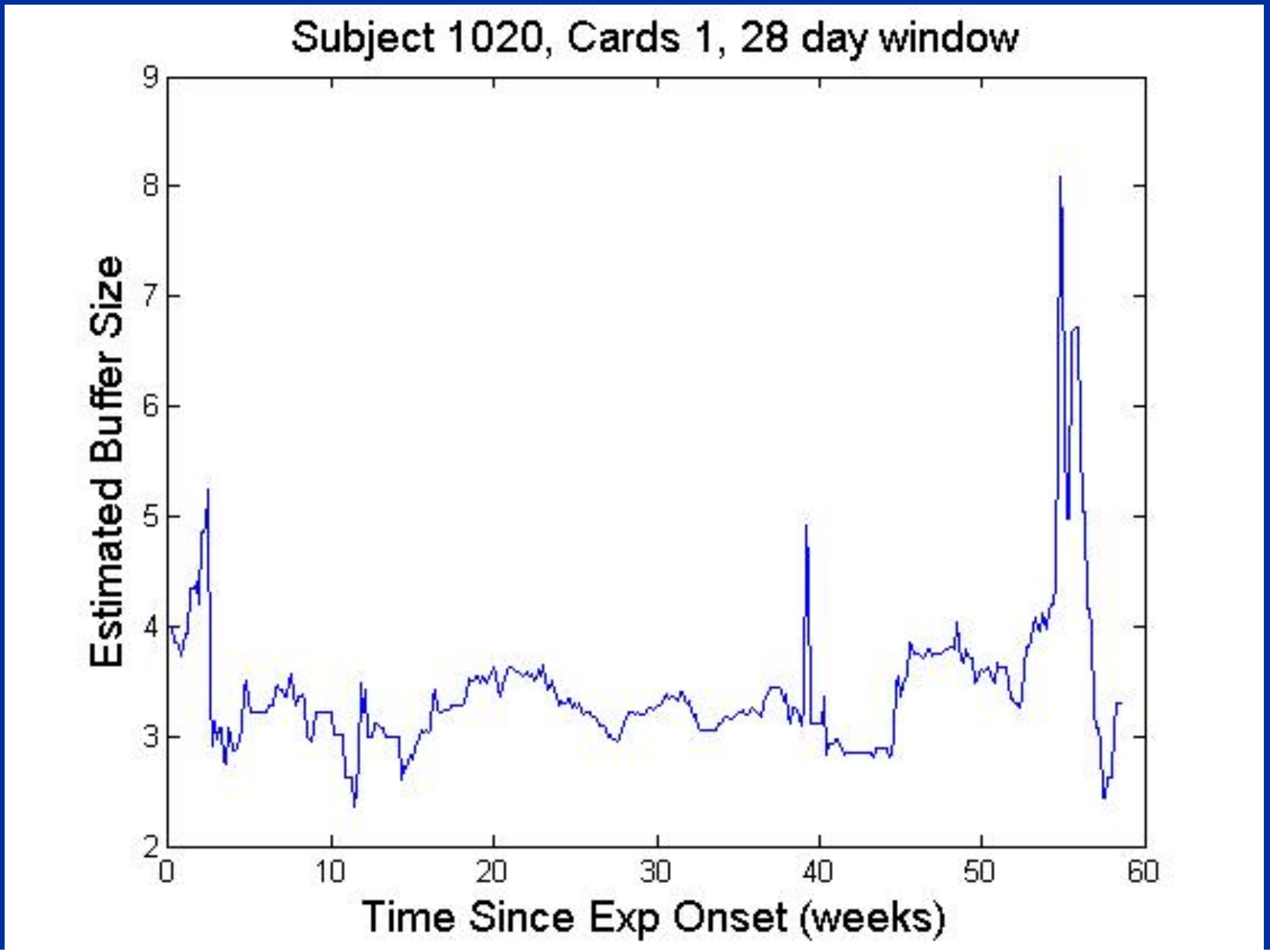


Tracking working memory capacity over time



Measurement of Heart Rate Variability to Estimate Stress

- Measure heart rate and estimate heart rate variability (HRV)
- Use HR and HRV to infer:
  - Level of activity
  - Stress, recovery and relaxation

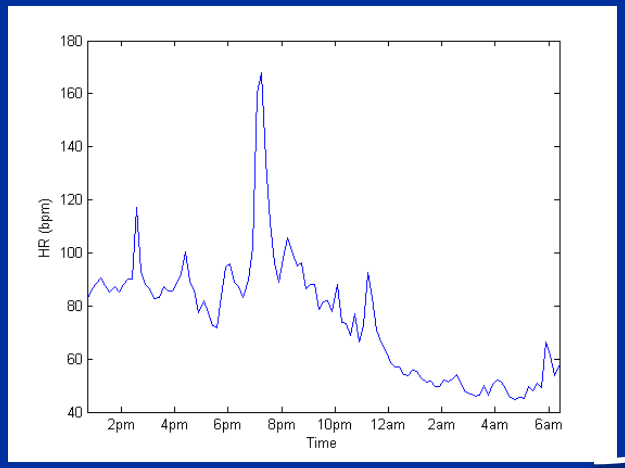
Clean → Estimate Heart Rate → Heart Rate Variability

www.firstbeat.fi
www.pulseon.com

Korhonen, 2014

Model based transformation of HR into physical activity

Background parameters



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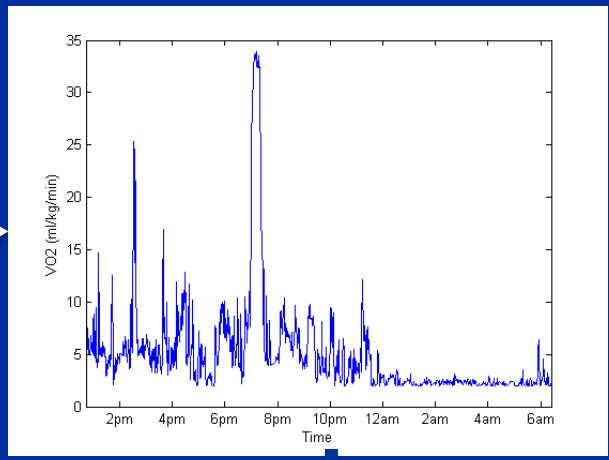


HRV analysis based on physiological model and big-data-based calibration

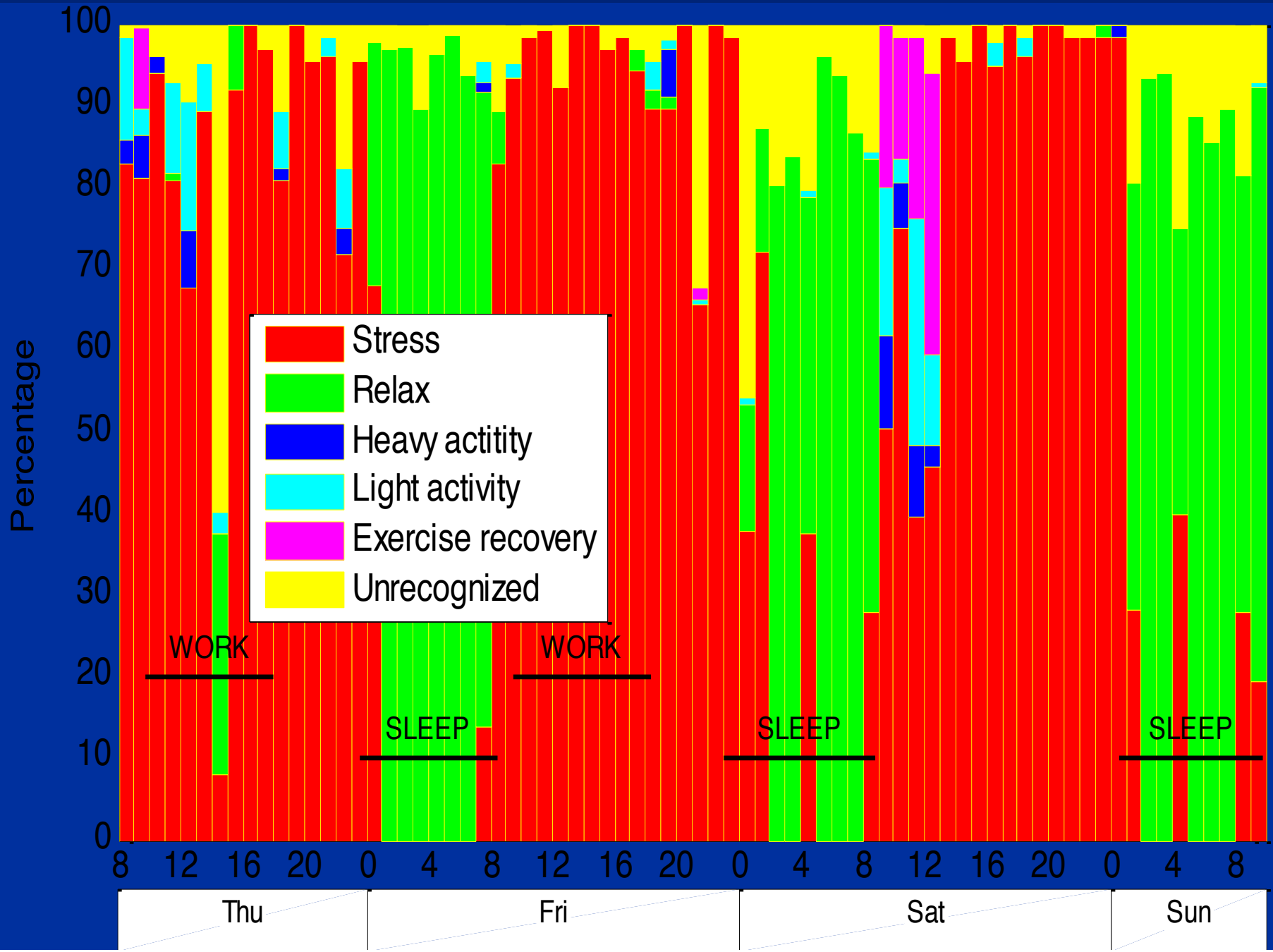
Classification of physiological state and quantification of physical activity

31 mins of physical activity

Goal: ACSM recommendations

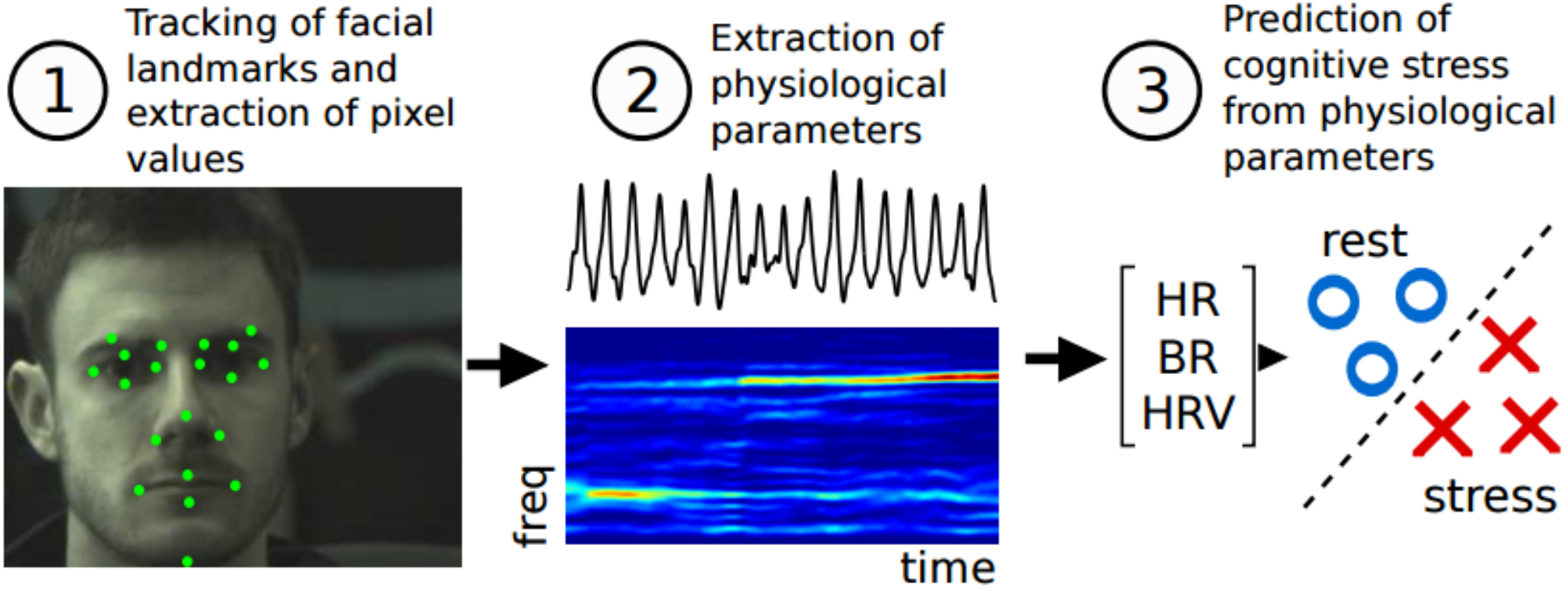
Korhonen, 2014

Individual Stress & Activity



Remote Monitoring of Stress with Heart Rate Variability

Continuous monitoring thermal image with infrared camera



McDuff, D. et al *Remote measurement of cognitive stress via heart rate variability.* EMBC, 2014

Take-home Messages

1. Measurement processes transforming data from unobtrusive, continuous monitoring to information require explicit computational models of individuals
2. Computational modeling and visualization are tools that enable us to derive useful behavioral metrics for individuals
3. There are many behavioral metrics useful for diagnostics and interventions include speed of walking, activity, working memory, stress recovery

Questions?

Contact:

Misha Pavel, PhD
m.pavel@neu.edu

Consortium on Technology for Proactive Care
Northeastern University

Bringing It All Back Home: Challenges and Summary

OPPORTUNITIES IN DELIVERING HOME AND COMMUNITY TRANSITION SERVICES

- Individualized / person-centered assessment and intervention
- Bundled payment systems offer the potential to be creative with funds and services including prevention and in-home services
- Translating measures developed with state-of-the-science methods, i.e., item response theory, to generate on-going, just-in-time assessments of ability, prognosis and next steps
- Improving technologies to provide assessment if intra-variability in everyday performance over time
- Improving evidence of effective behavioral interventions; knowledge translation into usable in home protocols
- Leveraging technologies and interventions developed for older persons with early cognitive decline
- Predicting / providing feedback on momentary capacity and risk

Attitudes About Monitoring

- Older adults are willing to trade privacy for increased independence and ability to age in place.
  - Adult children had more concern
- Cognitive health was most important health concern (quality of life & independence).

- Jimison, HB and Pavel, M. Integrating Computer-Based Health Coaching into Elder Home Care, Technology and Aging, eds. Mihailidis, A., Boger, J., Kautz, H., and Normie, L., IOS Press, Amsterdam, The Netherlands, 2008.

Privacy Implications

- Need for modeling preferences for data sharing
  - Coach or community health worker
  - Various clinicians
  - Family members
  - Neighbors, etc.
- Further work on the appropriate level of summarization for each member of the care team

Lessons Learned

Algorithm Issues

- New analytic models for developing behavioral markers derived from sensor data
- Dynamic user models
- Tailored message generation
- Privacy / Security – tailored data sharing
- User centered design – ease of use

Protocol Issues

- Need to have a variety of activities for novelty and sustained engagement
- Coaching (automated and in-person) important

Summary

Considerations when Designing eHealth Behavior Change Interventions

- Make use of sensors and data analytic models
- Remote, just-in-time, continuous care
- Integrate principles of health behavior change
- Usability
- Access issues, culture, literacy, etc.
- Integrate family & informal caregivers into the health care team (untapped resource)
- Security & privacy issues
- Business model

QUESTIONS / COMMENTS?

e-mail: *ron_seel@shepherd.org*

Obtaining CME/CE Credit

If you would like to receive continuing education credit for this activity, please visit:

http://ibia.cds.pesgce.com

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- McMillan TM, Teasdale GM. Death rate is increased for at least 7 years after head injury: a prospective study. Brain. 2007;130(10):2520-7.
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- Carlson KF, Meis LA, Jensen AC, et al. Caregiver reports of subsequent injuries among veterans with traumatic brain injury after discharge from inpatient polytrauma rehabilitation programs. *J. Head Trauma Rehabil.* Jan-Feb 2012;27(1):14-25.