

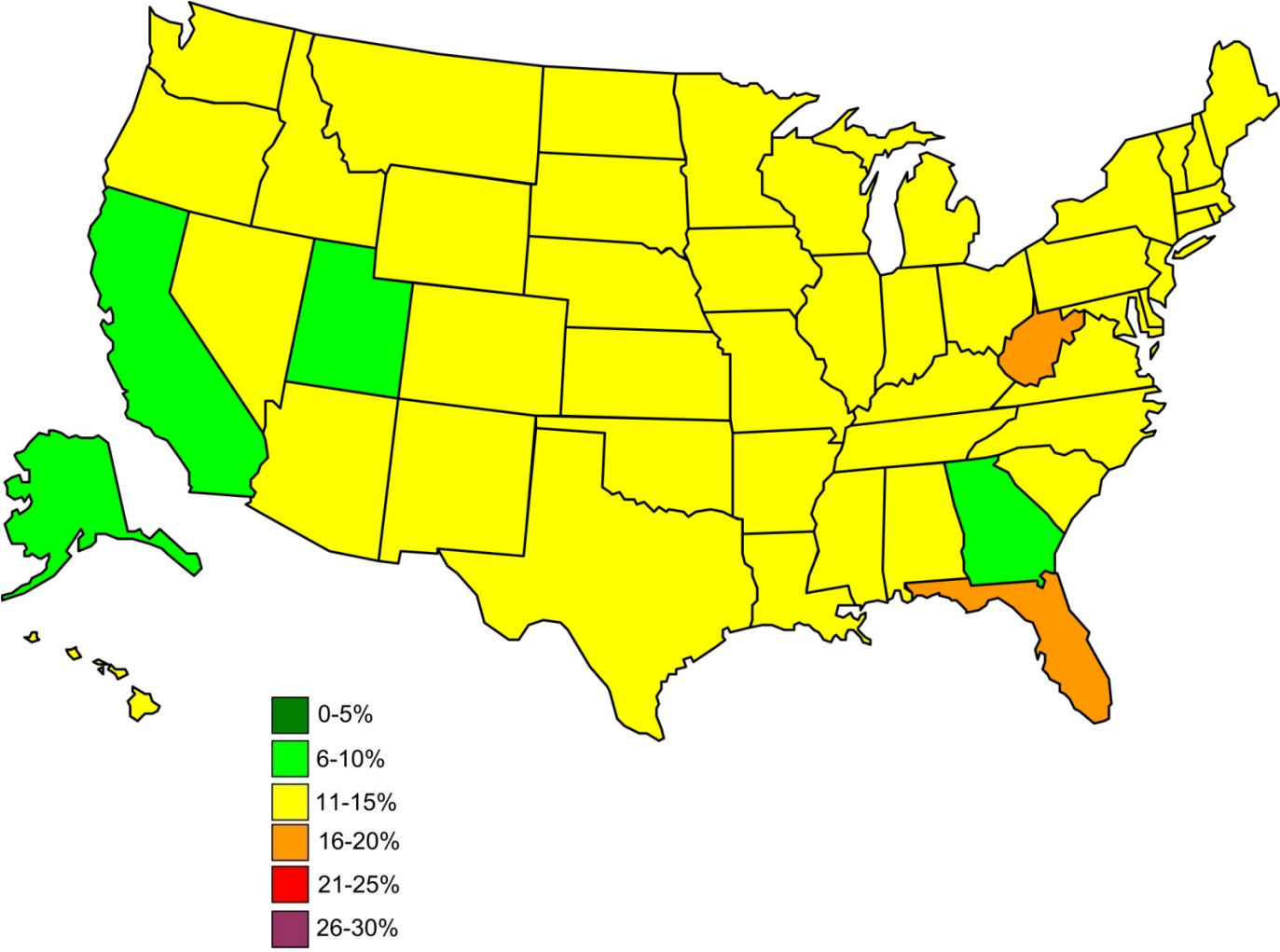
Selected Topics Communications and Mobile Computing (Smart Health)

TU Graz

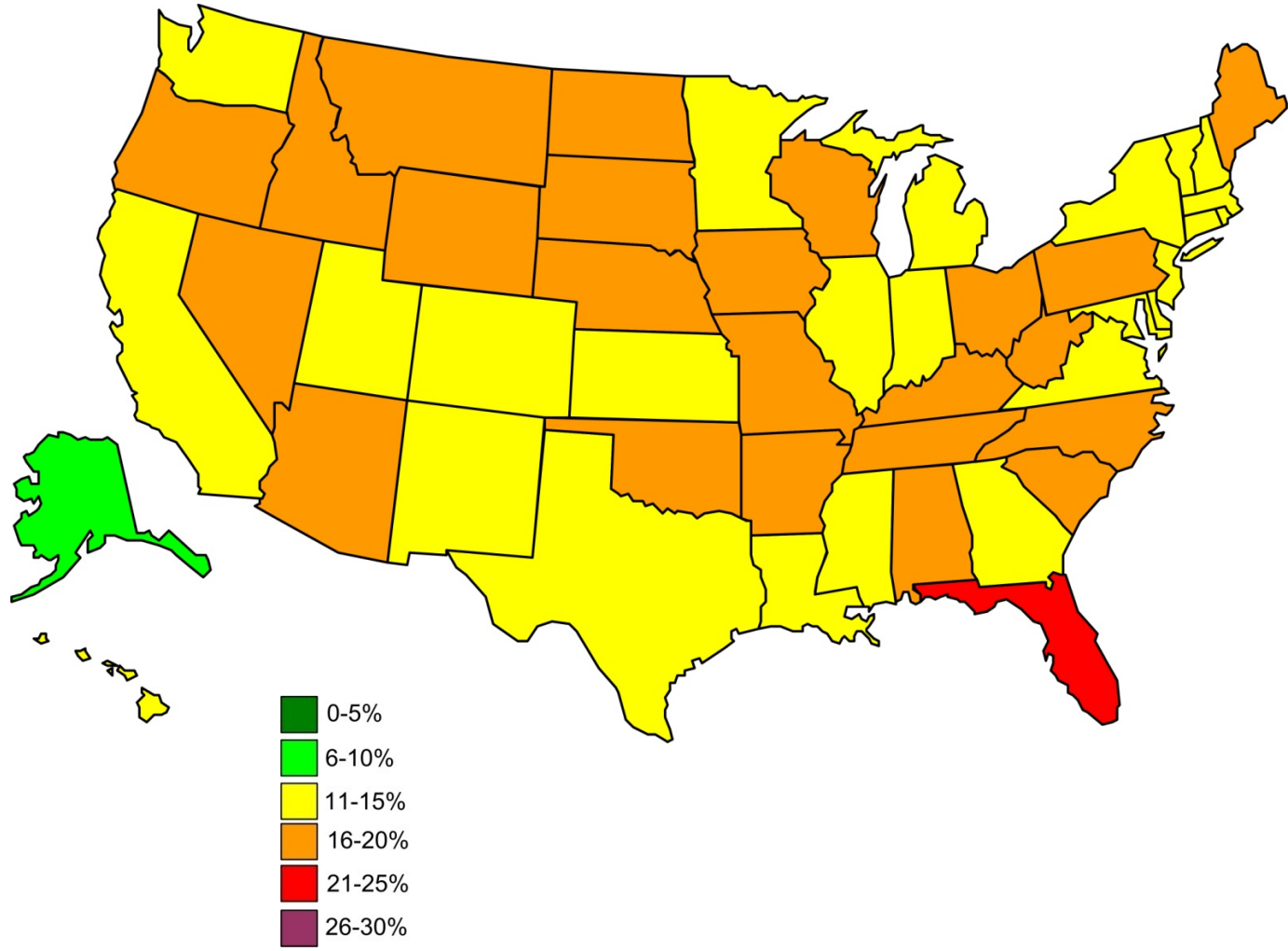
University of Notre Dame



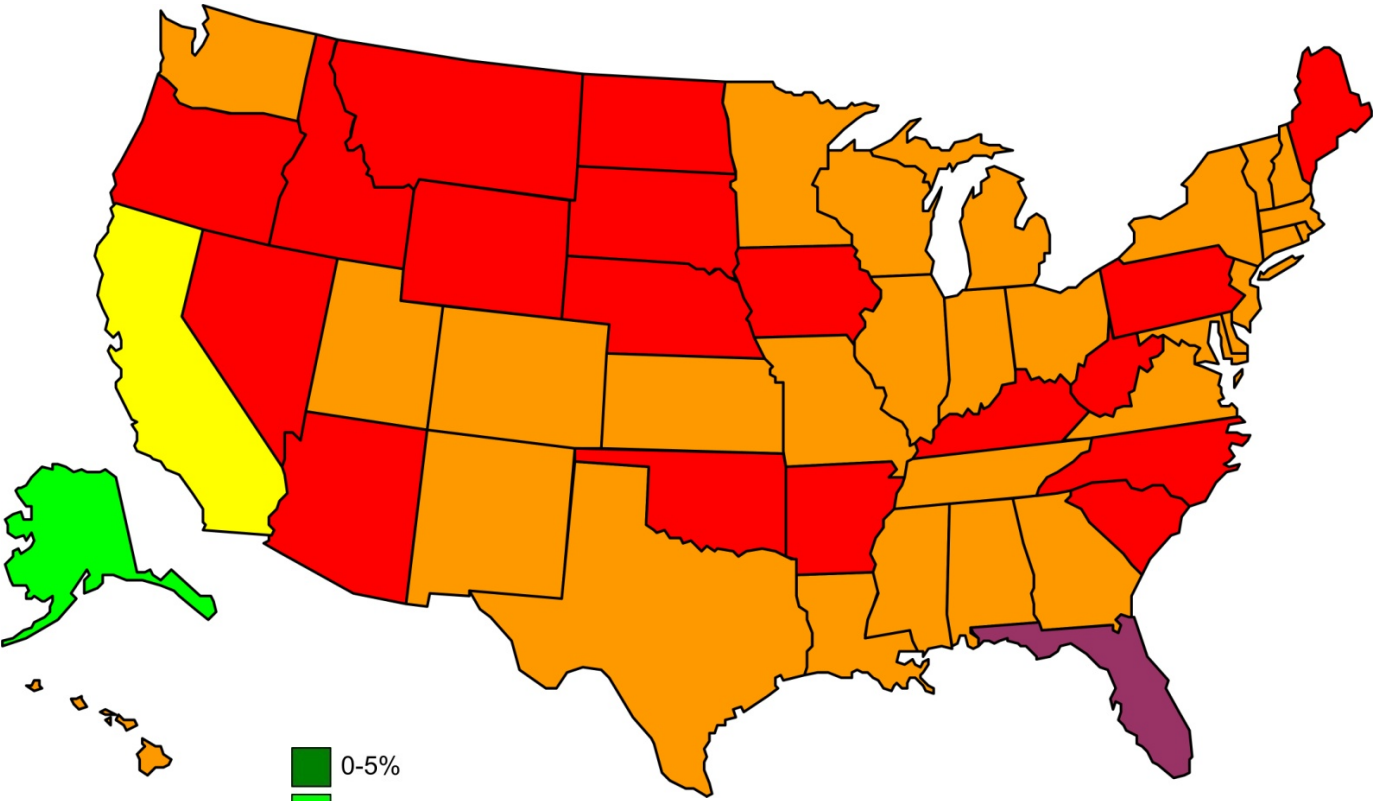
Percentage of Population Age 65+ in 2005



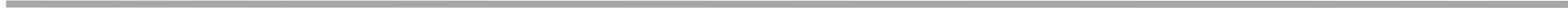
Percentage of Population Age 65+ in 2015



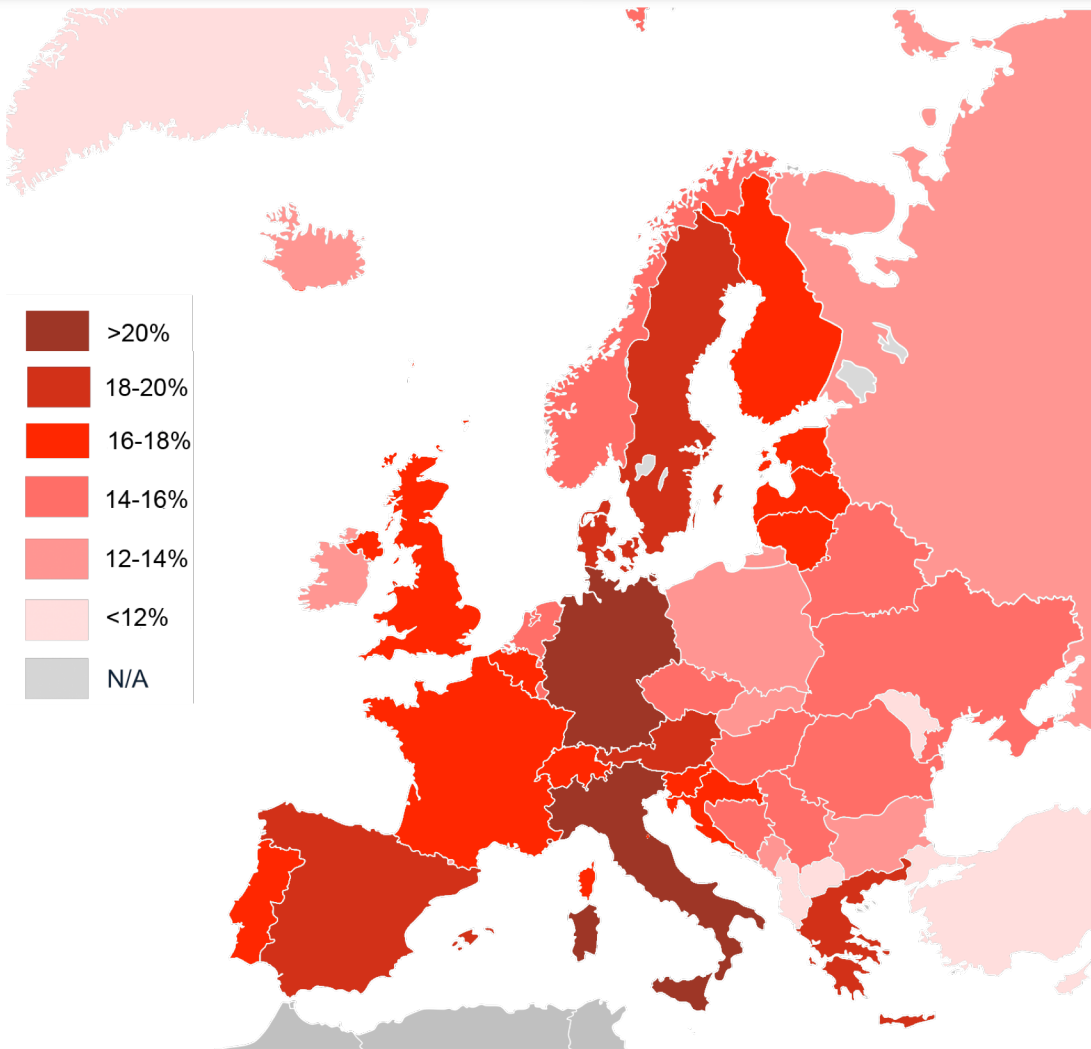
Percentage of Population Age 65+ in 2025



- 0-5%
- 6-10%
- 11-15%
- 16-20%
- 21-25%
- 26-30%



Percentage of Population Age 65+ in 2010



Potential Impairments of Aging Population

- **Memory performance:** difficulties remembering (long-term and short-term)
- **Cognitive performance:** difficulties acquiring knowledge and understanding through thought, experience, and the senses
- **Functional performance:** reduction of physical abilities
- **Dementia:** decline in mental ability severe enough to interfere with daily life

Memory Loss

- Many different types of memory, including:
 - Short-term (or working) memory (< 1 min)
 - Long-term (lifetime) memory
 - Sensor memory: visual (iconic), auditory (echoic), smell-based (olfactory), taste-based, or haptic (touch-based) memory
- Initial memory impairment occurs in short-term memory; long-term memory is often retained until late-stage dementia

Cognitive Function

- Cognitive function refers to how a person becomes aware of, perceives, or comprehends ideas; includes intellectual thinking, judgment, reasoning
- It declines gradually while young and more rapidly among older adults (>60s)
- Many other medical and psychological factors can influence cognitive function

Executive Function

- Executive function refers to a set of mental or cognitive skills believed to be controlled by the frontal lobe, anterior cingulate, prefrontal cortex, basal ganglia, and thalamus
- Two main types of executive functions:
 - Organization: attention, managing time, planning and organizing, remembering details, sequencing, and working memory
 - Regulation: self-control, emotional regulation, decision-making, and moral reasoning
- Impairments in executive function can lead to difficulty planning, difficulty to multitask, emotional swings and changes, loss of fine motor skills, apathy, and socially inappropriate behaviors

Behavioral and Psychological Symptoms of Dementia (BPSD)

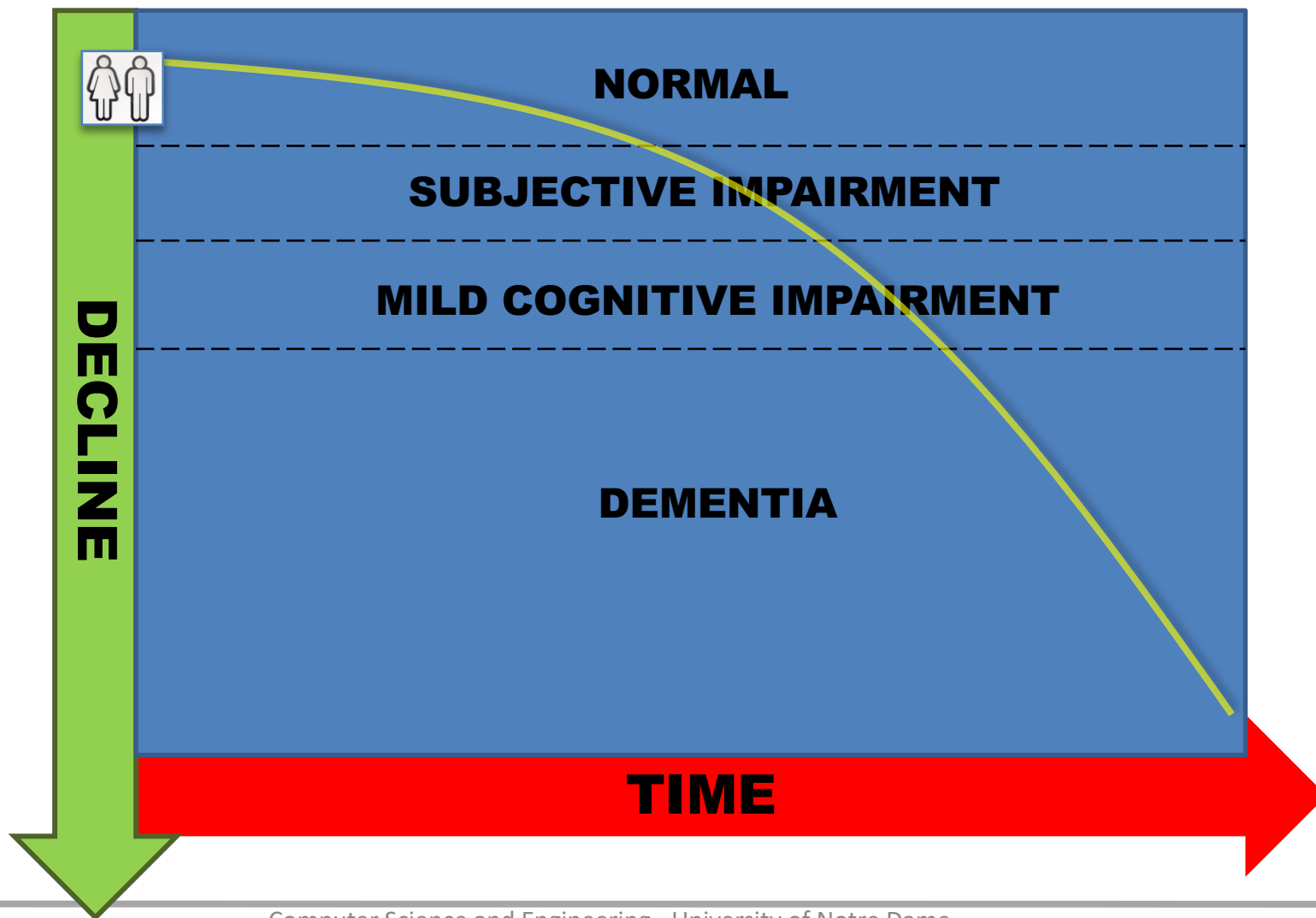
- Disturbed perception, thought content, mood, or behavior; occur frequently in patients with dementia
- Mood disorders (apathy, depression, dysphoria)
- Sleep disorders: insomnia, hypersomnia, circadian rhythm disorders, obstructive sleep apnea
- Psychotic symptoms: delusions, hallucinations
- Agitation: pacing, wandering, aggression, anxiety

- Leads to increased suffering, early institutionalization, increased cost of care, and causes significant loss in the QoL for patient & caregivers
- About 2/3 of people with dementia experience some BPSD at some point (may rise to 70-80% among patients residing in nursing homes)

Abnormal Cognitive States

- Subjective memory complaints
 - Problems remembering
 - But no cognitive or functional deficits
- Mild cognitive impairment (MCI)
 - Memory complaints and some cognitive deficits
 - But no functional deficits
- Dementia
 - Cognitive and functional deficits

Dementia Progression



Types of Dementia

The different kinds of dementia

Dementia is not one thing. There are several routes to similar symptoms

ALZHEIMER'S 62%

Causes problems with memory, language and reasoning. 5% of cases start before age 65

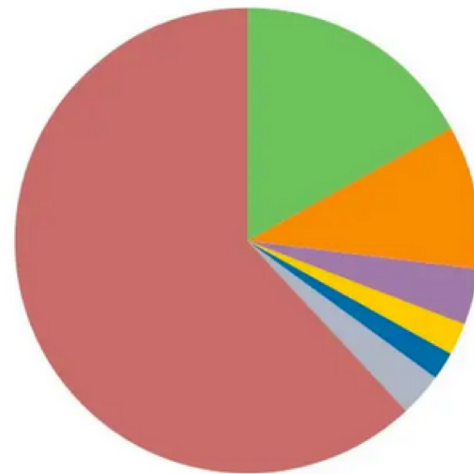
VASCULAR DEMENTIA 17%

Impaired judgement, difficulty with motor skills and balance. Heart disease and strokes increase its likelihood

MIXED DEMENTIA 10%

Several types of dementia contribute to symptoms. Most common in people over 85

SOURCE: ALZHEIMERS.ORG.UK



OTHER 3%

Conditions such as Creutzfeldt-Jacob disease; depression; multiple sclerosis

DEMENTIA WITH LEWY BODIES 4%

Caused by Lewy body proteins. Symptoms can include hallucinations, disordered sleep

FRONTOTEMPORAL DEMENTIA 2%

Personality changes and language problems. Most common onset between the ages of 45 and 60

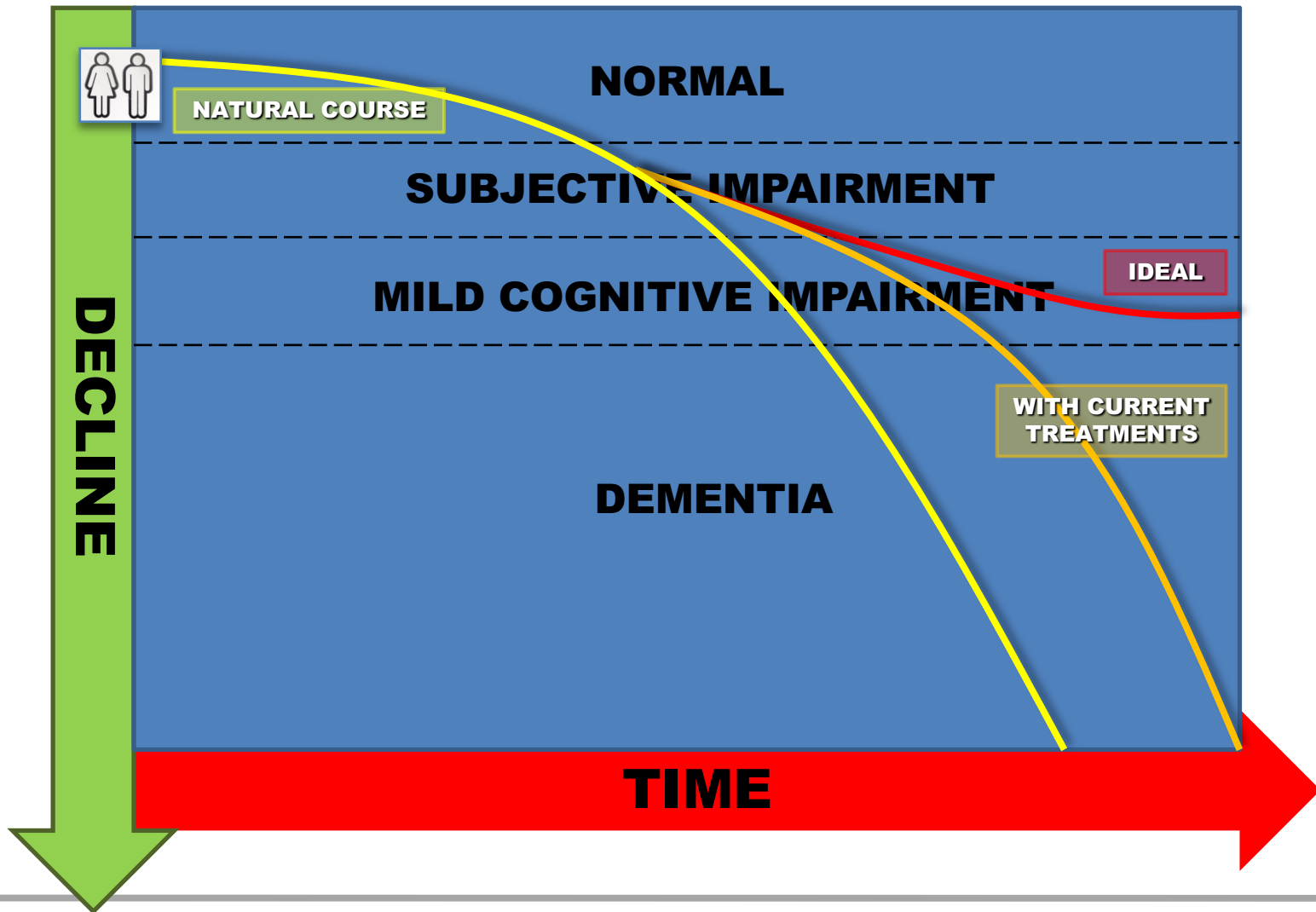
PARKINSON'S DISEASE 2%

Can give rise to dementia symptoms as the condition progresses

Goals of Treatment

- What?
 - Improve or preserve ADL function
 - Reduce caregiver burden
 - Enhance quality of life
- How?
 - Improve or preserve cognitive function
 - Improve or preserve behavioral function
 - Slow down deterioration
 - Manage psychiatric and behavioral problems

Treatment



Diagnosis of Dementia

- Significant deterioration in two or more areas of cognitive function that is severe enough to interfere with a person's ability to perform everyday activities, e.g.:
 - Memory
 - Language skills
 - Visual perception
 - Ability to focus and pay attention
 - Ability to reason and solve problems
- The loss of brain function is severe enough that a person has **difficulties performing normal everyday tasks**

Alzheimer's: 3 Stages

- Progressive neurodegeneration with increasing impairments
- Three stages:
 - **Early** or **mild** stage, during which the clinical symptoms include mild cognitive decline and functional impairments
 - **Middle** or **moderate** stage, during which there are moderate impairments
 - **Late** stage or **severe** (or end-stage), with severe manifestations

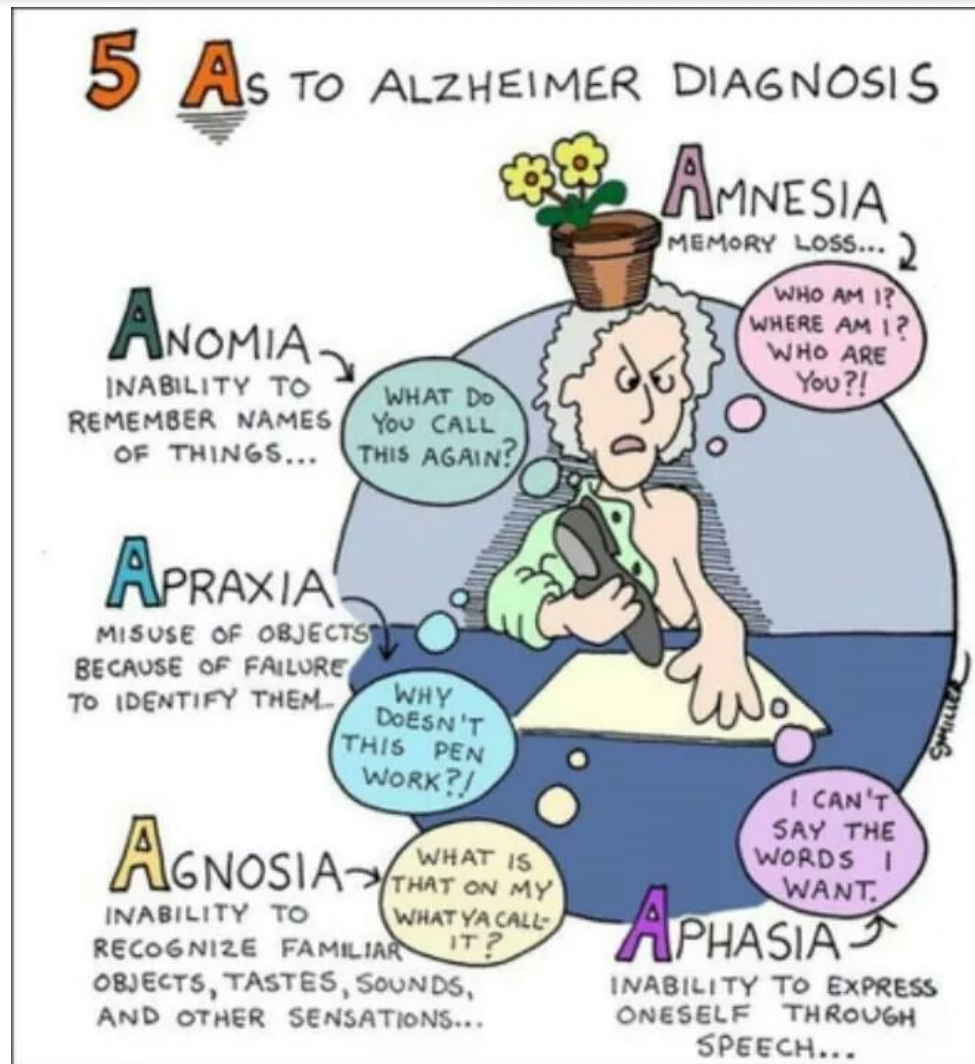
Alzheimer's: 7 Stages

- No impairment
- Very mild decline (minor memory issues)
- Mild decline (others may notice memory issues)
- Moderate decline (simple math; short-term memory; managing finances/bills; details about life history)
- Moderately severe (dressing, recalling simple details, significant confusion)
- Severe (confusion, unawareness of environment, recognizing others, bowel and bladder control, personality changes, wandering, needing assistance)
- Very severe (nearing death; communication, swallowing)

Alzheimer's: Risk Factors

- Age
 - Gender
 - Race
 - Genetics (ApoE4)
 - Parental History
 - Stress / inflammation
 - Midlife hypertension
 - Midlife hypercholesterolemia
 - Obesity
 - Diabetes
 - Sleep disturbances
 - Healthcare neglect (nutrition, exercise, ...)
-

Common Symptoms in Dementia



Aphasia

- Problems with language, comprehension
 - Initially characterized by fluent aphasia (reading/writing impaired)
 - Able to initiate and maintain conversations
 - Syntax and grammar intact, but speech is vague with nonspecific phrases like “the thing”
 - Later language can be severely impaired with mutism, echolalia
-

Apraxia

- Inability to carry out motor activities previously able to do despite intact motor function
- Contributes to loss of ADLs



Agnosia

- The inability to recognize or identify objects despite intact sensory function
 - Typically occurs later in the course of illness
 - Can be visual or tactile

Object agnosia



Testing

- Thorough history (medical, psychiatric, neurological)
 - Are ADL/IADLs affected?
 - Physical and neurological exam
 - Cognitive testing (initial screening, then more detailed if needed)
 - Labs and imaging (rule out reversible causes)
 - Consider neuropsychological testing or referral to psychiatry or neurology
-

Cognitive Screening Tests

- Mini-Mental Status Exam (MMSE)
 - Montreal Cognitive Assessment (MoCA)
 - Mini-Cog – combines clock drawing and three item memory test
 - Saint Louis University Mental Status (SLUMS)
-

Screening Test: MMSE


- Useful to have at **baseline**
 - Can track changes over time
 - In Alzheimer's, patients lose 3 points/year
 - Careful of false positives in those with little education
 - Careful of false negatives in those with high premorbid intellectual functioning
-

Screening Test: MMSE

Mini-Mental State Examination (MMSE)

Patient's Name: _____ Date: _____

**Instructions: Ask the questions in the order listed.
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 of the week? Month?"
5		"Where are we now: State? County? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then 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. Number of trials: _____
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, ...) Stop after five answers. 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

Screening Test: MoCA

- Comprehensive, not easy!
 - Catches those with higher premorbid functioning levels
 - Is free unlike MMSE
 - Mocatest.org
-

MONTREAL COGNITIVE ASSESSMENT (MOCA)

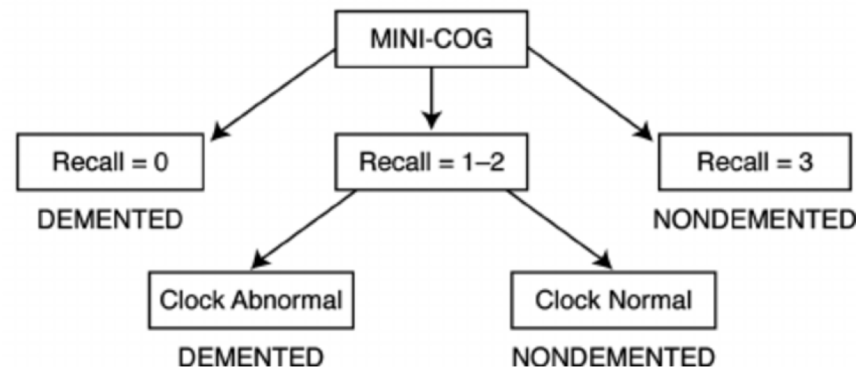
NAME : _____
 Education : _____ Date of birth : _____
 Sex : _____ DATE : _____

VISUOSPATIAL / EXECUTIVE		Copy cube	Draw CLOCK (Ten past eleven) (3 points)	POINTS			
		<input type="checkbox"/>	<div style="border: 1px solid black; height: 100px; width: 100%;"></div>	<input type="checkbox"/> /5			
NAMING							
			<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> ___/3				
MEMORY	Read list of words, subject must repeat them. Do 2 trials. Do a recall after 5 minutes.	FACE	VELVET	CHURCH	DAISY	RED	No points
	1st trial	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	2nd trial	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
ATTENTION	Read list of digits (1 digit/ sec.). Subject has to repeat them in the forward order	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 8	<input type="checkbox"/> 5	<input type="checkbox"/> 4	___/2
	Subject has to repeat them in the backward order	<input type="checkbox"/> 7	<input type="checkbox"/> 4	<input type="checkbox"/> 2			
	Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors	<input type="checkbox"/> FBACMNAAJKLBAFAKDEAAAJAMOF AAB					___/1
	Serial 7 subtraction starting at 100	<input type="checkbox"/> 93	<input type="checkbox"/> 86	<input type="checkbox"/> 79	<input type="checkbox"/> 72	<input type="checkbox"/> 65	___/3
		4 or 5 correct subtractions: 3 pts, 2 or 3 correct: 2 pts, 1 correct: 1 pt, 0 correct: 0 pt					
LANGUAGE	Repeat : I only know that John is the one to help today. <input type="checkbox"/>						___/2
	The cat always hid under the couch when dogs were in the room. <input type="checkbox"/>						
	Fluency / Name maximum number of words in one minute that begin with the letter F <input type="checkbox"/> _____ (N ≥ 11 words)						___/1
ABSTRACTION	Similarity between e.g. banana - orange = fruit <input type="checkbox"/>	train - bicycle <input type="checkbox"/>	watch - ruler <input type="checkbox"/>				___/2
DELAYED RECALL	Has to recall words WITH NO CUE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Points for UNCUED recall only
Optional	Category cue	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	Multiple choice cue	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
ORIENTATION	<input type="checkbox"/> Date	<input type="checkbox"/> Month	<input type="checkbox"/> Year	<input type="checkbox"/> Day	<input type="checkbox"/> Place	<input type="checkbox"/> City	___/6
© Z. Nasreddine MD Version November 7, 2004		Normal ≥ 26 / 30		TOTAL		___/30	
www.mocatest.org				Add 1 point if ≤ 12 yr edu			

Screening Test: MINI-COG

1. Instruct the patient to listen carefully to and remember these 3 words: banana-sunrise-chair
2. Instruct the patient to draw the face of a clock, after the numbers are placed, ask them to draw the hands of the clock to read “one ten”
3. Ask the patient to repeat the 3 previously stated words

The Mini-Cog scoring algorithm. The Mini-Cog uses a three-item recall test for memory and the intuitive clock-drawing test. The latter serves as an “informative distractor,” helping to clarify scores when the memory recall score is intermediate.



Clock Drawing Test- Abnormal

Figure 2

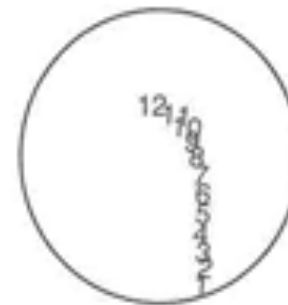
Brief Screening Exams
Clock Drawing Test



Mildly Impaired Sample

Figure 3

Brief Screening Exams
Clock Drawing Test



Moderately/Severely Impaired Sample

Screening Test: SLUMS

- Better psychometric properties than MMSE, with scoring normed to educational level
 - http://medschool.slu.edu/agingsuccessfully/pdfsurveys/slumsexam_05.pdf
-

Screening Test: SLUMS

VAMC SLUMS Examination

Questions about this assessment tool? E-mail aging@slu.edu.

Name _____ Age _____
Is patient alert? _____ Level of education _____

1 1. What day of the week is it?

1 2. What is the year?

1 3. What state are we in?

4. Please remember these five objects. I will ask you what they are later.
Apple Pen Tie House Car

5. You have \$100 and you go to the store and buy a dozen apples for \$3 and a tricycle for \$20.
1 How much did you spend?
2 How much do you have left?

6. Please name as many animals as you can in one minute.
1 0-4 animals **2** 5-9 animals **3** 10-14 animals **4** 15+ animals

7. What were the five objects I asked you to remember? 1 point for each one correct.

8. I am going to give you a series of numbers and I would like you to give them to me backwards.
For example, if I say 42, you would say 24.
1 87 **2** 649 **3** 8537

9. This is a clock face. Please put in the hour markers and the time at ten minutes to eleven o'clock.
2 Hour markers okay
2 Time correct

1 10. Please place an X in the triangle.

1 Which of the above figures is largest?

11. I am going to tell you a story. Please listen carefully because afterwards, I'm going to ask you some questions about it.
Jill was a very successful stockbroker. She made a lot of money on the stock market. She then met Jack, a devastatingly handsome man. She married him and had three children. They lived in Chicago. She then stopped work and stayed at home to bring up her children. When they were teenagers, she went back to work. She and Jack lived happily ever after.

2 What was the female's name? **2** What work did she do?
2 When did she go back to work? **2** What state did she live in?

_____/8
TOTAL SCORE



SAINT LOUIS
UNIVERSITY



SCORING

HIGH SCHOOL EDUCATION		LESS THAN HIGH SCHOOL EDUCATION
27-30	Normal	25-30
21-26	MNCD*	20-24
1-20	Dementia	1-19

* Mild Neurocognitive Disorder

SH Tariq, N Tumosa, JT Chibnall, HM Perry III, and JE Morley. The Saint Louis University Mental Status (SLUMS) Examination for Detecting Mild Cognitive Impairment and Dementia is more sensitive than the Mini-Mental Status Examination (MMSE) - A pilot study. J Am Geriatr Psych (in press).

Course of Alzheimer's Disease

Mild (MMSE 20-24) – primarily memory and visuospatial deficits, mild executive functioning impairment

Moderate (MMSE 11-20) – more pronounced aphasia, apraxia, loss of IADLs, may need increased assistance with ADLs, often exhibiting neuropsychiatric symptoms

Severe (MMSE 0-10) – severe language disturbances, pronounced neuropsychiatric manifestations, neurological symptoms (rigidity, incontinence, dysphagia, gait disturbance)

Death 8-12 years after the diagnosis

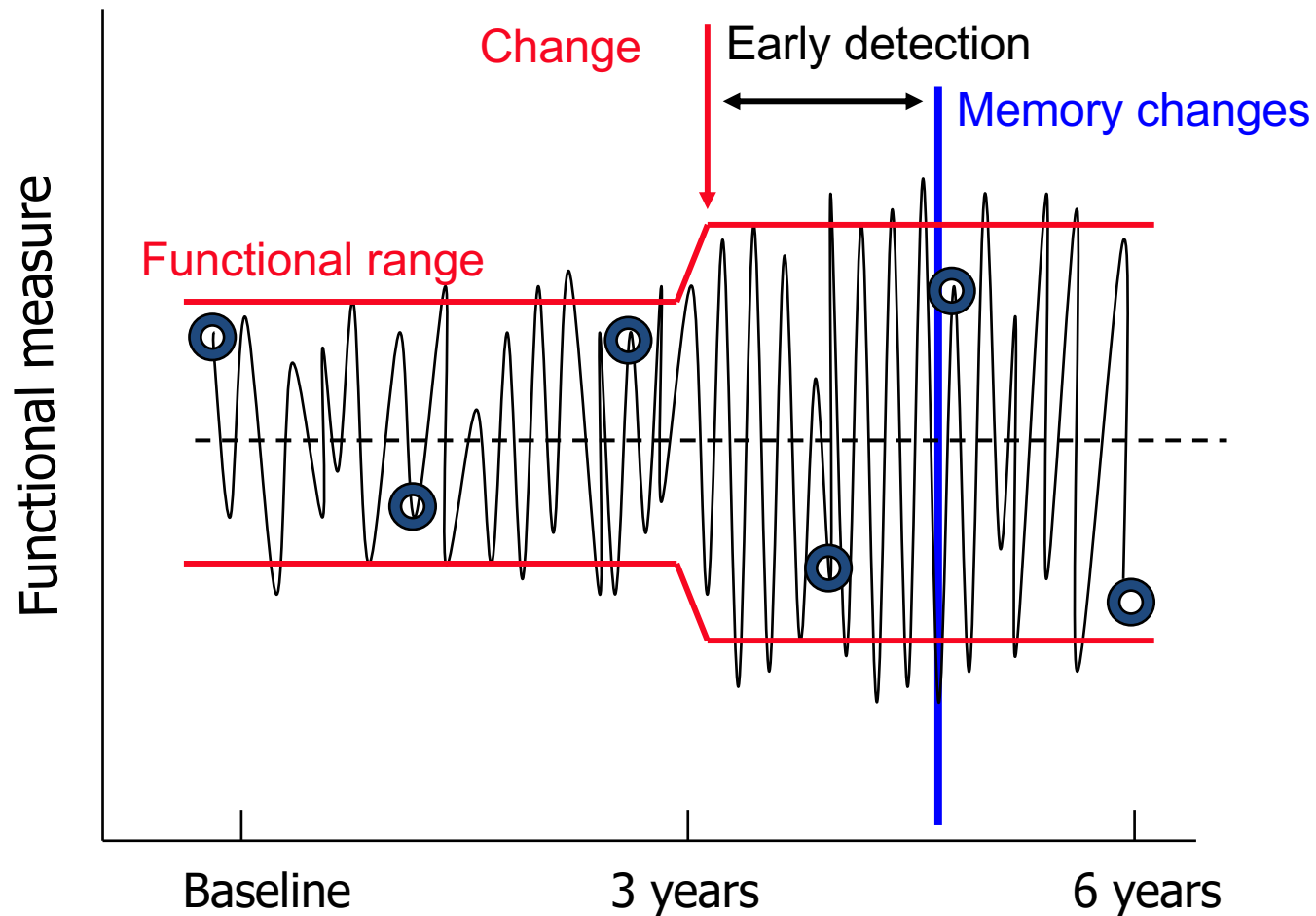
Institutionalization common with increasing neuropsychiatric issues, loss of ADLs, caregiver stress

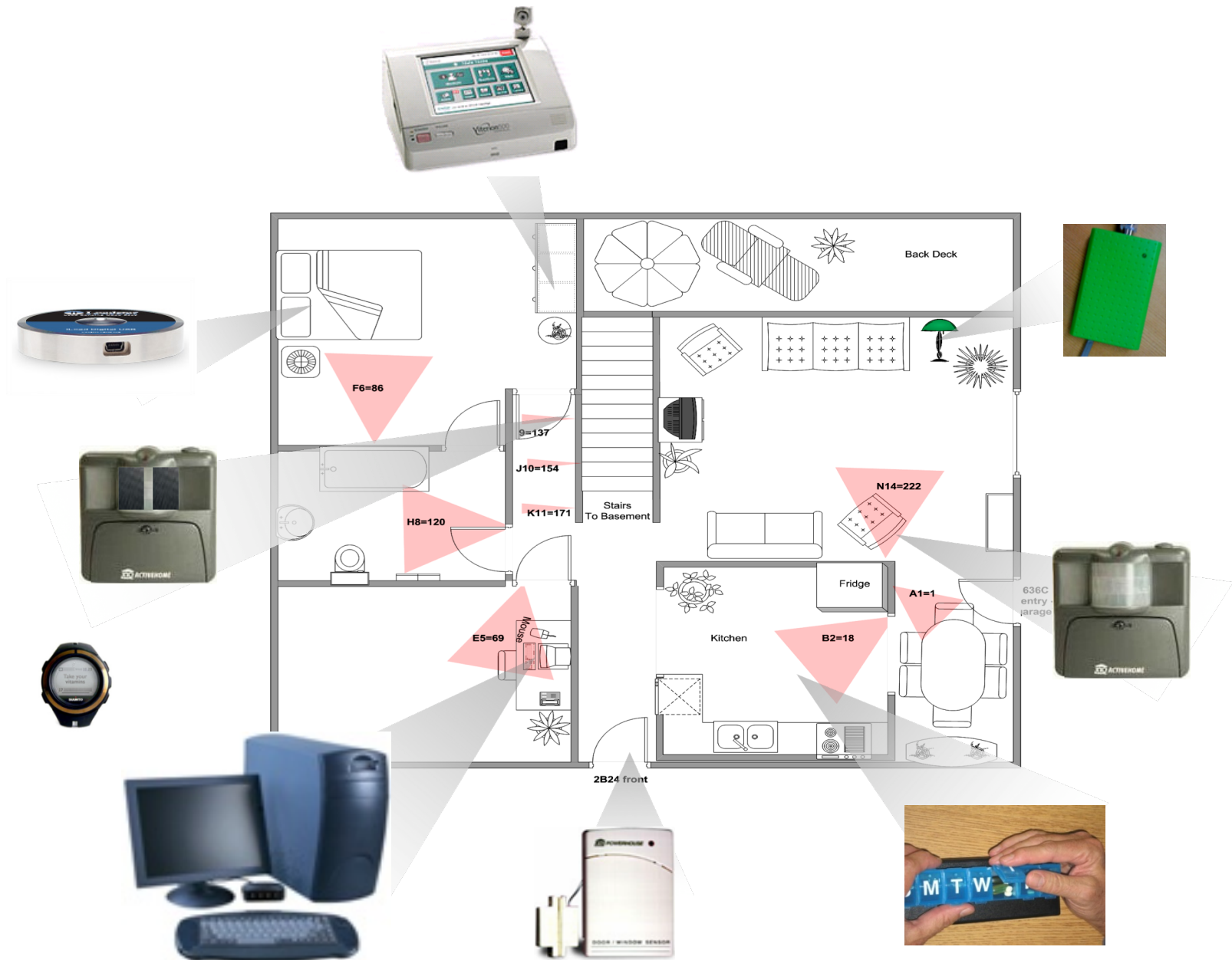
Out-of-Clinic Assessment

Identify meaningful change in real-time, by changing both the timing and place for assessments

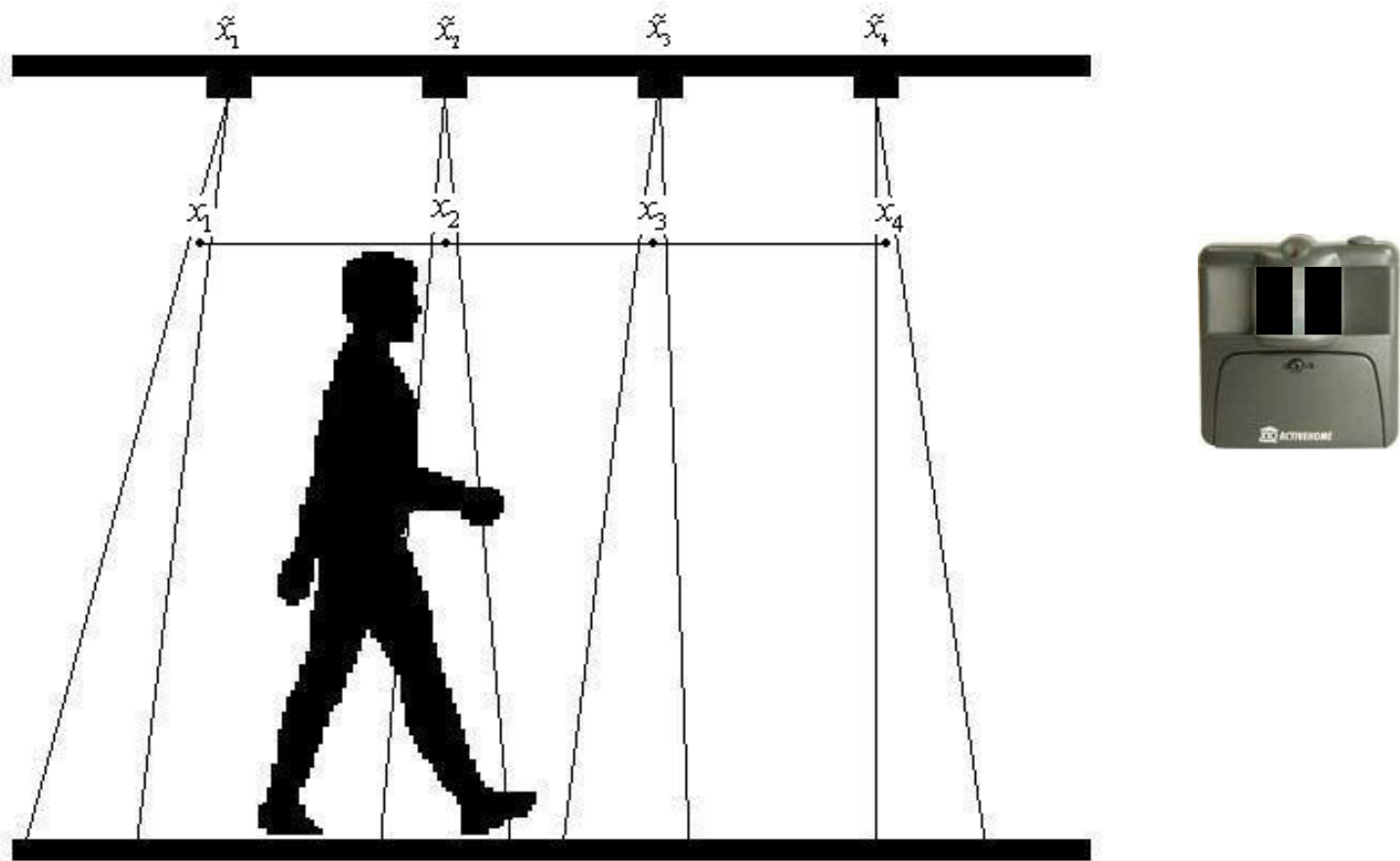
- Bring the **locus of assessment** into the daily life of the home and community
- Record events in **real-time** as they occur
- Be **minimally obtrusive** or in the background of daily activity – “ambient assessment”
- Record **continuously**

Approach: Detecting Early Changes





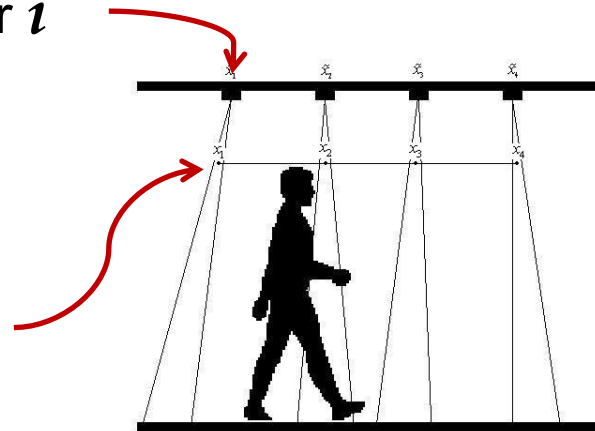
Measuring Walking Speed



Approach

\tilde{x}_i : physical location
of sensor i

x_i : Location at
which sensor i
detects motion



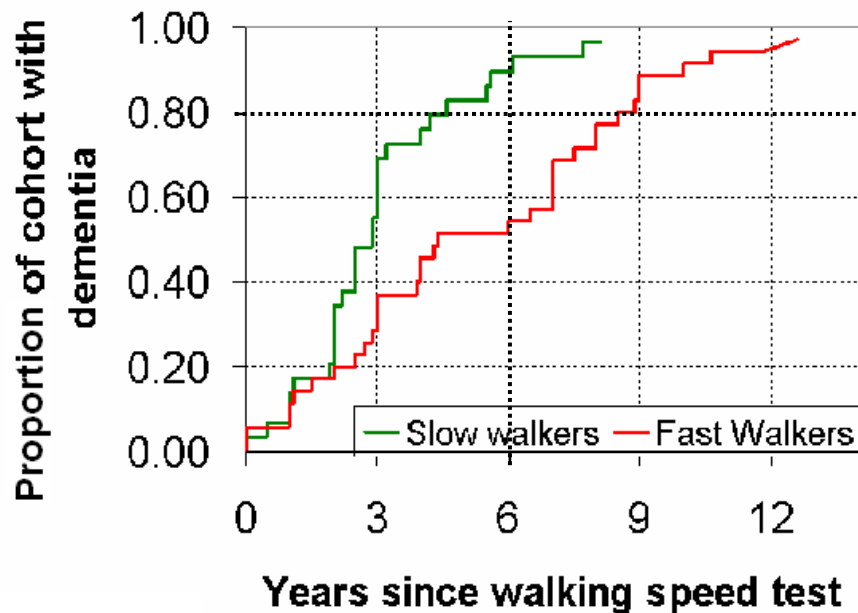
Location of movement triggering
sensor i is at $\{x_i + e_i\}$

Velocity of movement between
sensor **1** and sensor **2** is then
calculated as:

$$v_{12} = \frac{\{x_2 + e_2\} - \{x_1 + e_1\}}{t_2 - t_1}$$

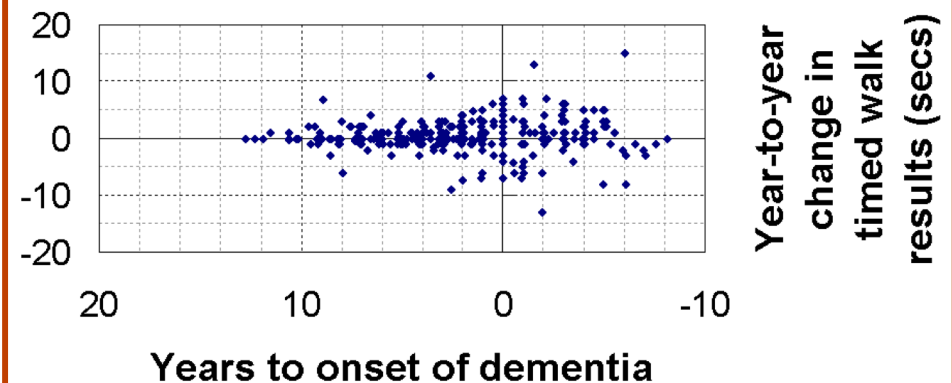
Detect Cognitive Changes via Walking Speed

Hayes, et al., Int. Conf. Alz. Disease 2006

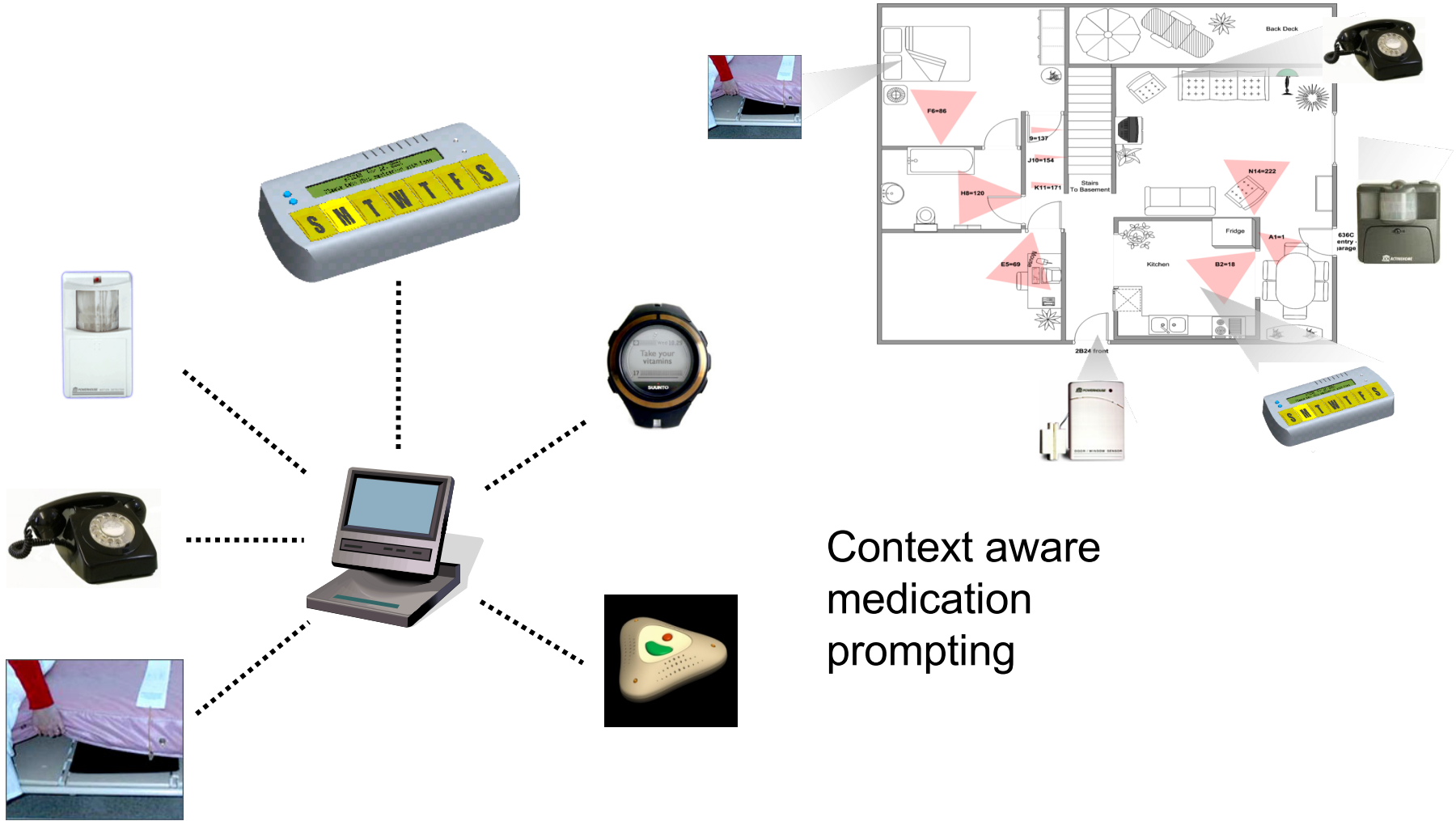


Slow walkers develop dementia earlier than fast walkers

Variability in walking speed increases as people develop dementia

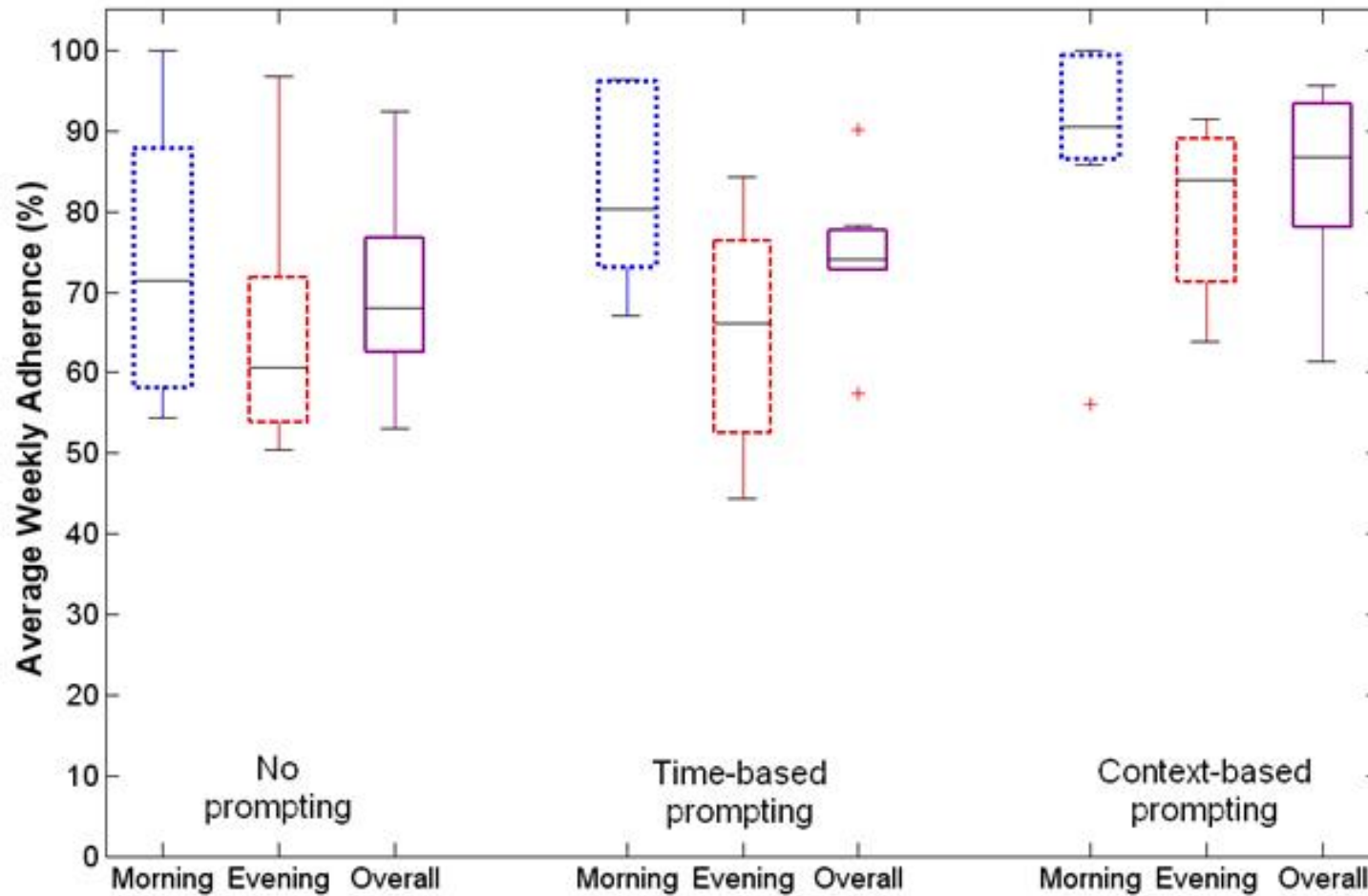


Helping People to Remember



Context aware medication prompting

Context Aware Medication Prompting



Fall Detection: Buddiband

- Detects changes in typical activity levels; if a user's activity levels significantly diminish, contact is made with the user or carer



Wandering: Buddiband

- Track user with GPS sensor (in shoe insole)



Eating Reminder

- A fragrance-release system designed to stimulate appetite among people with dementia. The mains-powered unit releases three food fragrances a day, adjustable to coincide with the user's mealtimes



Concussions

- Complex pathophysiological process that affects the brain, induced by traumatic biomechanical forces

1.2 Million Youth Concussions Per Year
50% FB Players Have Sustained A Concussion
35% Suffered Multiple Concussions
80% Symptoms Worsen Over Weeks
50% Return To Play Too Soon
70% Would RTP Concussed
41% Would Not Leave A Game
50 H.S. Football Players Have Died Since 97

School of hard knocks

A concussion occurs when a violent blow to the head causes the brain to slam against the skull beyond the ability of the cerebrospinal fluid to cushion the impact. Between 1996 and 2001, NFL teams reported nearly 900 concussions.

1 When a football player takes a hit to the head, speeds range from 17 to 25 miles per hour with a force averaging 98 times the force of gravity.

2 The shock wave passes through the brain and bounces back off the skull. The concussion usually occurs at the opposite side from the point of impact.

3 The impact can cause bruising of the brain, tearing of blood vessels and nerve damage.

A study commissioned by the NFL revealed most hits occurred from a blow to the side of the head, often on the lower half of the face.

Symptoms

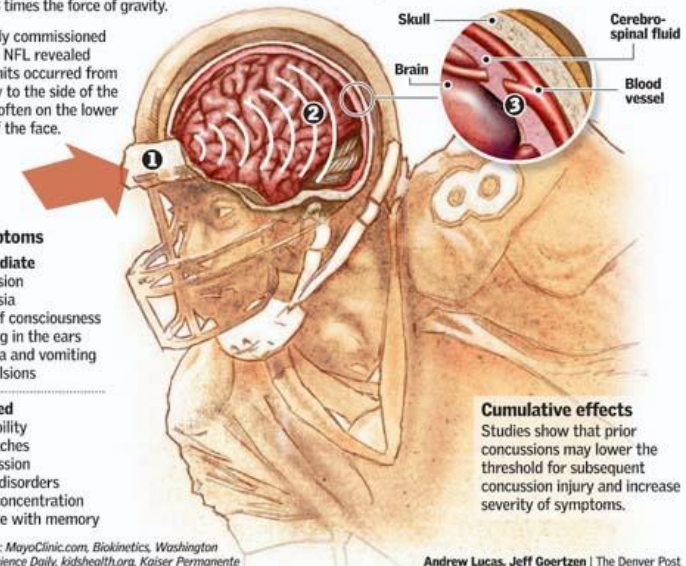
Immediate

Confusion
Amnesia
Loss of consciousness
Ringing in the ears
Nausea and vomiting
Convulsions

Delayed

Irritability
Headaches
Depression
Sleep disorders
Poor concentration
Trouble with memory

Sources: MayoClinic.com, Biokinetics, Washington Post, Science Daily, kidshhealth.org, Kaiser Permanente

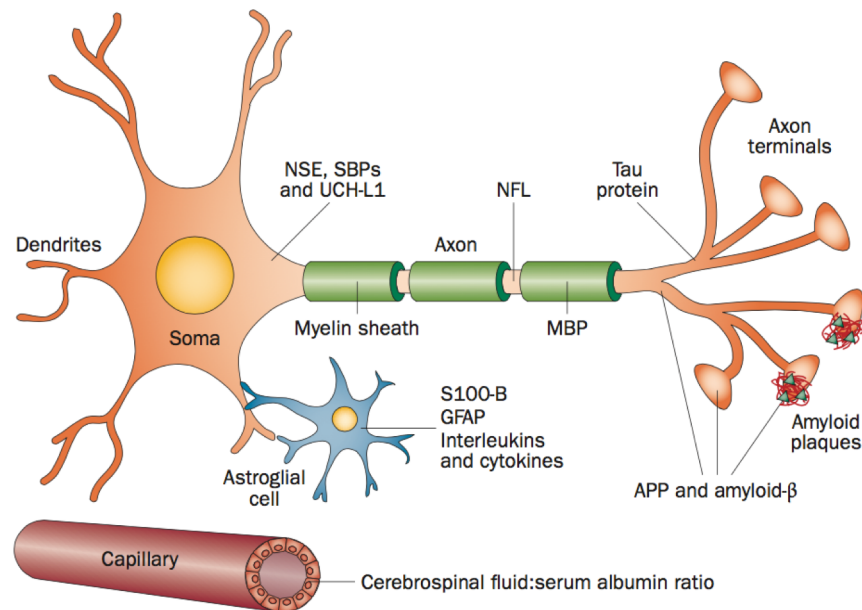


Cumulative effects

Studies show that prior concussions may lower the threshold for subsequent concussion injury and increase severity of symptoms.

What Happens During a Concussion?

- Brain hits the skull
- Impact results in bruising and possible nerve damage
- Trauma damages astroglial cells, which release S-100B (calcium-binding protein)

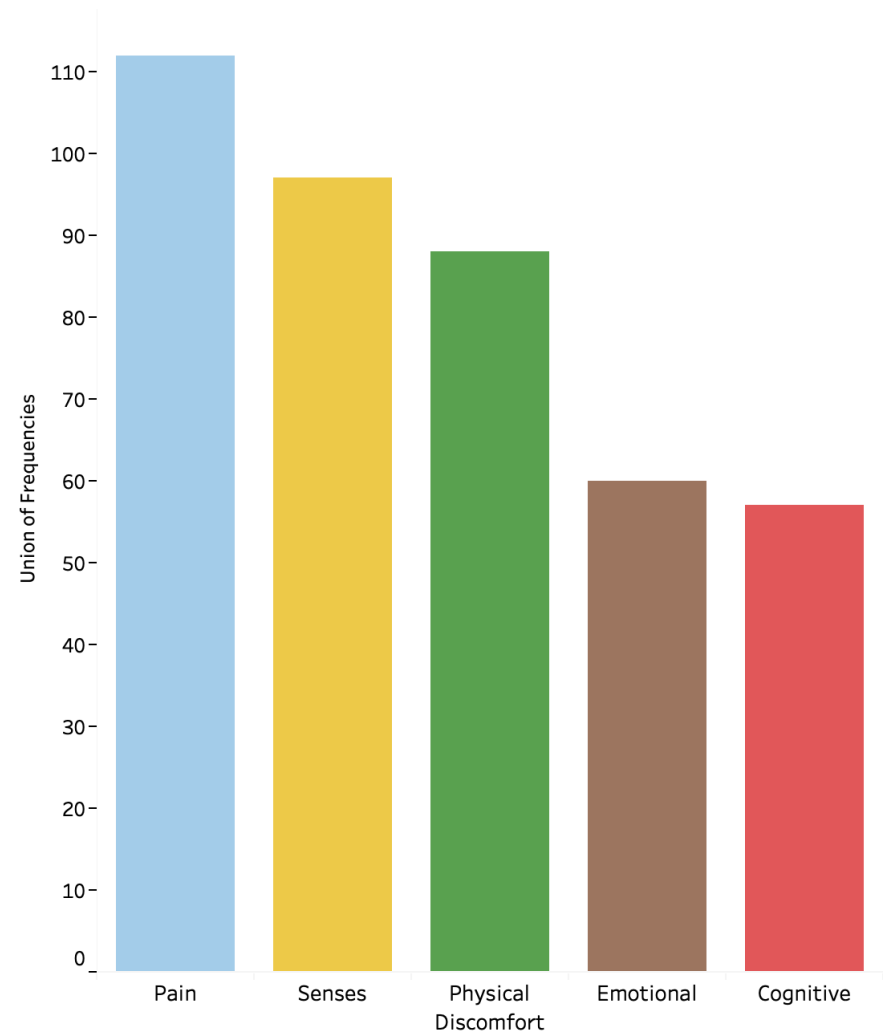


Signs and Symptoms

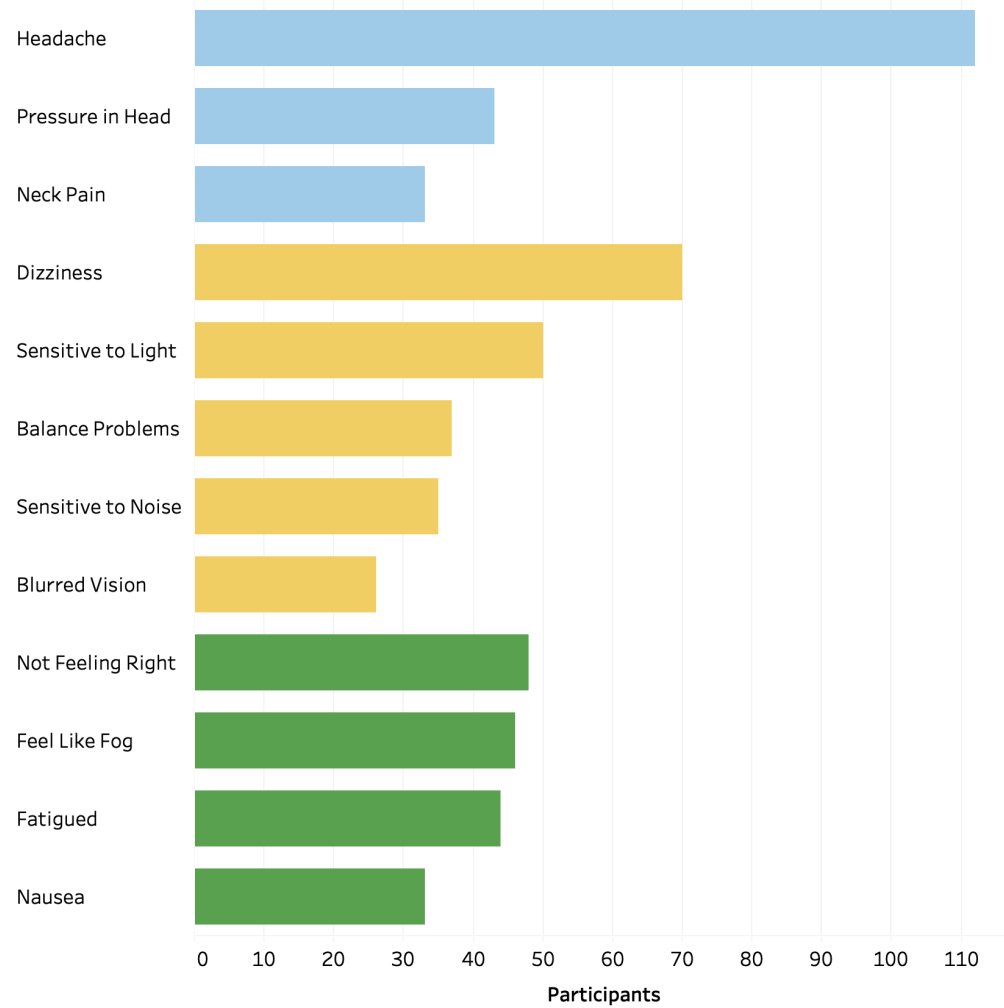
- Somatic (e.g., headache)
 - Cognitive (e.g., feeling like in a fog, slowed reaction time)
 - Emotional and behavioral (e.g., lability, irritability)
 - Physical (e.g., loss of consciousness, amnesia)
 - Sleep disturbance (e.g., drowsiness, insomnia)
-

Signs and Symptoms

Category	Symptoms
Pain	Headache, Neck pain, Pressure in head
Senses	Sensitive to noise, Sensitive to light, Blurred vision, Balance problems, Dizziness
Physical discomfort	Fatigue, Feeling like fog, Not feeling right, Drowsy, Nausea
Emotional	Irritable, Nervous, Sad, Feeling emotional, Feeling down
Cognitive	Difficulty remembering, Difficulty concentrating

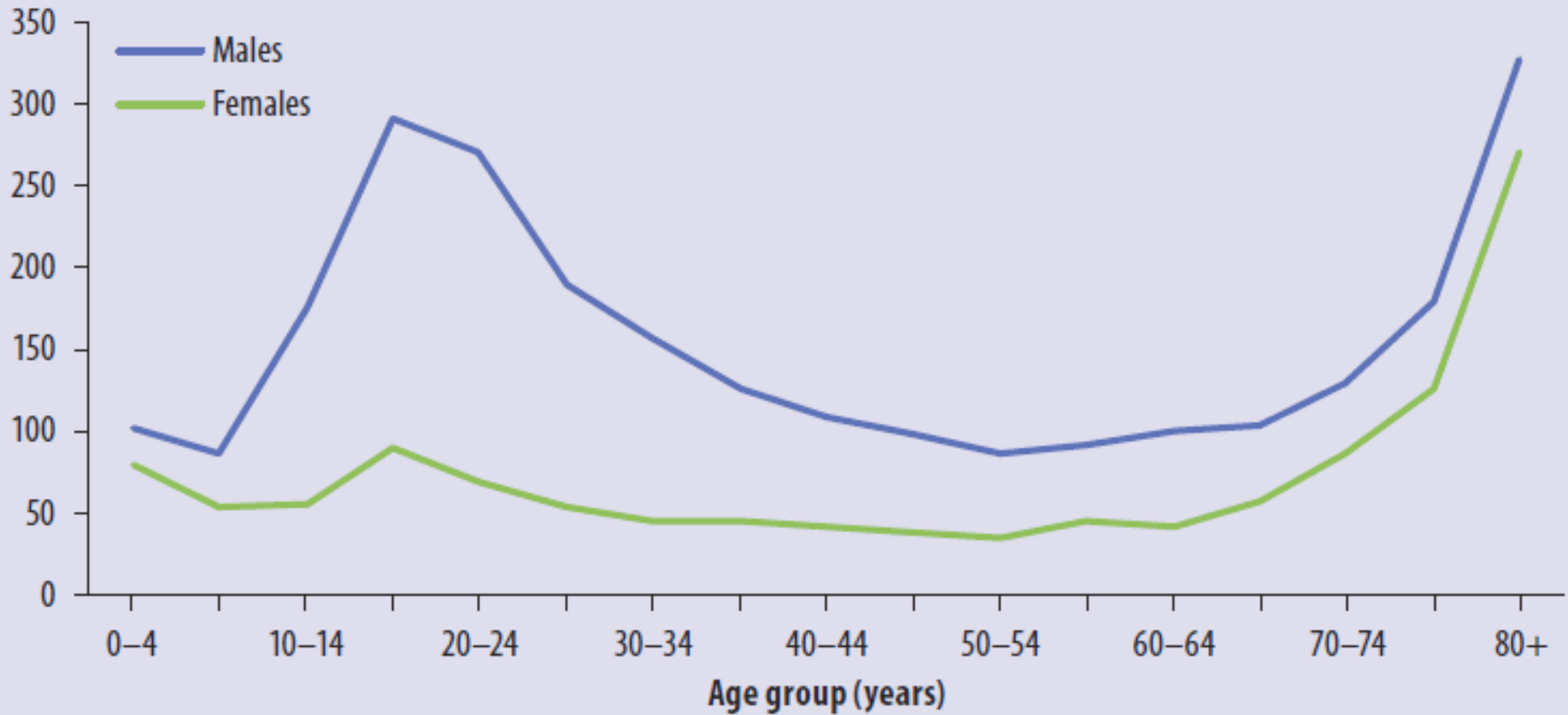


Signs and Symptoms



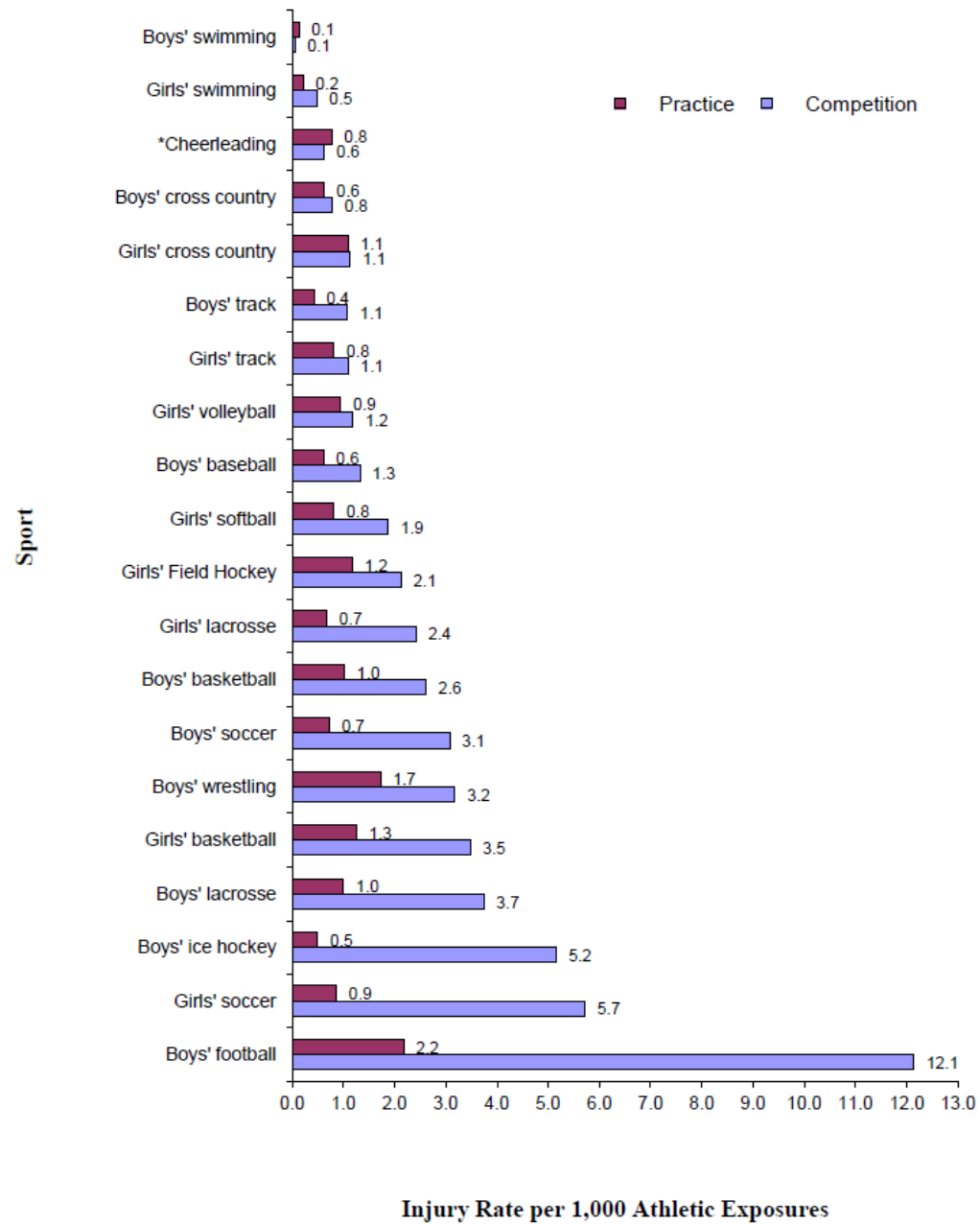
Rates By Gender & Age

Rate per 100,000



Source: Table A4.

Figure 1: Convenience Sample Injury Rates per 1,000 Athletic Exposures by Sport and Type of Athletic Exposure, High School Sports-Related Injury Surveillance Study, US, 2012-13



Long Term Consequences

- Temporary or permanent (lifelong physical, emotional, or cognitive disabilities)
 - Personality can be altered (usually for the worse); depression; suicide
 - Ability to work or maintain relationships or care for oneself can be reduced or destroyed
 - Abuse of alcohol and drugs is common
 - Can devastate the survivor's family (divorce rate is above 75%, high bankruptcy rate)
 - Loss of motor control; seizures
 - Dementia; Alzheimer's (earlier onset, higher risk); Parkinson's
 - Second-impact syndrome (often deadly)
 - Shortened sports career; inability to work
 - Law suits
 - Financial burden of TBI (estimated to exceed \$400 billion)
-

Concussion Testing: ImPACT

Sample questions from ImPact test

The ImPact test is administered at the start of a sports season to determine an athlete's baseline results, and again following a concussion to determine if his or her brain has recovered from the trauma. The memory and recognition tests, samples shown below, are conducted in conjunction with a general healthy history questionnaire and a survey of recent symptoms.

SYMBOL MATCHING

Evaluates visual processing speed, learning and memory



Click on the number that corresponds to the following symbol:



Symbols are shown with corresponding numbers. As a symbol is displayed below, the subject must click on the matching number above. After 27 matches, the subject must remember the correct symbol-number pairing.

SOURCE: ImPact

DESIGN MEMORY

Evaluates attentional processes and visual recognition memory



Was this one of the designs displayed?

Yes

No

Twelve designs are presented for 750 milliseconds, twice to facilitate learning. The subject is then shown a series of correct and incorrect designs and asked if each was displayed previously.

COLOR MATCH

Evaluates reaction time, impulse control/response inhibition

RED

BLUE

GREEN

Some words are displayed in their matching color (e.g. RED appears in a red color) and some do not (e.g. BLUE appears in a green color). The subject is instructed to quickly click on the word box only if the word and color match.

LAURA SPARKS - State Journal

Concussion Testing: SAC

FIGURE 1 **Standard Assessment of Concussion-SAC FORM A**

Name: _____ Team: _____ Examiner: _____ Date of Exam: _____ Time: _____ Exam (Circle One): BLine Injury Post-Px/Game
Day 1 Day 2 Day 3 Day 5 Day 7 Day 90

Introduction:
I am going to ask you some questions. Please listen carefully and give your best effort.

Orientation:
What Month is it? _____ 0 1
What's the Date Today? _____ 0 1
What's the Day of the Week? _____ 0 1
What Year is it? _____ 0 1
What Time is it right now? (within 1 hr) _____ 0 1
Award 1 point for each correct answer.

ORIENTATION TOTAL SCORE

Immediate Memory:
I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order.

LIST	TRIAL 1	TRIAL 2	TRIAL 3
Elbow	0 1	0 1	0 1
Apple	0 1	0 1	0 1
Carpet	0 1	0 1	0 1
Saddle	0 1	0 1	0 1
Bubble	0 1	0 1	0 1

TOTAL

Trials 2 & 3: I am going to repeat that list again. Repeat back as many words as you can remember in any order, even if I said the word before.
Complete all 3 trials regardless of score on trial 1 & 2. Score 1 pt. for each correct response.
Total score equals sum across all 3 trials.
Do not inform the subject that delayed recall will be tested.

IMMEDIATE MEMORY TOTAL SCORE

Exertional Maneuvers:
If subject is not displaying or reporting symptoms, conduct the following maneuvers to create conditions under which symptoms are likely to be elicited and detected. These measures need not be conducted if a subject is already displaying or reporting any symptoms. If not conducted allow 2 minutes to keep time delay constant before testing Delayed Recall. These methods should be administered for baseline testing of normal subjects.

Exertional Maneuvers	
5 Jumping Jacks	5 Push-Ups
5 Sit ups	5 Knee Bends

Neurologic Screening:

Loss of Consciousness/ Witnessed Unresponsiveness No Length: _____ Yes
Post-Traumatic Amnesia? No Length: _____ Yes
Retrograde Amnesia? Poor recall of events before injury No Length: _____ Yes

Strength

	Normal	Abnormal
Right Upper Extremity		
Left Upper Extremity		
Right Lower Extremity		
Left Lower Extremity		

Sensation - examples:
Finger-to-Nose/Romberg

Coordination - examples:
Tandem Walk/Finger-Nose-Finger

Concentration:
Digits Backward: I am going to read you a string of numbers and when I am done, you repeat them back to me backwards, in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7.
If correct, go to next string length. If incorrect, read trial 2. Score 1 pt. for each string length. Stop after incorrect on both trials.

4-9-3	6-2-9	0	1
3-8-1-4	3-2-7-9	0	1
6-2-9-7-1	1-5-2-8-6	0	1
7-1-8-4-6-2	5-3-9-1-4-8	0	1

Months in Reverse Order: Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'll say December, November...Go ahead.
1 pt. for entire sequence correct.
Dec-Nov-Oct-Sept-Aug-Jul-Jun-May-Apr-Mar-Feb-Jan 0 1

CONCENTRATION TOTAL SCORE

Delayed Recall:
Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order. Circle each word correctly recalled. Total score equals number of words recalled.

Elbow Apple Carpet Saddle Bubble

DELAYED RECALL TOTAL SCORE

SAC Scoring Summary:
Exertional Maneuvers & Neurologic Screening are important for examination, but not incorporated into SAC Total Score.

Orientation	/5
Immediate Memory	/15
Concentration	/5
Delayed Recall	/5
SAC Total Score	/30

Post Concussion Symptom Questionnaire

Name: _____ Date: _____
Sport: _____

Instructions:
We would like to know if you now suffer any of the symptoms given below. As many of these symptoms may occur normally, we would like you to compare yourself now with before the injury. Please select a number based on the following:
0 = Not experiencing at all
1 = No more of a problem than usual
2 = A mild problem
3 = A moderate problem
4 = A severe problem

Compared with before the injury, do you now (over the last 24 hours) suffer from:

Headaches	0	1	2	3	4
Feelings of dizziness	0	1	2	3	4
Noise sensitivity (upset by loud noise)	0	1	2	3	4
Sleep disturbances	0	1	2	3	4
Fatigue, tiring more easily	0	1	2	3	4
Being irritable, easily angered	0	1	2	3	4
Feeling depressed or tearful	0	1	2	3	4
Feeling frustrated or impatient	0	1	2	3	4
Forgetfulness, poor memory	0	1	2	3	4
Poor Concentration	0	1	2	3	4
Taking longer to think	0	1	2	3	4
Blurred vision	0	1	2	3	4
Light sensitivity (upset by bright light)	0	1	2	3	4
Double vision	0	1	2	3	4
Restlessness	0	1	2	3	4

Are you experiencing any other difficulties?
Please specify and rate as above:

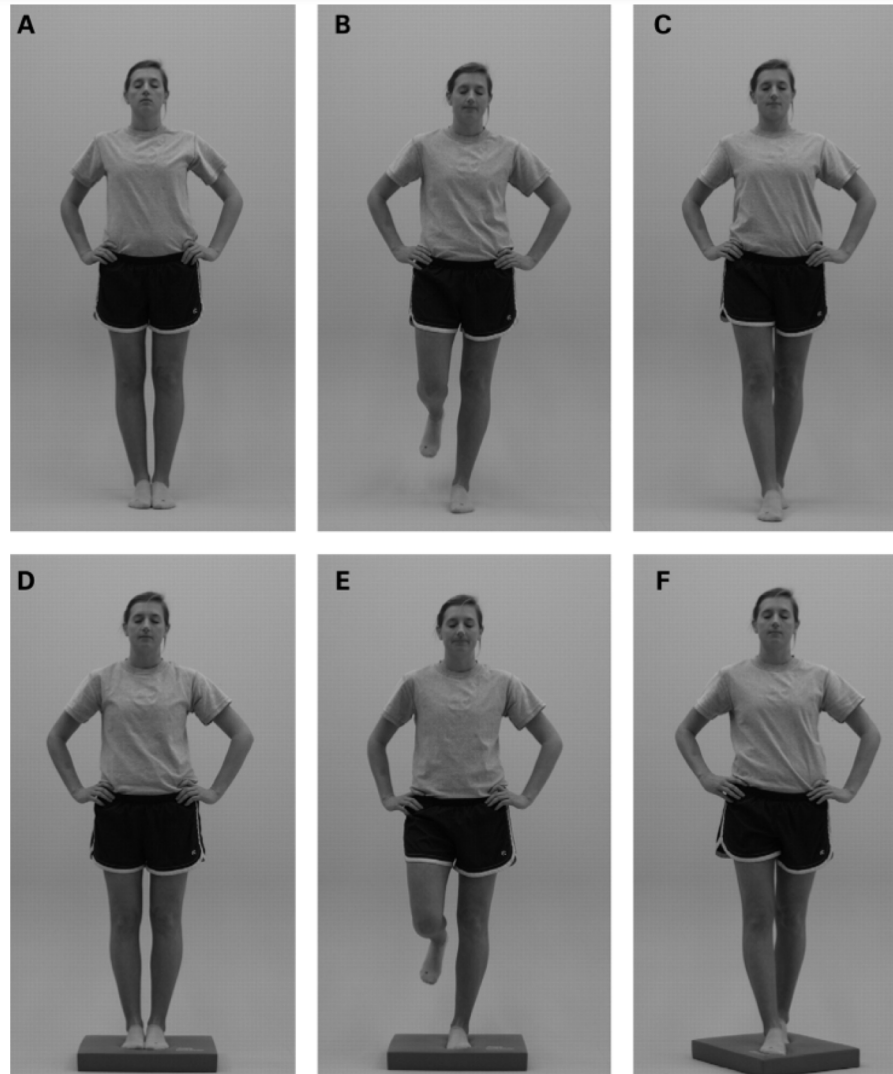
1. _____	0	1	2	3	4
2. _____	0	1	2	3	4

Total _____

Concussion Testing: King-Devick

<p>DEMONSTRATION CARD</p>	<p>TEST I</p> <p>2 — 5 — 8 — 0 — 7 3 — 7 — 9 — 4 — 6 5 — 3 — 1 — 6 — 4 7 — 9 — 7 — 3 — 5 1 — 5 — 4 — 9 — 2 6 — 5 — 5 — 7 — 3 3 — 1 — 8 — 6 — 4 5 — 3 — 7 — 5 — 2</p>
<p>TEST II</p> <p>3 7 5 9 0 2 5 7 4 6 1 4 7 6 3 7 9 3 9 0 4 5 2 1 7 5 3 7 4 8 7 4 6 5 2 9 0 2 3 6</p>	<p>TEST III</p> <p>5 4 1 8 0 4 6 3 5 9 7 5 4 2 7 3 2 6 9 4 1 4 5 1 3 9 3 4 8 5 5 1 6 3 1 4 3 5 2 7</p>

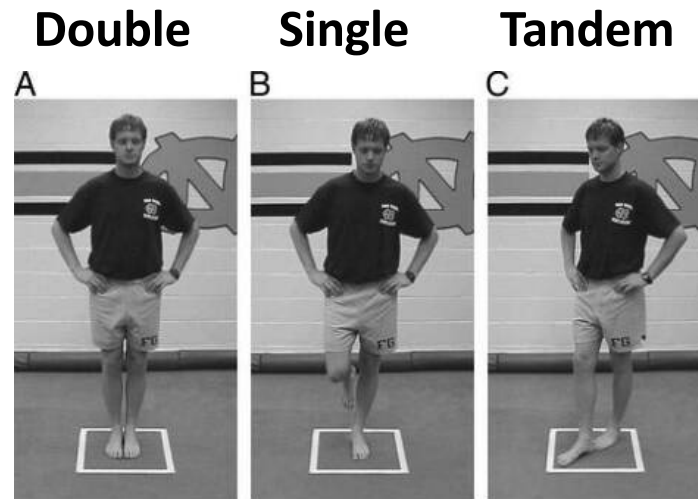
Balance Error Scoring System (BESS)



Balance Error Scoring System (BESS)

1. Hands lifted off of iliac crests
2. Opening eyes
3. Step, stumble, or fall
4. Moving hip into more than 30 degrees of flexion or abduction
5. Lifting forefoot or heel
6. Remaining out of testing position for more than 5 sec

Errors are 1 point each
& totaled across all
test conditions



- Three stances on firm surface for 20 seconds each
- Maximum 10 points for each stance
- Scored out of 30

<https://www.youtube.com/watch?v=rB5Mb8KS5rE>

Timed Tandem Gait

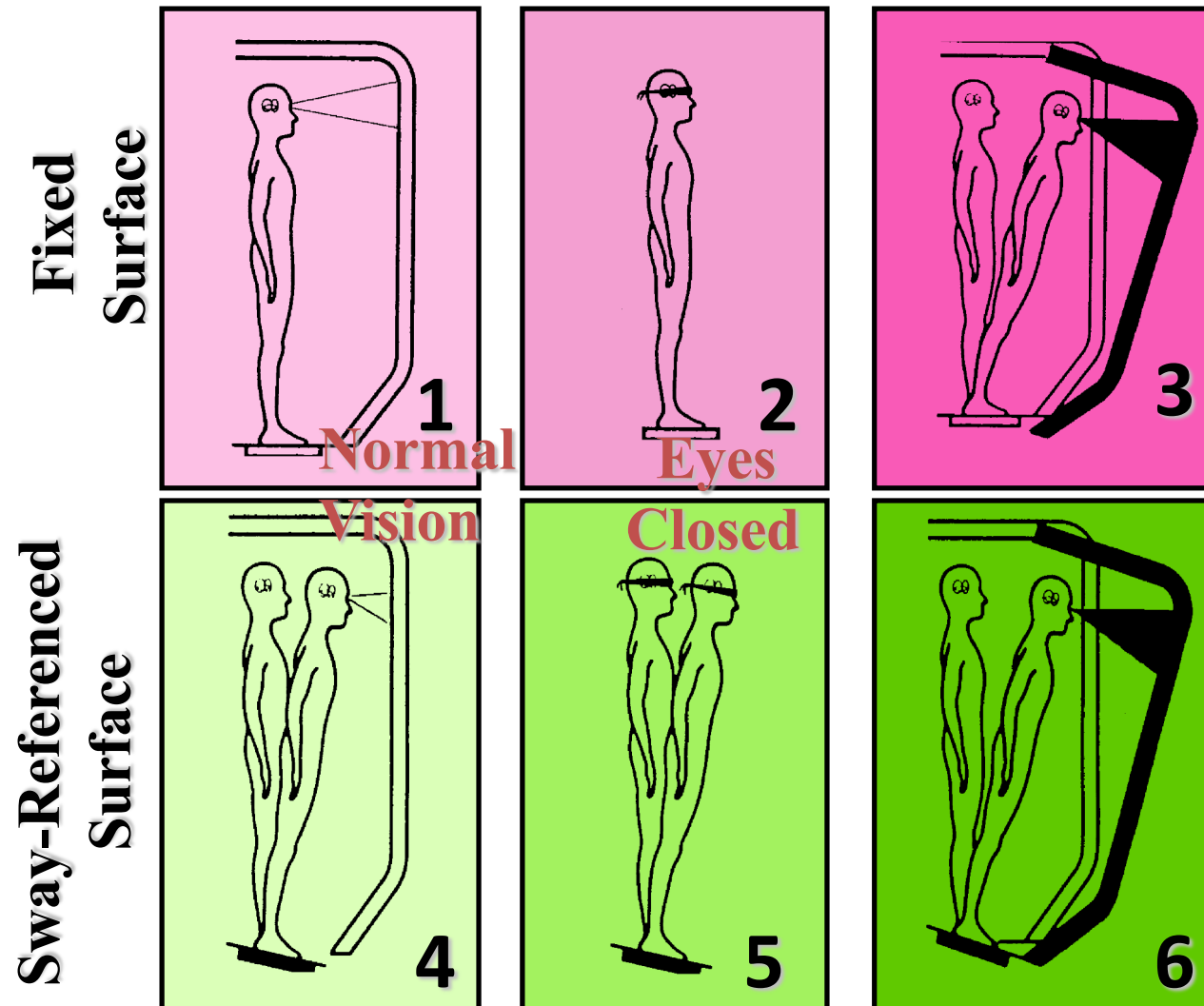
- Baseline heel-toe walk along a straight line 4 times with highest number as a “baseline”
 - Repeat at times of injury for comparison
 - More consistent compared to BESS however fatigability can play a role in performance
 - https://www.youtube.com/watch?v=ehjpG_0TobM
-

Computerized Dynamic Posturography

- Sensory Organization Test (SOT)
 - Assesses functional balance focusing on the visual, vestibular, and somatosensory systems
 - Age related normative data
 - Helps with functional goal setting and treatment planning
- <https://www.youtube.com/watch?v=HT1xe4JaV7w>



Computerized Dynamic Posturography



Eye Tracking

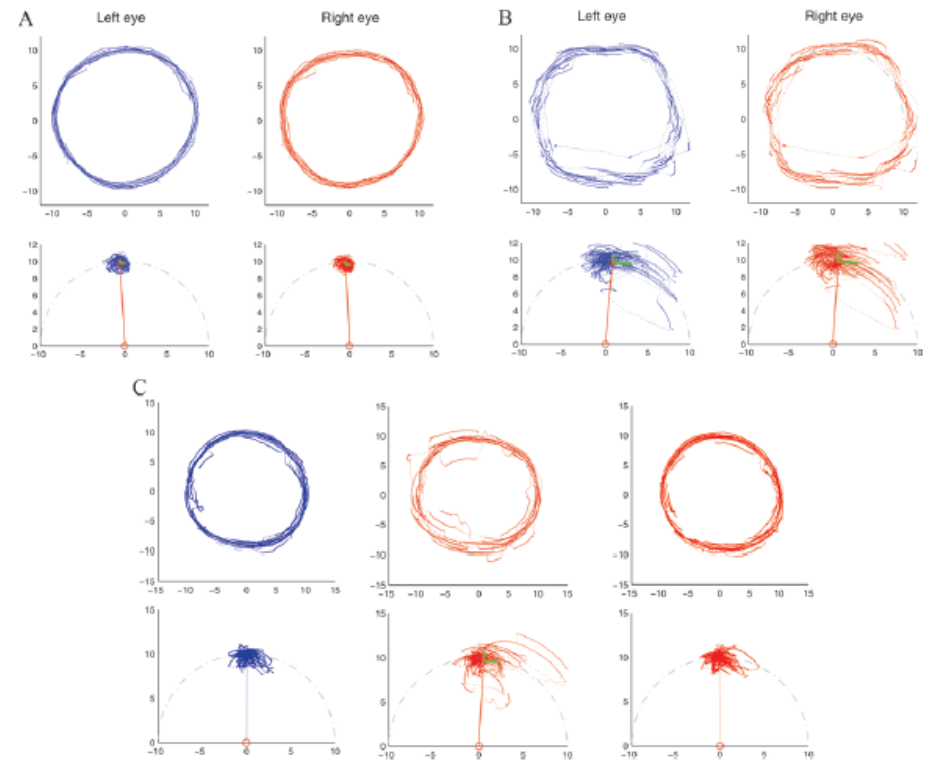
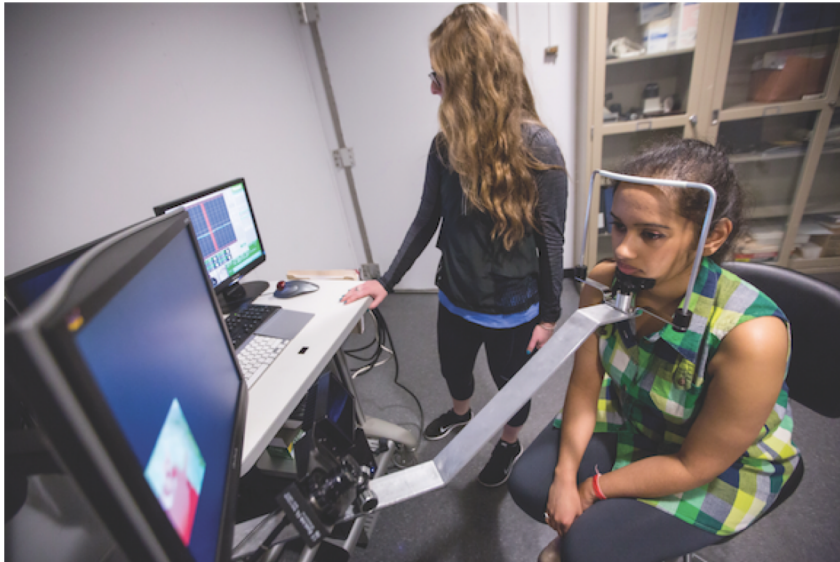
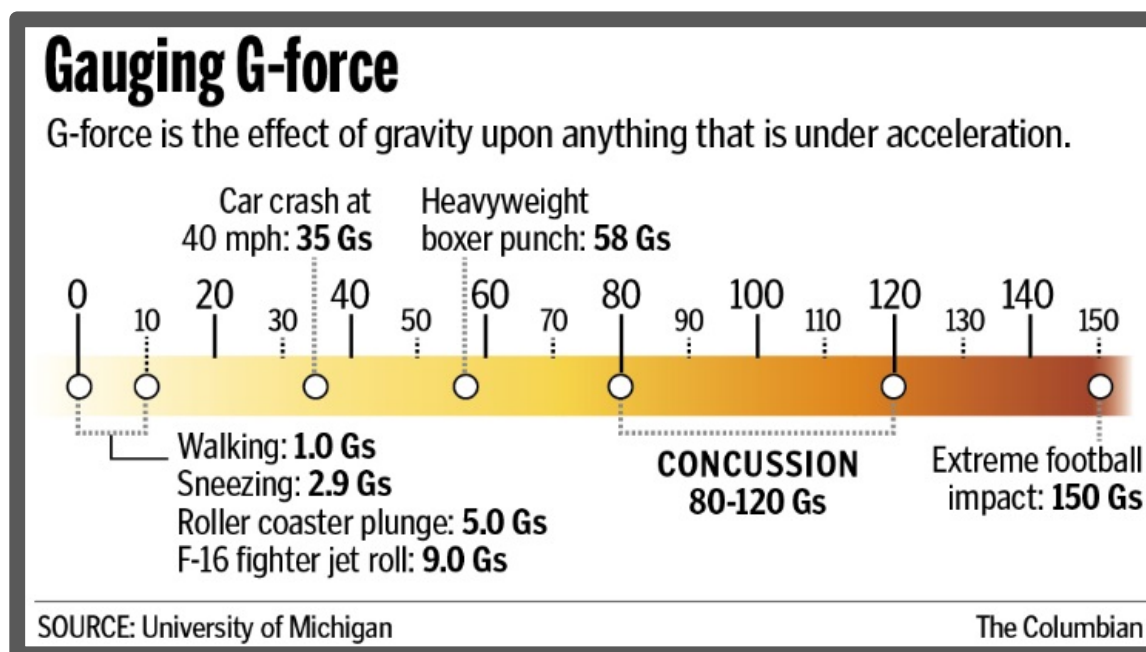


FIG. 3. Representative scattergrams of gaze positions (blue indicates left eye, and red indicates right eye) relative to the target; gaze positions were gathered at a frequency of 500 Hz. Circular patterns represent the path of the eye following a dot moving in a circle, and the semicircular pattern represents the eye position versus the target. Deviation from a target trajectory (dashed line) in both normal (A) and postconcussive (B) patients. A concussion signal is indicated by eye positions jumping ahead of the dot shown in B and C. From left to right (C), patient data at baseline, immediately postconcussion, and 2 days postconcussion.

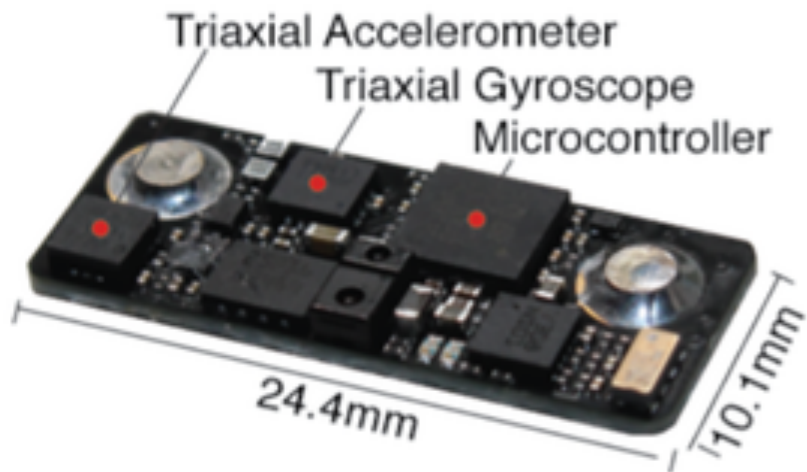
Concussion Detection

- Measure G-Force impact to the head in order to determine risk of concussion

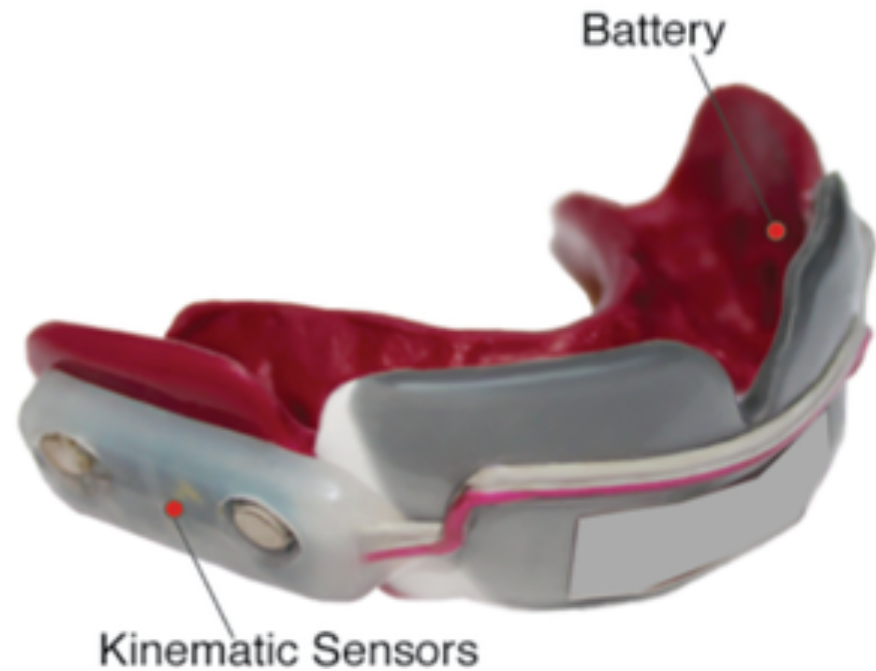


Concussion Detection

A Instrumentation



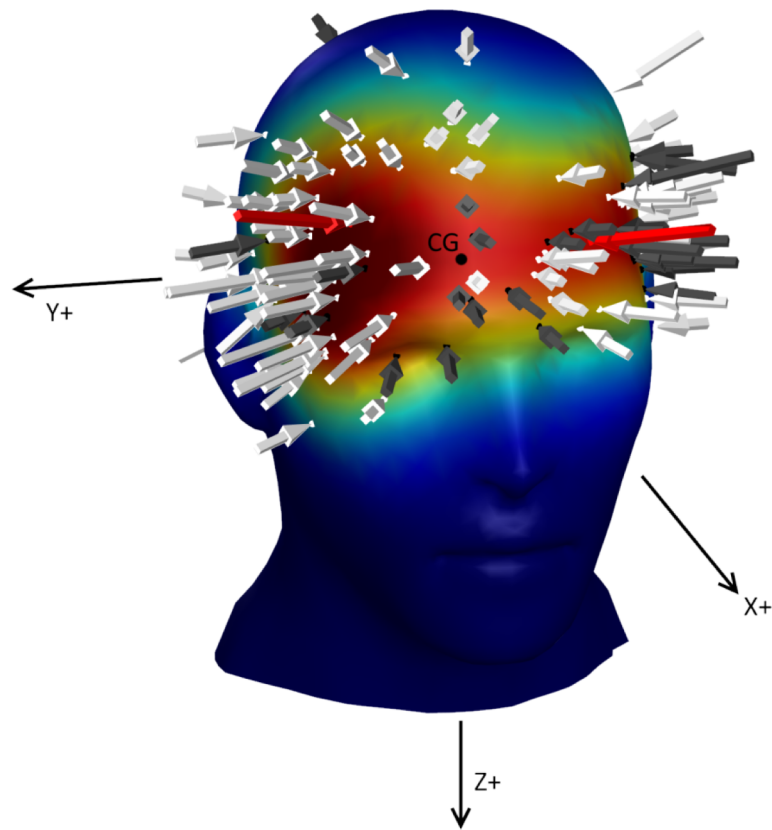
B Mouthguard



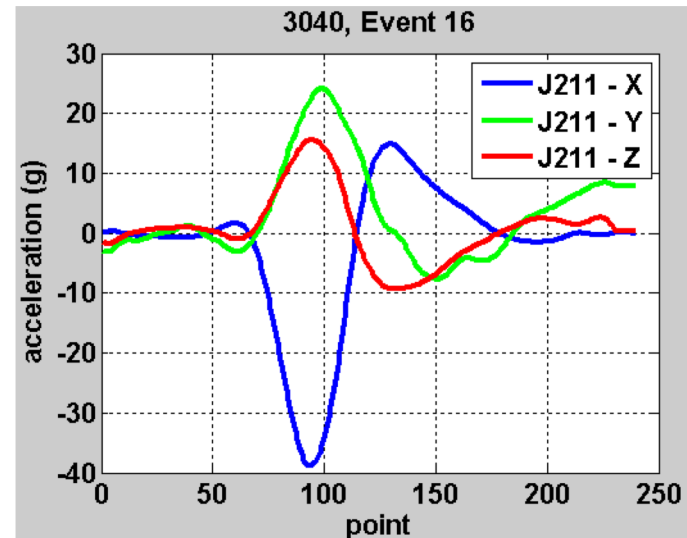
Concussion Detection



Concussion Detection

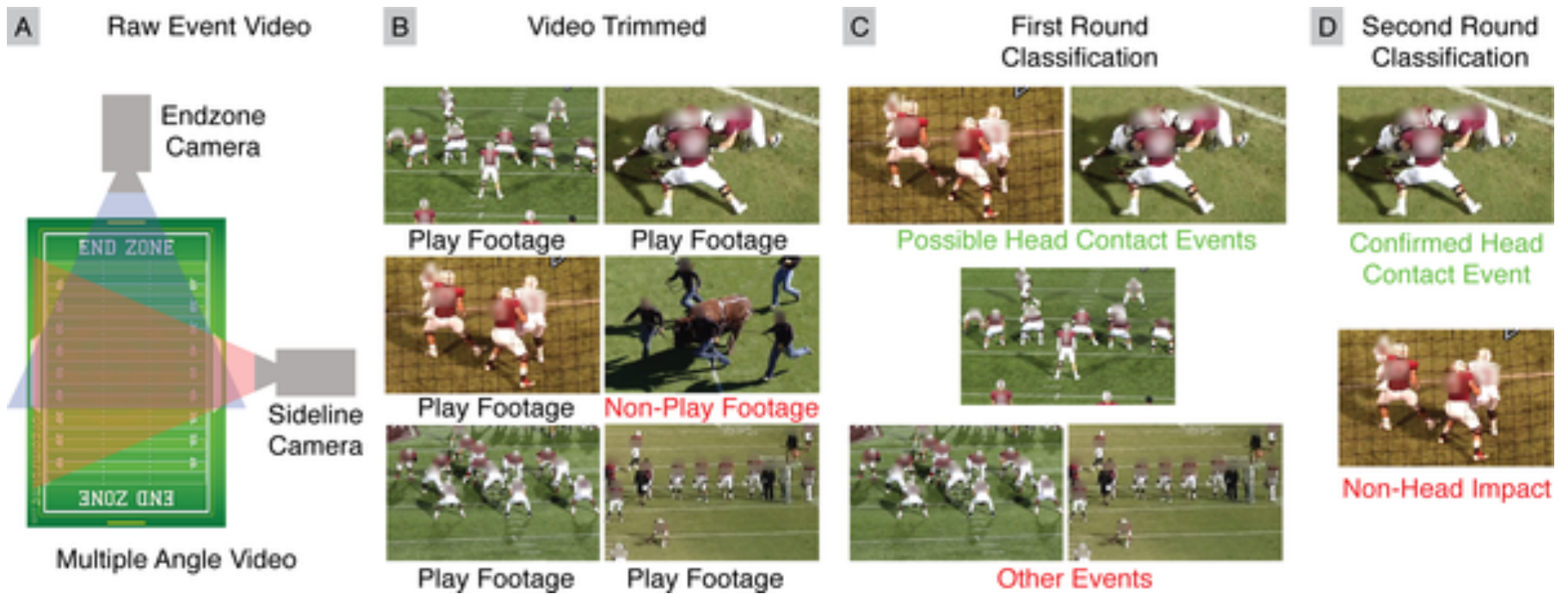


Direction, Location and Magnitude for all Impacts in Boxing, American Football



Impact counts
Impact locations
Impact severity
Rotational forces

Video Assessment

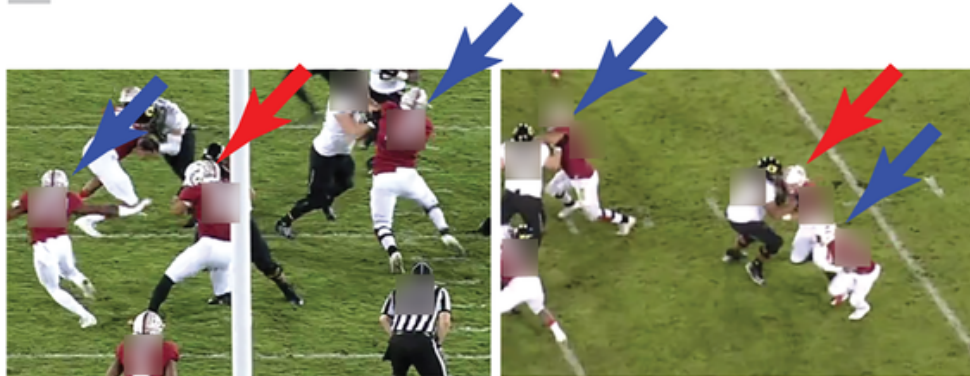


Video Assessment



Video Assessment

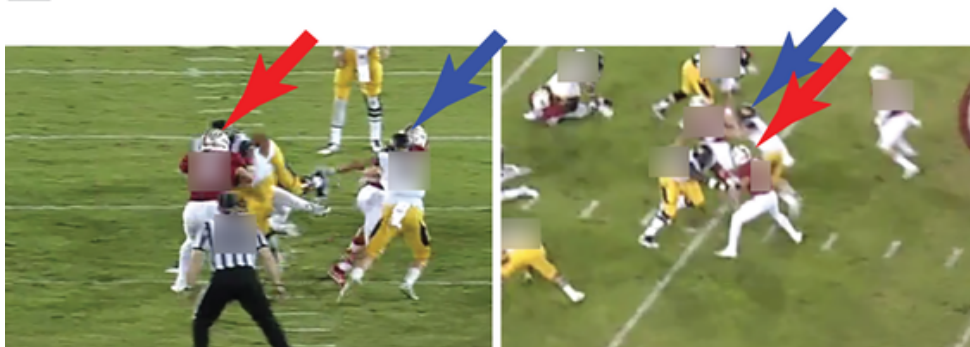
A Multi-View Confirmed Head Contact



Endzone View
Possible Contact

Sideline View
Confirmed Contact

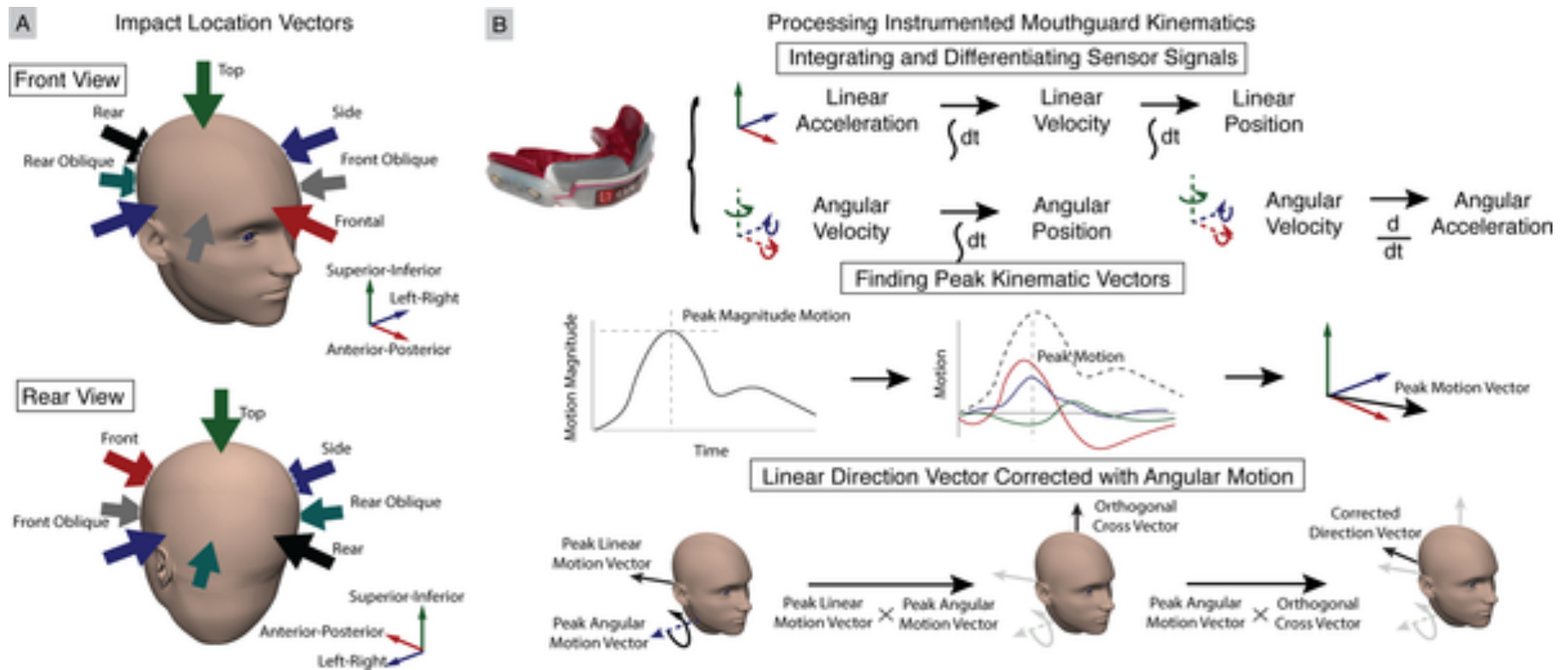
B Multi-View False Positive Head Contact



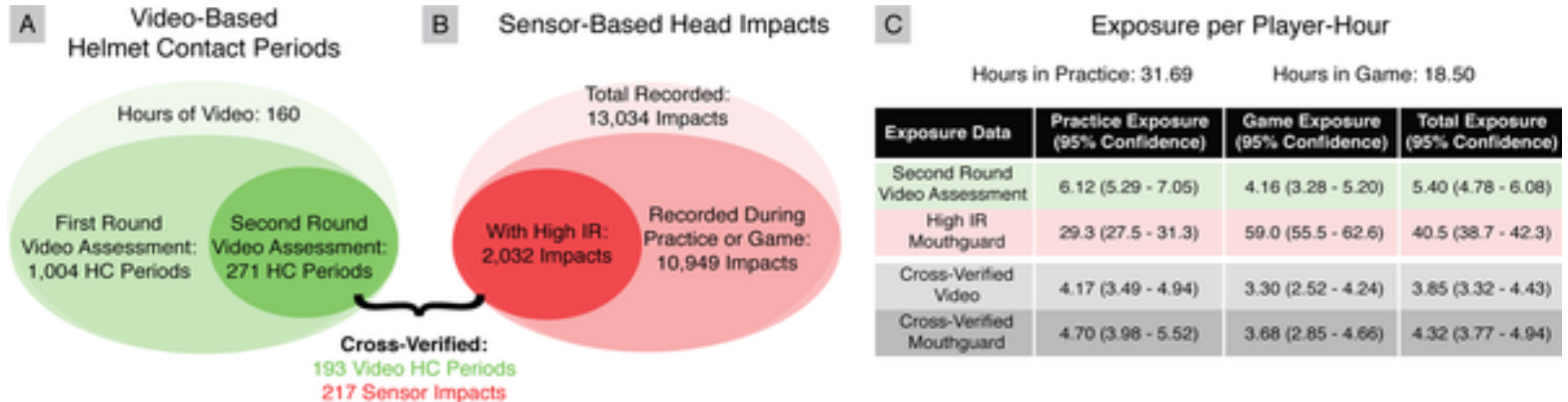
Endzone View
Possible Contact

Sideline View
No Head Contact

Video + Sensor Assessment



Video + Sensor Assessment



Video/Sensor Assessment – Pros/Cons

- Low-cost of vision (e.g., two cameras); 1+ motion sensor per athlete
- Obstructed view for vision
- Difficulties estimating level of impact using vision (e.g., depending on angles)
- Motion sensors can detect impact and head motion
- Impact of sensors on athlete performance
- Generally difficulty determining impact count, severity, and location
- Possible to combine both

Video/Sensor Assessment – Pros/Cons

- Sub-concussive hits!
 - Hits below concussion threshold
 - Repetitive hits have similar effect as one large impact
 - Also linked to CTE (chronic traumatic encephalopathy)

