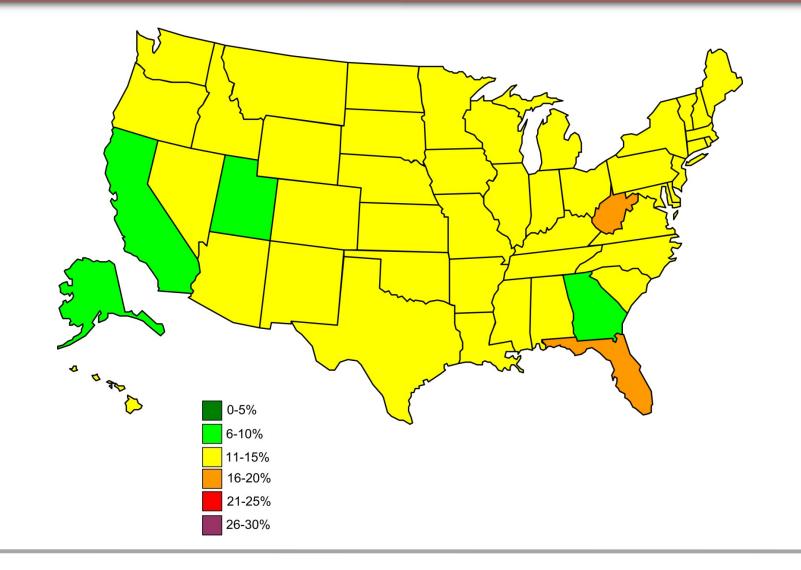
Selected Topics Communications and Mobile Computing (Smart Health)

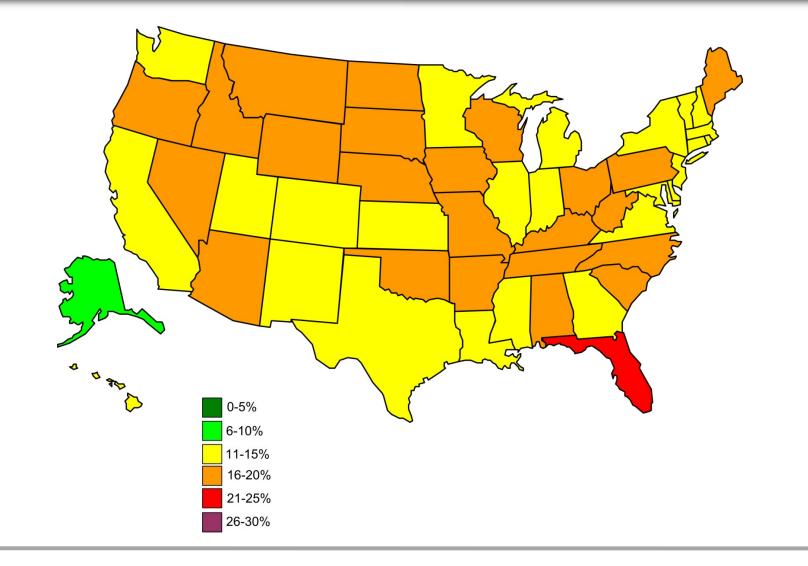
TU Graz University of Notre Dame

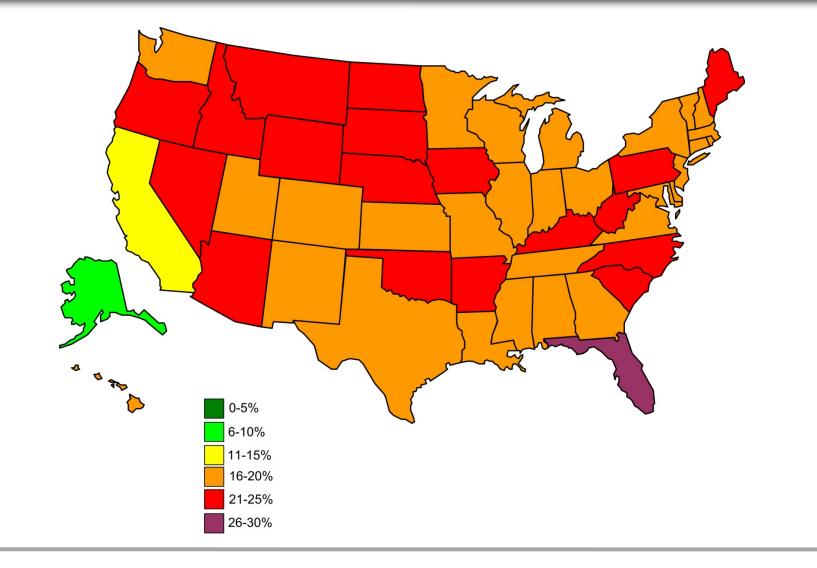


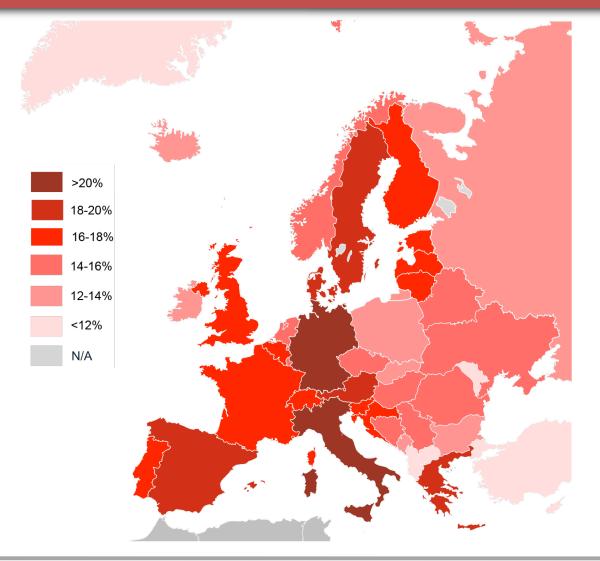


Computer Science and Engineering - University of Notre Dame









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), smellbased (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

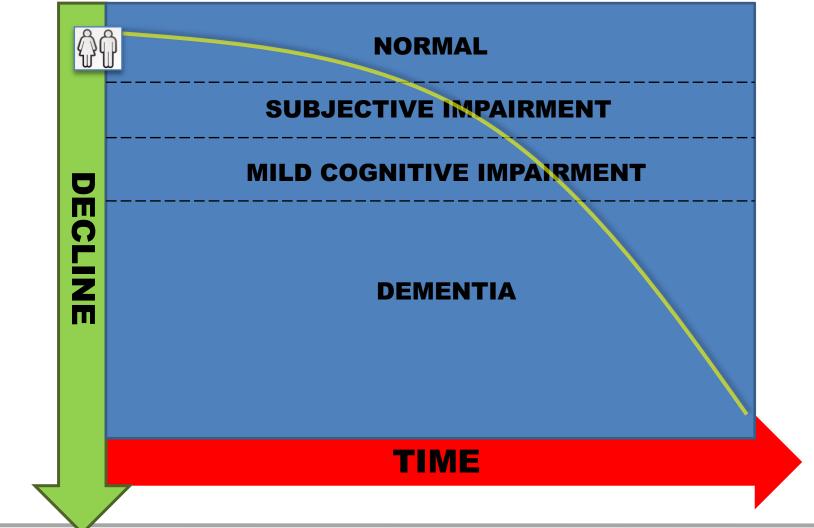
Behavioral and Psychological Symptoms of Dementia (BPSD)

- 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



Computer Science and Engineering - University of Notre Dame

Types of Dementia

The different kinds of dementia

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

ALZHEIMER'S 62%

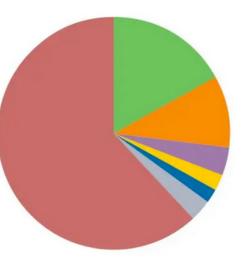
Causes problems with memory, language and reasoning. 5% of cases start before age 65

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 Creutzfeld-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

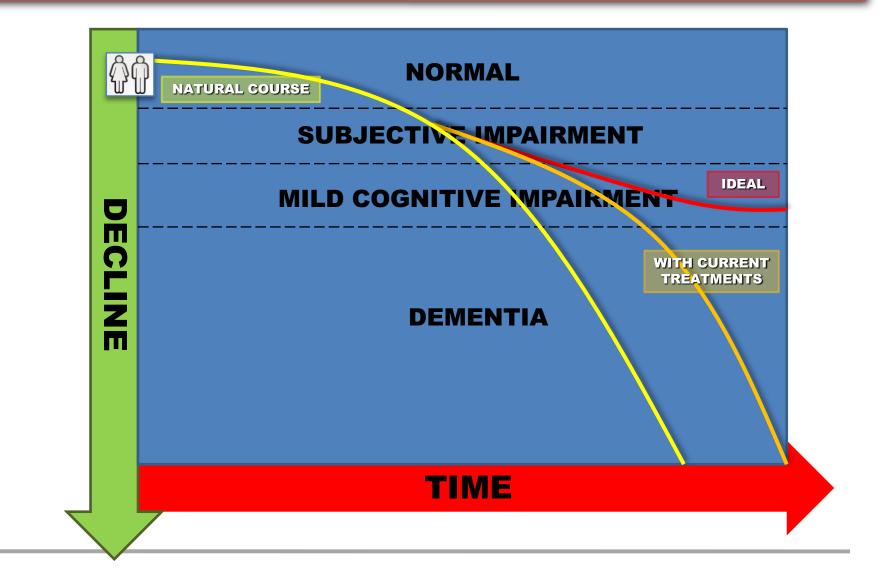
PARKINSON'S DISEASE 2%

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

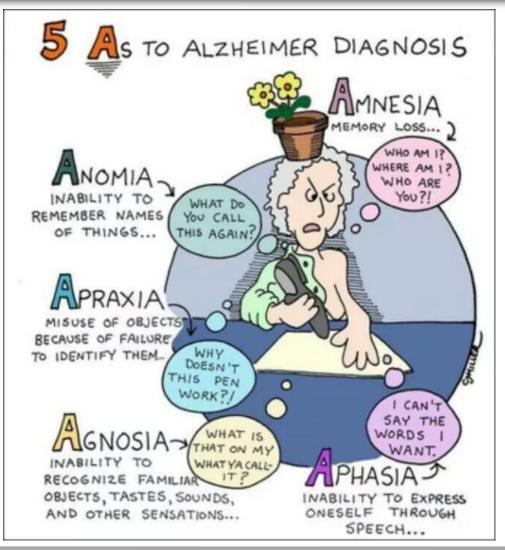
Alzheimer's: 7 Stages

- 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:

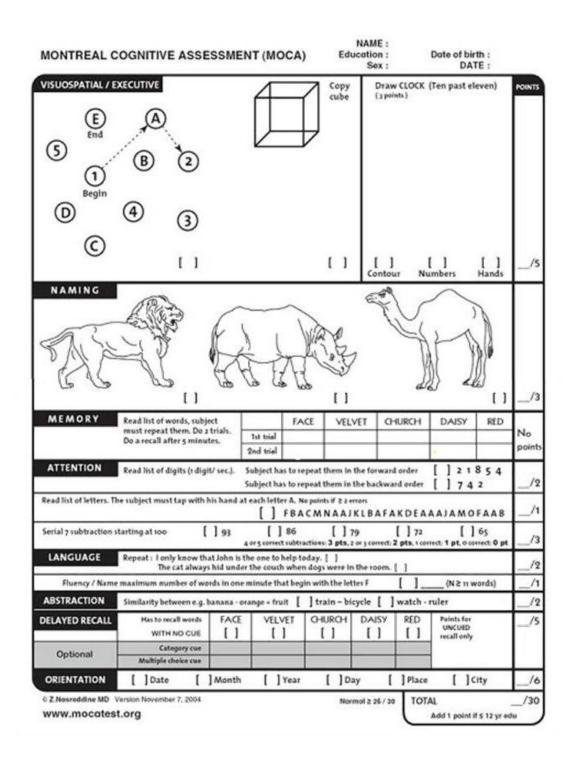
Date:

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

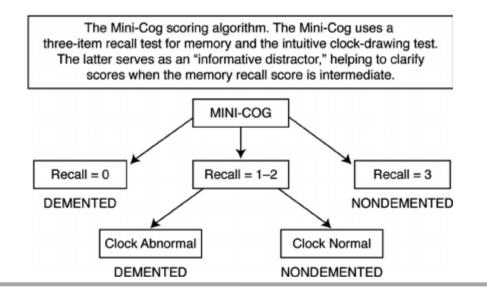
Screening Test: MoCA

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

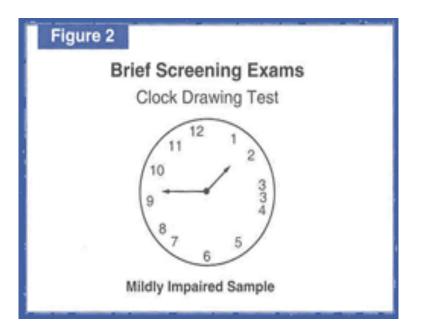


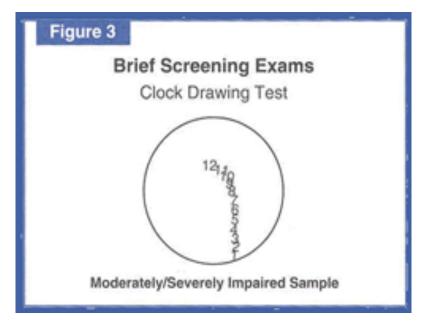
Screening Test: MINI-COG

- Instruct the patient to listen carefully to and remember these
 3 words: banana-sunrise-chair
- 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



Clock Drawing Test- Abnormal

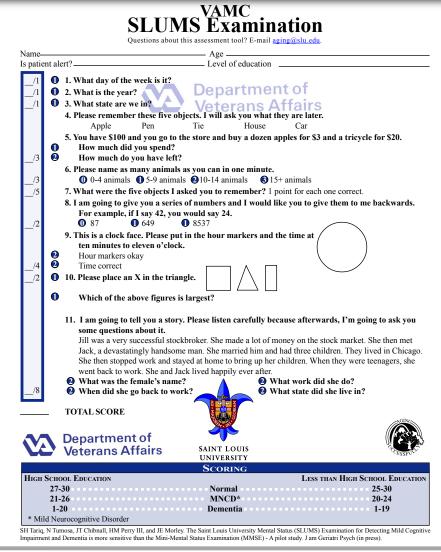




Screening Test: SLUMS

- Better psychometric properties than MMSE, with scoring normed to educational level
- <u>http://medschool.slu.edu/agingsuccessfully/pdfsurvey</u> <u>s/slumsexam_05.pdf</u>

Screening Test: SLUMS



Computer Science and Engineering - University of Notre Dame

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

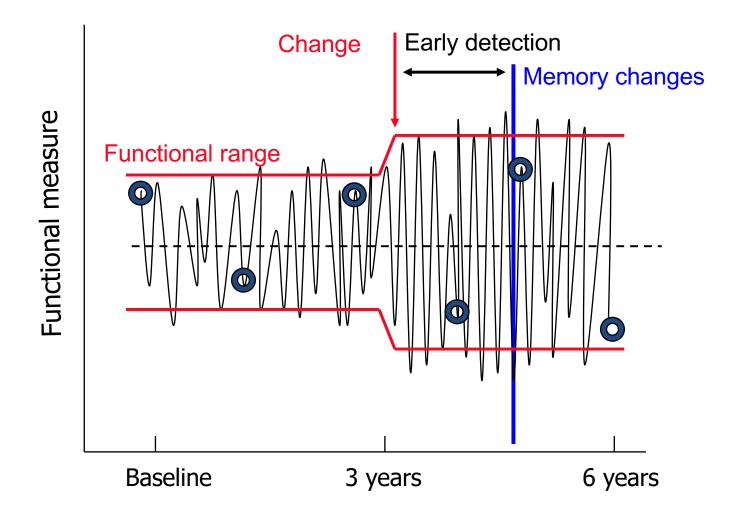
Institutionalization common with increasing neuropsychiatric issues, loss of ADLs, caregiver stress

Out-of-Clinic Assessment

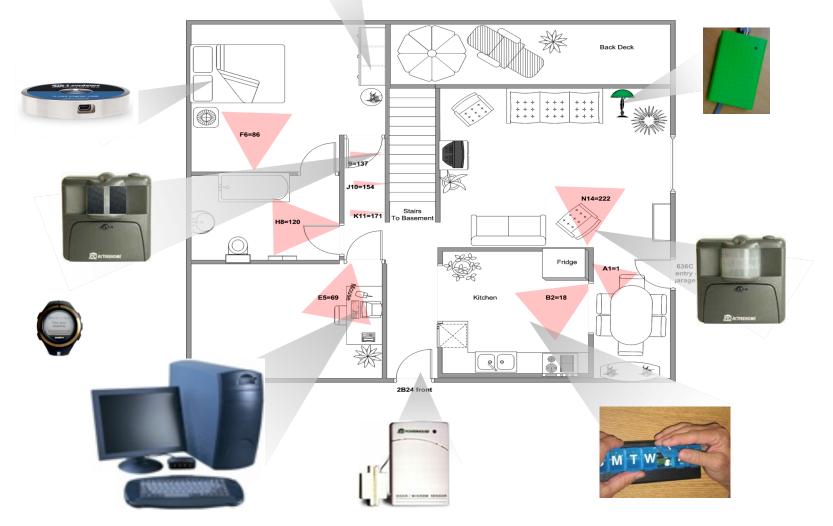
Identify meaningful change in real-time, by changing both the timing and place for assessments

- 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

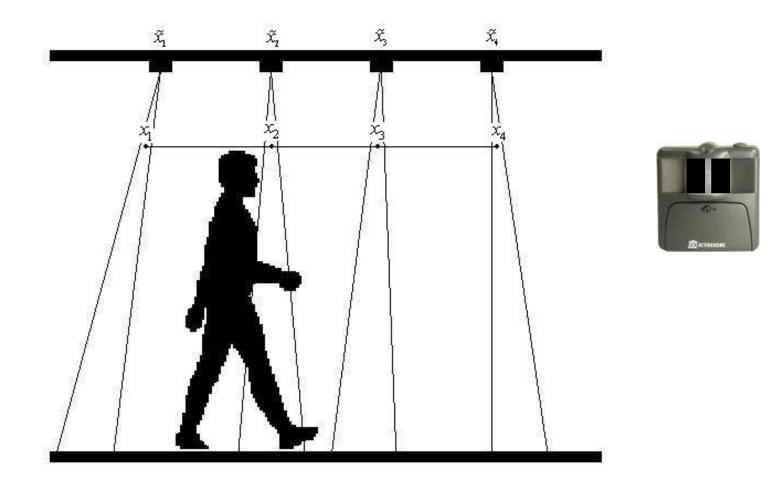
Approach: Detecting Early Changes



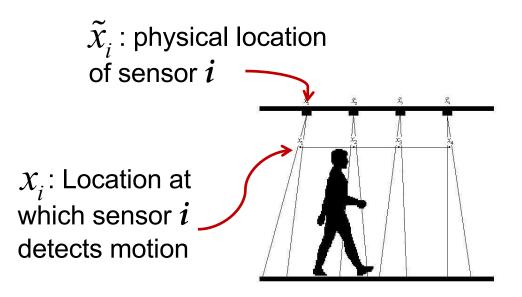




Measuring Walking Speed



Approach

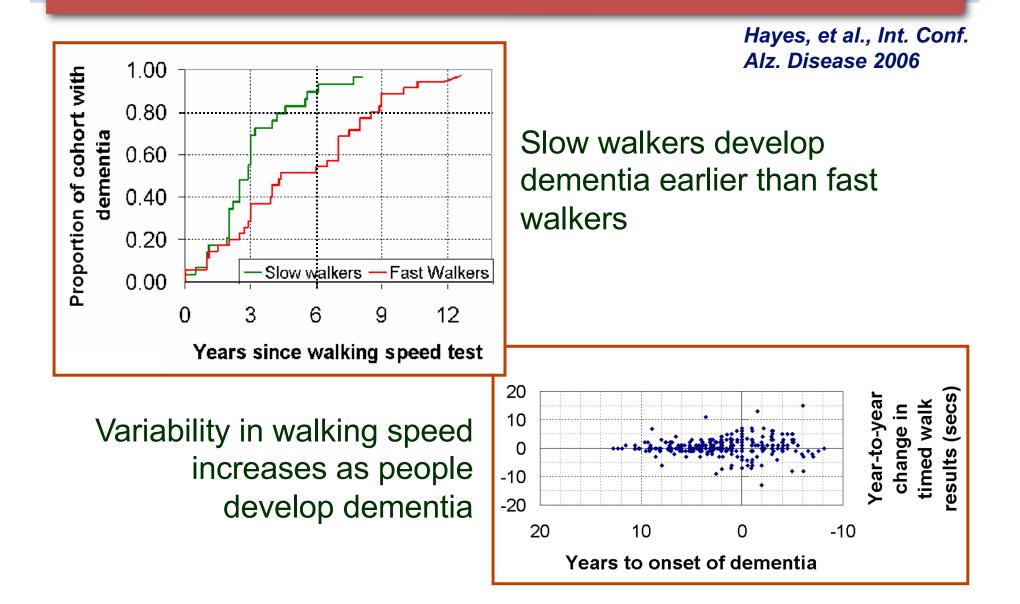


Location of movement triggering sensor \boldsymbol{i} is at $\{x_i + e_i\}$

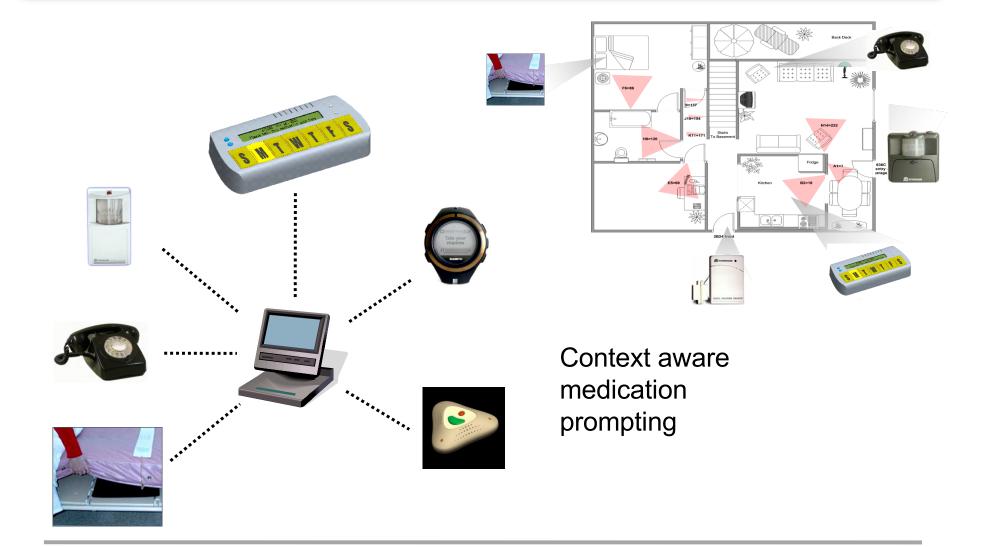
Velocity of movement between sensor 1 and sensor 2 is then calculated as:

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

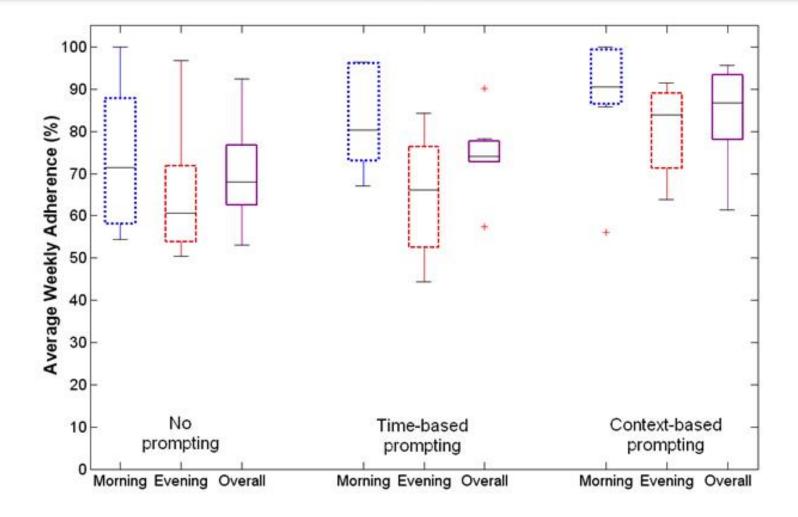
Detect Cognitive Changes via Walking Speed



Helping People to Remember



Context Aware Medication Prompting



Hayes et al., Telemedicine and e-Health, 2009.

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 mainspowered 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

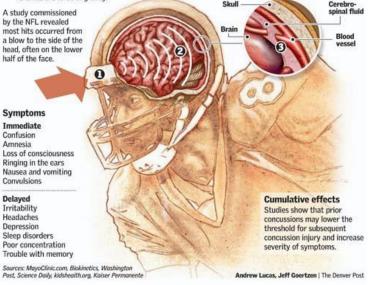
1.2 Million Youth Concussions Per Year 50% FB Players Have Sustained A Concussion 35% Suffered Multiple Concussions 80% Symptoms Worsen Over Weeks 50% Return To Play Too Soon 70% Would RTP Concussed 41% Would Not Leave A Game 50 H.S. Football Players Have Died Since 97

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.

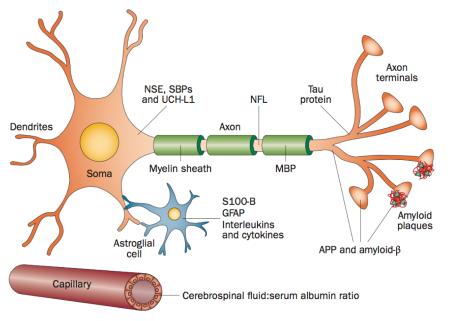
1 When a football player takes a hit to the head, speeds 2 The shock wave passes through the brain and bounces back off the skull. The range from 17 to 25 miles per concussion usually occurs at the opposite hour with a force averaging side from the point of impact. 98 times the force of gravity.

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



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)

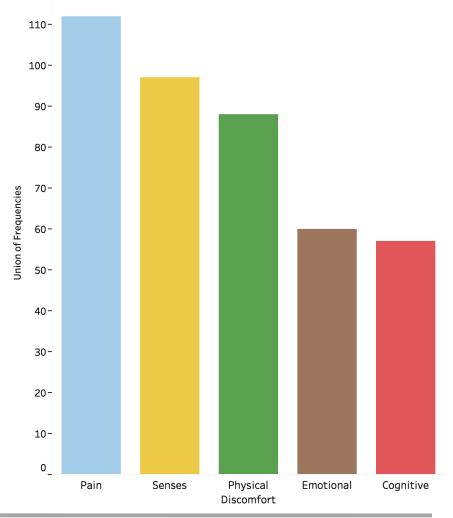


Signs and Symptoms

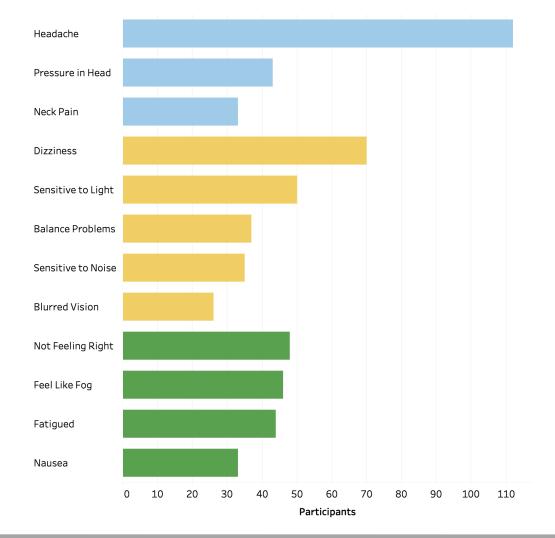
- Somatic (e.g., headache)
- Cognitive (e.g., feeling like in a fog, slowed reaction time)
- Emotional and behavioral (e.g., lability, irritability)
- Physical (e.g., loss of consciousness, amnesia)
- Sleep disturbance (e.g., drowsiness, insomnia)

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	Fatigue, Feeling like fog, Not feeling right,
discomfort	Drowsy, Nausea
Emotional	Irritable, Nervous, Sad, Feeling emotional,
	Feeling down
Cognitive	Difficulty remembering, Difficulty concen-
	trating



Signs and Symptoms



Computer Science and Engineering - University of Notre Dame

Rates By Gender & Age

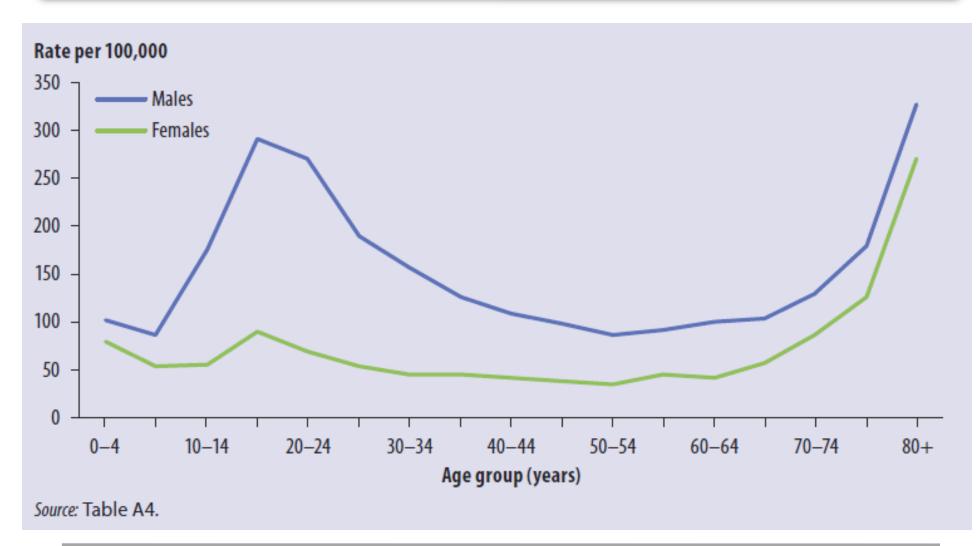
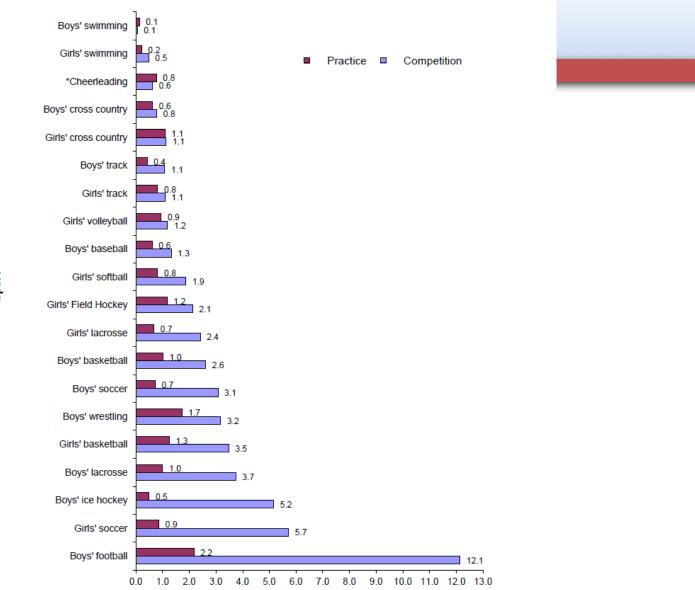


Figure 1: Convenience Sample Injury Rates per 1,000 Athletic Exposures by Sport and Type of Athletic Exposure, High School Sports-Related Injury Surveillance Study, US, 2012-13



Sport

Injury Rate per 1,000 Athletic Exposures

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)

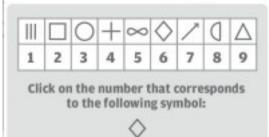
Concussion Testing: ImPACT

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



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

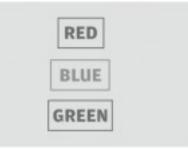
Evaluates attentional processes and visual recognition memory



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



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: SCAT

SCAT3[™]

Sport Concussion Assessment Tool – 3rd Edition

Name

Date/Time of Injury: Date of Assessment

What is the SCAT3?¹

The SCAT3 is a standardized tool for evaluating injured athletes for concussion and can be used in athletes aged from 13 years and older. It supersedes the original SCAT and the SCAT2 published in 2005 and 2009, respectively². For younger persons, ages 12 and under, please use the Child SCAT3. The SCAT3 is designed for use by medical professionals. If you are not qualified, please use the Sport Concusion Recognition Tool¹. Preseason baseline testing with the SCAT3 can be helpful for interpreting post-injury test scores.

Specific instructions for use of the SCAT3 are provided on page 3. If you are not familiar with the SCAT3, please read through these instructions carefully. This tool may be freely copied in its current form for distribution to individuals, teams, groups and organizations. Any revision or any reproduction in a digital form re-quires approval by the Concussion in Sport Group. NOTE: The diagnosis of a concussion is a clinical judgment, ideally made by a

medical professional. The SCAT3 should not be used solely to make, or exclude, the diagnosis of concussion in the absence of clinical judgement. An athlete may have a concussion even if their SCAT3 is "normal".

What is a concussion?

A concussion is a disturbance in brain function caused by a direct or indirect force to the head. It results in a variety of non-specific signs and/or symptoms (some examples listed below) and most often does not involve loss of consciousness Concussion should be suspected in the presence of any one or more of the following:

- Symptoms (e.g., headache), or
- Physical signs (e.g., unsteadiness), or
 Impaired brain function (e.g. confusion) or
- Abnormal behaviour (e.g., change in personality)

SIDELINE ASSESSMENT

Indications for Emergency Management NOTE: A hit to the head can sometimes be associated with a more serious brain

injury. Any of the following warrants consideration of activating emergency pro-cedures and urgent transportation to the nearest hospital:

- Glasgow Coma score less than 15
- Deteriorating mental status
 Potential spinal injury
- Progressive, worsening symptoms or new neurologic signs

Potential signs of concussion?

If any of the following signs are observed after a direct or indirect blow to the head, the athlete should stop participation, be evaluated by a medical profes-sional and should not be permitted to return to sport the same day if a concussion is suspected

Any loss of consciousness?	Y	N
"If so, how long?"		
Balance or motor incoordination (stumbles, slow/laboured movements, etc.)?	Y	٥
Disorientation or confusion (inability to respond appropriately to questions)?	Y	1
Loss of memory:	Y	١
"If so, how long?"		
"Before or after the injury?"		
Blank or vacant look:	Y	١
Visible facial injury in combination with any of the above:	Y	0

1 Glasgow coma scale (GCS)

🔊 FIFA 🎴 👀 🧟 FEI

Examiner

Bost our response (E)

Best eye response (E)	
No eye opening	1
Eye opening in response to pain	2
Eye opening to speech	3
Eyes opening spontaneously	4
Best verbal response (V)	
No verbal response	1
Incomprehensible sounds	2
Inappropriate words	3
Confused	4
Oriented	5
Best motor response (M)	
No motor response	1
Extension to pain	2
Abnormal flexion to pain	3
Flexion/Withdrawal to pain	4
Localizes to pain	5
Obeys commands	6
Glasgow Coma score (E + V + M)	of 15

GCS should be recorded for all athletes in case of subsequent deterioration.

Maddocks Score³

"I am going to ask you a few questions, please listen carefully and give Modified Maddocks questions (1 point for each correct answer)	your best	effort."	
What yenue are we at today?	0	1	1

Maddocks score		of 5
Did your team win the last game?	0	1
What team did you play last week/game?	0	1
Who scored last in this match?	0	1
Which half is it now?	0	1

Notes: Mechanism of Injury ("tell me what happened"?):

Any athlete with a suspected concussion should be REMOVED FROM PLAY, medically assessed, monitored for deterioration (i.e., should not be left alone) and should not drive a motor vehicle until cleared to do so by a medical professional. No athlete diag-nosed with concussion should be returned to sports participation on the day of Injury.

3

ne

a head injury?

Name

Age

Examiner Sport/team/school:

BACKGROUND

Years of education completed: Dominant hand:

Have you ever been diagnosed with depression, anxiety Y N or other psychiatric disorder? Has anyone in your family ever been diagnosed with Y N any of these problems? Are you on any medications? If yes, please list: Y N

Date:

Gender:

Date/time of injury:

right left neither

M F

Y N

Y N

SCAT3 to be done in resting state. Best done 10 or more minutes post excercise

SYMPTOM EVALUATION

How many concussions do you think you have had in the past? When was the most recent concussion? How long was your recovery from the most recent concussion? Have you ever been hospitalized or had medical imaging done for Y

Have you ever been diagnosed with headaches or migraines?

Do you have a learning disability, dyslexia, ADD/ADHD?

"You should score you	rself on the follow	ing s			sed on I	iow you	teel no	w~.
	non	e	m	ild	moo	ierate	se	vere
Headache	0		1	2	3	4	5	6
"Pressure in head"	0		1	2	3	- 4	5	6
Neck Pain	0		1	2	3	4	5	6
Nausea or vomiting	0		1	2	3	4	5	6
Dizziness	0		1	2	3	- 4	5	6
Blurred vision	0		1	2	3	- 4	5	6
Balance problems	0		1	2	3	4	5	6
Sensitivity to light	0		1	2	3	- 4	5	6
Sensitivity to noise	0		1	2	3	4	5	6
Feeling slowed dow	n O		1	2	3	4	5	6
Feeling like "in a for)" O		1	2	3	4	5	6
"Don't feel right"	0		1	2	3	4	5	6
Difficulty concentration	ting 0		1	2	3	4	5	6
Difficulty remember	ring 0		1	2	3	4	5	6
Fatigue or low energy	gy O		1	2	3	4	5	6
Confusion	0		1	2	3	4	5	6
Drowsiness	0		1	2	3	4	5	6
Trouble falling aslee	p 0		1	2	3	4	5	6
More emotional	0		1	2	3	4	5	6
Irritability	0		1	2	3	4	5	6
Sadness	0		1	2	3	4	5	6
Nervous or Anxious	0		1	2	3	4	5	6
*							_	
Total number of s								
Symptom severity	score (maximum	poss	Die 13	2)				
Do the symptoms g	et worse with ph	iysici	al act	ivity?			Y	
Do the symptoms g	et worse with m	enta	lacti	vity?			Y	
self rated			lf rat	ed and	clinicia	ın moni	tored	
clinician intervie	w	_		ed with				
Overall rating: If y							ow diff	erer
the athlete acting of		her u	sual	self?				
Please circle one respon	se:							
no different	very different			unsure			N/A	

Scoring on the SCAT3 should not be used as a stand-alone method to diagnose concussion, measure recovery or make decisions about an athlete's readiness to return to competition after concussion. Since signs and symptoms may evolve over time, it is important to consider repeat evaluation in the acute assessment of concussion.

COGNITIVE & PHYSICAL EVALUATION

Cognit Standardi						sion	(SAC)4		
Orientatio	on (1 o	oint fo	r each	correct a	answer				
What mont								0	1
What is the	date	today	R					0	1
What is the	day o	of the	weel	k?				0	1
What year i	is it?							0	1
What time	is it rig	ght n	ow? (within 1	hour)			0	1
Orientatio	n sco	re							of
Immediate									
	Tr			frial 2			Alternative wa		
elbow	0	1	0	1	0	1	candle	baby	finger
apple	0	1	0	1	0	1	paper	monkey	penny
carpet	0	1	0	1	0	1	sugar	perfume	blanke
saddle	0	1	0	1	0	1	sandwich	sunset	lemon
bubble	0		0		U	1	wagon	iron	insect
Total									
Immediate									of
Concentra List				Alterna		it liet			
4-9-3	_	0	1	6-2-9	ene org	it ist	5-2-6	4-1-5	
3-8-1-4		0	1	3-2-7-	0		1-7-9-5	4-9-6	-8
6-2-9-7-1		0	1	1-5-2-			3-8-5-2-7	6-1-8	
7-1-8-4-6-2	,	0	1	5-3-9-			8-3-1-9-6-4		-8-5-6
Total of 4	· ·			3-3-9-	1-4-0		0-3-1-3-0-4	7-2-4	-0-3-0
Dec-Nov-O Concentra	ct-Sep tion s	ot-Au	g-Jul-	Jun-Ma			1 pt. for entire s -Feb-Jan	equence corre 0	1
Dec-Nov-O	ct-Sep tion s	nt-Aug score	g-Jul-	Jun-Ma	ау-Арг	-Mar		0	1 of
Dec-Nov-O Concentra Neck E Range of m Findings: Balance Do one or bot Footwear (s Modified B	ct-Sep stion s cxan notion e ey h of the shoes, Balance	nin score nin e follor bare ce Eri	g-Jul- atic Tenc nina wing to foot, ror So	Don: derness atior ests. braces, coring	ay-Apr U tape, Syste	etc.)	-Feb-Jan and lower lin	0 nb sensation	1 of
Dec-Nov-O Concentra Neck E Range of m Findings: Do one or bot Footwar (s Modified E Which foot Testing surf	ct-Sep ition s ition s ition s ition s ition e eo th of the shoes, Balane was t	nin kan bare ce En ested	g-Jul- atic Tenc nina wing to foot, ror Si ((i.e. v	Jun-Ma Dn: derness atior ests. braces, coring which is t	ay-Apr U tape, Syste	etc.)	-Feb-Jan and lower lin	0 nb sensation	1 of
Dec-Nov-O Concentra Range of m Findings: Balance Do one or bot Footwear (s Modified B Which foot Testing surf Condition	ct-Sep ition s xan hotion e e) h of the shoes, Balane was t face (h	nin kan kan kan kan kan kan kan kan kan ka	g-Jul- atic Tenc nina wing to foot, ror Si ((i.e. v	Jun-Ma Dn: derness atior ests. braces, coring which is t	ay-Apr U tape, Syste	etc.)	-Feb-Jan and lower lin	0 nb sensation	1 of a&streng t Ri
Dec-Nov-O Concentra Range of m Findings: Balance Do one or bot Footwear (s Modified B Which foot Testing surf Condition Double leg	ct-Sep ition s ixan notion the fun- shoes, Balan was the face (h	nin core e follon bare ce En ested hard f	g-Jul- atic Tenc ving to foot, ror Su l (i.e. v loor, '	Jun-Ma Dn: derness braces, coring which is t	: U tape, Syste	etc.)	-Feb-Jan and lower lin	0 nb sensation	1 of a&streng t Ri Erro
Dec-Nov-O Concentra Range of m Findings: Balanco Do one or bot Footwear (e) Modified I Which foot Testing surf Condition Double leg Single leg s	ct-Sep ition s ition s ition s ition s ition hotion hotion hotion hotion hotion shoes, Balann was t face (h stance	nin can e follow bare ce En ested hard f e: (non-ce	g-Jul- Tenc Tenc nina wing to foot, ror So l (i.e. v loor, 1	Jun-Ma Dn: derness derness braces, braces, coring which is t field, eff	ay-Apt U tape, Syste the nor	etc.)	-Feb-Jan and lower lin	0 nb sensation	1 of & streng t Ri Erro Erro
Dec-Nov-O Concentra Neck E Range of m Findings: Balanc Do one or bot Footwear (s Modified I Which foot Testing surf Condition Double leg Single leg s Tandem sta	ct-Sep ition s ition s ition s ition s ition hotion hotion hotion hotion hotion shoes, Balann was t face (h stance	nin can e follow bare ce En ested hard f e: (non-ce	g-Jul- Tenc Tenc nina wing to foot, ror So l (i.e. v loor, 1	Jun-Ma Dn: derness derness braces, braces, coring which is t field, eff	ay-Apt U tape, Syste the nor	etc.)	-Feb-Jan and lower lin	0 nb sensation	1 of
Dec-Nov-O Concentra Neck E Range of m Findings: Balanco Do one or bot Footwear (e) Modified I Which foot Testing surful Condition Double leg Single leg S Tandem sta And/Or	ct-Sep ition s ition ition s ition itio	nin can e follow bare ce En ested hard f e: (non-ce	g-Jul- Tenc Tenc nina wing to foot, ror So l (i.e. v loor, 1	Jun-Ma Dn: derness derness braces, braces, coring which is t field, eff	ay-Apt U tape, Syste the nor	etc.)	-Feb-Jan and lower lin	0 nb sensation	1 of & streng t Ri Erro Erro
Dec-Nov-O Concentra Neck E Range of m Findings: Balanc Do one or bot Footwear (s Modified I Which foot Ventor foot Testing surf Condition Double leg Single leg S Tandem sta	ct-Sep ition s ition s ition s ition s ition ce e ition stance tance itance ince (n stance tance ince (n stance	ce Eri e follon bare e steed hard f e: (non-do	g-Jul- Tenc Tenc nina wing to foot, ror So l (i.e. v loor, 1	Jun-Ma Dn: derness derness braces, braces, coring which is t field, eff	ay-Apt U tape, Syste the nor	etc.)	-Feb-Jan and lower lin	0 nb sensation	1 of & streng t Ri Erro Erro
Dec-Nov-O Concentra Neck E Range of m Findings: Balance Do one or bot Footwear (e) Modified I Which foot Testing surf Condition Double leg Single leg s Tandem sta And/or Tandem gu	ct-Sep tion s tion s totion e e) th of the shoes, Balane was t face (h stance ince (n ait ^{4,7} f 4 trial b coo	ce En e follon bare ce En ested hard f e: (non-do s):	g-Jul- atic Tenc nina wing tr foot, ror Su loor, 1 loor, 1 domina minan	Jun-Ma Dn: derness braces, braces, coring which is to field, et if field, et if foot at	: U stape, Syste tc.) : back): secor	etc.) etc.) m (B i-dom	-Feb-Jan and lower lin	0	1 of a & streng t Ri Erre Erre
Dec-Nov-O Concentra Range of m Findings: Balance Do one of bot Footwear 6 Modified I Which foot Testing surf Condition Double leg Single leg s Tandem sta And/or Tandem gt Time (best of Upper lime	ct-Sep tion s totion e e) th of the thoses, Balane was t face (h stance face (h stance face (h) stance face (h) stance s	ce En con-do s): cion ce tion ce En ce	g-Jul- atic Tenc nina wing tr foot, ror Su loor, 1 loor, 1 domina minan	Jun-Ma Dn: derness braces, braces, coring which is to field, et if field, et if foot at	: U stape, Syste tc.) : back): secor	etc.) etc.) m (B i-dom	-Feb-Jan and lower lin	0	1 of & streng t Rij Erro Erro
Dec-Nor-O Concentra Reale of m Findings: Balance Modified 2 Workin foot Double leg Single leg 2 Condition Double leg 8 Condition Double leg 8 Time best o Concentration Upper la man Coordinat	ct-Sep tion s hotion e e> h of the shoes, Balane was t face (h stance ince (n ait ^{4,7} f 4 trial b coo was t icon second icon second	ce Ern e follow bare ce Ern ested aard f e: (non-do s): s):	g-Jul- Tenc Tenc tina tion, ti	Jun-Ma atior ests. braces, coring which is t field, ef ant foot): t foot at	: U stape, Syste tc.) : back): secor	etc.) etc.) m (B i-dom	-Feb-Jan and lower lin	0	1 of s & streng t Ri Erro Erro Erro
Dec-Nov-O Concentra Range of m Findings: Balance Do one or bot Footward (6) Modified B Which foot Testing surf Condition Double leg Single leg s Tandem sta And / Or Tandem sg Time (best of Coordii Upper lime	ct-Sep ition s ition s itio	ce En e follow bare ce En ested fon-do s): s): core	g-Jul- Tence Tenco	Jun-Ma atior ests. braces, coring which is t field, ef ant foot): t foot at	: U stape, Syste tc.) : back): secor	etc.) etc.) m (B i-dom	-Feb-Jan and lower lin	0	1 of s & streng t Ri Erro Erro Erro

Concussion Testing: SAC

SAC Total Score /30

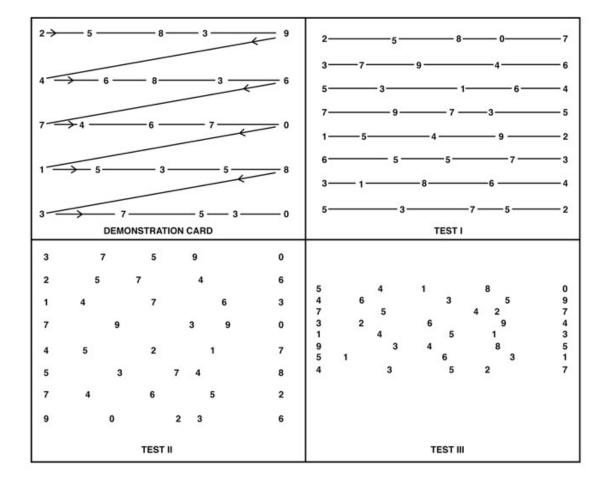
	-		-			RM
Name:						
-		Examiner:		Neurologic Screening:		
Team:		Examiner:		Loss of Consciousness/	No	Yes
Date of Exam:		Time:		Witnessed Unresponsiveness	Length:	
Exam (Circle Or	ne): BLine Injury Post	-Px/Game		Post-Traumatic Amnesia? Poor recall of events after injury	No Length:	Yes
Day 1	Day 2 Day 3	Day 5 Day 7	Day 90	Retrograde Amnesia? Poor recall of events before injury	No Length:	Yes
				Strength	Normal	Abnormal
Introduction	1:			Right Upper Extremity		
	sk you some questions. Ple	ease listen carefully and	give your best effort.	Left Upper Extremity		
				Right Lower Extremity Left Lower Extremity		
Orientation:						
What Month is i			0 1	Sensation - examples:		
What's the Date			0 1	Finger-to-Nose/Romberg		
What's the Day What Year is it?			0 1	Coordination - examples:		
	right now? (within 1 hr.)		0 1	Tandem Walk/Finger-Nose-Finger		
	each correct answer.			A second s		
		t you a list of words and	l when 1 am done.	Digits Backward: I am going to read yo done, you repeat them back to me backwa to you. For example, if I say 7-1-9, you wo If correct, go to next string length. If incorrect, in Stop after incorrect on both trials	ards, in reverse or uld say 9-1-7.	der of how I rea
	Memory: ast your memory. I will read many words as you can re		i when I am done,	done, you repeat them back to me backwa to you. For example, if I say 7-1-9, you we If correct, go to next string length. If incorrect, r Stop after incorrect on both trials. 4-9-3 6-2-9	ards, in reverse on uld say 9-1-7. ead trial 2. Score 1	der of how I rea pt. for each string 0
l am going to te repeat back as LIST	est your memory. I will read many words as you can re TRIAL 1	emember, in any order. TRIAL 2	TRIAL 3	done, you repeat them back to me backwa to you. For example, if I say 7-1-9, you wo If correct, go to next string length. If incorred, r Stop after incorrect on both trials. 4-9-3 6-2-9 3-8-1-4 3-2-7.	ards, in reverse on uld say 9-1-7. ead trial 2. Score 1	der of how I rea pt. for each string 0 0
I am going to te repeat back as LIST Elbow	est your memory. I will read many words as you can re TRIAL 1 0 1	emember, in any order. TRIAL 2 O 1	trial 3 0 1	done, you repeat them back to me backway to you. For example, if 1 say 7-1-9, you woy If correct, go to next string length. If incorrect, it Stop after incorrect on both triats. 4-9-3 6-2-9 3-8-1-4 3-2-7 6-2-9-7-1 1-5-2	ards, in reverse on uld say 9-1-7. ead trial 2. Score 1 .9 .8-6	der of how I rea pt. for each string 0 0 0
l am going to te repeat back as LIST Elbow Apple	est your memory. I will read many words as you can re TRIAL 1 0 1 0 1 0 1	emember, in any order. TRIAL 2 O 1 O 1	TRIAL 3 0 1 0 1	done, you repeat them back to me backwa to you. For example, if I say 7-1-9, you wo If correct, go to next string length. If incorred, r Stop after incorrect on both trials. 4-9-3 6-2-9 3-8-1-4 3-2-7.	ards, in reverse on uld say 9-1-7. ead trial 2. Score 1 .9 .8-6	der of how I rea pt. for each string 0 0
l am going to te repeat back as LIST Elbow Apple Carpet	est your memory. I will read many words as you can re TRIAL 1 0 1 0 1 0 1 0 1	emember, in any order. TRIAL 2 0 1 0 1 0 1 0 1	TRIAL 3 0 1 0 1 0 1 0 1	done, you repeat them back to me backway to you. For example, if 1 say 7-1-9, you woy If correct, go to next string length. If incorrect, it Stop after incorrect on both triats. 4-9-3 6-2-9 3-8-1-4 3-2-7 6-2-9-7-1 1-5-2	ards, in reverse on uld say 9-1-7. ead trial 2. Score 1 .9 .8-6 .1-4-8	der of how I rea pt. for each string 0 0 0 0 0
l am going to te repeat back as LIST Elbow Apple Carpet Saddle	st your memory. I will read many words as you can re TRIAL 1 0 1 0 1 0 1 0 1 0 1	member, in any order. TRIAL 2 0 1 0 1 0 1 0 1 0 1	TRIAL 3 0 1 0 1 0 1 0 1 0 1	done, you repeat them back to me backword to you. For example, if 1 say 7-1-9, you woild control for the string length. If incorrect, if stop after incorrect on doub trais. 4-9-3 6-2-9 3-8-1-4 3-2-7 6-2-9-7-1 1-5-2 7-1-8-4-6-2 5-3-9	rds, in reverse on uld say 9-1-7. ead trial 2. Score 1 -9 -8-6 -1-4-8 he months of the	der of how I rea pt. for each string 0 0 0 0 0 0 0 0 0 0 0 0 0
l am going to te repeat back as LIST Elbow Apple Carpet	est your memory. I will read many words as you can re TRIAL 1 0 1 0 1 0 1 0 1	emember, in any order. TRIAL 2 0 1 0 1 0 1 0 1	TRIAL 3 0 1 0 1 0 1 0 1	done, you repeat them back to me backwork to you. For example, if 1 say 7-1-9, you wo if carrect, go to next string length. If incorrect, r. Stop after incorrect or both trais. 4 9-3 6-2-9 3-8-1-4 3-2-7 6-2-9 3-8-1-4 3-2-7 6-2-9 7-1 1-5-2 7-1.8-4-6-2 5-3-9 Months in Reverse Order: Now tell me IS tart with the last month and go I NovemberCo ahead. November	rds, in reverse on uld say 9-1-7. ead trial 2. Score 1 -9 -8-6 -1-4-8 he months of the	der of how I rea pt. for each string 0 0 0 0 0 0 0 0 0 0 0 0 0
I am going to te repeat back as LIST Elbow Apple Carpet Saddle Bubble TOTAL Trials 2 & 3: 1	est your memory. I will read many words as you can re TRUAL 1 0 1 0 1 0 1 0 1 0 1 am going to repeat that lis	member, in any order. TRIAL 2 0 1 0 1 0 1 0 1 0 1 0 1 0 1 t again. Repeat back as	TRIAL 3 0 1 0 1 0 1 0 1 0 1 0 1	done, you repeat them back to me backwork to you. For example, f1 says 7-1-9, you wut transcript, f1 says 7-1-9, you wut 4-9-3 4-9-3 3-8-1-4 3-8-1-4 3-8-1-7 6-2-9-7-1 5-2-9-	rds, in reverse or uld say 9-1-7. ead trial 2. Score 1 9 8-8-6 .1-4-8 he months of the hackward. So y	der of how I rea pt. for each string 0 0 0 0 0 0 0 0 0 0 0 0 0
I am going to te repeat back as LIST Elbow Apple Carpet Saddle Bubble TOTAL Trials 2 & 3: 1 as you can rem Complete all 3 tria	est your memory. I will read many words as you can re TRLL 1 0 1 0 1 0 1 0 1 0 1 am going to repeat that II ember in any order, even 1 the ingradress of score on that in	member, in any order. TRIAL 2 0 1 0 1 0 1 0 1 0 1 0 1 t again. Repeat back as f I said the word before.	TRIAL 3 0 1 0 1 0 1 0 1 0 1 0 1 many words	done, you repeat them back to me backwork to you. For example, if 1 asyr 7-1-9, you wuitted to the second to th	rds, in reverse or uld say 9-1-7. ead trial 2. Score 1 9 8-8-6 .1-4-8 he months of the hackward. So y	der of how I rea pt. for each string 0 0 0 0 0 0 0 0 0 0 0 0 0
I am going to te repeat back as LIST Elbow Apple Carpet Saddle Bubble TOTAL Trials 2 & 3: 1 as you can rem Complete all 3 tria Total score equals	st your memory. I will read many words as you can re TRIAL 1 0 1 0 1 0 1 0 1 0 1 0 1 am going to repeat that lis ember in any order, even i	Immember, in any order. TEIAL 2 0 1 0 1 0 1 0 1 0 1 1 0 2 1 3 1 4 again. Repeat back as f1 said the word before. 8.2. Scare 1 pt, for each code 1	TRIAL 3 0 1 0 1 0 1 0 1 0 1 0 1 many words	done, you repeat them back to me backwork to you. For example, if 1 say 7-1-9, you wuitty for correct, op to next string length. If incorrect, Step after incorrect and but traits. 4-9-3 6-2-9 3-8-1-4 3-2-7 6-2-9-7-1 1-5-2 7-1-8-4-6-2 5-3-9 Months in Reverse Order: Now tell me to Start with the last month and go to November, cos abead. 1 pt. for entire sequence correct. Dec-Nov-Oct-Sept-Aug-Jul-Jun-May-Apr -	rds, in reverse or uld say 9-1-7. ead trial 2. Score 1 9 8-8-6 .1-4-8 he months of the hackward. So y	der of how I rea pt. for each string 0 0 0 0 0 0 0 0 0 0 0 0 0
I am going to te repeat back as LIST Elbow Apple Carpet Saddle Bubble TOTAL Trials 2 & 3: 1 as you can rem Complet al 3 7 complete al 3 7 Total score equals Do not inform the	est your memory. I will read many words as you can re TRIAL 1 0 1 0 1 0 1 0 1 au going to repeat that lis ember in any order, even i la ngoings of core on tain i	member, in any order. TRIAL 2 0 1 0 1 0 1 0 1 1 0 1 1 1 again. Repeat back as 1 said the word before. 8 2. Scort J.t. for each or be destad.	TRIAL 3 0 1 0 1 0 1 0 1 0 1 0 1 many words	done, you repeat them back to me backwork to you. For example, if I say 7-1-9, you we if correct, go to next string length. If incorrect, no string after incorrect on solutions. 4:0-3 6-2-9 3:8-1-4 3-2-7 6:2-9:7-1 1-5-2 7:1-8-4-6-2 7-3-9 Months in Reverse Order: Now tell me I Start with the last month and go I NovemberGo ahead. 1 pt. for entire sequence correct. Dec-Nov-Oct-Sept-Aug-Jul-Jun-May-Apr CONCENTRATION TOTAL SCORE	rids, in reverse or util say -1-7. <i>ead trial 2 Score 1</i> 9 8-6 1-4-8 he months of the ackward. So y Mar-Feb-Jan d a few times ea tr in any order. <i>C</i>	der of how I rea pt. for each string 0 0 0 vear in revers 0 1 say Dec 0 1 say Dec
I am going to te repeat back as LIST Elbow Apple Carpet Saddle Bubble TOTAL Trials 2 & 3: 1 as you can rem Complet al 3 7 complete al 3 7 Total score equals Do not inform the	st your memory. I will read many words as you can re TRIAL 1 0	member, in any order. TRIAL 2 0 1 0 1 0 1 0 1 1 0 1 1 1 again. Repeat back as 1 said the word before. 8 2. Scort J.t. for each or be destad.	TRIAL 3 0 1 0 1 0 1 0 1 0 1 0 1 many words	done, you repeat them back to me backwork to you. For example, if 1 say 7-1-9, you wu if correct, op to next string length. If incorrect, Step after incorrect on both traits. 4-9-3 6-2-9 3-8-1-4 3-2-7 6-2-9-7-1 1-5-2 7-1-8-4-6-2 5-3-9 Months in Reverse Order: Now fell me I Start with the last month and go I November, G. abaad. 1 pt. for entire sequence correct. Dec-hov-Oct-Sept-Aug-Jul-Jun-May-Apr CONCENTRATION TOTAL SCORE Delayed Recall: Do you remember that list of words I rea words from the list as you can remembe recalled. Total score equals number of words I rea	rids, in reverse or util say -1-7. <i>ead trial 2 Score 1</i> 9 8-6 1-4-8 he months of the ackward. So y Mar-Feb-Jan d a few times ea tr in any order. <i>C</i>	der of how I rea pt. for each string 0 0 0 e year in reverse 0 1 say Dec 0 1 1 1 1 1 1 1 1 1 1 1 1 1
am going to te repeat back as LIST Elbow Apple Carpet Saddle Bubble TOTAL Trials 2 & 3: 1 as you can rem Complete al 3 ris Total core equals De net inform the IMMEDIATE	st your memory. I will read many words as you can re TRIAL 1 0	TELL 2 O I 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 2 2 2 0 1 2.8 2.8 0 1 0 1 be dested. 5 2 0 1 0 1	TELAL 3 1 0 1 0 1 0 1 0 1 0 1 many words mext regionse.	done, you repeat them back to me backwork to you. For example, if 1 say 7-1-9, you wu if correct, op to next string length. If incorrect, Step after incorrect on both traits. 4-9-3 6-2-9 3-8-1-4 3-2-7 6-2-9-7-1 1-5-2 7-1-8-4-6-2 5-3-9 Months in Reverse Order: Now fell me I Start with the last month and go I November-, Go ahead. 1 pt. for entire sequence correct. Dec-hov-0c1-Sep1-Aug-Jul-Jun-May-Apr CONCENTRATION TOTAL SCORE Delayed Recall: Do you remember that list of words I rea words from the list as you can remember recalled. Total score equals number of words I re	rds, in reverse or util say -1-7. ead trial 2. Score 1 9 8-6 1-4-8 he months of the he months of the hackward. So y Mar-Feb-Jan d a few times ea tr in any order. Called.	der of how I rea pt. for each string 0 0 0 e year in reverse 0 1 say Dec 0 1 1 1 1 1 1 1 1 1 1 1 1 1
iam going to te repeat back as LIST Elbow Apple Carpet Saddle Bubble TOTAL Trials 2 & 3: 1 as you can rem Complete al 3 tri trial score equals Do nd inform the IMMEDIATE 1 Exertional P If subject is not create condition	est your memory. I will read- many words as you can re- trike 1 0	member, in any order. TERL 2 0 1 0 1 0 1 0 1 1 again. Repeat back as t again. Repeat back	TRIAL 3 0 1 0 1 0 1 0 1 0 1 many words	done, you repeat them back to me backwork to you. For example, if 1 say 7-1-9, you wu d' cornet, op to next string length. If incorrect, Step after incorrect on both traits. 4-9-3 6-2-9 3-8-1-4 3-2-7 6-2-9-7-1 1-5-2 7-1-8-4-6-2 5-3-9 Months in Reverse Order: Now tell me I Start with the last month and go I November, Go abead. 1 pt. for entire sequence correct. Dec-Nov-Oct-Sept-Aug-Jut-Jun-May-Apr CONCENTRATION TOTAL SCORE Delayed Recall: Do you remember that list of words I rea words from the list as you can rememb recalled. Total score equals number of words I Elbow Apple Cal DeLayed RecAll TOTAL SCORE	rds, in reverse or util say -1-7. ead trial 2. Score 1 9 8-6 1-4-8 he months of the he months of the hackward. So y Mar-Feb-Jan d a few times ea tr in any order. Called.	der of how I rea pt. for each string 0 0 0 e year in reverse 0 1 say Dec 0 1 1 1 1 1 1 1 1 1 1 1 1 1
am going to te repeat back as LIST Elbow Apple Carpet Saddle Bubble TOTAL Trials 2 & 3: 1 as you can rem Complete al 3 dist Total score equals Do nal firom the IMMEDIATE I Exertional T if subject is not create condition measures nee	st your memory. I will read many words as you can re TRIAL 1 0 1 0 1 0 1 0 1 0 1 am going to repeat that it ember in any order, even it he regardless of score on that it esum across al 3 trais. scolect that delayed neat will MEMORY TOTAL SCOR MEMORY TOTAL SCOR MEMORY TOTAL SCOR daneuvers:	member, in any order. TRUL 2 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 2 2 0 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 2 4 4 5 - 5 - 5 - 6 - 1 2 1 2 1 3 1 3 1 3 1 3 1 3 1 3 <	TRIAL 3 0 1 0 1 0 1 0 1 many words	doe, you repeat them back to me backwork to you. For example, ff 1 say 7-1-9, you wut transcript, ff 1 say 7-1, you wut transcript, find transcript, find transcript, find transcript, find transcript, for the list a you can remember reacter equate number of words none librow Apple Elbow Apple Delayed Decall to failscore Start gastript, find transcript, find transcri	rds, in reverse or uld say 9-1-7. ead trial 2 Score 1 9 8-6 1-4-8 he months of the sackward. So y Mar-Feb-Jan d a few times ea ir in any order. <i>C</i> called. Saddl	der of how I rea pt. for each string 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1
am going to te repeat back as LIST Elbow Apple Carpet Saddle Bubble TOTAL Trials 2 & 3: I as you can rep Complete al 3 tri Trials 20: 43 and Donate al 3 tri Trials 20: 43 and D	est your memory. I will read- many words as you can re- trike 1 0	member, in any order. TERL 2 0 1 0 1 0 1 0 1 0 1 1 0 1 4 again. Repeat back as 1 I said the word before as 2. Score 1 pt. for each or he astad. E mptoms. conduct the for are likely to be elicited subject is already dia minutes to keep time	TRIAL 3 0 1 0 1 0 1 0 1 0 1 many words many words many words Identify a second secon	done, you repeat them back to me backwork to you. For example, if 1 say 7-1-9, you wu d' cornet, op to next string length. If incorrect, Step after incorrect on both traits. 4-9-3 6-2-9 3-8-1-4 3-2-7 6-2-9-7-1 1-5-2 7-1-8-4-6-2 5-3-9 Months in Reverse Order: Now tell me I Start with the last month and go I November, Go abead. 1 pt. for entire sequence correct. Dec-Nov-Oct-Sept-Aug-Jut-Jun-May-Apr CONCENTRATION TOTAL SCORE Delayed Recall: Do you remember that list of words I rea words from the list as you can rememb recalled. Total score equals number of words I Elbow Apple Cal DeLayed RecAll TOTAL SCORE	rds, in reverse or uld say 9-1-7. ead trial 2 Score 1 9 8-6 1-4-8 he months of the sackward. So y Mar-Feb-Jan d a few times ea ir in any order. <i>C</i> called. Saddl	der of how I rea pt. for each string 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1
am going to te repeat back as LIST Elbow Apple Carpet Saddle Bubble TOTAL Trials 22 43: 1 as you can rem Complete all 3 tri Total 2024 3: 1 Internet 1 1 Exertional 1 If subject is not create condition measures nee any symptom	st your memory. I will read- many words as you can re- TRIAL 1 0 1 0 1 0 1 0 1 0 1 am going to repeat that lis ember in any order, even 1 is ngotess of score on train 1 as mances at 3 reads. a spect that delayed read will MEMORY TOTAL SCOR MEMORY TOTAL SCOR displaying or reporting sy ns under which symptoms d not be conducted if a	member, in any order. TERL 2 0 1 0 1 0 1 0 1 0 1 1 0 1 4 again. Repeat back as 1 I said the word before as 2. Score 1 pt. for each or he astad. E mptoms. conduct the for are likely to be elicited subject is already dia minutes to keep time	TRIAL 3 0 1 0 1 0 1 0 1 0 1 many words many words many words Identify a second secon	doe, you repeat them back to me backwork to you. For example, ff 1 say 7-1-9, you wut transcript, ff 1 say 7-1, you wut transcript, find transcript, find transcript, find transcript, find transcript, for the list a you can remember reacter equate number of words none librow Apple Elbow Apple Delayed Decall to failscore Start gastript, find transcript, find transcri	rds, in reverse or uld say 9-1-7. ead trial 2 Score 1 9 8-6 1-4-8 he months of the sackward. So y Mar-Feb-Jan d a few times ea ir in any order. <i>C</i> called. Saddl	der of how I rea pt. for each string 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1
am going to te repeat back as LIST Elbow Apple Carpet Saddle Bubble TOTAL Trials 2 & 3: I as you can rep Complete al 3 tri Trials 20: 4 and 1 Complete al 3 tri Complete al 4 tri Complete al 3 tri Complete al 4 tri Complete al 3 tri Complete al 3 tri Complete al 3 tri Complete al 3 tri Complete al 4 tri Complete al 3 tri Complete al 4 tri Comple	st your memory. I will read- many words as you can re- TRIAL 1 0 1 0 1 0 1 0 1 0 1 am going to repeat that lis ember in any order, even 1 is ngotess of score on train 1 as mances at 3 reads. a spect that delayed read will MEMORY TOTAL SCOR MEMORY TOTAL SCOR displaying or reporting sy ns under which symptoms d not be conducted if a	member, in any order. TERL 2 0 1 0 1 0 1 0 1 0 1 1 0 1 4 again. Repeat back as 1 I said the word before as 2. Score 1 pt. for each or he astad. E mptoms. conduct the for are likely to be elicited subject is already dia minutes to keep time	TRIAL 3 0 1 0 1 0 1 0 1 0 1 many words many words many words Identify a second secon	done, you repeat them back to me backword of you. For example, fil say 7-1-9, you wu for your for example, fil say 7-1-9, you wu for your fill of the same fill	rds, in reverse or utility and the second of	der of how I reac pt. for each string 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1
am going to te repeat back as LIST Elbow Apple Carpet Saddle Bubble TOTAL Trials 22 43: 1 as you can rem Complete all 3 tri Total 2024 3: 1 Internet 1 1 Exertional 1 If subject is not create condition measures nee any symptom	est your memory. I will read- many words as you can re- trikk 1 0	member, in any order. TERL 2 0 1 0 1 0 1 0 1 0 1 1 0 1 4 again. Repeat back as 1 I said the word before as 2. Score 1 pt. for each or he astad. E mptoms. conduct the for are likely to be elicited subject is already dia minutes to keep time	TRIAL 3 0 1 0 1 0 1 0 1 0 1 many words many words many words Identify a second secon	done, you repeat them back to me backwork to you. For example, if 1 say 7-1-9, you wu for exerce, go to next sing length. If incorrect, of 3-8-1-4	rds, in reverse or utility and the second of	der of how I reac pt. for each string 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1

Instructions	ALC: NOT STREET, STREE	1000	1 Total	-	4.44
Instructions: We would like to know if you now suffer any (of the symptoms a	iven belov	v. As man	v of these	e symp-
toms may occur normally, we would like you select a number based on the following:					
0 = Not experiencing at all 1 = No more of a problem than					
2 = A mild problem	USUAI				
3 = A moderate problem					
4 = A severe problem					
					10-11
Compared with before the injury, do you n	ow (over the last	24 hours) suffer f	rom:	
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		1	2	3	4
Taking longer to think		1	2	3	4
Blurred vision		1	2	3	4
Light sensitivity (upset by bright light)		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:					
	0				
	0				

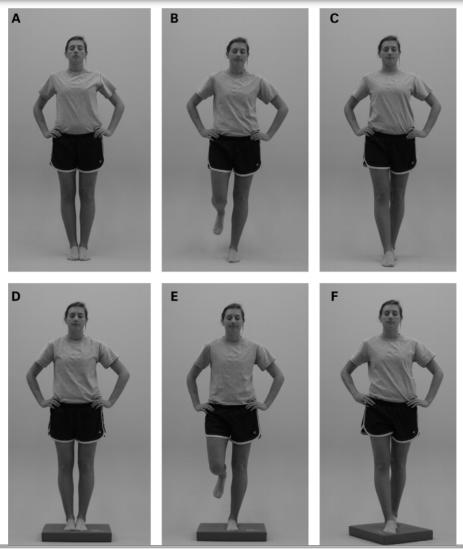
Post Concussion Symptom Questionnaire

Computer Science and Engineering - University of Notre Dame

Concussion Testing: King-Devick



Balance Error Scoring System (BESS)



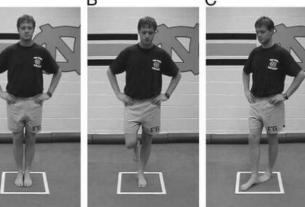
Computer Science and Engineering - University of Notre Dame

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

Double Single Tandem A B C



- 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

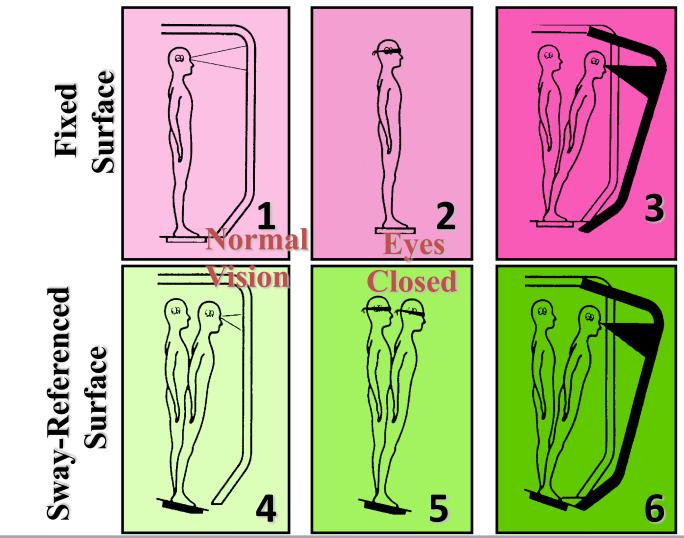
- Baseline heel-toe walk along a straight line 4 times with highest number as a "baseline"
- Repeat at times of injury for comparison
- More consistent compared to BESS however fatigability can play a role in performance
- <u>https://www.youtube.com/watch?v=ehjpG_0TobM</u>

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



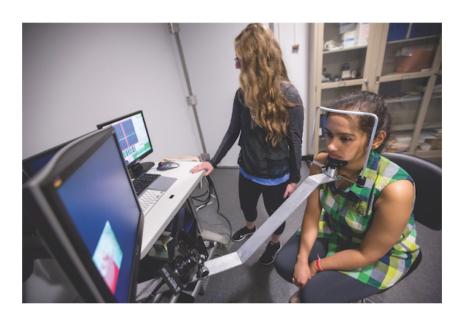
Computerized Dynamic Posturography



Computer Science and Engineering - University of Notre Dame

Eye Tracking

А



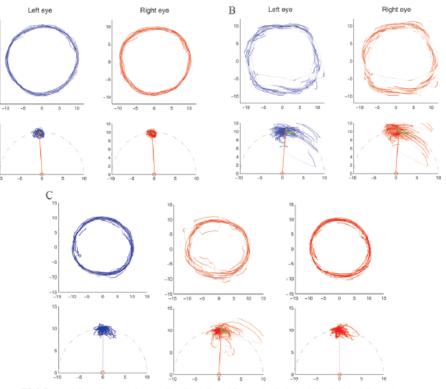
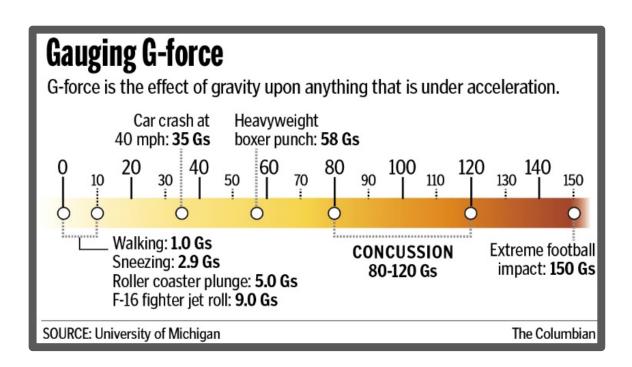
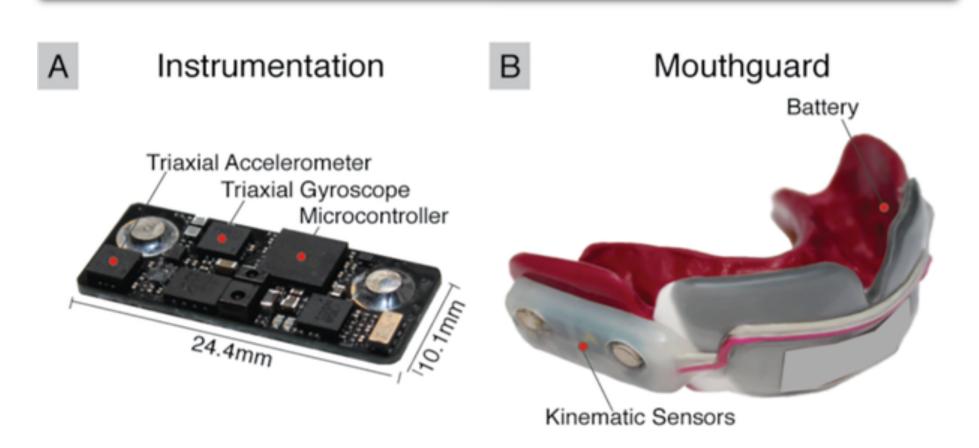


FIG. 3. Representative scattergrams of gaze positions (blue indicates left eye, and red indicates right eye) relative to the target; gaze positions were gathered at a frequency of 500 Hz. Circular patterns represent the path of the eye following a dot moving in a circle, and the semicircular pattern represents the eye position versus the target. Deviation from a target trajectory (dashed line) in both normal (A) and postoncussive (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.

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



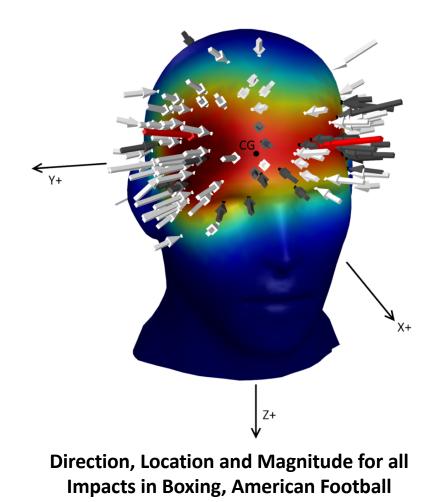


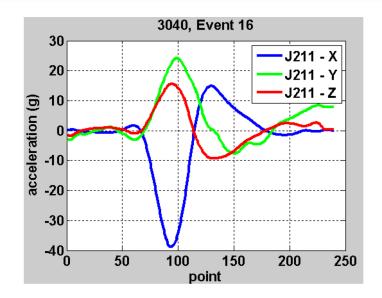






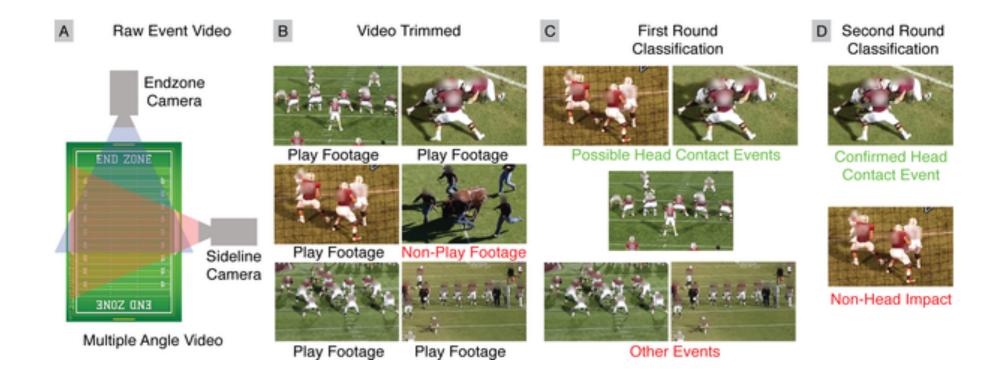
Computer Science and Engineering - University of Notre Dame





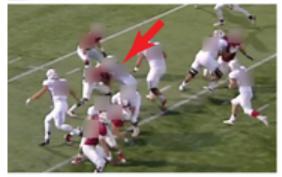
Impact counts Impact locations Impact severity Rotational forces

Video Assessment

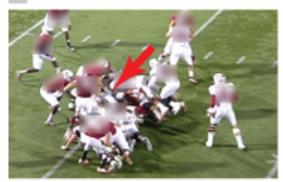


Video Assessment

Helmet Contact



Obstructed View D







No Contact

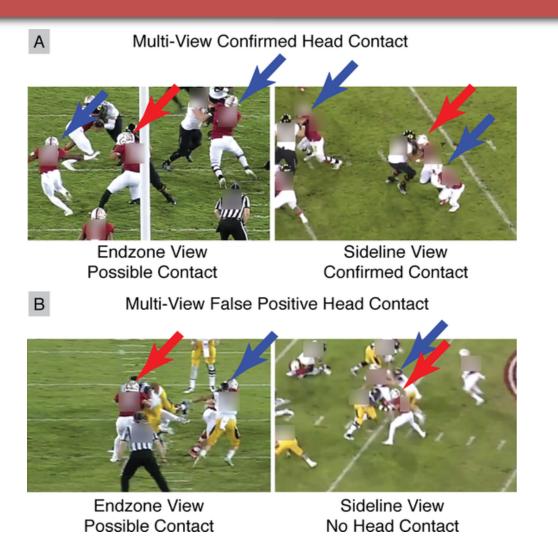
C



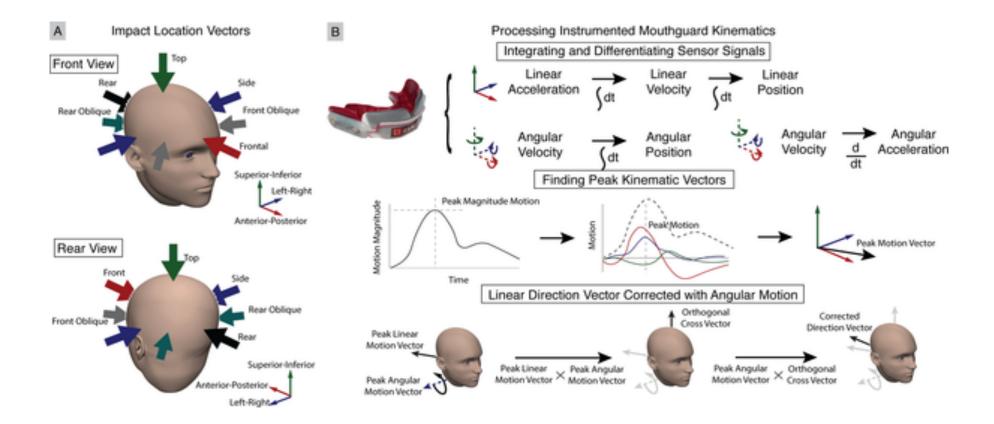
Not in Video



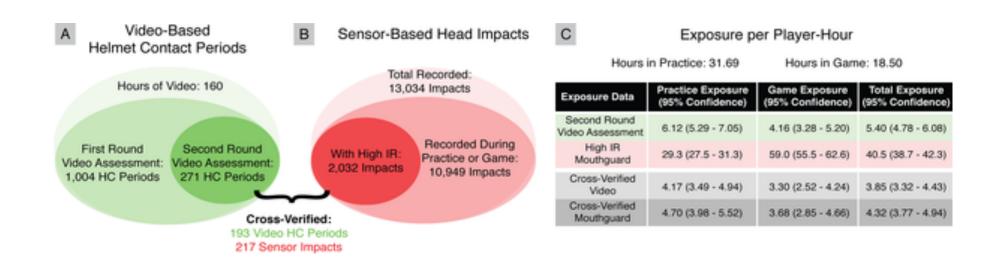
Video Assessment



Video + Sensor Assessment



Video + Sensor Assessment

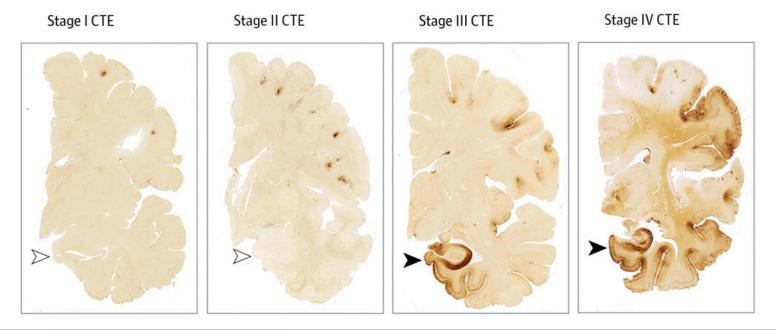


Video/Sensor Assessment – Pros/Cons

- 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)



Computer Science and Engineering - University of Notre Dame