Assessment of ROTC Cadet Performance Capabilities from Virtual Reality Metrics and Survey Responses

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1

Introduction

- Operational effectiveness of military personnel dependent on mental and physical capabilities[1,2]
  - Battlefield scenarios require situational awareness and split-second decisions
- Persistently prolonged response time can result from mild traumatic brain injury (mTBI)[1]
  - Impaired connectivity among brain networks adversely affects speed and accuracy of decision-making[3]

2

Introduction

- Emotional, physical, behavioral and cognitive well-being linked to brain processing efficiency[4]
  - Immersive virtual reality (VR) offers precise control of stimuli and measurement of responses[5]
- Sleep disruption and mood disorders (depression, anxiety, stress) common after mTBI[4]
  - Mood disorders adversely affect neurocognitive function (prolonged response time)[6]

Introduction

- History of mTBI associated with increased lower extremity injury among ROTC cadets[7]
  - Poor sleep increases injury risk,[8] and sleep extension improves neurocognitive function[9]
- Perceptual-motor test metrics derived from VR testing may reveal impairment of interrelated neural processes[10]

Purpose

- To determine whether immersive VR perceptual-motor metrics associate with ROTC cadets' subjective ratings of overall wellness

Participants

- 40 College ROTC cadets
  - 30 Male
    - Age 21.0 ± 2.8 years (Range 18-30)
  - 10 Female
    - Age 20.0 ± 1.4 years (Range 18-22)

Exclusionary criterion: injury precluding weightbearing activity

IRB #16-122

Overall Wellness Index: 10 categories of 82 self-reported problems.

Physical Problems
- ☐ Headaches
- ☐ Pressure in head
- ☐ Neck pain
- ☐ Muscle aches
- ☐ Nausea/vomiting
- ☐ Light sensitivity
- ☐ Noise sensitivity
- ☐ Joint aches
- ☐ Urinary incontinence
- ☐ Bowel incontinence
- ☐ General discomfort

Sleep/Stamina Problems
- ☐ Sleeping less
- ☐ Sleeping more
- ☐ Trouble falling asleep
- ☐ Fatigue/lethargy
- ☐ Drowsiness
- ☐ Feeling slowed down

Muscle Control Problems
- ☐ Muscle weakness
- ☐ Involuntary movements
- ☐ Muscle twitching
- ☐ Muscle jerking
- ☐ Difficulty walking
- ☐ Tremor (oscillating motions)
- ☐ Changed handwriting
- ☐ Trouble using tools
- ☐ Difficulty using hands or feet
- ☐ Trouble swallowing

Balance/Orientation Problems
- ☐ Postural swaying/falling
- ☐ Spinning sensations
- ☐ Dizziness
- ☐ Lost in familiar environment
- ☐ Trouble seeing things properly
- ☐ Difficulty recognizing faces
- ☐ Impaired perception of objects

Altered Sensations
- ☐ Vision changes
- ☐ Tingling
- ☐ Numbness
- ☐ Body pains
- ☐ Other changed sensations

Mood/Emotional Problems
- ☐ Suppression of emotions
- ☐ Emotional instability
- ☐ Depression/sadness
- ☐ Anxiety
- ☐ Nervousness
- ☐ Irritability

Behavior Control
- ☐ Apathy/lack of motivation
- ☐ Loss of inhibitions
- ☐ Extreme religiosity
- ☐ Delusions
- ☐ Personality changes
- ☐ Agitation/aggression
- ☐ Violent outbursts
- ☐ Obsession/compulsion
- ☐ Repetitive behaviors
- ☐ Criminal behavior
- ☐ Impaired hygiene
- ☐ Altered eating habits
- ☐ Hallucinations

Memory-Related Problems
- ☐ Misplaced objects
- ☐ Asking questions repetitively
- ☐ Missed appointments
- ☐ Difficulty remembering past events

Thinking-Related Problems
- ☐ Planning/organizing difficulty
- ☐ Multi-tasking difficulty
- ☐ Problem-solving difficulty
- ☐ Mental rigidity (inflexibility)
- ☐ Impulsive responses
- ☐ Mental fogginess
- ☐ Difficulty concentrating
- ☐ Bad decisions
- ☐ Confusion

Language-Related Problems
- ☐ Impaired writing
- ☐ Impaired spelling
- ☐ Impaired reading
- ☐ Trouble choosing words
- ☐ Slurred speech, difficulty articulating words
- ☐ Stuttering
- ☐ Incorrect word use/mispronunciation
- ☐ Increased speech output
- ☐ Impaired language comprehension
- ☐ Decreased speech output
- ☐ Impaired word comprehension

5-0 Raw Score for Each of 10 Problem Categories

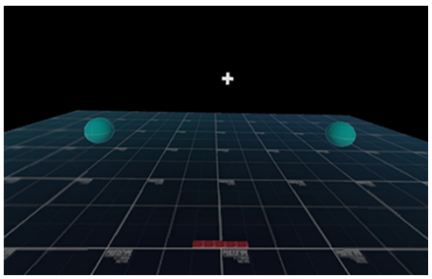
5	4	3	2	1	0
○	○	○	○	○	○
Current Week Any Extent	Past 12 Months Frequently	Past 12 Months Infrequently	> 1 Year Ago Frequently	> 1 Year Ago Infrequently	Not at All Over the Past 2 Years

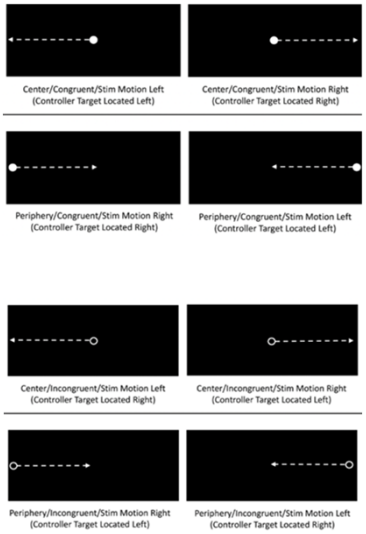
7

Perceptual-Motor Efficiency

Immersive Virtual Reality Test

- 40 trials requiring lunging/reaching responses to horizontally moving dots
- Auditory tone and controller vibration feedback provided when target contacted





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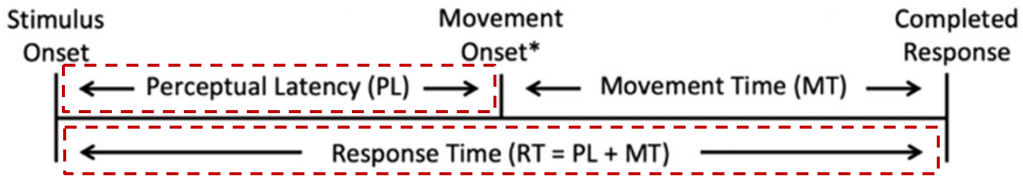
Operational Definitions for VR Metrics



- **Perceptual Latency:** Eyes (6˚), Neck (6˚), Arm (10 cm), Step (10 cm)
- **Response Time:** Eyes (Max), Neck (Max), Arm (Max), Step (Max)
  - Receiver operating characteristic and cross-tabulation analyses used to quantify strength of associations between immersive VR metrics and OWI scores (cumulative score and categorical raw scores for problem frequency and temporal proximity)

Methods: VR Test Metrics

- 40-Trial Mean and Trial-to-Trial Intra-Individual Variability (IIV)
  - Perceptual Latency (PL): Eyes, Neck, Arm, Step
  - Response Time (RT): Eyes, Neck, Arm, Step
- Speed-Accuracy Composite Metric: Rate Correct Score (RCS)
  - Calculated from Arm Movements (Hand Controller)
    - RCS-PL = Number Correct / Sum of PL Values
    - RCS-RT = Number Correct / Sum of RT Values

Results: Factors Associated with Suboptimal Wellness*

* OWI ≤ 90 of 100-Point Max (Score Below Median Value)

Results of Receiver Operating Characteristic and Cross-Tabulation Analyses						
Variable	**AUC**	**Cut-Point**	**P-value***	**Sensitivity**	**Specificity**	**OR (95% CI)**
History of Concussion	-	Yes/No	.040	.29	.96	9.17 (0.96, 87.78
Neck – PL IIV	.689	≥ 0.241	.020	.77	.61	5.06 (1.25, 20.48)
Rate Correct Score - PL	.578	≤ 1.147	.033	.65	.70	4.19 (1.10, 15.90)

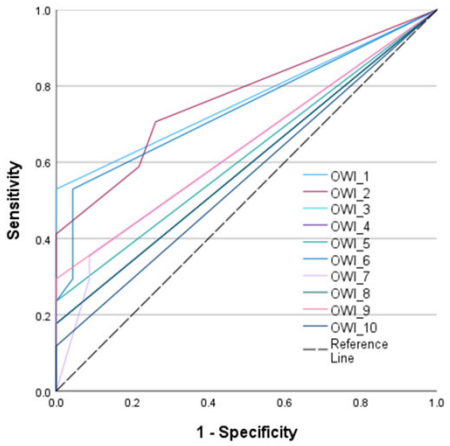
* Fischer's exact 1-sided test

History of Concussion: 15% (6/40)

Results: Strongest Categorical Raw Scores Contributing to Suboptimal Overall Wellness Index Score*

* 5-0 Raw Scores for 10 Categories Summed (50-point Max)
Multiplied by 2 and Subtracted from 100 to Derive 0-100 OWI Score
(Higher Score = Better Overall Wellness)

5	4	3	2	1	0
Current Week Any Extent	Past 12 Months Frequently	Past 12 Months Infrequently	> 1 Year Ago Frequently	> 1 Year Ago Infrequently	Not at All Over the Past 2 Years



OWI ≤ 90 of 100 Points

OWI Category	AUC	Raw Score	P-value*	Sensitivity	Specificity	OR (95% CI)
Mood/Emotional (5-0)	.765	≥ 1	<.001	.53	.96	24.75 (2.69, 227.61)
Sleep/Stamina (5-0)	.767	≥ 1	.006	.71	.74	6.80 (1.68, 27.52)
Head/Neck/Body Pain (5-0)	.743	≥ 1	<.001	.53	1.00	False-Positive = 0

* Fischer's exact 1-sided test

3 Key OWI Problem Categories (15-Point Raw Score Maximum)

- Head/Neck/Body Pain (5-0)
- Sleep/Stamina Problems (5-0)
- Mood/Emotional Problems (5-0)

Raw Score ≥ 3 (Median)

Results of Receiver Operating Characteristic and Cross-Tabulation Analyses						
Variable	**AUC**	**Cut-Point**	**P-value***	**Sensitivity**	**Specificity**	**OR (95% CI)**
Rate Correct Score - PL	.596	≤ 1.147	.025	.62	.74	4.55 (1.18, 17.52)
Neck – PL IIV	.639	≥ 0.241	.107	.67	.58	2.75 (0.76, 9.95)
Arm/Target – RT IIV	.617	≥ 0.643	.008	.57	.84	7.11 (1.58, 32.06)
Arm/Target – RT Avg	.622	≥ 1.374	.049	.57	.74	5.09 (0.98, 14.23)

* Fischer's exact 1-sided

Results: Associations of VR Metrics with Disordered Sleep

OWI Sleep/Stamina Problems Category Score ≥ 1 of 5 Points

Results of Receiver Operating Characteristic and Cross-Tabulation Analyses						
Variable	**AUC**	**Cut-Point**	**P-value***	**Sensitivity**	**Specificity**	**OR (95% CI)**
Neck – PL IIV	.712	≥ 0.207	.011	.94	.41	11.77 (1.32, 105.01)
Arm/Target – RT IIV	.677	≥ 0.643	.007	.61	.82	7.07 (1.68, 29.83)
Rate Correct Score - PL	.664	≤ 1.147	.014	.67	.73	5.33 (1.37, 20.71)
Arm/Target – RT Avg	.654	≥ 1.374	.033	.61	.73	4.19 (1.10, 15.90)

* Fischer's exact 1-sided

Discussion

- VR Perceptual Latency Metrics: Neck IIV and Rate Correct Score associated with:
  - Suboptimal Overall Wellness Index Score ≤ 90 of 100 Max
  - 3 Key Problem Categories Cumulative Raw Score ≥ 3 of 15 Max
    - Sleep/Stamina, Mood/Emotional, and Head/Neck/Body Pain
  - Sleep/Stamina Response other than "Not at All Over the Past 2 Years"
- History of Concussion associated with Suboptimal OWI Score ≤ 90
  - OR = 9.17; 29% Sensitivity; 96% Specificity; p = .040

Clinical Relevance

- Intra-Individual Variability in responses to successive stimuli is believed to be a behavioral manifestation of impaired connectivity among brain networks[3]
- Neck rotation inconsistency (Perceptual Latency IIV) may be linked to vestibular dysfunction from mTBI[11]
- Disordered sleep appears to be a sensitive indicator of neuronal injury and neurodegeneration that relates to inadequate clearance of toxic metabolites through the glymphatic system[4]

Clinical Relevance

- A common pathophysiological mechanism may link inefficient perceptual-motor function, disordered sleep, pain sensitivity, and mood/emotional problems with or without history of mTBI[4,10]
- Immersive VR provides meaningful measurements of perceptual-motor function that can be combined with survey responses to identify individual ROTC cadets who may possess an impairment of brain processing, which might otherwise remain undetected

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