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Reliability of Accelerometer-Based Reaction Time Tests

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Abstract

- Laboratory camera-based motion capture data, while reliable, is not a realistic tool to use outside of a laboratory to measure reaction time
  - Requires hardware that makes it impractical in non-laboratory settings
- Accelerometers measure linear triaxial accelerations, and are wireless miniature MEMS devices and can be easily affixed on the hand
- If accelerometers were proven to be as accurate as motion capture systems at obtaining reaction time, accelerometer-dependent devices, such as a drop stick, could serve as a reliable and portable tool to quickly and easily diagnose slowed reaction times which are indicative of a concussion

Introduction

- Concussions in high contact sports are very prevalent (football and soccer)
- Slowed reaction time can be an early indicator of concussion and can help diagnose a concussion within minutes of the event (Honda *et al.*, 2010)
- Diagnosis of a concussion is vital in the early stages
- If improperly treated, concussions can lead to long term symptoms as well as CTE (Chronic Trauma Encephalopathy)
- In turn, CTE can lead to increased likelihood of clinical depression and dementia-like syndromes

Materials

- Accelerometer
- Foam pad
- Stick
- Infrared Reflective Markers
- Inertial sensor
- Tripod

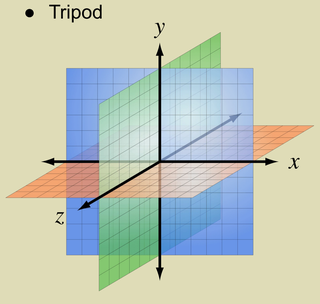

Figure 1: Example of triaxial motion displayed by a 3-axis graph

Figure 2: Infrared reflective markers used in both accelerometer reaction time motion capture and camera-based motion capture

Methods

- "Drop Stick Test" is determined by how long it takes a person to respond to an object being dropped by measuring reaction time as well as movement time (Del Rossi et al., 2014)
- 1st series (Standard): Participants stood on ground and foam pad to indicate reaction time along with somatosensory noise
- 2nd series (Dual-task element): Same as 1st series, along with placing a computer screen in the participant's peripheral vision
- Time stamps from both the accelerometer as well as infrared markers were lined up to conclude if there was consistent discrepancy between the accelerometer and the motion capture reaction time

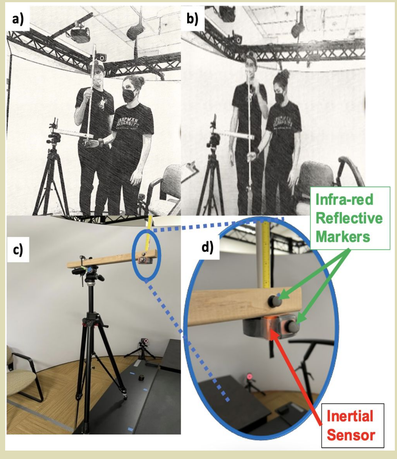

Figure 3: Process of conducting concussion study.

Figure 4: XSENS accelerometer in comparison to hand

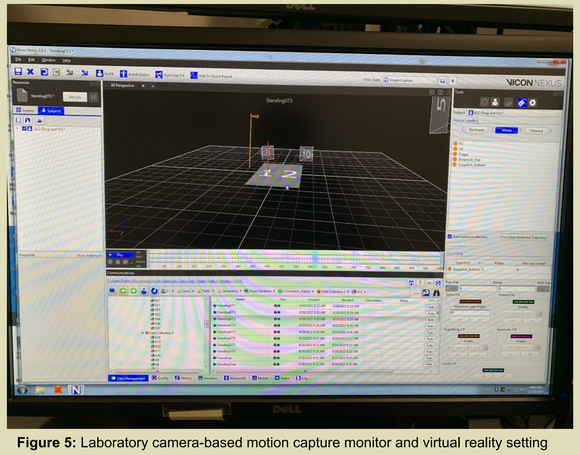

Figure 5: Laboratory camera-based motion capture monitor and virtual reality setting

Results and Discussion

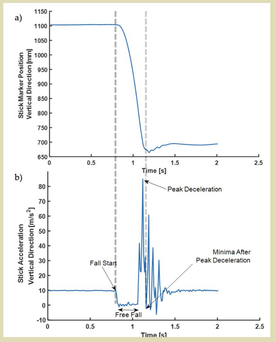

Figure 5: Data collected from the motion capture system (a) and the accelerometer sensor (b).

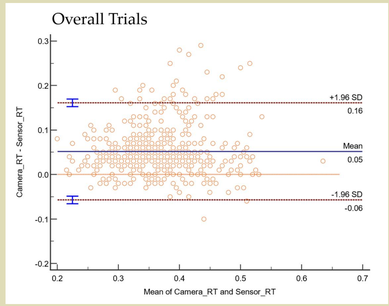

Figure 6: Plotted differences between the camera and sensor systems RT versus the mean of two measurements for the overall trial with all conditions.

Condition	Consistency		Absolute Agreement			
	ICC	ICC Confidence Interval 95%	ICC	ICC Confidence Interval 95%	Datapoints	Pearson Correlation Coefficient
Overall	0.82	[0.78 to 0.85]	0.71	[0.14 to 0.86]	480	0.69
Standing	0.78	[0.71 to 0.83]	0.66	[0.10 to 0.84]	190	0.64
Sitting	0.70	[0.56 to 0.80]	0.57	[0.02 to 0.78]	100	0.55
Single Task	0.79	[0.75 to 0.83]	0.65	[-0.03 to 0.84]	370	0.66
Dual Task	0.75	[0.64 to 0.83]	0.69	[0.42 to 0.82]	110	0.61
Foam Standing	0.88	[0.84 to 0.91]	0.79	[0.18-0.91]	190	0.79
Firm Standing	0.78	[0.71 to 0.83	0.66	[0.10 to 0.84]	190	0.64

Table 1: Intra-class correlation (ICC) between accelerometer sensors and motion capture camera systems. Based on the 95% confidence interval of the ICC estimate, values less than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and greater than 0.90 are indicative of poor, moderate, good, and excellent reliability, respectively (Koo, 2016).

Condition	Bias	95% CI bias	Lower LOA	95% CI of Lower LOA	Upper LOA	95% CI of Upper LOA
Overall	0.05	[0.04 to 0.05]	-0.05	[-0.06 to -0.04]	0.16	[0.15 to 0.16]
Standing	0.05	[0.04 to 0.06]	-0.06	[-0.07 to -0.04]	0.16	[0.15 to 0.18]
Sitting	0.05	[0.04 to 0.06]	-0.06	[-0.08 to -0.04]	0.18	[0.16 to 0.20]
Single Task	0.05	[0.05 to 0.06]	-0.04	[-0.05 to -0.03]	0.16	[0.15 to 0.17]
Dual Task	0.03	[0.02 to 0.04]	-0.07	[-0.09 to -0.05]	0.14	[0.12 to 0.16]
Foam Standing	0.04	[0.04 to 0.05]	-0.04	[-0.05 to -0.03]	0.14	[0.12 to 0.15]
No Foam Standing	0.05	[0.04 to 0.06]	-0.06	[-0.07 to -0.04]	0.16	[0.15 to 0.18]

Table 2: Average accelerometer bias values for each trial condition, with accompanying upper and lower limits of agreement (LOA)

- Bland-Altman plots showed consistent overall bias of 0.05 seconds
- Consistency between the two measurement systems was 0.82 overall
- Absolute agreement between the two measurement systems was 0.71 overall

Conclusion

- Accelerometer-based sensors record reaction time data with a consistent bias compared to motion capture systems
- Accelerometer-based sensors can reliably be used to record reaction times, as long as bias is taken into account
- Limitations:
  - Data collected in laboratory setting, and therefore cannot make firm statements on validity in a field setting
  - Data collected under tight protocol settings, which may not translate to field settings
- Future directions:
  - Further data collection in field setting could reveal validity of measurement techniques outside of the laboratory

References: