Lessons Learned From Using Bio- and Environmental Sensing in Construction: A Field Implementation

Wonil Lee*
Giovanni Migliaccio
Ken-Yu Lin

University of Washington

Francesca Russo

University of Naples Federico II
Motivation

• Industry Workforce Trends
  – Fatalities and Injuries
  – Health Issues
  – Presenteeism and Absenteeism
  – Stagnant Labor Productivity Improvement
  – Labor Shortage
Motivation

• Factors Affecting Workforce Performance and Health

- Socio-cultural Factors (e.g. Financial Situation)
- Organizational Factors (e.g. Education and Training)
- Teamwork Factors (e.g. Communication)
- Task Factors (e.g. Work Schedule)
- Environmental Factors (e.g. Temperature)
- Individual Factors (e.g. Physiological Status)
Problem Statement

- Worker’s physical strain affects:
  - Productivity
  - Quality
  - Safety
  - Health

Off-the-Shelf Sensor Technologies

- Wearable Biosensors
- Environmental Sensors
Objectives

• Sharing findings and lessons learned from:
  – Field monitoring study of bio- and environmental sensors
  – Participants administration and observer effect issues
Data Collection Methods

• Biosensor
  – Zephyr BioHarness™3

• Environmental Sensor
  – Davis Instruments Corp. Vantage Pro2™ Plus
Data Collection Methods

• Other Instruments:
  – GPS location tracking
  – Perceived fatigue level
  – Workers’ major tasks performed
  – Video recording
Data Collection

• Five healthy workers
• Mid-rise building construction site
• Seattle, Washington State, US
• Schedule of Observations
  – July 29th to August 9th (2 Weeks)
  – October 14th to October 18th (1 Week)
Data Analysis

1. Empirical Validation of Previous Finding
   - Data Pre-Processing
   - Time Series Plot

2. Physiological Status
   - Physiological Acceptable Bounds
   - Heart Rate Zones

3. Physical Strain and Environmental Job Stressor
   - Physical Strain = f (Average HR)
   - Correlation Analysis
# Data Analysis

## • Subject Information

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<tr>
<th>Subject Codes</th>
<th>BMI</th>
<th>Major Task</th>
<th>Study Participation</th>
<th>Total Hours of Data Collected</th>
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<td>Summer</td>
<td>Fall</td>
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<td>S.4</td>
<td>30.4</td>
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<td>S.5</td>
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<td>Layout; Pour Watch</td>
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Findings

Heart Rate (Beats per minute)

Breathing Rate (Breaths per minute)
Findings

• Physical Strain Level Measured by HR
Findings

- Seasonal Comparison of Worker’s Physical Strain Level

<table>
<thead>
<tr>
<th>Subject Codes</th>
<th>Summer (Jul. 29 – Aug. 2)</th>
<th>Fall (Oct. 14-18)</th>
<th>Two-sample t-test Summer vs. Fall</th>
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<td>Min</td>
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Clothing Insulation

- Summer
- Fall
Findings

• Wet-Bulb Globe Temperature (WBGT)
  \[ \text{WBGT} = 0.7T_w + 0.2T_g + 0.1T_a \]
  • \( T_w \): Natural wet-bulb temperature
  • \( T_g \): Globe temperature
  • \( T_a \): Ambient temperature

• WBGT (F˚) and Physical Strain (HR: bpm)

<table>
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Lessons Learned

• Use of GPS Trackers
• Confounding Factors
• Fear of Reporting to Supervisors
• Fear of Underperforming against Peers
Lessons Learned

• Trades to be Observed
  – Less variability in scope and target outputs

• Use of Video Recording
  – Positioning several fixed cameras
  – Back-up via traditional manual work sampling
Industry Applications

Use of Biosensor

• S&H professionals:
  – Monitoring for workers’ potential overexertion

• Field management:
  – Managing workers’ task demands

• Laborers:
  – Self-pacing by tracking physical strain level
Special Acknowledgements

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Q&A

• Thank you for your attention!

– Wonil Lee, PhD Candidate, Department of Construction Management, University of Washington

– Email: wonillee@uw.edu