Controller Cognitive Workload Levels and Fatigue

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Presentation Objectives

• Illustrate why controller workload is measured and how we measure it

• Discuss relationship between cognitive workload and fatigue
Why measure?

Operators of hazardous liquids, gas transmission, and gas distribution control rooms

- are required by the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration to monitor
  - the general activity of their controllers to make sure they have enough time to analyze and to react to alarms.
Why measure?

- Controllers are responsible for the operation, monitoring and control of high risk operations.
- Controllers, because they are human, have Human Capabilities and Limitations.
Our Methodology

- Over the past six years we have conducted over 180 workload assessments with controllers in over 60 control rooms in the United States and Canada.

- Our methodology is based on:
  - modified NASA Task Load Index (NASA-TLX)
  - measures of task percentages.

- In 2015 we added an alertness measure to the workload assessments.

- Industry benchmarks for:
  - controller workload,
  - alertness
  - controller general activities (particular attention to responses to alarms and abnormal and emergency conditions)
Workload Ratings

- Mental Demand
- Physical Demand
- Time Demand
- Effort
- Frustration
- Performance

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Workload Ratings

Demands of the Task

- Physical Demand
- Time Demand
- Mental Demand

Performance
Effort
Frustration

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Workload Ratings

Demands of the Task

- Mental Demand
- Physical Demand
- Time Demand

Task Demands interacting with the Human Factors

- Effort
- Frustration

Time Demand

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Factors that impact Task Demands

- **CONTROLLER CHARACTERISTICS**
  - health, habits, attitude, home, age, experience, previous experience, self assessment

- **ENVIRONMENT**
  - windows, seating, air, heat, clean, lighting, TV

- **TECHNOLOGY**
  - SCADA displays, phones, radio

- **OTHER PEOPLE**
  - controllers, field personnel, customers, management

- **THE COMPANY**
  - culture, leadership, resources

- **DOCUMENTATION**
  - procedures, manuals, email

- **Training**

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The 9-point scale was adapted from the Karolinska sleepiness scale (KSS) developed by the Karolinska Institute in Sweden.

This is a self-report scale that measures drowsiness:
- extremely alert
- very alert
- alert
- rather alert
- neither alert nor sleepy
- some signs of sleepiness
- sleepy, it's no effort to stay awake
- sleepy, some effort to stay awake
- very sleepy, great effort to stay awake, fighting sleep
## Workload Assessments: Conducted 2010-2016

<table>
<thead>
<tr>
<th>Control Center Type</th>
<th>Number of Assessments</th>
<th>Number of Consoles</th>
<th>Number of Controllers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazardous Liquid</td>
<td>88</td>
<td>153</td>
<td>847</td>
</tr>
<tr>
<td>Gas Transmission</td>
<td>47</td>
<td>75</td>
<td>395</td>
</tr>
<tr>
<td>Gas Distribution</td>
<td>20</td>
<td>37</td>
<td>175</td>
</tr>
<tr>
<td>Both HL &amp; Gas</td>
<td>24</td>
<td>35</td>
<td>181</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>179</strong></td>
<td><strong>300</strong></td>
<td><strong>1598</strong></td>
</tr>
</tbody>
</table>

60 Control Rooms in U.S. and Canada/58915 hours assessed
Workload Assessments with Alertness Measures

- 48 workload assessments in 40 Control Rooms
- Total of 573 controllers
- Every hour for 12 hour shifts
- Every day of the week – night shift and day shift
- 25,167 hours rated
## Alertness Ratings

<table>
<thead>
<tr>
<th>Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>very sleepy, great effort to stay awake,...</td>
<td>0.1%</td>
</tr>
<tr>
<td>sleepy, some effort to stay awake</td>
<td>2.8%</td>
</tr>
<tr>
<td>sleepy, it's no effort to stay awake</td>
<td>0.7%</td>
</tr>
<tr>
<td>some signs of sleepiness</td>
<td>0.9%</td>
</tr>
<tr>
<td>neither alert nor sleepy</td>
<td>4.1%</td>
</tr>
<tr>
<td>rather alert</td>
<td>7.5%</td>
</tr>
<tr>
<td>alert</td>
<td>34.5%</td>
</tr>
<tr>
<td>very alert</td>
<td>27.3%</td>
</tr>
<tr>
<td>extremely alert</td>
<td>21.9%</td>
</tr>
</tbody>
</table>
### Alertness Ratings During Higher and Lower Workload Hours

<table>
<thead>
<tr>
<th>Alertness Level</th>
<th>Higher Workload Hours</th>
<th>Lower Workload Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>extremely alert</td>
<td>26.1%</td>
<td>18.9%</td>
</tr>
<tr>
<td>very alert</td>
<td>29.6%</td>
<td>24.4%</td>
</tr>
<tr>
<td>alert</td>
<td>37.9%</td>
<td>30.7%</td>
</tr>
<tr>
<td>rather alert</td>
<td>8.9%</td>
<td>5.8%</td>
</tr>
<tr>
<td>some signs of sleepiness</td>
<td>1.0%</td>
<td>0.8%</td>
</tr>
<tr>
<td>sleepy, it's no effort to stay awake</td>
<td>0.6%</td>
<td>0.7%</td>
</tr>
<tr>
<td>sleepy, some effort to stay awake</td>
<td>3.2%</td>
<td>2.3%</td>
</tr>
<tr>
<td>very sleepy, great effort to stay awake, fighting sleep</td>
<td>0.1%</td>
<td>0.2%</td>
</tr>
<tr>
<td>neither alert nor sleepy</td>
<td>4.9%</td>
<td>3.7%</td>
</tr>
</tbody>
</table>
## Alertness Ratings

<table>
<thead>
<tr>
<th>Pipeliner Alertness Percentages</th>
<th>Lower Workload Hours</th>
<th>Higher Workload Hours</th>
<th>All Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>extremely alert</td>
<td>18.9%</td>
<td>26.1%</td>
<td>21.9%</td>
</tr>
<tr>
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</tr>
<tr>
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<td>4.1%</td>
</tr>
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<td>0.8%</td>
<td>0.9%</td>
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<td>2.3%</td>
<td>2.8%</td>
</tr>
<tr>
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<td>0.1%</td>
<td>0.2%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>
Workload Benchmarks

- Average workload during all hours (n=25,167)
  - Day Shift  5.2
  - Night Shift  4.9
  - Overall  5.0

- Average workload during “higher” hours (n= 4029)
  - Day Shift  8.1
  - Night Shift  8.1
  - Overall  8.1
Task Demands Higher Workload Hours

- Pipeline Operations, 18.61%
- Monitoring, 33.82%
- Log Sheet Paperwork, 12.76%
- Face to Face Talks, 8.53%
- Phone Radio, 8.48%
- Sampling, Calibrating, Proving, Testing, 1.59%
- Abnormal Events, 6.42%
- Administrative Tasks, 7.29%
- Breaks, 2.85%
- Emergency Events, 0.29%

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<table>
<thead>
<tr>
<th>Task</th>
<th>All Hours</th>
<th>Higher Workload Hours</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipeline Operations</td>
<td>15.42%</td>
<td>18.61%</td>
<td>🟢</td>
</tr>
<tr>
<td>Monitoring</td>
<td>38.79%</td>
<td>33.82%</td>
<td>🔴</td>
</tr>
<tr>
<td>Sampling, Calibrating, Proving, Testing</td>
<td>1.29%</td>
<td>1.59%</td>
<td>🟢</td>
</tr>
<tr>
<td>Log Sheet Paperwork</td>
<td>11.31%</td>
<td>12.76%</td>
<td>🟢</td>
</tr>
<tr>
<td>Phone Radio</td>
<td>6.66%</td>
<td>8.48%</td>
<td>🟢</td>
</tr>
<tr>
<td>Face to Face Talks</td>
<td>9.66%</td>
<td>8.53%</td>
<td>🔴</td>
</tr>
<tr>
<td>Administrative Tasks</td>
<td>8.02%</td>
<td>7.29%</td>
<td>🔴</td>
</tr>
<tr>
<td>Responding to Abnormal Events</td>
<td>4.64%</td>
<td>6.42%</td>
<td>🟢</td>
</tr>
<tr>
<td>Responding to Emergency Events</td>
<td>0.10%</td>
<td>0.29%</td>
<td></td>
</tr>
<tr>
<td>Breaks</td>
<td>4.63%</td>
<td>2.85%</td>
<td>🔴</td>
</tr>
</tbody>
</table>
Discussion

- **Alertness**
  - The greatest percentages of the alertness ratings were at the top of the alertness scale: “extremely alert”, “very alert” and “alert” (84%)
  - During higher workload hours, the percentage of “extremely alert” ratings (26%) increased as compared to lower workload hours (19%). This is expected due to higher levels of stress associated with higher workload hours.

- **Workload**
  - The results show a relationship between controller alertness and workload levels.
  - The higher averages were at the lower and higher end of the alertness scale but there was not much variability.

- **Task Demands**
  - Monitoring takes up the majority of controllers’ time, this is followed by Pipeline Operations and then administrative work.
  - During higher workload hours the task demands change somewhat:
    - **Increases**
      - Operations
      - Log Sheet/Paperwork
      - Phone and Radio Communications
    - **Decreases**
      - Monitoring
      - Face to face communications
      - Administrative tasks
      - Breaks
Questions?
A Human Factors consulting group

We apply
• practical pipeline shift work experience
• control room management and consulting experience
• doctoral qualifications

To Develop
• control room management plans,
• pipeline human factors consulting
• fatigue risk management programs

For regulatory compliance and operational excellence.

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