Safety, Accidents, and Human Error

Human Factors Psychology
Dr. Steve

Safety and Accident Prevention

Accidents caused by multiple factors
- e.g., “human error,” equipment failure, improper equipment design, environmental factors, or interaction between factors

Accident deaths and injury in the U.S.
- 47,000 motor vehicle-related deaths / year
- 13,000 deaths due to falls / year
- 7,000 deaths due to poisoning / year

Cost of Workplace deaths and injuries
- $48 billion / year
- $780,000 / victim cost to society
- $420 cost / worker

Most Frequent Causes of Workplace Deaths and Injuries

<table>
<thead>
<tr>
<th>Injury</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overexertion</td>
<td>Motor-vehicle related</td>
</tr>
<tr>
<td>Impact accidents</td>
<td>Falls</td>
</tr>
<tr>
<td>Falls</td>
<td>Electrical current</td>
</tr>
<tr>
<td>Bodily reaction to chemicals</td>
<td>Drowning</td>
</tr>
<tr>
<td>Compression</td>
<td>Fire related</td>
</tr>
<tr>
<td>Motor vehicle accidents</td>
<td>Air transport related</td>
</tr>
<tr>
<td>Exposure to radiation/caustics</td>
<td>Poison</td>
</tr>
<tr>
<td>Rubbing or abrasions</td>
<td>Water transport related</td>
</tr>
<tr>
<td>Exposure to extreme temperatures</td>
<td>Other</td>
</tr>
</tbody>
</table>
Safety Legislation

• Prior to 1900’s employers assumed little responsibility for safety
• Companies defended themselves against accidents claiming:
  1. Contributory negligence (person's behavior contributed to the accident)
  2. Negligence of fellow employees
  3. Injured worker was aware of the hazards and knowingly assumed the risks

Workers’ Compensation and Liability

• Early laws provided compensation to workers for on-the-job injuries regardless of who was at fault.
  - These laws originally thrown out as unconstitutional (passed in 1917)
• Today there are different workers’ compensation laws in each state, with approximately 80% of all workers covered.
• To collect workers compensation, injury must:
  1. Arise from an accident
  2. Arise out of worker's employment
  3. Occur during course of employment

Goals of worker compensation:

• Provide income and medical benefits to work-accident victims or income to their dependents
• Provide a single remedy to reduce court delays, costs, and workloads arising out of perennial-injury litigation
• Eliminate payment of fees to lawyers and witnesses as well as time-consuming trials and appeals
• Encourage employer interest in safety and rehabilitation
• Promote the study of causes of accidents
Establishment of OSHA

**Occupational Safety and Health Administration**

(1970) - OSH Act set forth by fed government to impose safety standards on industry
- under the U.S. Department of Labor
- set standards for general and specific industries
- companies comply by: keeping records, keeping employees informed on safety matters, complying with standards for injury avoidance, etc...

NIOSH

- National Institute for Occupational Safety and Health
  - mainly for research and education functions
  - finds hazardous types of working conditions by reviewing research
  - human factors professionals use the standards or recommendations

Product Liability

- Suits filed against a company claiming that a product was defective and therefore caused injury or death
  - e.g. McDonald's hot coffee case (overturned by higher court)
- Is the product defective or inherently dangerous?
  - e.g. faulty car seat vs. a sharp knife
- Defective - failed to perform safely as an ordinary user would expect when it was used in an intended or reasonably foreseeable manner, or if the risk inherent in the design outweighed the benefits of that design
  - Reasonably foreseeable
  - The trade-off between risk and benefit
Factors that cause or contribute to accidents

- **The systems approach**: accidents occur because of the interaction between system components
- Direct causal factors in safety
  1. the employee performing a task
  2. the task itself
  3. any equipment directly or indirectly used in the task
  4. other factors - social/psychological & environmental

Personnel Characteristics

Factors affecting hazard recognition, decisions to act appropriately, & ability to act appropriately

- **Age & Gender**
  - younger people have more accidents - ages 15-24, mostly young males
- **Job Experience**
  - 70% of accidents occur within the first 3 years
- **Stress, Fatigue, Drugs, & Alcohol**
  - many employers drug test

Job Characteristics/Equipment

- **Job characteristics** - such as high physical workload, high mental workload, monotony, etc...
- **Equipment** - where most of the safety analysis is performed. This is due to problems with:
  - Controls and Displays
    - e.g. poorly designed, difficult to use, cumulative trauma, etc.
  - Electrical Hazards
    - e.g. occurs when a person is doing repairs and another person unknowingly turns the circuit on
  - Mechanical Hazards
    - results in cutting of skin, shearing, crushing, breaking, or straining
  - Pressure and Toxic Substance Hazards
    - asphyxiants, irritants, systemic poison, & carcinogens
The Physical Environment

- Illumination
  - Glare, phototropism, contrast
- Noise and Vibration
  - Affects dexterity, control, and health
- Temperature and Humidity
  - Heat exhaustion, inattention, restrictive clothing
- Fire Hazards
  - Open flames, electric sparks, & hot surfaces
- Radiation Hazards
  - Radioactive material - damage to human tissue
- Falls
  - Resulting in injury or death are relatively common

The Social Environment

- Human behavior is influenced by social context
  - Social norms, mgmt practices, morale, training, incentives
    - E.g., construction workers will not wear safety gear if no one else is

Human Error

- The Misnomer of Human Error - Error usually triggered by other things (e.g., poor design, management, violations of use and maintenance).
  - Error is the end result of these problems
  - Pilot error blamed on over 70% of airplane accidents
  - Operator error blamed on over 60% of nuclear power plant accidents
  - Doctor/Nurse errors in ICU occur at a rate of 1.7/patient per day
- Classifying types of error
  - Errors of omission - Operator fails to perform a procedural step
  - Errors of commission - Operator performs extra steps that are incorrect or performs a step incorrectly
**Taxonomy of Human Error**

**MISTAKES**
- Knowledge
- Rule

**Slips**
- Action Execution

**MISTAKES**
- Interpretation
- Situation Assessment

**Slips**
- Intention of Action

**LAPSES & MODE ERRORS**
- Memory

---

**Taxonomy of Human Error**

**MISTAKES**
- **Mistakes** - failure to come up with appropriate solution
  - Takes place at level of perception, memory, or cognition
- Knowledge-based Mistakes - wrong solution because individual did not accurately assess the situation.
  - Caused by poor heuristics/biases, insufficient info, info overload
- Rule-based Mistakes - invoking wrong rule for given situation
  - Often made with confidence

**Slips**
- **Slips** - Right intention incorrectly executed (oops!)
  - **Capture errors** - similar situation elicits action, which may be wrong in "this" situation. Likely to result when:
    - Intended action is similar to routine behavior
    - Either stimulus or response is related to incorrect response
    - Hit "3" instead of "8" on phone to hear next message, because "3" is what I hit to hear the first message
    - Response is relatively automated, not monitored by consciousness
    - Re-starting your car while the engine is already running
Taxonomy of Human Error
Lapses & Mode Errors

- **Lapses** - failure to carry out an action
  - Error of Omission (working memory)
  - Examples: Forgetting to close gas cap, failure to put safety on before cleaning gun, failure to remove objects from surgical patient
- **Mode Errors** - Making the right response, but while in the wrong mode of operation
  - Examples: leave keyboard in shift mode while trying to type a numeral, driving in wrong gear, going wrong direction because display was north-up when thought it was nose-up

Human Reliability Analysis

- **Human Reliability Analysis** - predict reliability of system in terms of probability of failure or mean time between failures (MTBF) when system is designed to work in parallel or series

**Series**

- Reliability = $0.9 \times 0.9 = 0.81$
- $P(failure) = 1 - 0.81 = 0.19$

**Parallel**

- Reliability = $1 - [(1 - 0.9)(1 - 0.9)]$
- $P(failure) = 1 - .99 = .01$

(see homework) (HW answers)

Technique for Human Error Rate Prediction (THERP)

**THERP components**

1. Human Error Probability
   - Ratio of errors made to possible errors
2. Event Tree
   - Diagram showing sequence of events
     - Probability of success or failure for each component
3. Other Moderating Factors
   - May add in multiplier to account for variables such as experience level, time, stress, etc.
**Error Prevention / Remediation**

1. **Task Design** – design tasks with working memory capacity in mind

2. **Equipment Design**
   - a) Minimize perceptual confusions – ease of discrimination
     - Ex: airplane controls that feel like what they do (flaps, wheels)
   - b) Make consequences of action visible – immediate feedback
     - Ex: preview window in some software programs
   - c) Lockouts – design to prevent wrong actions
     - Ex: car that will not let you lock door from outside without key
   - d) Reminders – compensate for memory failures
     - Ex: ATM reminds you to take your card

**Error Prevention / Remediation (continued)**

3. **Training** – provide opportunity for mistakes in training, so can learn from them
   - Ex: Simulation

4. **Assists and Rules** – checklists to follow
   - Ex: Pilot pre-flight checklist

5. **Error-tolerant systems** – system allows for error correction or takes over when operator makes serious error
   - Ex: Undo button
Approaches to Hazard Control

- Optimization standpoint - the most critical or “high-risk” hazards should receive top priority
  - e.g. MIL-STD-882B categories of hazard (matrix combines frequency and severity categories)

<table>
<thead>
<tr>
<th>Severity</th>
<th>Frequency</th>
<th>Catastrophic</th>
<th>Critical</th>
<th>Marginal</th>
<th>Negligible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent</td>
<td>1</td>
<td>3</td>
<td>7</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Probable</td>
<td>2</td>
<td>5</td>
<td>9</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Occasional</td>
<td>4</td>
<td>6</td>
<td>11</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Remote</td>
<td>8</td>
<td>10</td>
<td>14</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Improbable</td>
<td>12</td>
<td>15</td>
<td>17</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

1 = Highest priority, 20 = Lowest priority

Hazard Control Priority

Reduce Hazards by:

1. **Source** - designing out a hazard
   - Baby items too large to swallow
2. **Path** - barrier or safeguard
   - Guard on back of lawnmower to protect toes
3. **Person** - change behavior with training or warnings
   - Warning: fan blades can turn on while engine is off
4. **Administrative controls** - rules mandating behavior
   - Must wear safety belts

Safety Analysis

Sequence for identifying potential hazards and recommendations for hazard reduction: (Weinstein et al. 1978)

1. **Task Analysis** - How will product be used?
2. **Environment Analysis** - Where will product be used?
3. **User Analysis** - Who will use product?
4. **Hazard Identification** - What is likelihood of hazard with product?
5. **Generate Methods for Hazard Control** - What might eliminate hazards?
6. **Evaluate Alternatives** - How will alternative designs affect product performance?
7. **Select Hazard Control** - Given alternatives, what is best design to minimize hazards?
Hazard Identification

Methods for identifying potential hazards:

- **Preliminary Hazard Analysis**
  - simplest method
  - Development of a list of the most obvious hazards

- **Failure Modes and Effects Criticality Analysis (FMECA)**
  - Breaking down of physical system into subassemblies
  - Each subassembly is broken down further and each component is analyzed
  - Effect of each component's failure on other components is estimated

- **Fault Tree Analysis**
  - Top-down process
  - Works from incident to possible causes

Accident Investigation

Fact-Finding (OSHA recommendations)

- Interview witnesses as soon after accident as possible
- Inspect accident site before changes occur
- Take photos/sketches of scene
- Record all pertinent data on maps
- Get copies of all reports
- Obtain documents containing normal operating procedures/maintenance charts, reported abnormalities
- Keep complete accurate notes in bound notebook
- Record pre-accident conditions, accident sequence, post-accident conditions
- Document location of victims, witnesses, machinery, energy sources, and hazardous materials

Accident Investigation

Levels of Causes

<table>
<thead>
<tr>
<th>BASIC CAUSES</th>
<th>Management Safety Policy &amp; Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Personal Factors</td>
</tr>
<tr>
<td></td>
<td>Environmental factors</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INDIRECT CAUSES (SYMPTOMS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsafe Act</td>
</tr>
<tr>
<td>Unsafe Condition</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DIRECT CAUSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unplanned Release of Energy And/or Hazardous Material</td>
</tr>
</tbody>
</table>

ACCIDENT
| Personal Injury |
| Property Damage  |
Safety Programs

1. Identify risks to the company
   - identify hazards, hazard controls, accident frequency, & company losses due to accidents/incident claims

2. Implement safety programs, includes:
   - management involvement, accident investigation, recommendations for equipment, safety rules, personal protective equipment, employee training, safety promotion

3. Measuring program effectiveness
   - evaluated by assessing changes in safety behaviors, accident/incident rates, number of injuries or death, and number of days off due to injury

Risk-Taking and Warnings

- Risk-Taking as a Decision Process
  - People must know a hazard exists, know what actions are available, & know the consequences of the safe behavior vs. alternative behaviors

- Written Warnings and Warning Labels
  - Accurately convey the hazards of a product
  - Should include a signal word, info pertaining to the hazard, consequences, & necessary behavior
    - Danger: Immediate hazard likely results in severe injury
    - Warning: Hazard could result in injury
    - Caution: Hazard or unsafe use may result in minor injury