Liberty Mutual Research Institute for Safety

generating knowledge to help people live safer and more secure lives

Mission:
to advance scientific, business-relevant knowledge in workplace and highway safety, and work disability

- Center for Injury Epidemiology
- Center for Physical Ergonomics
- Center for Behavioral Sciences
- Center for Disability Research
Overview

- VIMS overview
- Perceptual-motor disruptions following exposure to VEs
- Prevalence and costs associated with falls in society
- At risk populations
- Mitigation techniques
- Research directions

Intent is to raise awareness of the potential safety implications of VE-induced perceptual-motor disturbances
Visually-Induced Motion Sickness (VIMS)

- The occurrence of motion sickness-like symptoms in the absence of any physical motion
- Frequently occurs with exposure to compelling visual representations of motion (vection)
- Many symptoms in common with “traditional” motion sickness
  - Nausea, vomiting, dizziness, ataxia, etc.
- Other symptoms unique to VIMS
  - Headache, eyestrain and long-term aftereffects
- First reports of occurrence in flight simulators in the mid-1950s

The potential for injurious falls during and after usage is a particularly critical concern from a safety perspective.
Potential Causal Factors

- Vection illusions
  - Wide field of view, moderate levels of detail (spatial frequency), oscillatory motion in the 0.2 Hz frequency range
  - Visual-vestibular interactions – vestibular activity is recruited by visual motion inputs – decorrelated visual-vestibular inputs may promote disorientation, sickness, etc.

- Spatiotemporal lags and asynchronies
  - Disruptions in the normal perception-action cycle
  - Usually caused by computation/update delays subsequent to movements and control inputs

- Vast individual differences (inter- and intra-)

- Frequency and amplitude of off-axis head motions (i.e., Pseudo-Coriolis Effect)

System ‘realism’ is often an issue – too much or too little
A Perception-Action Cycle Theory of VIMS

- The relationship between perception and action is ordinarily:
  - Predictable
  - Linear
  - Consistent
  - Refined by experience

- Any disruption to an otherwise invariant perception-action cycle is:
  - Disruptive to both elements of the cycle
  - Initiates a process of adaptation
  - Disorienting – possibly resulting in sickness

- Simulators and virtual environments can disrupt the cycle:
  - Amenable to adaptation under certain circumstances, less so under others

“Action is simply the control of perception.”
-- Dean H. Owen

The key to managing the VIMS problem may involve intelligent management of adaptation and re-adaptation.
The “Cost” of Adaptation

Improved adaptation to the rearranged sensory world of the simulator comes at the cost of having to re-adapt to the non-virtual world – increased susceptibility to falls.
# Unintentional Injuries

## 10 Leading Causes of Nonfatal Unintentional Injury, United States

2009, All Races, Both Sexes, Disposition: All Cases

To obtain the percentage of all injuries by cause, select the age group category at the top of each column.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Age Groups</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;1</td>
<td>1-4</td>
<td>5-9</td>
<td>10-14</td>
<td>15-24</td>
<td>25-34</td>
<td>35-44</td>
<td>45-54</td>
<td>55-64</td>
<td>65+</td>
</tr>
<tr>
<td>1</td>
<td>Unintentional Fall</td>
<td>147,280</td>
<td>Unintentional Fall</td>
<td>955,381</td>
<td>Unintentional Fall</td>
<td>631,381</td>
<td>Unintentional Fall</td>
<td>615,145</td>
<td>Unintentional Fall</td>
<td>791,629</td>
</tr>
<tr>
<td></td>
<td>Unintentional Struck by/Against</td>
<td>31,300</td>
<td>Unintentional Struck by/Against</td>
<td>372,402</td>
<td>Unintentional Struck by/Against</td>
<td>406,045</td>
<td>Unintentional Struck by/Against</td>
<td>574,267</td>
<td>Unintentional Struck by/Against</td>
<td>1,027,646</td>
</tr>
<tr>
<td></td>
<td>Unintentional Other Bite/Sting</td>
<td>10,922</td>
<td>Unintentional Other Bite/Sting</td>
<td>137,352</td>
<td>Unintentional Other Bite/Sting</td>
<td>104,940</td>
<td>Unintentional Other Bite/Sting</td>
<td>72,885</td>
<td>Unintentional Overexertion</td>
<td>276,076</td>
</tr>
<tr>
<td>4</td>
<td>Unintentional Fire/Burn</td>
<td>8,880</td>
<td>Unintentional Cut/Pierce</td>
<td>94,095</td>
<td>Unintentional Cut/Pierce</td>
<td>92,288</td>
<td>Unintentional Cut/Pierce</td>
<td>118,095</td>
<td>Unintentional Overexertion</td>
<td>703,809</td>
</tr>
</tbody>
</table>

**Centers for Disease Control – Emergency room visits only**
Wade et al (1995): Older adults show significantly higher postural sway in response to optical flow in moving rooms

Chang et al (Under Review): Children have higher levels of postural sway activity than adults in response to immersive video games
Growing proportion of 60+

Older Population by Age: 1900-2050 - Percent 60+, Percent 65+, and 85+
Mitigations and Research Needs

- To the greatest extent possible, systems should be designed to guard against VIMS and loss of postural control
- System usage variables (e.g., length of exposure, kinematics) should be monitored
- Valid and reliable prediction techniques for at risk individuals developed and consistently employed
  - E.g., Smart, Stoffregen & Bardy (2002) – Pre-exposure postural sway
- Increase understanding of adaptation and re-adaptation
  - A decrease in sickness over time during usage may come at the cost of increased risks of falls after usage
  - Development of guidelines for post-exposure re-adaptation latency
- Pre-exposure warnings and screening
  - E.g., “You must be this stable to ride the Virtual Pterodactyl”
- Post-exposure monitoring and debriefing of users
- We need better data on post-exposure postural sway and frequency severity of falls.
Postural Adaptation to Rearranged Perception-Action Relationships

- What is the time frame and course of adaptation – and re-adaptation – in response to altered perception-action couplings?
  - Performance of simple tasks (pointing, placing, throwing, etc.) in conjunction with varying degrees of disrupted visual input (lenses, prisms, helmet-mounted displays, etc.)
  - Does increased adaptation (in the form of improved task performance) correspond to improved control of posture? Same for re-adaptation
  - Does the extent of P-A Cycle disruption correspond to increased variance in postural sway (during and after adaptation sessions)?
  - Does posture adapt before, along with or after “finer” motor behaviors? And what, if any, correlation with sickness is observed.
  - Etc.
Other Safety & Liability Concerns

- Photic Seizures
  - Epileptic events caused by flashing light in the 1-10 Hz range (sometimes observed at higher frequencies)
  - Affects ~1.1 of every 10,000 people
  - Characterized by periods of “absence” – awake, but no response
    - Sometimes (rarely) progresses to generalized convulsions
  - Repeated photic seizures can lead to brain damage and lowered threshold to photic stimuli
    - Japan – TV cartoon with alternating red and blue frames at 12 Hz
      - Hundreds of Japanese children had absence attacks as a result

- Other issues
  - Stress and trauma effects from highly realistic immersion experiences
  - Slips, trips and falls upon encountering unseen hardware
Conclusions

- Simulators and virtual environments have significant, proven societal benefits – they are here to stay, and that’s a good thing

- As with nearly all technologies, there are risks that must be acknowledged and addressed
  - Failure to do so COULD result in issues with liability, worker’s compensation, etc.

- For compelling safety reasons, research must continue to focus on the causes of VIMS and ultimately its prevention

- In the meantime, mitigation is the best approach – but it must be seriously and consistently applied
Generating knowledge to help people live safer, more secure lives.

www.libertymutualgroup.com/researchinstitute