The Effects of Interruptions and Retention Interval on Prospective Memory in Simulated Air Traffic Control

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Air Traffic Control

- Multiple display elements
- Continuous sequence of evolving transient events
- Perform and prioritize multiple safety critical objectives
PM in Air Traffic Control

• Controllers sometimes must defer task actions (PM; Loft, 2014)
  • Defer conflict resolutions (Loft, Sanderson, Neal, & Mooij, 2007)
  • Deviate from standard routine (Loft & Remington, 2010)
  • Habit Capture

• PM Intentions created “on-the-fly” in the midst of other ongoing demands

• Evidence from incident reports, controller interviews, and recently laboratory investigations indicate PM errors do occur.

• We need to understand why to maintain safety (Shorrock, 2005; Dismukes, 2010)

• Recent work has applied theories and methods from PM to simulations of ATC (Fothergill, Loft, & Neal, 2009; Loft, 2014)

• However, the situational contexts which may exacerbate such errors are unclear.
  1. Interruptions?
  2. Retention Interval?
Role of Interruptions

• Interruptions and concurrent task demands ubiquitous in ATC
• Interruptions linked with several forms of memory errors – including PM errors (Einstein et al., 2003; Bowden, 2017)
• PM and interruptions are closely related constructs:
  • Interruptions can create PM tasks (Dodhia & Dismukes, 2009)
  • Interruptions necessitate remembering to ‘come back’
• Prediction: Interruptions should decrease PM performance
Retention Interval

• In ATC, length of retention intervals varies – but typically short (Shorrock, 2005)
• Mixed results of RI
  • Particularly for filler task duration
  • Retention intervals range from 30s to weeks
• Longer retention interval within ongoing task does negatively affect PM (Martin, Brown, & Hicks, 2011)
• Prediction: longer retention intervals decrease PM
Preparation and Recovery Time Hypotheses

• Benefit of time to consolidate intention prior to interruption (Trafton et al., 2003; Dodhia & Dismukes, 2009)
• Benefit of time to recover from interruption (Boehm-Davis & Remington, 2009)
• More time beneficial?
ATC Lab (Fothergill, Loft, & Neal, 2009)
Design

- 78 undergraduate students; after exclusions $n = 70$
- 32, 5-minute ATC scenarios over 2 days
- 2 (encoding time) x 2 (retrieval time) x 2 (interruption)
- Interruption was an additional 27s ATC sector

<table>
<thead>
<tr>
<th>Encode (before)</th>
<th>Retrieve (after)</th>
<th>Retention Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>L: 50s</td>
<td>L: 40s</td>
<td>117 (LL)</td>
</tr>
<tr>
<td>L: 50s</td>
<td>S: 0s (Immediate)</td>
<td>77 (LS)</td>
</tr>
<tr>
<td>S: 10s</td>
<td>L: 40s</td>
<td>77 (SL)</td>
</tr>
<tr>
<td>S: 10s</td>
<td>S: 0s (Immediate)</td>
<td>37 (SS)</td>
</tr>
</tbody>
</table>
Press the [SPACE] key to begin the experiment.
Statistical Analysis

• Generalized linear and linear mixed-effects models using R lme4 package (R Core Team, 2017; Bates, Mächler, Bolker, & Walker, 2015)
• Tested full model to partial model without fixed-effect of interest using chi-square tests on the log-likelihoods
• A maximal random effects structure was specified where possible (Barr, Levy, Scheepers, & Tily, 2013)
• PM/Habit-capture error defined as pressing H instead of required arrow key
Response Time Overall

Three-way interaction
$\chi^2(4) = 2.55, p = .63$

Main Effect Interruption
$\chi^2(1) = 5.61, p = .017$

<table>
<thead>
<tr>
<th>B</th>
<th>CI</th>
<th>P</th>
<th>R2 (Total)</th>
</tr>
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<tbody>
<tr>
<td>-121.45</td>
<td>-226.89 – -16.01</td>
<td>.028</td>
<td>.321%</td>
</tr>
</tbody>
</table>
Preparation and Recovery Hypothesis

Three-way interaction
\[ \chi^2(3) = 3.359, \ p = .33 \]

No evidence that allowing preparation or recovery time mitigates the effect of interruption

Therefore, error analyses collapsed into the simpler model of just retention interval.
## Interruption and Retention (Errors)

<table>
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<tr>
<th>Retention Interval Model: Linear Trend</th>
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<tbody>
<tr>
<td><strong>Odds Ratio</strong></td>
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<tr>
<td>1.48</td>
</tr>
</tbody>
</table>

Interruption x Retention Interval
\[ \chi^2(1) = 0.15, \ p = .19 \]

Interruption
\[ \chi^2(1) = 0.15, \ p = .70 \]

Retention Interval
\[ \chi^2(2) = 20.998, \ p = < .001 \]
Summary of Findings

• Interruptions increase RT – resumption lag
• No effect of interruption on Errors
  • Encoding PM during OT encouraged spontaneous processes/reactive control
  • Perhaps interruptions only impact proactive control
  • Test encoding of intention at start of experimental session
• No effect of consolidation/recovery
  • Likely due to lack of interruption effects
• Increasing retention increases errors
  • Consistent with retrospective memory research (Wixted & Ebbeson, 1991)
Human Factors Implications

- Minimise occurrence of longer retention intervals
- Display aids
- Automation systems
- Job design