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

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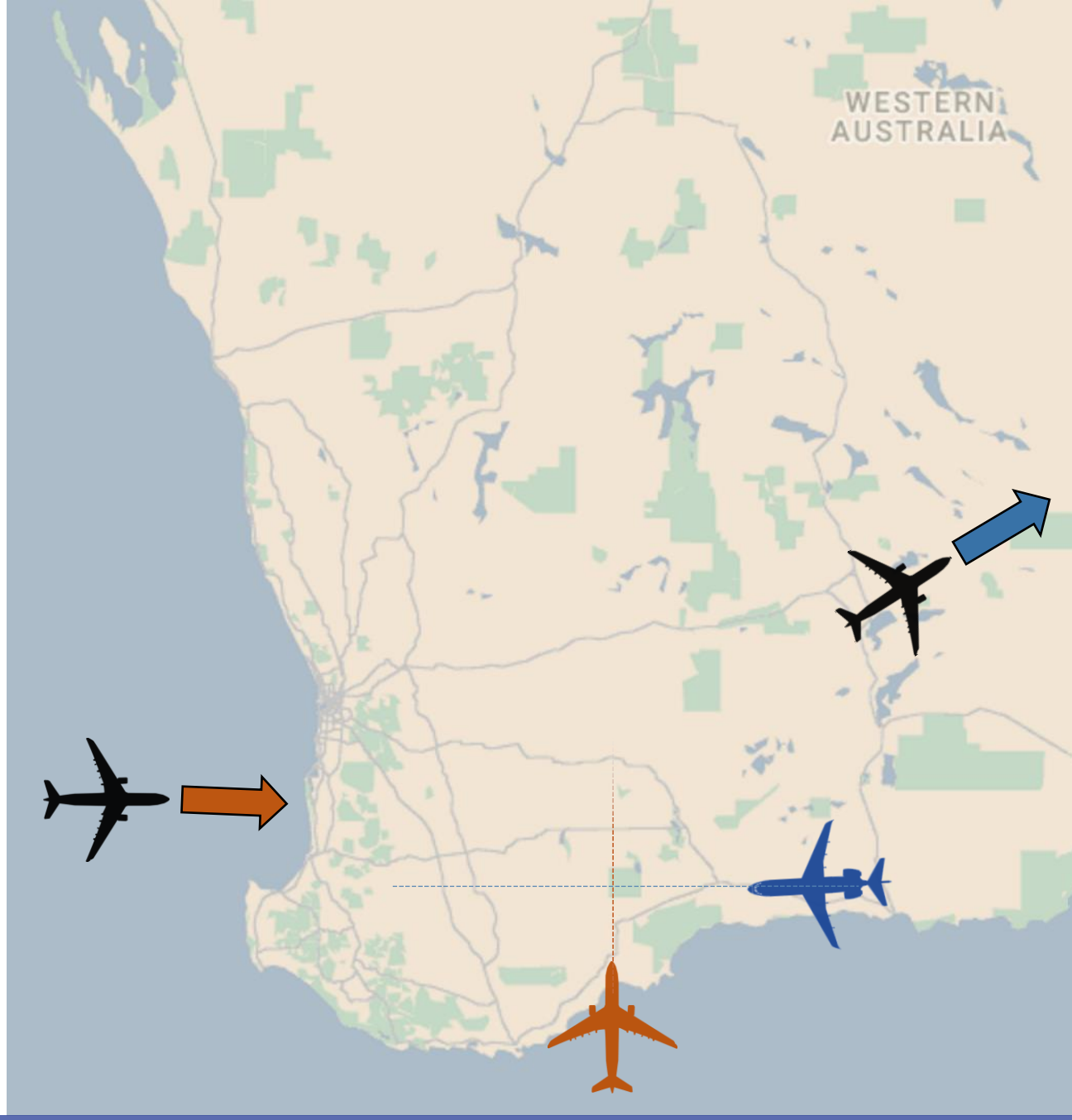
Air Traffic Control

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

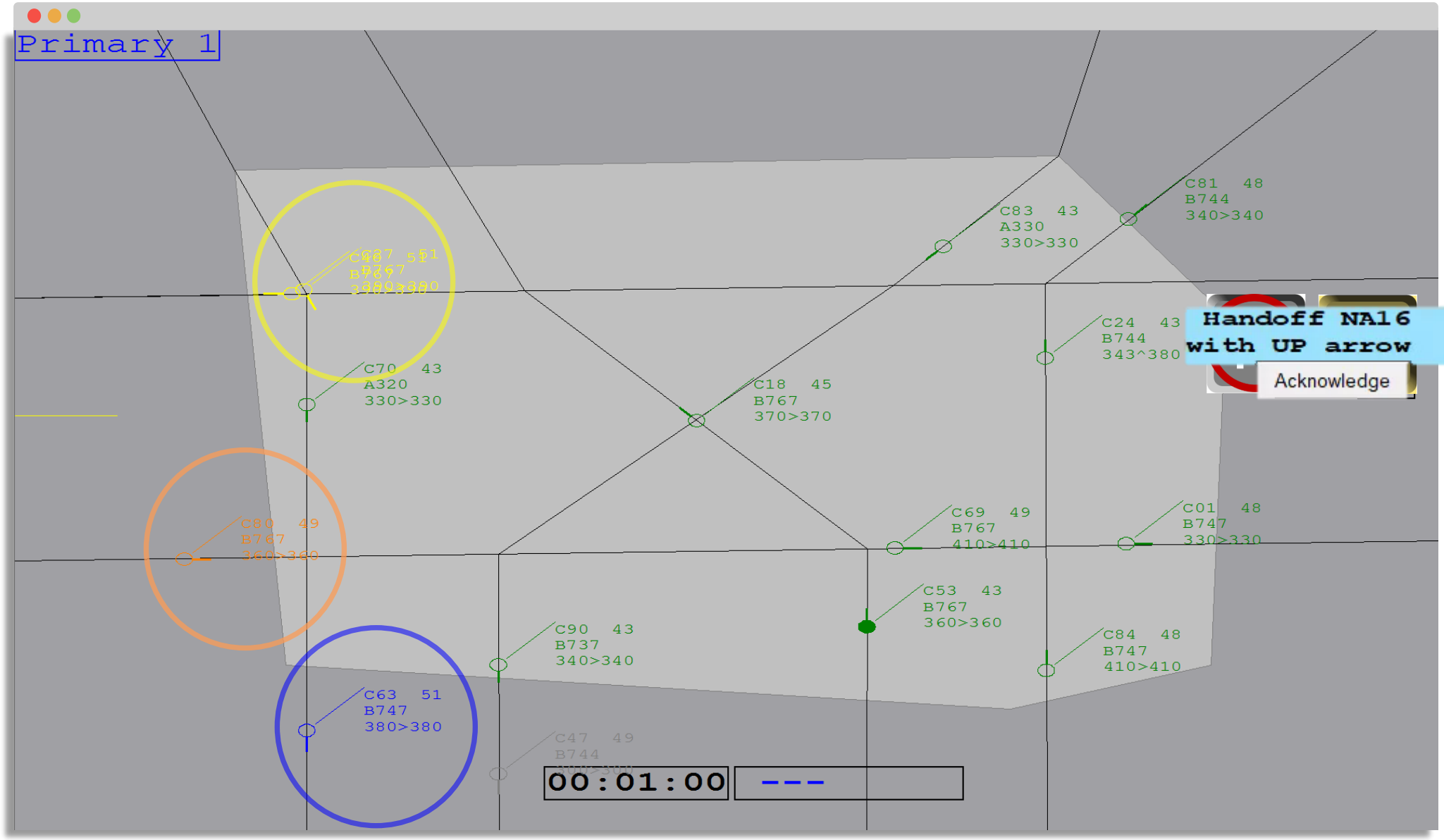
- **Interruptions and concurrent task demands ubiquitous in ATC**
- Interruptions linked with several forms of memory errors – including PM errors (Einstein et al., 2003; Bowden, 2017)
- PM and interruptions are closely related constructs:
  - Interruptions can create PM tasks (Dodhia & Dismukes, 2009)
  - 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

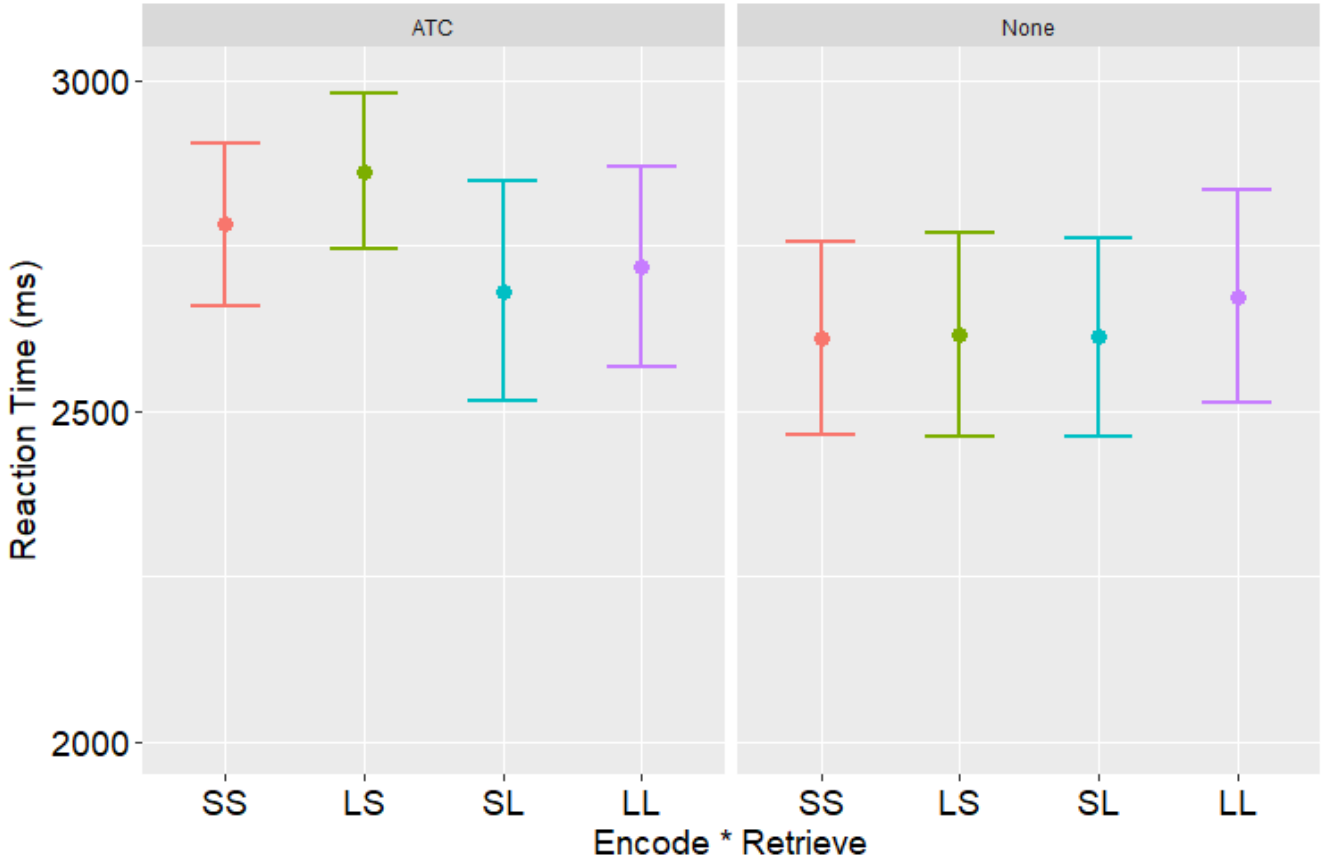
Encode (before)	Retrieve (after)	Retention Interval
L: 50s	L: 40s	117 (LL)
L: 50s	S: 0s (Immediate)	77 (LS)
S: 10s	L: 40s	77 (SL)
S: 10s	S: 0s (Immediate)	37 (SS)

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

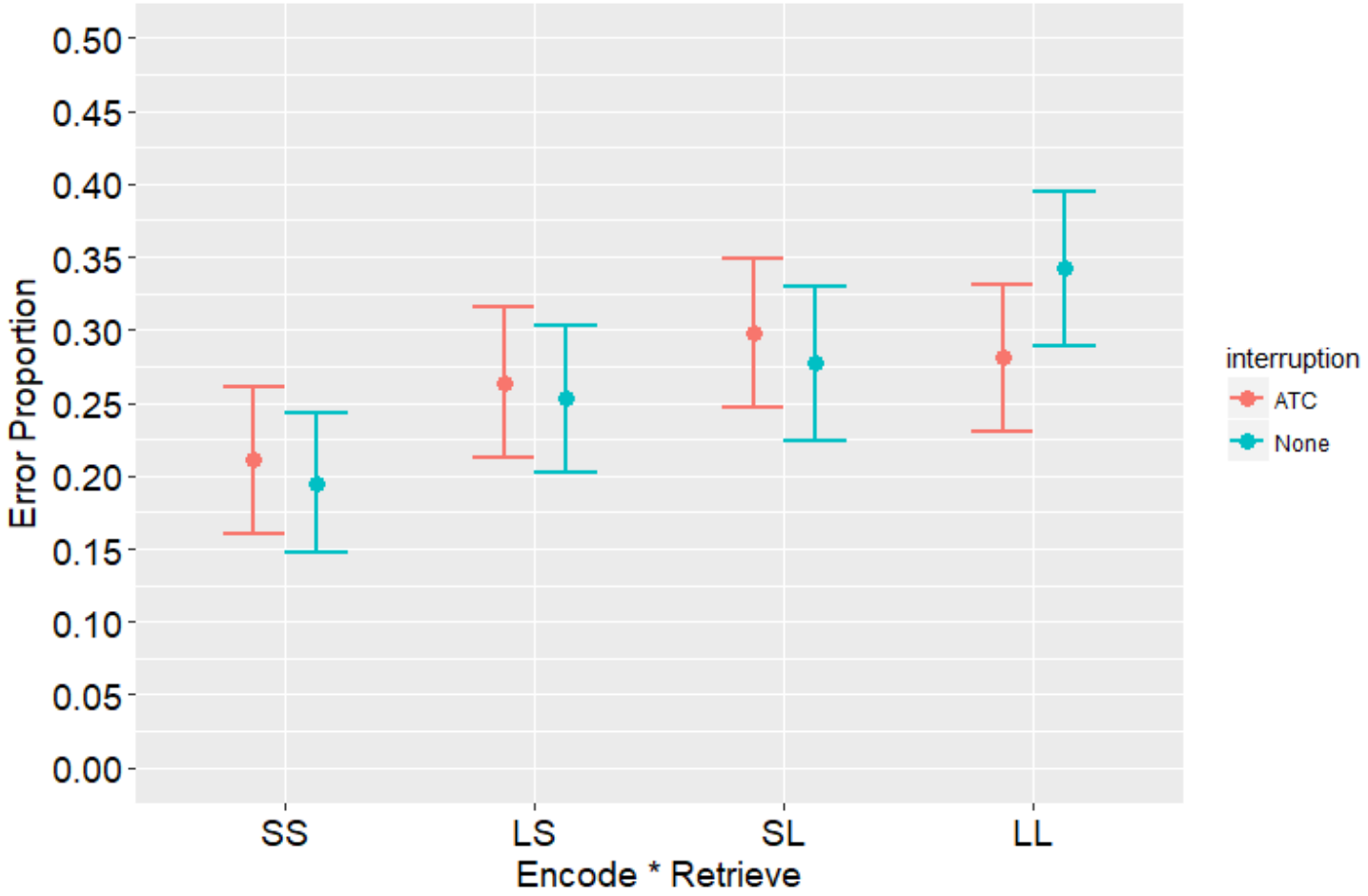
$\chi^2(4) = 2.55$, $p = .63$

Main Effect Interruption

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

B	CI	p	R2 (Total)
-121.45	-226.89 – -16.01	.028	.321%

Preparation and Recovery Hypothesis

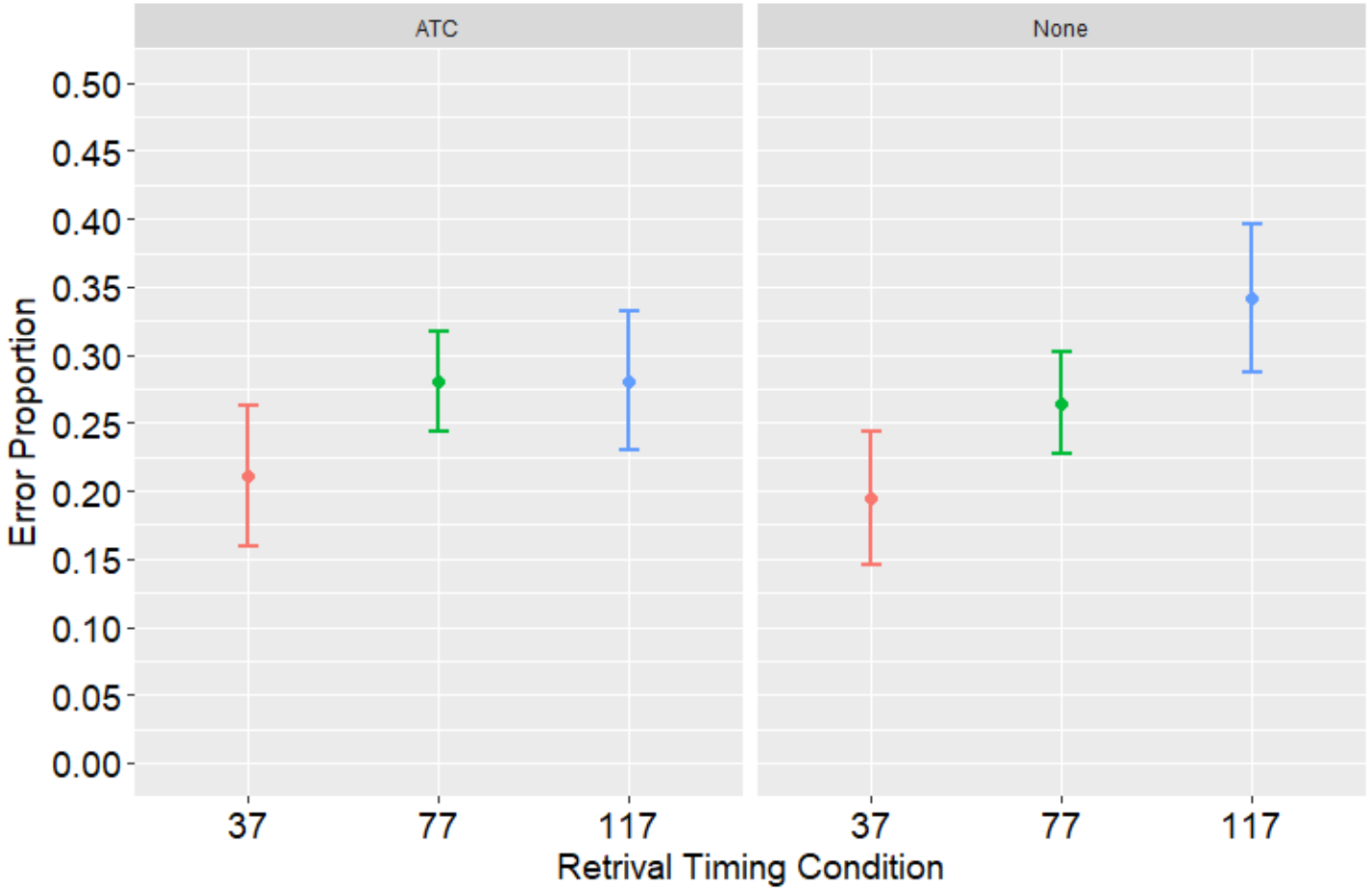


Three-way interaction
$\chi^2(3) = 3.359$, $p = .33$

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)



Interruption x Retention Interval

$\chi^2(1) = 0.15$, $p = .19$

Interruption

$\chi^2(1) = 0.15$, $p = .70$

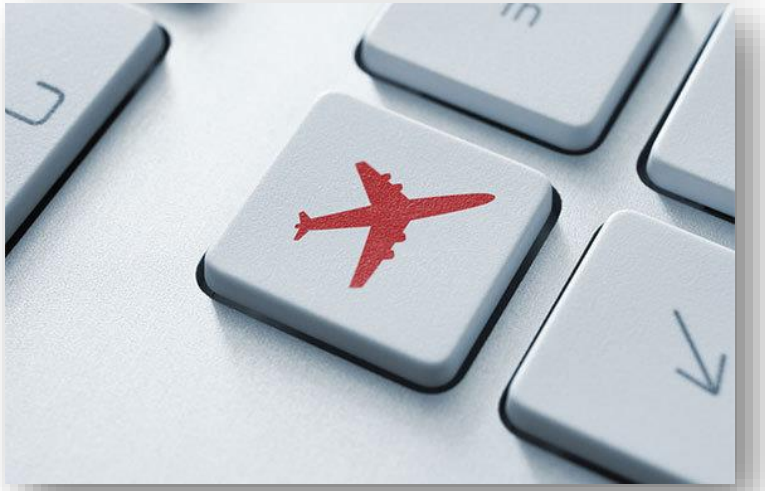
Retention Interval

$\chi^2(2) = 20.998$, $p = < .001$

Retention Interval Model: Linear Trend

Odds Ratio	CI	p	Tjur's D
1.48	1.14-1.92	.003	19.2%

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