The Problem State Resource : A Cognitive Bottleneck in Multitasking

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INTRODUCTION

- The main challenge of multitasking theories is predicting when and how tasks interfere.
- Based on **Threaded Cognition Theory**, interference is predicted when 2 or more tasks require a problem state.
- In the following experiment, a subtraction task and a text entry task have to be carried out simultaneously.
- Both the tasks have two versions: one that requires a **problem state** (**PS**)and one that doesn't.
- A significant over-additive interaction effect is observed showing interference between task was maximal when both the tasks require a problem state.
- To account for the observed behavior a computational cognitive model is built which confirms that PS bottleneck can explain the interference.

Theory

Threaded Cognition Theory

[Salvucci and Taatgen '08]

- An integrated theory of multitasking in which every task is represented by a thread.
- A thread associated with the goal of a task uses knowledge (e.g. declarative, procedural etc.) and resources to accomplish it.
- While the threads can act in parallel they are constrained by available resources which act serially in themselves

Problem State Resource

[Borst et al '10]

- Information in the problem state resource is directly accessible
- For instance while mentally solving $3x - 8 = 4$, the problem state can be used to store the intermediate solution $3x = 12$.
- If the information is present in the world it is not necessary to maintain a problem state.
- The concept arose from a series of blood oxygen level dependent activity in posterior parietal cortex that correlates with the transformation of mental representations [Anderson '05]
- If two tasks are competing for PS then the theory proposes moving the information to declarative memory. [Borst et al 10]

Experiment

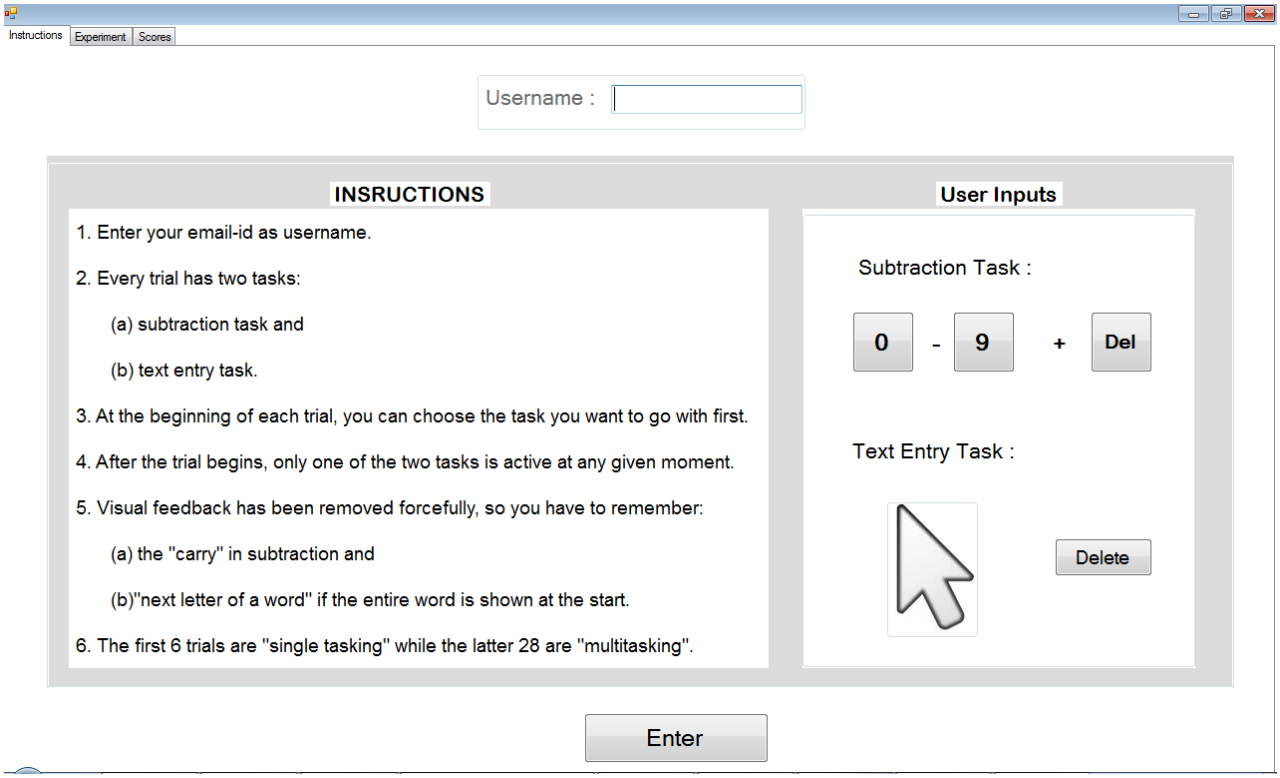


Fig 1: Instruction page for experiment. Participants had 10 trial runs before the real experiment began.

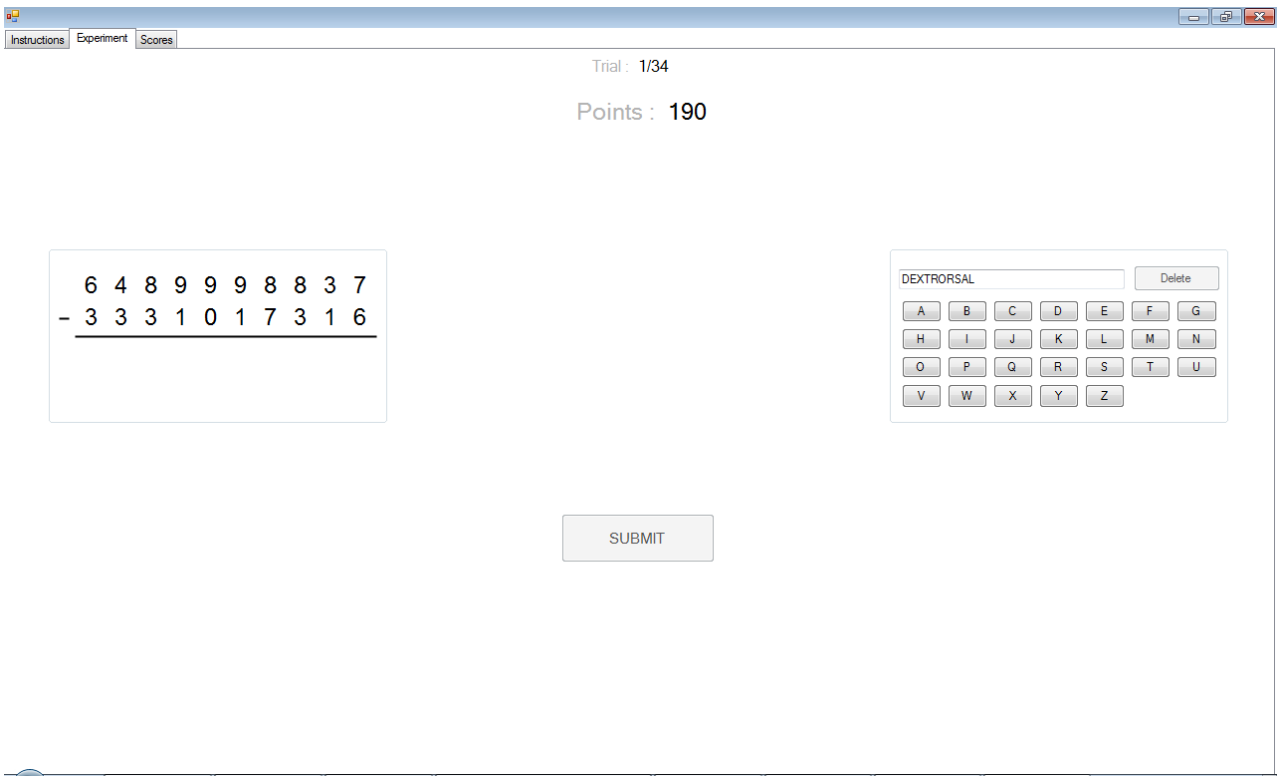
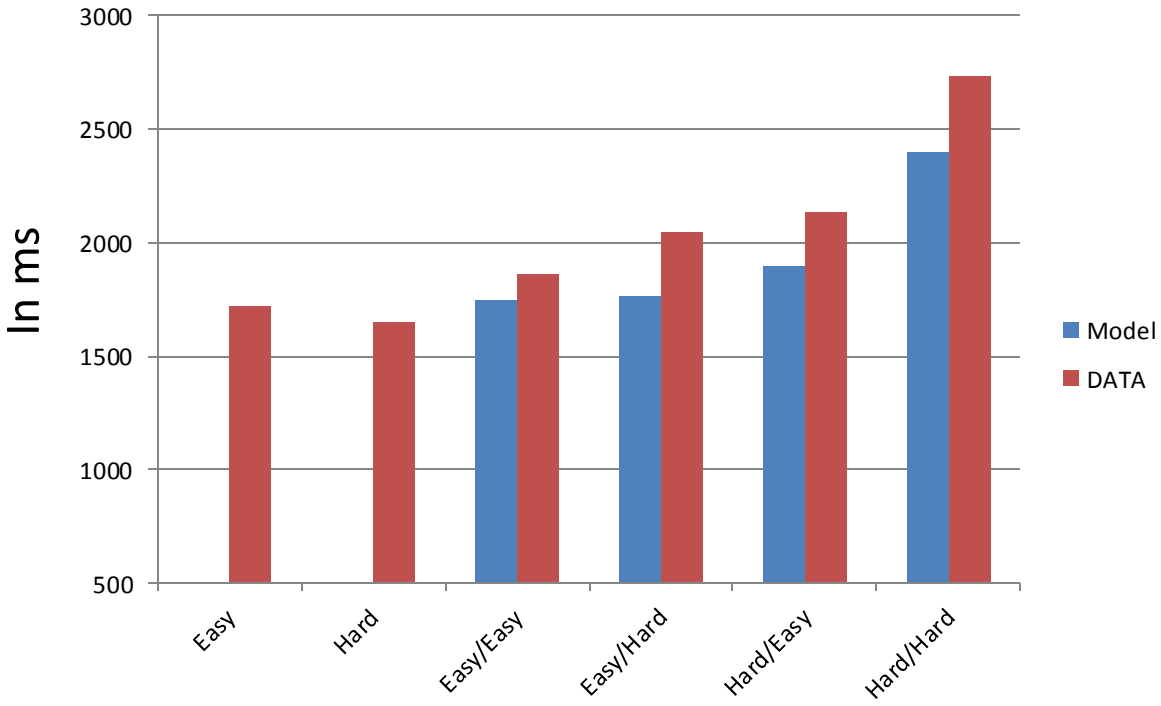


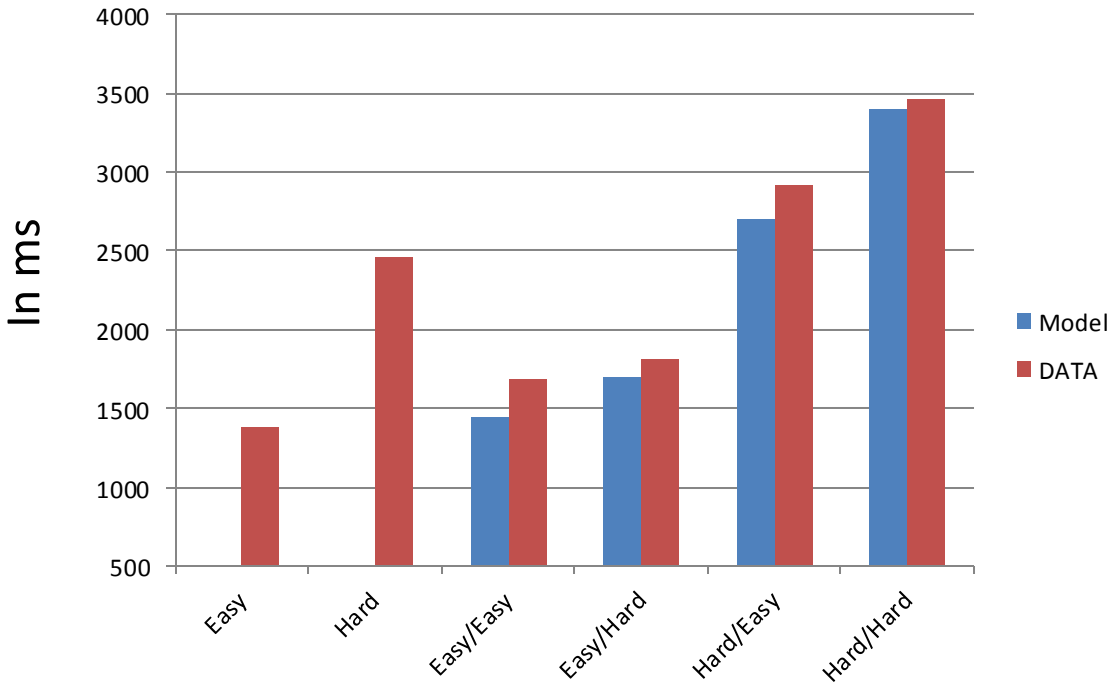
Fig 2: Trial page as shown on a 19" monitor. The width of both the subtraction interface and text entry measures 9cm, the separation between the two tasks is 10cm and the height of the interfaces is 4.8cm.

Results and Analysis

Text Entry RT



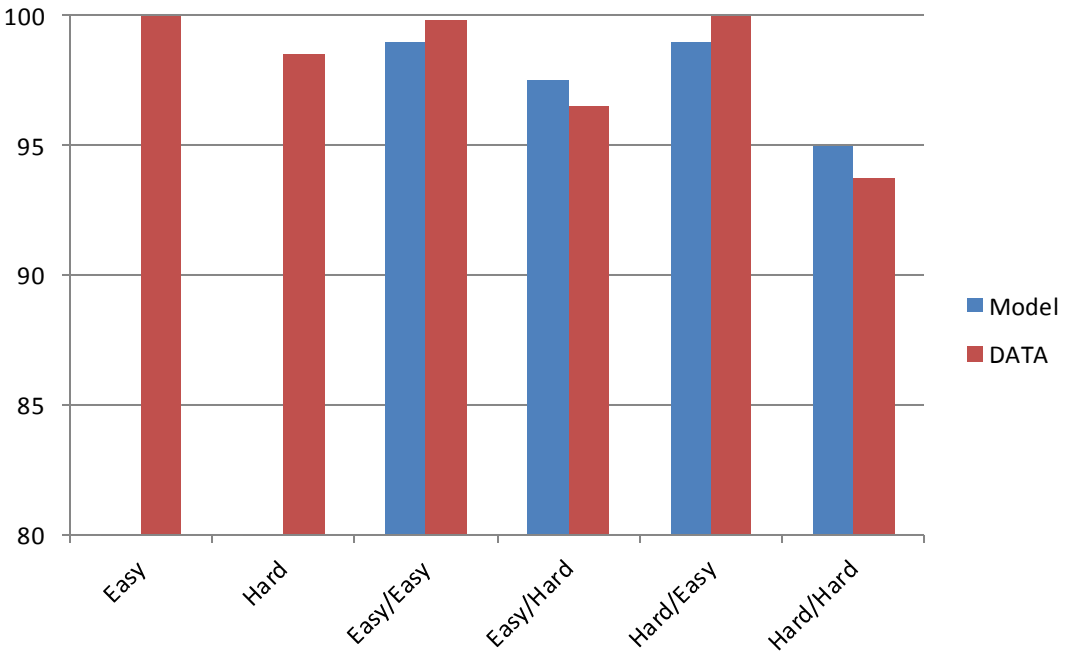
Subtraction RT



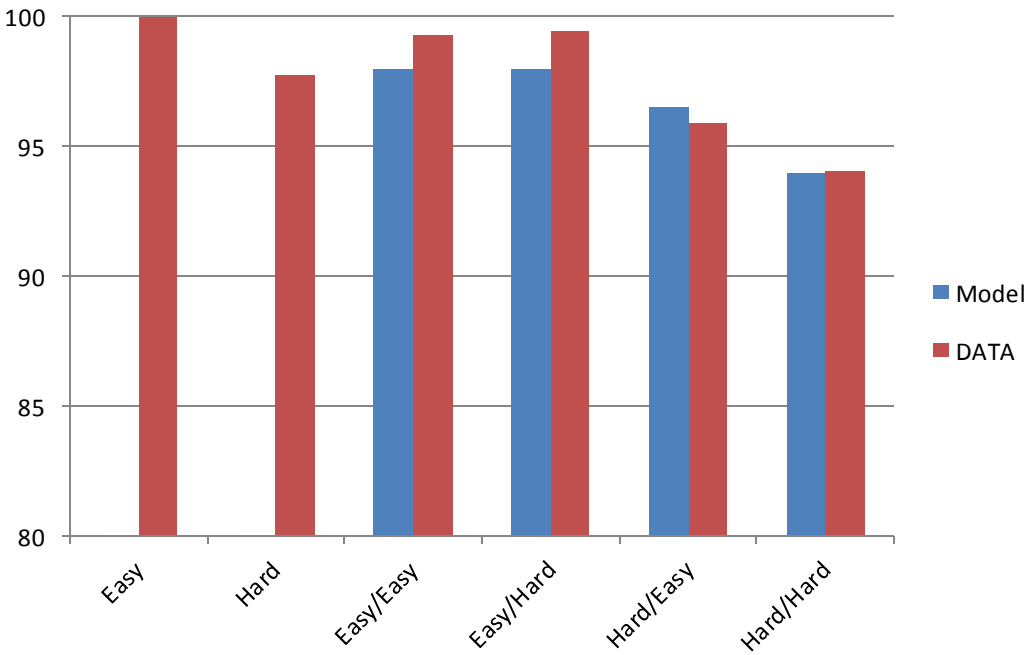
NOTE: Model is computational model in ACT-R [Borst et al '10]

Results and Analysis

Text Entry Accuracy



Subtraction Accuracy



Results and Analysis

ANOVA: Analysis of Variance (F,p)

- Is used to study interaction effects with multiple factors and levels
- It verifies the validity of the **null hypothesis**: the mean of all groups is equal
- F-statistic is indicative of the validity of the null hypothesis
- p is indicative of the probability of value of F given the null hypothesis

	S and T	S - hard	T-hard	S-easy	T-easy
F (Exp)	23.2	33.59	97.2	5.21	4.2
F(Paper)	22.15	10.78	47.16	1.88	0.14
P(Exp.)	<0.01	<0.01	<0.01	<0.001	0.015
P(Paper)	<0.01	<0.01	<0.01	<0.001	0.09

Fig 7: ANOVA analysis for Text Entry RT

References:

[1] Borst, Jelmer P., Niels A. Taatgen, and Hedderik van Rijn. "The problem state: A cognitive bottleneck in multitasking." *Journal of experimental psychology. Learning, memory, and cognition* 36.2 (2010): 363.

[2] Borst, J. P., and N. A. Taatgen. "The costs of multitasking in threaded cognition." Proceedings of the Eighth International Conference on Cognitive Modeling. 2007.

[3] Anderson, John R. "ACT: A Simple Theory of Complex Cognition John R. Anderson." *Cognitive modeling* 49 (2002).