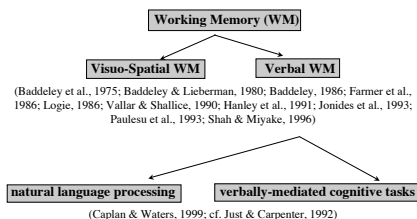


WM Background



Dual-Task Approach

Participants perform two tasks simultaneously:

- on-line sentence processing
- a non-linguistic verbally-mediated task.

Assumption:

We should observe a super-additive interaction when the complexity of both tasks is high *only if* the two tasks rely on overlapping pools of resources.

Previous dual-task experiments found either no interaction, or only a suggestion of one (e.g. King & Just, 1991; Just & Carpenter, 1992; Caplan & Waters, 1999; Gordon et al., 2002).

The secondary task usually involved storage of words/digits across the sentence processing task. Maybe the lack of interaction is due to the fact that storage involved in language processing is *qualitatively different* from storage involved in keeping track of lists of unconnected items?

WM in Sentence Comprehension

Dependency Locality Theory (DLT)

Gibson 1998, 2000

Two WM components are required for sentence comprehension:

- **Storage:** keeping track of partially processed syntactic dependencies
- **Integration:** connecting a newly input word into the structure that has been built thus far

Motivations

- (1) Inconclusive results reported by King & Just (1991) and Just & Carpenter (1992).
- (2) Lack of interactions in the dual-task experiments could be due to the distinctness of the storage processes involved.
- (3) No previous attempts to explore the potential interaction between integration processes in sentence comprehension and secondary tasks involving similar but non-linguistic on-line integration processes.

Experiment 1

Method

- Participants - 40 subjects
- Design - 2 x 2
- Factors:
 - syntactic complexity (subject/object-extracted relative clauses (RCs))
 - arithmetic complexity (simple additions, complex additions)

Materials

- **Language materials** - 32 sets of sentences (each with four versions as shown below)
 - Subject-extracted (easy), version 1:* The janitor who frustrated the plumber lost the key on the street.
 - Subject-extracted (easy), version 2:* The plumber who frustrated the janitor lost the key on the street.
 - Object-extracted (hard), version 1:* The janitor who the plumber frustrated lost the key on the street.
 - Object-extracted (hard), version 2:* The plumber who the janitor frustrated lost the key on the street.
- **Math materials** - randomly generated online for each participant with the following constraints:

Easy-math: initial addend 1-10, subsequent addends 1-3
Hard-math: initial addend 11-20, subsequent addends 4-6

Procedure



- self-paced region-by-region reading with a moving window display;
- each sentence had four regions (2nd region was the critical region);
- the addition task was presented above the sentence fragments simultaneously.

Sample Item (Low Syntactic Complexity/ Easy Math)

6
The janitor -----
----- +2
----- who frustrated the plumber -----
----- +1
----- lost the key -----
----- +3
----- on the street.

Type in the sum:

- Q1: The janitor frustrated the plumber. T or F?
Q2: The plumber lost the key on the street. T or F?

Experiment 2

Method

- Participants - 24 subjects
- Design - 2 x 2
- Factors:
 - syntactic complexity (subject/object-extracted relative clauses (RCs))
 - complexity of the spatial-rotation task (simple rotations, complex rotations)

Materials

- **Language materials** - 32 sets of sentences (each with four versions as shown below) Same as in Experiment 1.
- **Spatial task materials** - randomly generated online for each participant with the following constraints:

Easy condition: angles 5-90 degrees
Hard condition: 30-180 degrees

Procedure

Identical to Experiment 1.

Sample Item (Low Syntactic Complexity/ Easy Spatial Task)

Move the mouse to the final summed location direction.
Q1: The janitor frustrated the plumber. T or F?
Q2: The plumber lost the key on the street. T or F?

Experiment 1 - Conclusions

When both tasks are difficult (as in region 2 where both syntactic and arithmetic complexity are manipulated), there is an *additional cost* that is higher than would be predicted if the two tasks relied on independent resource pools.

On-line sentence comprehension and on-line arithmetic processing must rely on *overlapping pools of WM resources*.

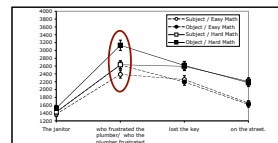
Experiment 1 - Alternative Interpretation

The observed interaction could be due to *shared attentional resources* (task-switching).

- Language and arithmetic processing rely on independent WM resource pools.
- Resources are required to switch between the two tasks.
- In the difficult conditions, either (1) the switches are more difficult, or (2) more switches are required.

Results & Conclusions

Experiment 1



Reaction Times

-In critical region 2 we observed two main effects and a significant interaction.

- Main effect of **arithmetic complexity**: complex additions slower
(F(1,39)=45.41; p < .001; F2(1,31)=32.49; p < .001).
- Main effect of **syntactic complexity**: object extractions slower
(F(1,23)=43.94; p < .001; F2(1,31)=27.27; p < .001).
- Significant **interaction**
(F(1,39)=4.61; p < .05; F2(1,31)=5.36; p < .05).

Comprehension Question Performance

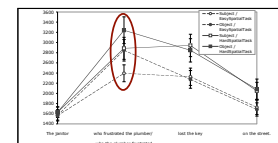
- Across conditions - 79%.
- Main effect of **syntactic complexity**
(F(1,23)=9.65; p < .005; F2(1,31)=4.42; p < .05).
- Marginal effect of **arithmetic complexity** in the subjects analysis
(F(1,39)=3.28; p = .08; F2(1,31)=2.62; p = .12).

Arithmetical Accuracy

- Across conditions - 88.7%.
- Main effect of **arithmetical complexity** (hard math items - lower accuracies)
(F(1,39)=9.45; p < .005; F2(1,31)=7.21; p < .02).

Arithmetic complexity	Linguistic complexity	
	Subject-extraction (Easy)	Object-extraction (Hard)
Easy arithmetic	93.4 (2.0)	89.4 (2.1)
Hard arithmetic	85.6 (2.7)	86.3 (2.2)

Experiment 2



Reaction Times

-In critical region 2 we observed two main effects but NO interaction.

- Main effect of **spatial task complexity**: hard spatial task conditions slower
(F(1,23)=19.97; p < .001; F2(1,31)=5.83; p < .05).
- Main effect of **syntactic complexity**: object extractions slower
(F(1,23)=14.14; p < .005; F2(1,31)=14.79; p < .005)
- No interaction (numerically in the opposite direction)
(F<1. ps>.39)

Comprehension Question Performance

- Across conditions - 83%.
- No significant effects/interactions.

Spatial Task Accuracy

- Across conditions - 30.3 degrees off from the correct answer.
- Main effect of complexity of the **spatial task** (hard spatial task items - lower accuracies)
(F(1,23)=18.36; MSE=2676; p < .0005; F2(1,31)=22.28; MSE=3568; p < .0005)

Spatial Task complexity	Linguistic complexity	
	Subject-extraction (Easy)	Object-extraction (Hard)
Easy rotations	24.5 (1.7)	25.6 (1.8)
Hard rotations	36.4 (2.4)	34.8 (2.2)

How to pull apart the alternatives?

- (1) Tap non-verbal working memory: dual-task experiment with a spatial secondary task. [Experiment 2.]
- (2) Eliminate the dual-task component:
 - test subjects on math and sentence comprehension separately;
 - divide subjects into 2+ groups based on their performance on the math task;
 - look for group by syntactic complexity interaction in the sentence comprehension performance.
 [Work in progress.]

Experiment 2 - Conclusions

The lack of an interaction argues against the attentional account of the interaction observed in Experiment 1.

On-line sentence comprehension and on-line arithmetic processing must rely on overlapping pools of WM resources.

Future Work

What is the exact nature of the overlap in verbal WM resources for sentence comprehension and arithmetic processing?
Maybe both tasks involve exact computations in contrast to the spatial task, which involves approximate computations