Re-examining Evidence for Separate Sentence Processing Resources

Rienk G. Withaar & Laurie A. Stowe *

Waters et al. (1987) Re-examined

**Goal.** Re-examining the evidence for separate working memory systems from a whole-sentence anomaly-judgment experiment reported in Waters, Caplan, & Hildebrandt (1987).

**Manipulations.**

*Propositions*: 1 proposition sentences (1P) vs. 2 proposition sentences (2P)

*Relative Clause*: Subject-relative (SR) vs. object-relative (OR) clauses

*Memory load*: No load vs. load (counting from 1 to 6 out loud)

**Example Sentences.**

1PSR: It was the gangsters that broke into the warehouse.

1POR: It was the broken clock that the jeweller adjusted.

2PSR: The man hit the landlord that requested the money.

2POR: The meat that the butcher cut delighted the customer.

**The Separate Resource Hypothesis.** Waters et al. (1987) argue for separate resources because: a) syntactic and propositional effects did not interact, and b) propositional, but not syntactic complexity, interacted with articulatory suppression (cf. Baddeley, 1986).

**A Possible Confound.** Some of Waters et al.’s (1987) 2P, but none of their 1P sentences contained center-embedded clauses. Thus, the propositional effect may have been syntactic rather than semantic.

**Experiment 1: A Replication without Center-Embedded Clauses**

**Method**

*Subjects.* Thirty-six undergraduate students served as paid subjects (native speakers of Dutch with normal vision).

*Materials.*

1PSR: Het waren de duivels die de schepper vervloekten.

It were the devils who the creator cursed.

‘They were the devils who cursed the creator.’

1POR: Het waren de duivels die de schepper vervloekte.

It were the devils who the creator cursed.

‘They were the devils who the creator cursed.’

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2PSR: Ik bevrijdde de arts die de architecten verborg.
    I freed the doctor\textsubscript{sg} who the architects\textsubscript{pl} hid\textsubscript{sg}.
    ‘I freed the doctor who hid the architects.’

2POR: Ik bevrijdde de arts die de architecten verborgen.
    I freed the doctor\textsubscript{sg} who the architects\textsubscript{pl} hid\textsubscript{pl}.
    ‘I freed the doctor who the architects hid.’

There were 6 targets per condition, divided over 2 lists; all were semantically plausible.

Procedure. Same as Waters et al. (1987: exp. 3). There were 2 blocks: no load vs. load.

Results of Experiment 1

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Mean RTs per Condition}
\end{figure}

\begin{table}[h]
\centering
\begin{tabular}{lcc}
\hline
\textbf{Effect} & \textbf{F1} & \textbf{F2} \\
Proposition & p < .001 & p < .001 \\
Relative Clause & p < .05 & p < .05 \\
Load & p < .05 & p < .001 \\
\hline
\end{tabular}
\caption{RT Analysis: Significant Effects in both F1 and F2}
\end{table}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Mean Error Proportion per Condition}
\end{figure}

\begin{table}[h]
\centering
\begin{tabular}{lcc}
\hline
\textbf{Effect} & \textbf{F1} & \textbf{F2} \\
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\hline
\end{tabular}
\caption{Error Analysis: Significant Effects in both F1 and F2}
\end{table}
Conclusion

The replication of the independent effects of syntactic and propositional complexity without using center-embedded clauses supports a separate resource theory.

Subjects tended to reject ORs due to a mismatch between NP1 and the embedded verb. Unlike Waters et al.’s (1987) subjects, our subjects showed faster reaction times, but higher error rates. This suggests that there is a speed-accuracy trade-off.

The lack of interaction between concurrent articulation and propositional complexity may indicate that Waters et al.’s (1987) interaction is due to center-embedding rather than to propositional complexity.
Experiment 2: SRs vs. ORs and Type of Embedding

Method

Subjects and Procedure. Thirty-two undergraduate students served as paid subjects (same criteria as in experiment 1); the same procedure was used as in experiment 1.

Manipulations.
Embedding: Right-embedded (RE) vs. center-embedded (CE) relative clauses.
Relative Clause: Subject-relative (SR) vs. object-relative (OR) clauses
Memory load: No load vs. load (counting from 1 to 6 out loud)

Materials.
RESR: De studenten prijzen de fotograaf die de uitgevers accepteert.
       The students praise the photographer who the publishers accepts.
       ‘The students praise the photographer who accepts the publishers.’
REOR: De studenten prijzen de fotograaf die de uitgevers accepteren.
       The students praise the photographer who the publishers accept.
       ‘The students praise the photographer who the publishers accept.’
CESR: De fotograaf die de uitgevers accepteert, prijst de studenten.
       The photographer who the publishers accepts, praises the students.
       ‘The photographer who accepts the publishers, praises the students.’
CEOR: De fotograaf die de uitgevers accepteren, prijst de studenten.
       The photographer who the publishers accept, praises the students.
       ‘The photographer who the publishers accept, praises the students.’

Results of Experiment 2

Figure 3. Mean RTs per Condition

Table 3
RT Analysis: Significant Effects in both F1 and F2

<table>
<thead>
<tr>
<th>Effect</th>
<th>F1</th>
<th>F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embedding</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Relative Clause</td>
<td>p &lt; .05</td>
<td>p &lt; .05</td>
</tr>
<tr>
<td>Load</td>
<td>p &lt; .05</td>
<td>p &lt; .001</td>
</tr>
<tr>
<td>Embedding by Load</td>
<td>p &lt; .05</td>
<td>p &lt; .05</td>
</tr>
</tbody>
</table>
Figure 4. Mean Error Proportion per Condition

Table 4

<table>
<thead>
<tr>
<th>Effect</th>
<th>F1 Effect</th>
<th>F2 Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embedding</td>
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</tr>
<tr>
<td>Load</td>
<td>p &lt; .05</td>
<td>ns</td>
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</tbody>
</table>

**Conclusion**

The interaction of embedding by load suggests that Waters et al.’s (1987) interaction of propositional complexity by load is in fact an interaction of embedding by load.

**General Discussion**

The present data offers support for separate resources and extends the model proposed by Caplan and colleagues. Instead of distinguishing a syntactic and a semantic processor, it seems necessary to assume more than two sentence-processing resources.

Present data also resolve a paradox between the data in Waters et al. (1987: exp. 3) and in Caplan, Alpert, & Waters (1998). Caplan et al. (1998) found increased regional cerebral blood flow for 1P vs. 2P in postero-inferior regions. Since concurrent articulation activates anterior brain regions (Vallar, di Betta, & Silveri, 1997), it appears highly unlikely that concurrent articulation and propositional processing are carried out by the same system. Our data show that they do not interact and therefore need not activate the same brain area(s).

**References**