Working memory in young and senior, native and non-native language users

Implications for theory and research
Working memory

Elusive concept:

- Many different theories

- Inconsistent use of terms and labels in the literature:
  - Working memory, verbal working memory, long-term working memory, short-term memory, phonological loop/memory, articulatory loop, central executive
Working memory

(Baddeley 2003)
Working memory

Central executive

Visuo-spatial sketchpad

Episodic buffer

Phonological Loop

Long-term memory

(Baddeley 2003)
Working memory

Phonological loop has two subsystems

(Baddeley 2003)
Working memory

(Baddeley 2003)
Working memory

- Active information processing and management
- Relatively un-domain-specific

(Baddeley 2003)
Working memory

Associated with:
- Passive storage only
- Domain-specific
- Automatic activation of long term memory information.

(Baddeley 2003)
Controversies

- Is there one single resource or do separate resources exist for storage and processing?
  - Single: High processing demands go at the expense of storage and vice versa (e.g., Daneman and Carpenter 1980)
  - Separate: High processing demands do not affect syntactic analysis (Waters and Caplan, 1996)
Controversies

- Is working memory separate from long-term memory?

(Cowan 2005)
Controversies

- Is working memory separate from long-term memory?
  - Cowan 2005: WM information is activated long-term memory knowledge.
  - Individual variation is due to how well someone can activate LTM information, which may be a matter of experience.
Controversies

- How does working memory relate to other cognitive capacities, such as attention, inhibition, and processing speed?

  - The essence of WM is: maintaining attention (Cowan 2005)
  
  - Faster processing leaves more resources for storage (Towse, Hitch, & Hutton 2001)
Controversies

- How do you measure working memory or its subcomponents?

- Is it possible to measure storage and processing functions separately?
Agreement

- Working memory is limited!
  - This is true for all subsystems (central executive, the store, the articulatory loop).
  - There is individual variation in WM capacity.

- If processing is automatic, then WM is not burdened.
Working memory and language

Individual variation in WM capacity can explain individual differences in:

- Linguistic aptness in the L1
  (Daneman & Carpenter, 1980; Just & Carpenter, 1992; Waters & Caplan, 1996, 2005, and so forth...)

- L2 learning ability
  (Service 1992; Service & Kohonen, 1995; Atkins & Baddeley 1998; Gathercole et al 1999; Kormos & Safar 2008)
Working memory and language

The effects of a limited WM capacity should be visible especially:

- When linguistic processing is relatively demanding / effortful (as opposed to undemanding / effortless / automatic)

- For people for whom linguistic processing is relatively demanding / effortful
Today

■ To what extent are these expectations borne out by our data (that compare different kinds of groups)?

■ And what does that mean for the controversies just discussed.
Study 1: Studies in Listening (Stilis)

- 5-year project: NWO small program
  “Towards a theory of second-language proficiency: The case of segmenting and comprehending oral language”

Research team: Jan Hulstijn
Rob Schoonen
Sible Andringa
Catherine van Beuningen
Nomi Olsthoorn
Tineke van der Linde
Netta Meijer
Stilis goals

Identification of components in listening comprehension ability

- **Linguistic knowledge**
  - Phonology, prosody, syntax, semantics; the kind of knowledge that enables segmentation and parsing processes

- **Efficiency in the application of linguistic knowledge**

- **Cognitive factors**
  - Working memory and reasoning ability may moderate the ability to successfully and efficiently construct sentence and discourse meaning
### Study 1: Participants

<table>
<thead>
<tr>
<th></th>
<th>Lower-level education</th>
<th>Higher-level education</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young native speakers (20-35 years)</td>
<td>60</td>
<td>61</td>
<td>121</td>
</tr>
<tr>
<td>Senior native speakers (60-75 years)</td>
<td>63</td>
<td>58</td>
<td>121</td>
</tr>
<tr>
<td>Young non-native speakers (&gt;B1, 20-35 years)</td>
<td>55</td>
<td>63</td>
<td>118</td>
</tr>
</tbody>
</table>
Andringa et al., 2012

Comparison of NSs and NNSs

Listening Comprehension

Linguistic Knowledge
- Segmentation accuracy
- Grammatical processing accuracy
- Receptive vocabulary

Language Processing Speed
- Segmentation RT
- Self-paced listening RT
- Grammatical processing RT
- Semantic processing RT
- Word monitoring RT

Working Memory
- digit span (4 tasks)
- Non-word recognition span

IQ
- Non-verbal reasoning from WAIS III
Van Beuningen et al.,

**Comparison of Young & Senior NSs**

- **Listening Comprehension**
  - Linguistic Knowledge
    - Segmentation accuracy
    - Grammatical processing accuracy
    - Receptive vocabulary
  - Language Processing Speed
    - Segmentation RT
    - Self-paced listening RT
    - Grammatical processing RT
    - Semantic processing RT
    - Word monitoring RT
  - Working Memory
    - digit span (4 tasks)
    - Non-word recognition span
  - IQ
    - Non-verbal reasoning from WAIS III
  - Nonverbal Processing Speed
    - Non-verbal RT
  - Age
Analyses: Structural equation modelling

- Combination of factor analysis and multiple regression

Diagram showing relationships between Listening, Knowledge, Processing Speed, Memory, and IQ variables.
Results: Correlations with Listening Comprehension

<table>
<thead>
<tr>
<th></th>
<th>Young NSs</th>
<th>Young NNSs</th>
<th>Senior NSs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>.75*</td>
<td>.96*</td>
<td>.76*</td>
</tr>
<tr>
<td>Lang. proc. speed</td>
<td>-.65*</td>
<td>-.67*</td>
<td>-.60*</td>
</tr>
<tr>
<td>Working memory</td>
<td>.65*</td>
<td>.32</td>
<td>.52*</td>
</tr>
<tr>
<td>IQ</td>
<td>.42*</td>
<td>.51</td>
<td>.51*</td>
</tr>
<tr>
<td>Age</td>
<td>.10</td>
<td>Not tested</td>
<td>-.19*</td>
</tr>
<tr>
<td>Nonverbal processing speed</td>
<td>.03</td>
<td>Not tested</td>
<td>-.11</td>
</tr>
</tbody>
</table>

at $\alpha < .05$, 2-tailed
## Results: Unique variance explained in Listening comp.

<table>
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<th>Senior NSs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>.61</td>
<td>.95</td>
<td>.68</td>
</tr>
<tr>
<td>Lang. proc. speed</td>
<td>-.46</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Working memory</td>
<td>-</td>
<td>-</td>
<td>.23</td>
</tr>
<tr>
<td>IQ</td>
<td>-</td>
<td>.26</td>
<td>-</td>
</tr>
<tr>
<td>Age</td>
<td>-</td>
<td>Not tested</td>
<td>-.20</td>
</tr>
<tr>
<td>Nonverbal processing speed</td>
<td>-</td>
<td>Not tested</td>
<td>-</td>
</tr>
</tbody>
</table>
## Results: Correlations with WM factor

<table>
<thead>
<tr>
<th></th>
<th>Working Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Young NSs</td>
</tr>
<tr>
<td>Knowledge</td>
<td>.58*</td>
</tr>
<tr>
<td>Lang. proc. speed</td>
<td>-.45*</td>
</tr>
</tbody>
</table>

*at $\alpha < .05$, 2-tailed*
Relevant observations (1)

- WM is correlated to discourse comprehension: replicates many previous studies, but:
  - Correlation is lowest for the NNS
  - Correlation is highest for the Young NS

- WM explains unique variation only for Senior NSs
Study 2: Janse & Andringa (in prep.)

Individual differences in the recognition of words taken from slurred fast speech

- Which factors explain individual differences in word recognition of senior NSs?
Janse & Andringa, in prep.

Model for Senior NSs

- **Word recognition accuracy in clean speech**
- **Word recognition Accuracy in degraded speech**

**Linguistic Knowledge**
- Receptive vocabulary

**Working Memory**
- Backward digit span (visual)
- Auditory nonword repetition
- Reading span

**Information processing speed**
- Digit-Symbol substitution
- Letter string comparison

**Hearing Acuity**
### Results: Correlations with Word Recognition

<table>
<thead>
<tr>
<th></th>
<th>WR accuracy clean speech</th>
<th>WR accuracy degraded sp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>.29*</td>
<td>.21*</td>
</tr>
<tr>
<td>Working memory</td>
<td>.54*</td>
<td>.42*</td>
</tr>
<tr>
<td>Information processing speed</td>
<td>-.40*</td>
<td>-.37*</td>
</tr>
<tr>
<td>Hearing</td>
<td>-.61*</td>
<td>-.69*</td>
</tr>
</tbody>
</table>

* at $\alpha < .05$, 2-tailed
Results: *Regression weights*

<table>
<thead>
<tr>
<th></th>
<th>WR accuracy clean speech</th>
<th>WR accuracy degraded sp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>WR acc. clean speech</td>
<td>n.a.</td>
<td>.61</td>
</tr>
<tr>
<td>Knowledge</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Information processing</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working memory</td>
<td>.42</td>
<td>-</td>
</tr>
<tr>
<td>Hearing</td>
<td>-.50</td>
<td>-.32</td>
</tr>
</tbody>
</table>
Janse & Andringa, in prep.

Model for Senior NSs

- Word recognition accuracy in clean speech
- Word recognition accuracy in degraded speech
- Linguistic Knowledge
  - Receptive vocabulary
- Working Memory
  - Backward digit span (visual)
  - Auditory nonword repetition
  - Reading span
- Information processing speed
  - Digit-Symbol substitution
  - Letter string comparison
- Hearing Acuity
## Results: Regression weights

<table>
<thead>
<tr>
<th></th>
<th>WR accuracy in degraded sp.</th>
<th>WR accuracy in clean speech</th>
</tr>
</thead>
<tbody>
<tr>
<td>WR in degraded speech</td>
<td>n.a.</td>
<td>.71</td>
</tr>
<tr>
<td>Knowledge</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Information processing speed</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Working memory</td>
<td>.25</td>
<td>.22</td>
</tr>
<tr>
<td>Hearing</td>
<td>-.63</td>
<td>-</td>
</tr>
</tbody>
</table>

Sible Andringa, Barcelona: May 2013
Relevant observations (2)

- WM is related to Word Recognition accuracy by Senior NSs: it explains unique variation.

- WM is significantly stronger implicated in Clean speech (which should be relatively undemanding)
Back to Stilis

Stilis data included several language measures, both speed and accuracy: All administered to Young NS, Senior NS and NNS.

- Are there differences between groups in correlation between WM and language measures?
# Results:

*Accuracy measures: Correlations with WM*

<table>
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<th>NNSs</th>
<th>Senior NSs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segmentation acc.</td>
<td>.38*</td>
<td>.38*</td>
<td>.28*</td>
</tr>
<tr>
<td>Grammatical proc. acc.</td>
<td>.11</td>
<td>.15</td>
<td>.23*</td>
</tr>
<tr>
<td>Semantic processing acc.</td>
<td>.06</td>
<td>.19</td>
<td>.15</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>.33*</td>
<td>.14</td>
<td>.30*</td>
</tr>
</tbody>
</table>
Results:

*Speed measures: Correlations with WM*

<table>
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<th>NNSs</th>
<th>Senior NSs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segmentation speed</td>
<td>-.41*</td>
<td>-.29*</td>
<td>-.40*</td>
</tr>
<tr>
<td>Grammatical proc. speed</td>
<td>-.29*</td>
<td>-.08</td>
<td>-.14</td>
</tr>
<tr>
<td>Semantic processing speed</td>
<td>-.52*</td>
<td>-.18</td>
<td>-.25*</td>
</tr>
<tr>
<td>Word monitor</td>
<td>-.01</td>
<td>.00</td>
<td>.01</td>
</tr>
</tbody>
</table>
Back to Stilis

The items for some Stilis tasks (measuring subskills of listening) were manipulated:

1) Segmentation ability
   - Listen to short stretches of speech and identify (correctly) the (number of) words
   - speed and accuracy
   - Items were a) fully articulated or b) reduced
2) Semantic processing

- Participants see 2 short responses on screen. They hear a sentence and have to decide which is an appropriate response to the sentence heard.
- Only speed (ceiling in accuracy)
- Sentences of a) high and b) low frequency wording
Model tested: Does WM explain \textit{additional variance} in scores based on demanding items.
Results Segmentation Accuracy

- WM Factor loadings onto “undemanding”:
  - Young NS (.37*) = Senior NS* (.37) > Non-NS (.26)*

- Does WM explain sign. extra variance in reduced items?
  - For all groups: No!

- Does WM explain sign. extra variance in full items?
  - For Young NS: Yes
Results Segmentation Speed

- WM Factor loadings onto “undemanding”:
  - Young NS (-.44*) > Senior NS* (-.40) > NNS (-.36)*

- Does WM explain sign. extra variance in reduced items?
  - For all groups: No

- Does WM explain sign. extra variance in full items?
  - For Young NS and NNS: Yes
Results Semantic processing speed

- WM Factor loadings onto “undemanding”:
  - Young NS (-.52*) = Senior NS* (-.26) > NNS (.20)*

- Does WM explain sign. extra variance in reduced items?
  - For all groups: No!

- Does WM explain sign. extra variance in reduced items?
  - For all groups: No!
What about the different measures of WM?

Stilis:

- Non-word recognition:
  - insensitive to individual differences in language tasks

- For all groups: Auditory tasks generally correlated slightly better than visual tasks

- For the NNS: the Forward task generally correlated better than backward tasks
What about the different measures of WM?

Janse & Andringa, in prep.

Analysis repeated with single memory scores:

- Reading span and Digit span predicted nothing anymore
- Only Non-Word Repetition predicted variance
Summary of findings

- These results are consistently at odds with the notion that:
  1) WM will especially make a difference for those groups for whom linguistic processing is more demanding/non-automatic
  2) WM is especially important when linguistic processing is somehow more demanding/non-automatic
- If anything, the opposite was true!
Summary of findings

- Working Memory is most strongly related to highly proficient language use
- Working Memory is implicated most when language processing is effortless.
Controversies

- Is it possible to measure storage and processing functions separately?

Were our results due to the measures used?

- Digits spans probably measure storage more than processing
- However, using Digit Spans, we replicated Daneman and Carpenter (1980) and many others
Controversies

- Is there one single resource or do separate resources exist for storage and processing?
  - Our data do not speak to this issue.
  - Is the distinction valid / real?
Chicken or egg?

- Is the assumption that more WM leads to better use and more learning correct?
  - No!
  - There is a correlation: More WM goes together with better use or more learning.
  - But correlation is not causation!
Chicken or egg?

- Does higher language proficiency lead to better scores on WM tasks?
  - Might well be!
  - Perhaps WM capacity develops along with language proficiency.
Controversies

- Is working memory separate from long-term memory?

  Our data:
  - At odds with Baddeley’s model
  - In agreement with Long-term WM models?
Practical implications

What is a digit span measuring?

- Measures of WM probably (also) tap multiple cognitive functions
  - Attention: Needed to maintain LTM information active
  - processing speed

- These underlying functions may be the true predictors of language use and (consequently) learning
Thank you for listening!

Questions?

Many thanks to:
Catherine van Beuningen, Jan Hulstijn, Esther Janse, Tineke van der Linde, Netta Meijer, Nomi Olsthoorn & Rob Schoonen.
More about our research?

