Measuring working memory in aphasia: Comparing performance on the complex span and N-back tasks

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BACKGROUND

- **Deficits in working memory (WM)** are amongst the most widely acknowledged cognitive impairments in aphasia. However, there is still on-going debate what tasks should be used to assess WM in aphasia (Wright & Fergadiotos, 2012).
- **Complex span tasks** - participants perform a processing task (e.g., sentence reading) while memorizing and maintaining a set of stimuli (e.g., words) for later recall/recognition. Require coordination of storage with on-going processing demands, i.e. *shifting* between two concurrent tasks.
  - Verbal complex span tasks rely on extensive language processing and are criticized for being just another measure of language abilities (McDonald & Christiansen, 2002)
  - Gold standard for assessing WM capacity in cognitive psychology within various theoretical frameworks (Conway et al., 2005)
  - Persons with aphasia (PWA) perform worse compared to controls (Tompkins et al., 1994; Ivanova & Hallowell, 2012, 2014)
  - Performance related to general language processing measures in both controls (Daneman & Merikle, 1996) and PWA (Caspari et al., 1998; Sung et al, 2009)
- **N-back tasks** - participants are presented with a continuous string of stimuli and are instructed to judge whether an item matches a previous one presented n items before. Require continuously *updating* a set of items in the focus of attention.
  - Even tasks with verbal stimuli do not require extensive language processing, i.e. the task is different from a language task
  - Most common WM task in neuroimaging studies (Chien, Moore, & Conway, 2011; Owen et al., 2005) with no clear underlying theoretical framework
  - PWA perform worse compared to controls (Christensen & Wright, 2010; Mayer & Murray, 2012)
  - No significant relationship with general language processing measures found (Christensen & Wright, 2010; Mayer & Murray, 2012)
- Several investigations comparing the two tasks in healthy controls have demonstrated weak or no relationship between the two tasks (Jaeggi et al., 2010; Kane et al., 2007), although limited conflicting findings have also been reported (Schmiedek et al., 2009). Performance on the two tasks has never been compared in the aphasia population.

AIMS OF THE STUDY

- **Directly investigate the relationship between performance on complex span tasks and N-back tasks in aphasia**
- **Explore the relationship between different WM measures and language processing in aphasia**

METHOD

Participants – 34 individuals with mild to moderate post-stroke aphasia

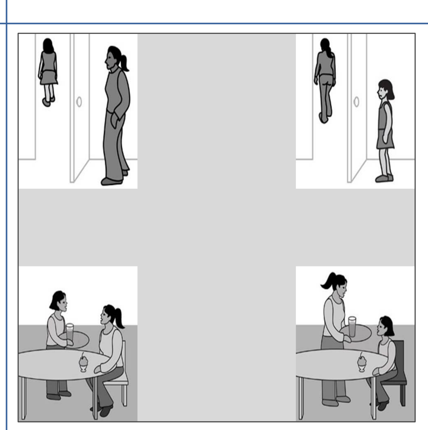
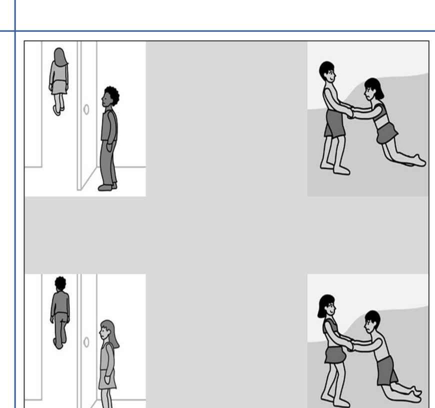
M / F: 15 / 19   *Age*: M = 54.1 ± 8.8 years   *Months post-onset*: M = 30.7 ± 27.6 months   *Aphasia:* Nonfluent = 22, Fluent = 12

WM tasks (all verbal material was presented in Russian)

Complex span task – Modified Listening Span (MLS) task (Ivanova & Hallowell, 2014)

Match sentences to pictures and remember a separate set of words for later recall (sets of sentences and words become progressively longer: from 2 to 6; 3 sets of each size were presented).

Scores: proportion of correctly recognized elements per set, maximum set size correctly recognized, proportion of correctly matched sentences.

Verbal stimuli	The girl is serving the woman.	Sweater	The boy is leaving the girl.	Pumpkin	(recognition display)
Visual stimuli		Blank screen		Blank screen	

N-back tasks: series of disyllabic high-frequency words consisting of 20 different stimuli were presented aurally. ISI = 2000 msec.

2-back – recognize a word that matched one presented 2 items back (there were no 1-, 3- or 4-back lures). 150 words presented with 36 targets (24%).

miska → pchela → *miska* → salat → banan → palec → vilka → *palec* → *vilka*

(dish → bee → *dish* → salad → banana → finger → fork → *finger* → *fork*)

0-back – recognize a specific word – 'topor' (ax). 100 words were presented with 24 targets (24 %).

Scores: Target hit rate (TH), False alarm rate (FA), Target hit reaction time (TH RT), sensitivity d'= Z (TH) – Z (FA)

Language tasks – standardized aphasia language test in Russian

Quantitative Assessment of Speech in Aphasia (QASA; Tsvetkova et al, 1981) – overall comprehension score composed of five subtests (comprehension of a dialogue, comprehension of single words (nouns and verbs), comprehension of sentences of varying length and difficulty, following commands) and overall production score composed of five subtests (dialogue, naming nouns and verbs, sentence production, picture description).

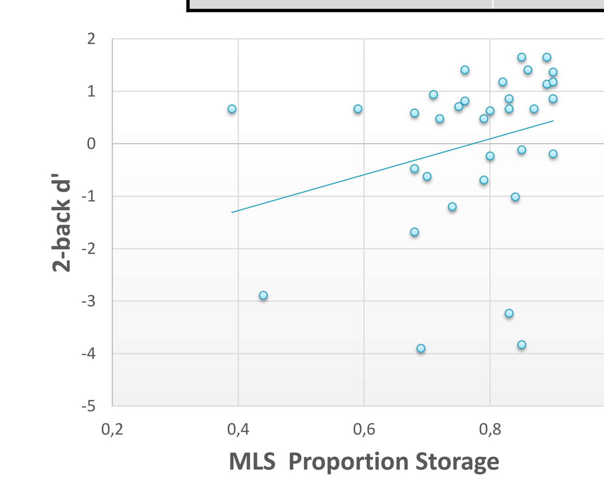
RESULTS

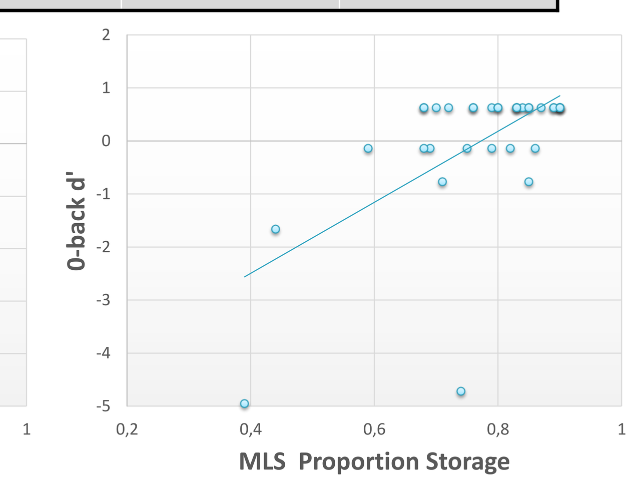
1. Descriptive statistics

	M	SD	Range
MLS proportion storage	.77	.12	.39 – .9
MLS max storage	4.00	1.26	2 – 6
MLS processing	.93	.09	.65 – 1.00
2-back TH rate	.92	.10	.61 – 1.00
2-back FA rate	.03	.04	.00 – .17
2-back TH RT	1070	165	793 – 1453
2-back d'	.00	1.53	-3.90 – 1.65
0-back TH rate	.99	.03	.83 – 1.00
0-back FA rate	.01	.02	.00 – .09
0-back TH RT	879	169	584 – 1219
0-back d'	.00	1.34	-4.95 – .63
QASA comprehension	136	14	92 – 150
QASA production	114	24	35 – 150

2. Spearman correlations between WM measures (n = 34)

	MLS proportion storage	MLS max storage	MLS processing
2-back TH rate	.157	.206	.172
2-back FA rate	**-.410***	**-.431***	-.295
2-back TH RT	-.006	.119	-.042
2-back d'	**.408***	**.425***	.280
0-back TH rate	.205	.258	.242
0-back FA rate	**-.402***	-.305	-.099
0-back TH RT	.093	.167	-.021
0-back d'	**.497****	**.445****	.256





3. Spearman correlations between WM measures and language measures (n = 34)

QASA overall scores	MLS proportion storage	MLS max storage	MLS processing	2-back TH rate	2-back FA rate	2-back TH RT	2-back d'	0-back TH rate	0-back FA rate	0-back TH RT	0-back d'
Comprehension	**.357***	.323	**.483***	.054	-.201	-.057	.150	.268	-.128	.049	.303
Production	.182	.147	.332	-.280	-.017	.063	-.184	.177	-.210	.039	.304

4. Impact of aphasia type on correlational patterns (between group differences in WM and language measures were n.s.)

	MLS prop. & 2-back d'	MLS prop. & 0-back d'	MLS prop. & QASA compr.	2-back d' & QASA compr.	0-back d' & QASA compr.
Nonfluent (n = 22)	**.555***	.389	**.433***	.179	.340
Fluent (n = 12)	.179	**.648***	.128	.011	.195

*Note. * p < .05 , ** p < .01; 2-tailed.*

DISCUSSION

- Moderate correlations were observed between performance on complex span task and N-back tasks.
  - While the relationship was significant, it accounts for only 16-24% variance, i.e. the tasks are more different than they are similar. The tasks do seem to tap into distinct cognitive mechanisms (shifting vs. updating).
- Most importantly, performance on the two type of tasks relates differently to higher level cognition – in our case, language comprehension.
  - This is in line with previous results in healthy controls and aphasia. Possibly performance on MLS task was related to language processing because of its more complex cognitive nature compared to N-back tasks.
- The distinct pattern of performance in fluent and nonfluent aphasia, especially given comparable severity, is intriguing.
  - Nonfluent aphasia – potentially cognitive limitations underlie their language difficulties, leading to stronger relations between cognitive tasks and between cognitive tasks and language.
  - Fluent aphasia – possibly fundamental lexical-semantic language impairment leads to difficulties in performance of even basic language-mediated cognitive tasks.
- *Thus, findings with different WM tasks cannot be fully equalized and generalized.*
- **Future directions for exploration**
  - More in-depth investigation of the current phenomena: larger groups, regression analysis
  - Neural substrate underlying deficits in performance (using VLSM)
  - Nonverbal WM tasks

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