Aging, Resource Allocation, and Reading with Visual Noise

Xuefei Gao[1], Brian R. Levinthal[2], and Elizabeth A. L. Stine-Morrow[1]

Beckman Institute & Department of Educational Psychology[1]; Department of Psychology[2], University of Illinois at Urbana-Champaign, IL

RATIONALE

- Aging is associated with sensory declines that may make encoding of the surface form of language especially difficult. The Effortfulness Hypothesis (Wingfield et al., 2005) implies that word-level processing (e.g., signal decoding) may consume attentional resources among older readers and so decrease the capacity available for semantic integration of the textbase in language comprehension. In the current study, we tested this hypothesis by measuring readers' allocation of attentional resources to word and textbase features as they read sentences embedded in varying levels of visual noise, which would make signal decoding difficult.

METHODS

Participants

Table 1. *Individual differences for participants*

	Old		Young	
	Mean	SD	Mean	SD
n	36		36	
Age	69.1	6.9	23.5	3.9
Education (years)	15.9	2.7	16.0	1.9
Vocabulary (WAIS-R subtest)	51.1	8.3	52.9	7.9
FDS	7.2	1.3	7.3	1.1
BDS	5.8	1.1	5.5	1.4
LLS *	4.3	1.2	5.8	1.4
LRS *	4.2	1.0	5.5	1.4

Notes: FDS = Forward Digit Span; BDS = Backward Digit Span; LLS = Loaded Listening Span (average number of words recalled); LRS = Loaded Reading Span (average number of words recalled). * significant group difference, p<.001

Materials and Design

- Text materials for this study were three sets of 24 18-word sentences dealing with diverse topics in science, nature and history (Stine-Morrow et al., 2001; Stine-Morrow et al., 2008). The three sets were counterbalanced across three levels of dynamic visual noise generated using Matlab software on an iMac 17" LCD monitor (1440*900 with 32-bit color, OS 10.4.10) by changing a randomly selected proportion of pixels to a new randomly selected grayscale value after each refresh (.3=low noise, .5=medium noise, .7=high noise).

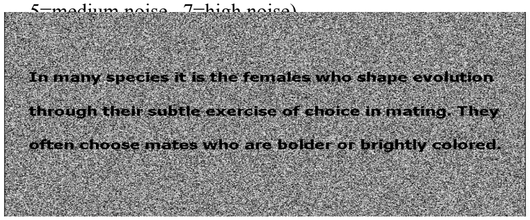

Figure 1. *Sample of display at high noise.*

Procedure

- Participants read sentences word-by-word in a self-paced fashion in a *moving window* paradigm for periodic probed recall.

Text Analysis and Calculation of Resource Allocation

- Texts were analyzed in terms of word-level and textbase-level linguistic features that reflected different linguistic computations. RT for each individual participant were decomposed by regressing them onto these features to estimate how time was allocated to various levels of the sentence processing while reading was taxed by visual noise.

- Word-level features included the number of syllables and log word frequency; textbase-level features contained in the regression were whether the word was a new concept in the passage with dummy-coding (0/1) and cumulative conceptual load at sentence boundaries estimated by multiplying the total number of new conceptual arguments introduced in the sentence by the dummy-coded variable for the sentence-final word.

Table 2. *Levels of sentence processing*

Processing Level	*Text Variable*	*Theoretical Process*
Word-level	Syllables	Orthographic decoding
	Log word frequency	Lexical access
Textbase-level	New concept	Immediate processing of new conceptual information
	Cumulative conceptual load at sentence boundaries	Conceptual wrap-up

RESULTS

Patterns of Resource Allocation

- Means of individual parameters for each age group in each noise condition are shown in Tables 3 and 4. The age by noise interaction for word frequency was reliable, F(2,140)=3.051, p=.05, indicating older adults were particularly susceptible to visual noise at the word-level while reading.

Table 3. *Mean allocation parameters (msec) as a function of visual noise for older adults.*

	Low Noise			Medium Noise			High Noise		
Parameter	β		se	β		se	β		se
Syllable	50	***	11	42	***	8	56	***	9
Word frequency	-20	***	5	-30	***	5	-38	***	7
New concepts	89	***	17	84	***	17	75	***	18
Sentence boundary	106	***	19	115	***	19	105	***	16

β>0; *p<.05; **p< .01; ***p<.001.

Table 4. *Mean allocation parameters (msec) as a function of visual noise for younger adults.*

	Low Noise			Medium Noise			High Noise		
Parameter	β		se	β		se	β		se
Syllable	16	**	5	23	**	7	26	***	7
Word frequency	-18	***	4	-20	***	5	-15	**	5
New concepts	9		14	36	*	14	28	*	13
Sentence boundary	136	***	30	104	***	21	109	***	28

β>0; *p<.05; **p< .01; ***p<.001.

- In order to get reliable estimates of processing at the construct level, we created composites for word-level (syllable, word frequency) and textbase-level (new concept, integration at sentence boundaries) processes.

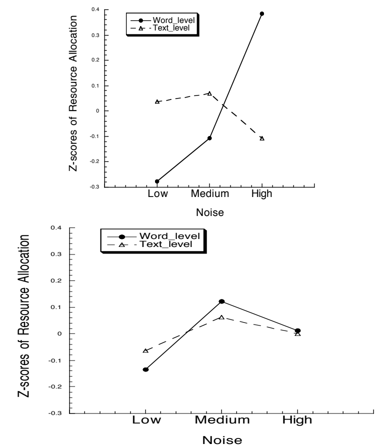

Figure 2. *Resource allocated to word-level and textbase-level processing as a function of visual noise for older (upper panel) and younger (lower panel) adults*

- For the older adults, we found a reliable interaction of noise and level of sentence processing, F(2,70)=3.026, p=.055, but such an effect was not observed for the younger adults, F(2,70)<1 (see Figure 2).

- For the older group only, increasing noise increased allocation to word-level processing, F(2.70)=4.137, p<.05, such that more time was needed for orthographic decoding and lexical access for low-frequency words. There was a non-significant trend for textbase-level processing to decrease with noise, F(2,70)<1. The noise hardly had any effect on allocation to word, F(2,70)<1, or textbase, F(2,70)<1, processing for the young.

- The three-way interaction of age, noise and level of processing did not reach significance, F(2,140)=1.453, p=.237, so that age differences in the noise by level interaction should be regarded with caution.

Recall Performance

- We found a marginally significant effect of noise, F(2,138)=2.899, p=.058, and no effect of age, F(1,69)<1, or age by noise interaction, F(2,138)<1 on recall performance (measured as proportion of propositions correctly recalled), although there was a trend for younger adults to show better recall than the old.

Table 5. *Correct recall for both groups of participants measured by percentage*

Noise condition	Old	S D	Young	S D
Low	0.55	0.03	0.58	0.03
medium	0.57	0.03	0.57	0.03
high	0.58	0.03	0.61	0.03

Working Memory, Recall and Sensitivity to Two Levels of Processing

- Correlations of working memory, word-level and textbase-level resource allocation, and recall performance are shown in Table 6. Recall performance was independently predicted by both WM and textbase-level resource allocation, but was not correlated with word-level resource allocation.

Table 6. *Working memory, sensitivity to word and textbase features and recall performance (correlations of the averages)*

	WM	Word	Textbase	Recall
WM		-0.19	-0.14	0.39**
Word			0.51**	0.06
Textbase				0.29*
Recall				

*p<.05; **p<.01

CONCLUSION

- For the older adults only, there was a significant interaction between visual noise and level of processing, but this effect was not observed for the young.
- In the face of a degenerated linguistic signal, older readers attempted to adjust their resource allocation so as to encode the surface form of text. Younger adults, in contrast, who as a group had larger working memory capacity, could offset orthographic decoding challenges without allocating extra resources to lexical access and without sacrificing the resources used for text-level meaning making.
- Readers' sensitivity to the textbase features of the sentence is highly correlated with subsequent recall performance, independent of working memory capacity.
- These findings are consistent with the Effortfulness Hypothesis: simulated sensory declines (i.e., visual noise) will tax older readers' lexical access at the expense of resources available for semantic integration.

We are grateful for support from the National Institute on Aging
(Grant R01 AG13935)
Contact Information: email: gao5@uiuc.edu

REFERENCES

- Stine-Morrow, E. A. L., Milinder, L., Pullara, P., & Herman, B. (2001). Patterns of resource allocation are reliable among younger and older readers. *Psychology and Aging, 16,* 69-84.
- Stine-Morrow, E. A. L., Miller, L. M. S., Gagne, D. D., & Hertzog, C. (2008). Self-regulated reading in adulthood. *Psychology and Aging, 23,* 131-153.
- Wingfield, A., Tun, P. A., & McCoy, S. L. (2005). Hearing loss in older adults: What it is and how it interacts with cognitive performance. *Current Directions in Psychological Science, 14,* 144-148.