Reading and Resource Allocation with Visual Noise

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ABSTRACT

♠ The Effortfulness Hypothesis suggests that simulated or age-related sensory declines may decrease capacity for semantic integration in language comprehension. We tested this hypothesis by measuring resource allocation during reading. College students (n=36) read three sets of passages word-by-word, one at each of three levels of dynamic visual noise. There was a reliable interaction between processing level (word- vs. textbase-level) and noise, such that visual noise increased resources allocated to word-level processing, at the cost of attention paid to textbase-level processing. Supporting the Effortfulness Hypothesis, this study shows that sensory challenges may interact with higher-level cognitive functions, such as reading and learning from text.

RATIONALE

♠ Language comprehension happens simultaneously at distinct yet interactive levels of processing, such as word-level orthographic decoding and textbase-level conceptual integration. The Effortfulness Hypothesis (Wingfield et al., 2005) implies that sensory declines associated with aging or simulated noise will make the word-level processing (i.e., signal decoding) "effortful" such that there are fewer attentional resources available for textbase-level processing (i.e., semantic integration) in language comprehension. In the current study, we examined the effects of visual noise on language comprehension using a resource allocation approach, which allowed us to decompose word reading times and dissociate the differential effects of noise on word-level and textbase-level processes during online sentence processing.

METHODS

Participants

♠ 36 college students were recruited for this study. They participated either for course credit or for payment.

Table 1. *Individual Differences for Participants*

	Mean	SD
Age (years)	20.1	1.3
Education (years)	14.0	1.3
Vocabulary (WAIS-R subtest)	46.2	6.6
WM span	5.2	1.3

Notes: WM span=mean Reading and Listening Span (Daneman & Carpenter, 1980)

Materials and Design

♠ Three sets of 24 18-word sentences dealing with diverse topics in science, nature and history (Stine-Morrow et al., 2001) were used. Each set was only read once at one of three levels of dynamic visual noise.

♠ Visual noise was created on one monitor using Matlab 5.2.1 software by changing a randomly selected proportion of pixels to a new randomly selected grayscale value after each refresh (0=no noise, .5=low noise, .7=high noise).

♠ Texts were presented on another monitor positioned perpendicularly to the first. The images of the text and the dynamic noise were combined using a beam splitter (a 2" optical cube), so that participants could read the text at various levels of masking through the cube (Figure 1).

♠ Texts were analyzed in terms of word-level and textbase-level linguistic features reflecting different linguistic computations (Table 2). RTs for each individual participant were decomposed by regressing them onto these features in order to estimate how time was allocated to these computations at each level of visual noise.

Table 2. *Levels of Sentence Processing*

Processing Level	*Text Variable*	*Theoretical Processes*
Word-level	Syllables	Orthographic decoding
	Log word frequency	Lexical access
Textbase-level	New concept (0/1)	Immediate processing of new conceptual information
	Cumulative conceptual load at sentence boundaries	Conceptual wrap-up

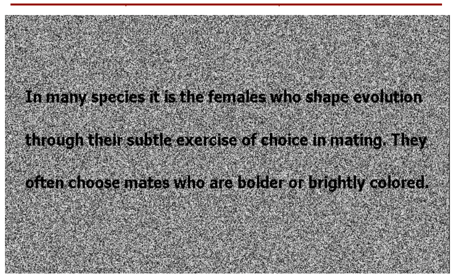

Figure 1. *A Demonstration of Text Embedded in Visual Noise* (static version; Note that in real experiment, text was presented in a word-by-word moving window fashion.)

Procedure

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

RESULTS

Patterns of Resource Allocation

♠ *Individual Parameters.* Mean resource allocation parameters in each noise condition are plotted in Figure 2. The main effects of visual noise on word frequency and on sentence wrap-up were significant, $F(2,70)=3.50$, $p<.05$; $F(2,70)=3.62$, $p<.05$, respectively, indicating more time was allocated to lexical access and less time was allocated to conceptual integration with increasing visual noise. Though the effects of noise on word length and on new concept processing were in the predicted direction (Figure 2), neither effect was significant, $F<1$ for both.

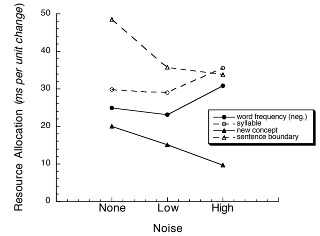

Figure 2. *Regression Coefficients as a Function of Noise and Levels of Sentence Processing*

♠ *Construct-level Analyses.* In order to get reliable estimates of processing at the construct level, composites representing word-level and textbase-level processing were created by averaging standardized z-scores of corresponding coefficients.

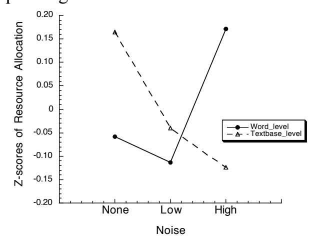

Figure 3. *Resource Allocated to Word-level and Textbase-level Processing as a Function of Visual Noise*

♠ There was a reliable interaction between processing level (word- vs. textbase-level processing) and noise, $F(2,70)=5.21$, $p=.008$. Visual noise increased resources allocated to word-level processing, $F(2,70)= 2.96$, $p=0.058$, at the cost of attention paid to semantic analysis (textbase-level process), $F(2,70)=3.95$, $p=0.024$.

♠ High working memory (WM) participants tended to allocate more attention to textbase processing (Word=-.10, se=.13; Textbase=.10, se=.16), while low-WM participants allocated more attention to word-level processing (Word=.10, se=.13; Textbase=-.10, se=.16), $F(1,34)=3.65$, $p=.065$, for the span by level interaction. This interaction did not vary with noise, $F<1$.

Recall Performance

♠ Recall performance was measured as the percentage propositions correctly recalled. The main effect of noise on recall (57.3%, 56.9% and 58.6% for none, low, and high levels of noise, respectively) was not significant, $F<1$.

♠ High-WM participants showed higher recall performance than low-WM ones (62% vs. 54%), $F(1,34)=4.93$, $p=.03$, but this difference was exaggerated in the no-noise condition, $F(2,68)=3.26$, $p<.05$.

Table 3. *Correlations between Textbase-level Resource Allocation and Recall as a Function of Noise* and *Working Memory (WM) Span*

	Low-span	High-span
No Noise	.045	.193
Low Noise	-.381	-.138
High Noise	-.524*	.611**

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

♠ Allocation to textbase processing was predictive of recall only when the noise was high. The correlation between textbase-level processing and recall was negative for low-span individuals and positive for high-span individuals.

CONCLUSION

♠ In the face of a degenerated linguistic signal, readers reallocated attentional resources so as to encode the surface form at the cost of resources for text-level semantic analysis. This was consistent with the Effortfulness Hypothesis.

♠ Recall performance, however, was surprisingly not depressed by visual noise.

♠ High-span readers showed higher recall than low-span readers under the no-noise condition. Under high noise, high-span readers only showed good recall if they allocated attention to the textbase. Strategies of low-span readers, by contrast, were disrupted by noise.

♠ These results provided partial support for the Effortfulness Hypothesis.

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