Can we use lexical knowledge to help identify words when letter recognition is difficult?

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Introduction

Can we use lexical knowledge to help identify words when letter recognition is impaired (e.g., when reading with low vision, or when print size is near the acuity limit)?

In the absence of top-down knowledge, any letter-identification errors will prevent words from being recognized.

The word superiority effect (e.g., Reicher, *JEP 81,* 1969) suggests that word context helps letter recognition. Could this help when letters are hard to identify?

Method

Participants

- 58 undergraduate students with normal (or corrected-to-normal) vision.

Stimuli

- *Letters:* 26 lower-case letters in Times-Roman.
- *Words:* Randomly selected without replacement from 575 common 4-letter words. Presented in Times-Roman.
- *Blur:* 3 levels of Gaussian blur:
  - mild blur (yielding 93%-correct letter recognition)
  - moderate blur (yielding 51%-correct letter recognition)
  - severe blur (yielding 28%-correct letter recognition)
- *Display:* Each blurred letter or word was presented on a classroom video projector.
- *Print size:* x-height subtended between 0.8° and 2.4° depending on where the student sat in the classroom. This size is at least 9 times larger than a typical student's reading acuity.

Procedure

Letter recognition

- Individual letters were displayed for 250ms followed by a mask for 3s while the students wrote down the letter they thought was presented.
- Each letter (a–z) was tested once with mild blur, 3 times with moderate blur, and 3 times with severe blur, randomly interleaved for a total of 186 trials.

Word recognition

- Individual words were displayed for 250ms followed by a mask for 5s while the students wrote down the word they thought was presented.
- 10 words were presented with mild blur, 50 words with moderate, and 50 words with severe blur, randomly interleaved for a total of 110 trials.

Results

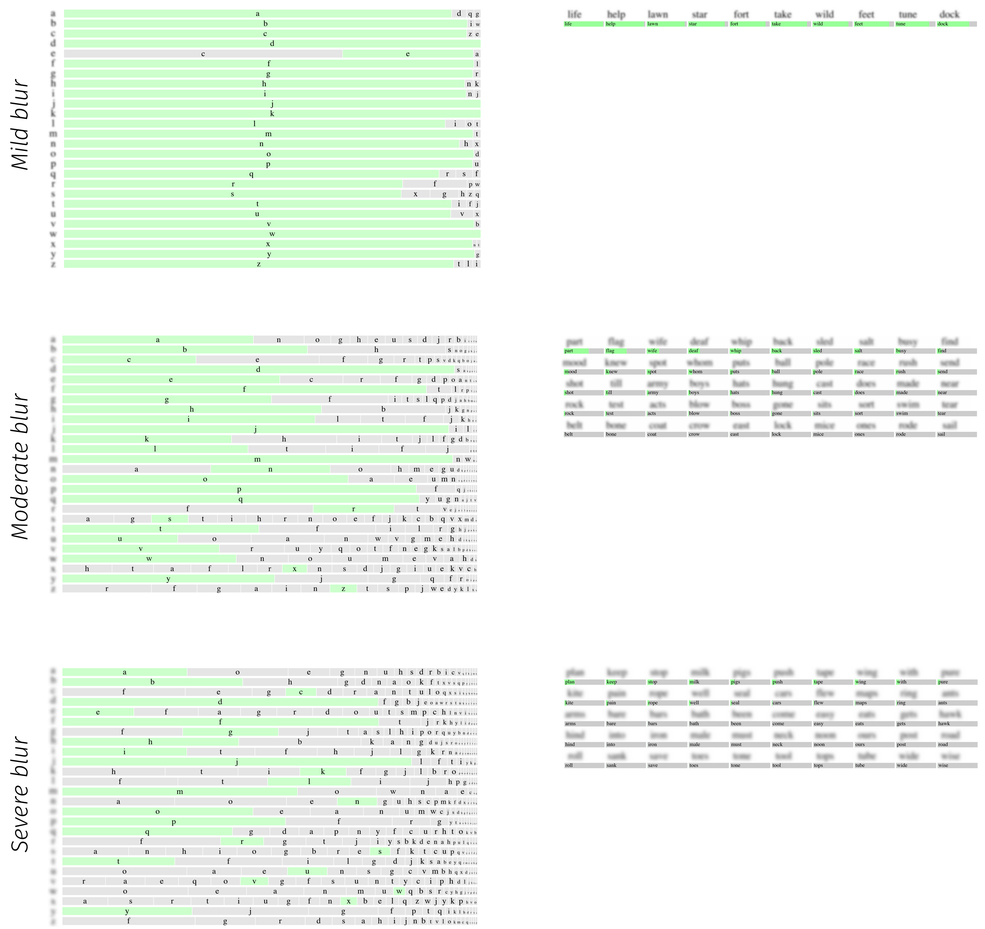

Figure 1. a) Pooled letter-recognition responses for each of the blurred letters. The blurred letter stimuli are shown in the left column, green bars show the proportion of correct responses, gray bars show incorrect responses. b) Pooled recognition accuracies for each of the blurred words: The size of the green bar indicates the proportion of students who correctly identified the word.

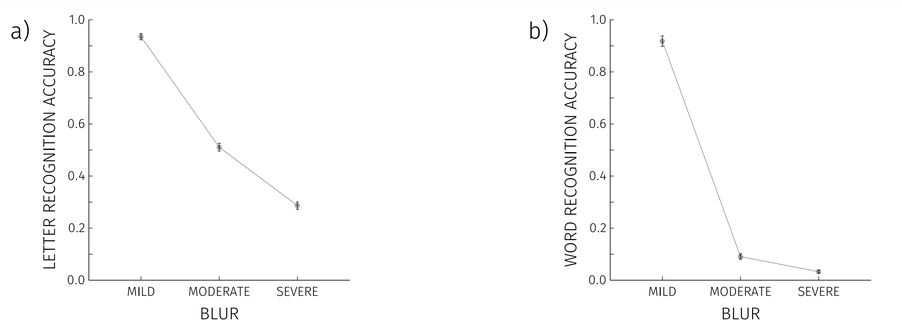

Figure 2. Overall recognition accuracy for the three levels of blur: a) letter recognition, b) word recognition.

Two models of lexical inference

We ran Monte Carlo simulations to measure the performance of two word-recognition models:

- *zero-Inference*: recognizes a word only if all the letters in the word are identified correctly,
- *ideal-observer:* makes optimum use of lexical information and the letter-recognition confusion matrix to determine word identity (Legge, Mansfield, & Chung, *Vision Research 41*, 2001; Pelli, Farrel, and Moore, *Nature 423*, 2003).

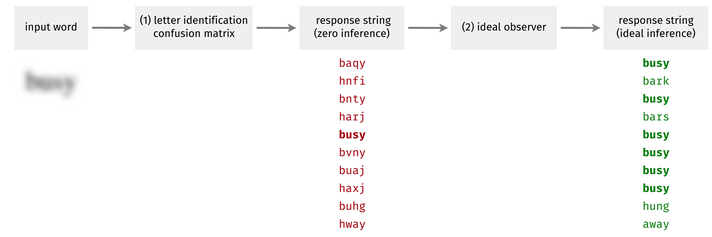

Figure 3. Modeling lexical inference. (1) The letters from the input word are passed through the letter-recognition confusion matrix to create a response string that contains letter identification errors. This response string models word recognition with zero inference. (2) The response string can be further processed by an ideal observer that selects the word from the lexicon that maximizes: **p(word|string)**. From Bayes theorem, $p(word|string) = \frac{p(string|word) \times p(word)}{p(string)}$ **p(string|word)** is calculated from the confusion matrix, **p(word)** and **p(string)** are both constants for these simulations.

With mild blur human performance is substantially better than the zero-inference model. But with moderate and severe blur, human performance is almost as poor as the zero-inference model.

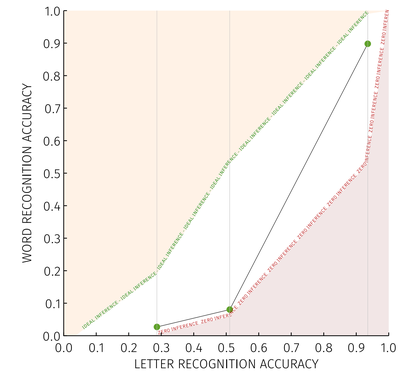

Figure 4. Word-recognition accuracy as function of letter-recognition accuracy, comparing human performance (green data points) with the *ideal-* and *zero-inference* models.

Conclusion

These findings indicate that, with 250ms exposures, lexical information may help determine word identity when letter-recognition errors are rare but this contribution becomes small when letter-recognition errors are common.