Impaired Oral Reading in Surface Dyslexia: Detailed Comparison of a Patient and a Connectionist Model

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Abstract

Mapping between orthography and phonology in the absence of semantics is investigated in a surface dyslexic patient, MP, and in a connectionist model. Both were tested on about 2500 monosyllabic words from the Seidenberg and McClelland corpus. We examined detailed effects of word frequency and spelling-sound consistency on naming accuracy and latency. We also performed an error analysis. While the general agreement in performance is encouraging, specific discrepancies suggest possible improvements of the model.

Summary

- The effects of word frequency and spelling-sound consistency on word and nonword reading accuracy are investigated in a brain-damaged patient, MP, and in an incompletely trained connectionist network.
- Both MP and the network exhibit the characteristic pattern of surface dyslexia in a number of word lists:
  - a frequency-by-consistency interaction, in which the reading of low-frequency exception words is disproportionately impaired
  - a predominance of "regularization" errors on exception words (e.g. DEAF $\Rightarrow$ "deef")
  - a preserved ability to read pronounceable nonwords (e.g. HEAF).
  - a reduced effect of regularity in words with ambiguous neighborhoods (e.g. –OW in NOW vs. LOW)
- MP fails to exhibit the expected interaction on a large corpus of predominantly consistent words presented more recently, suggesting that either (a) the highly consistent context invokes a "piecemeal" reading strategy, or (b) MP's sublexical processing has deteriorated.
- The results suggest that the <u>normal</u> sublexical system masters some but not all exception words, and that surface dyslexia arises when this system is isolated from semantics.

Background

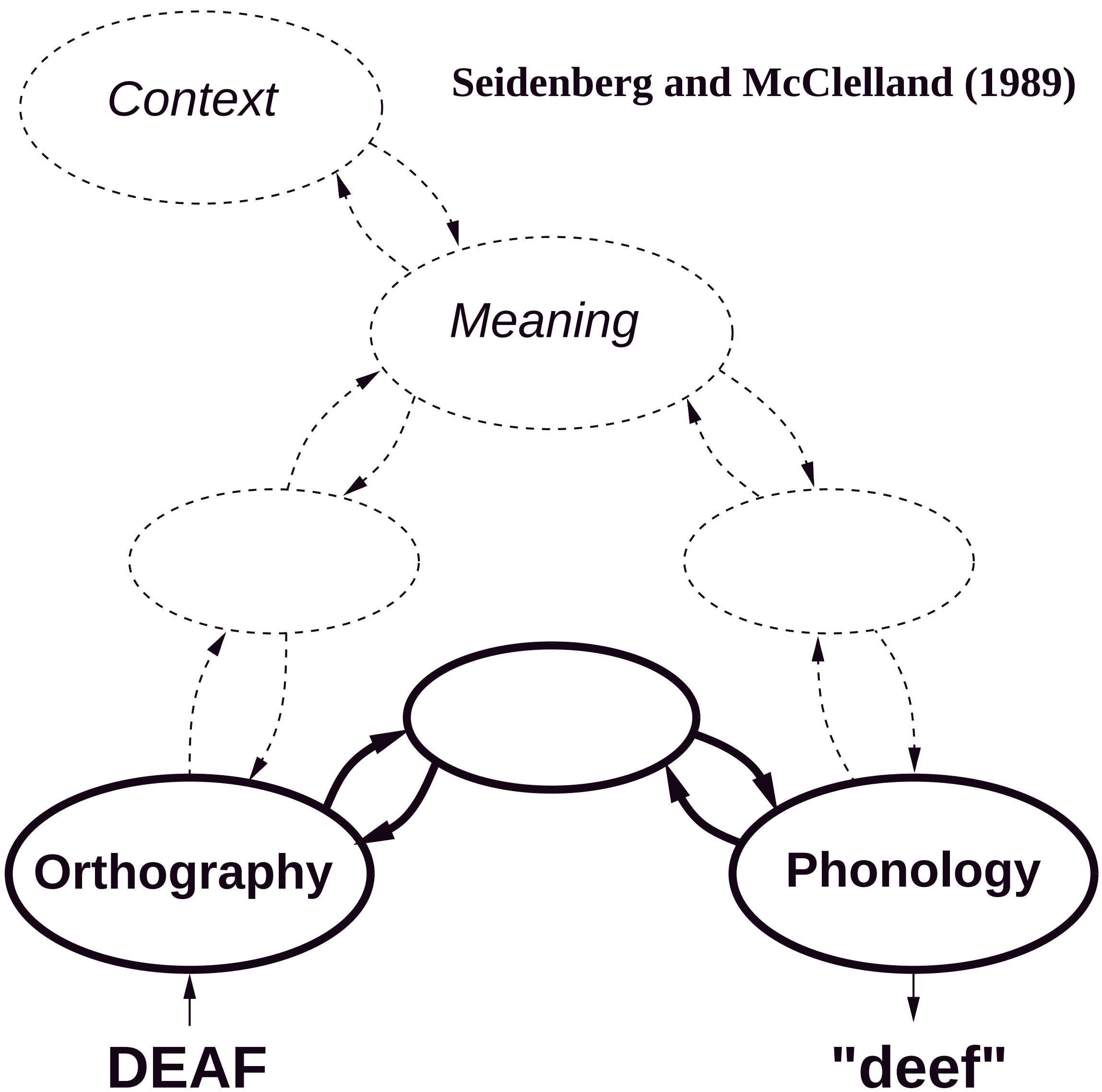
A considerable amount of knowledge about the organization and operation of the normal word reading system has come from detailed studies of brain-damaged patients with selective reading deficits. Particular patterns of performance of such acquired dyslexic patients suggests that the reading system has (at least) two procedures for pronouncing letter strings: (1) a sublexical procedure that derives pronunciations based on common spelling-sound correspondences, and (2) a lexical/semantic procedure that generates the pronunciation of a word via its meaning. Specifically, phonological/deep dyslexic patients are thought to have a selective impairment to the sublexical procedure, as evidenced by their inability to read pronounceable nonwords (e.g. HEAF). Conversely, surface dyslexic patients are thought to have a selective impairment to the lexical procedure, as they often mispronounce words that violate sublexical spelling-sound correspondences, particularly those of low frequency, most commonly producing a "regularization" error (e.g. DEAF ⇒ "deef").

Connectionist modeling has provided a useful formalism within which to explore detailed patterns of behavior in both normal and impaired word reading (e.g. Seidenberg & McClelland, 1989). Plaut and Shallice (1993) have replicated the diverse set of symptoms exhibited by deep dyslexic patients by lesioning attractor networks that map orthography to phonology via semantics. However, attempts to reproduce surface dyslexia by lesioning the Seidenberg and McClelland model of the sublexical procedure have been less successful (Patterson, Seidenberg, & McClelland, 1989).

One problem with the Seidenberg and McClelland model is that it fails to pronounce nonwords as well as skilled readers (Besner, Twilley, McCann, & Seergobin, 1990). More recently, Plaut and McClelland (1993) have re-implemented the sublexical procedure as an attractor network using improved orthographic and phonological representations. The network pronounces words (both regular and exception) and nonwords as well as skilled readers. In the current work, we use this network to explore whether surface dyslexia arises from a damaged sublexical procedure, or rather, from an intact but isolated sublexical procedure that normally works in concert with the semantic procedure and so need not master low-frequency exception words.

Surface Dyslexia

- Impaired reading of words with exceptional spelling-sound correspondences, particularly those of low frequency, usually yielding "regularizations" (e.g. DEAF ⇒ "deef").
- Normal ability to read pronounceable nonwords (e.g. HEAF).
- Severe impairment in naming objects as well as words.



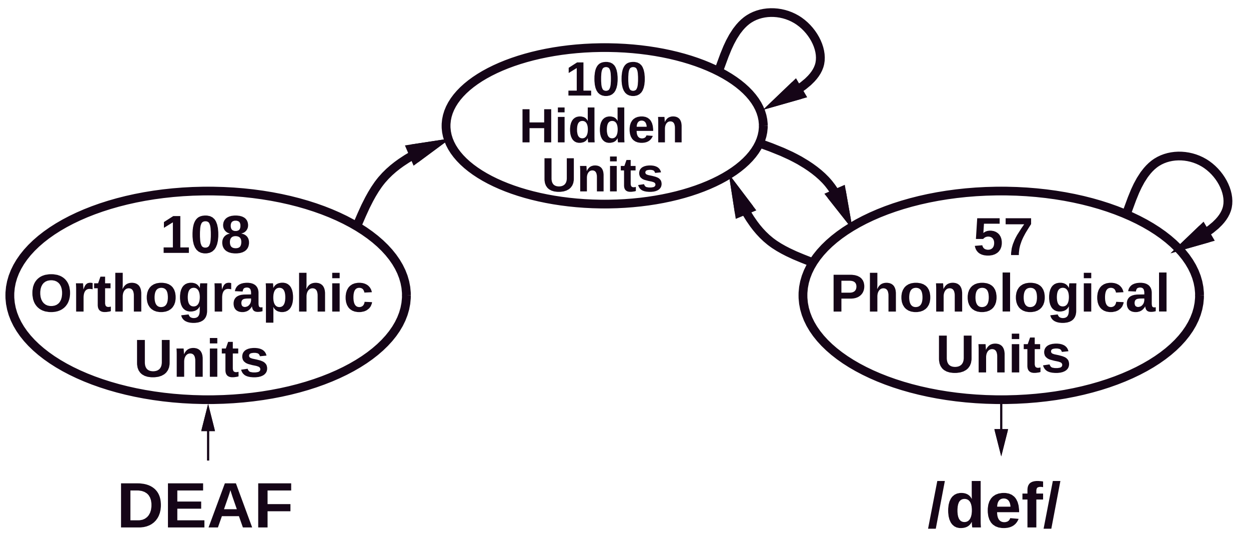
Patient MP

MP is a 75 year old, right-handed, English speaking female who sustained a closed head injury in 1982, causing extensive damage to the left-temporal region of the brain. MP has a severe deficit in comprehending both objects and words. For example, on the Pyramids and Palm Trees test, in which a target picture must be matched with one of two pictures (e.g. eskimo: igloo or house), MP scored 67% correct while normal, age-matched subjects score 99% correct. Similarly, in matching a written word to one of 5 pictures (the target, a semantically close and semantically distant distractor, a visual distractor and an unrelated picture), MP identified 12/40 items correctly whereas normal performance is 38.8/40. Of the 28 errors, MP picked a semantic distractor on 15 trials.

Aside from the marked deficit in semantic processing, MP has a profound surface alexia and surface agraphia. Her reading and writing performance has been tested extensively in the past and is the focus of several publications (Behrmann & Bub, 1992; Bub, Cancelliere, & Kertesz, 1985).

In the current investigation, several lists of words were developed to assess MP's oral reading (see below). The words appeared individually in the center of a computer screen (Mac Classic) for an unlimited exposure duration and MP was instructed to read them aloud. MP's responses were phonetically transcribed and accuracy was measured.

Plaut and McClelland (1993) Network



- **Representations**

	Phonology[a]
onset	s b p d t g k f v z T D S Z l r w m n h y
vowel	a @ e i o u A E I O U W Y ∧
coda	r l m n N b g d ps ks ts s f v p k t z S Z T D
	Orthography
onset	Y S P T K Q C B D G F V J Z L M N R W H U CH GH GN GU PH PS QU RH SH TH TS WH
vowel	E I O U A Y AI AU AW AY EA EE EI EU EW EY IE OA OE OI OO OU OW OY UE UI UY
coda	H R L M N B D G C X F V J S Z P T K BB CH CK DD DG FF GG GH GN GU KS LL NG NN PH PP PS QU RR SH SL SS TCH TH TS TT ZZ E ES ED

[a] /a/ in POT, /@/ in CAT, /e/ in BED, /i/ in HIT, /o/ in DOG, /u/ in GOOD, /A/ in MAKE, /E/ in KEEP, /I/ in BIKE, /O/ in HOPE, /U/ in BOOT, /W/ in NOW, /Y/ in BOY, /∧/ in CUP, /N/ in RING, /S/ in SHE, /Z/ in BEIGE, /T/ in THIN, /D/ in THIS.

- **Training**

  Back-propagation through (continuous) time on extended SM89 corpus (2998 words plus 101 grapheme-phoneme correspondences)

Initial Comparison: Damage vs. Incomplete Training

- **Lesioning procedure**
  - Corrupt weights of a set of connections with normally distributed noise (standard deviation reflects severity).
  - Results are averaged over 100 different samples of noise at a given severity.

	Correct Performance[a]					
	HFR	LFR	HFE	LFE	%Regularizations	NW[b]
MP[c]	95	93	83	41	~85	95.5
$_{O}{\Rightarrow}_{H}$(0.6)	80.0	79.0	55.3	51.3	49.4	73.7
Epoch 600	100	95.8	79.2	50.0	88.2	97.7

[a] Words from Taraban and McClelland (1987)

[b] Nonwords from Glushko (1979)

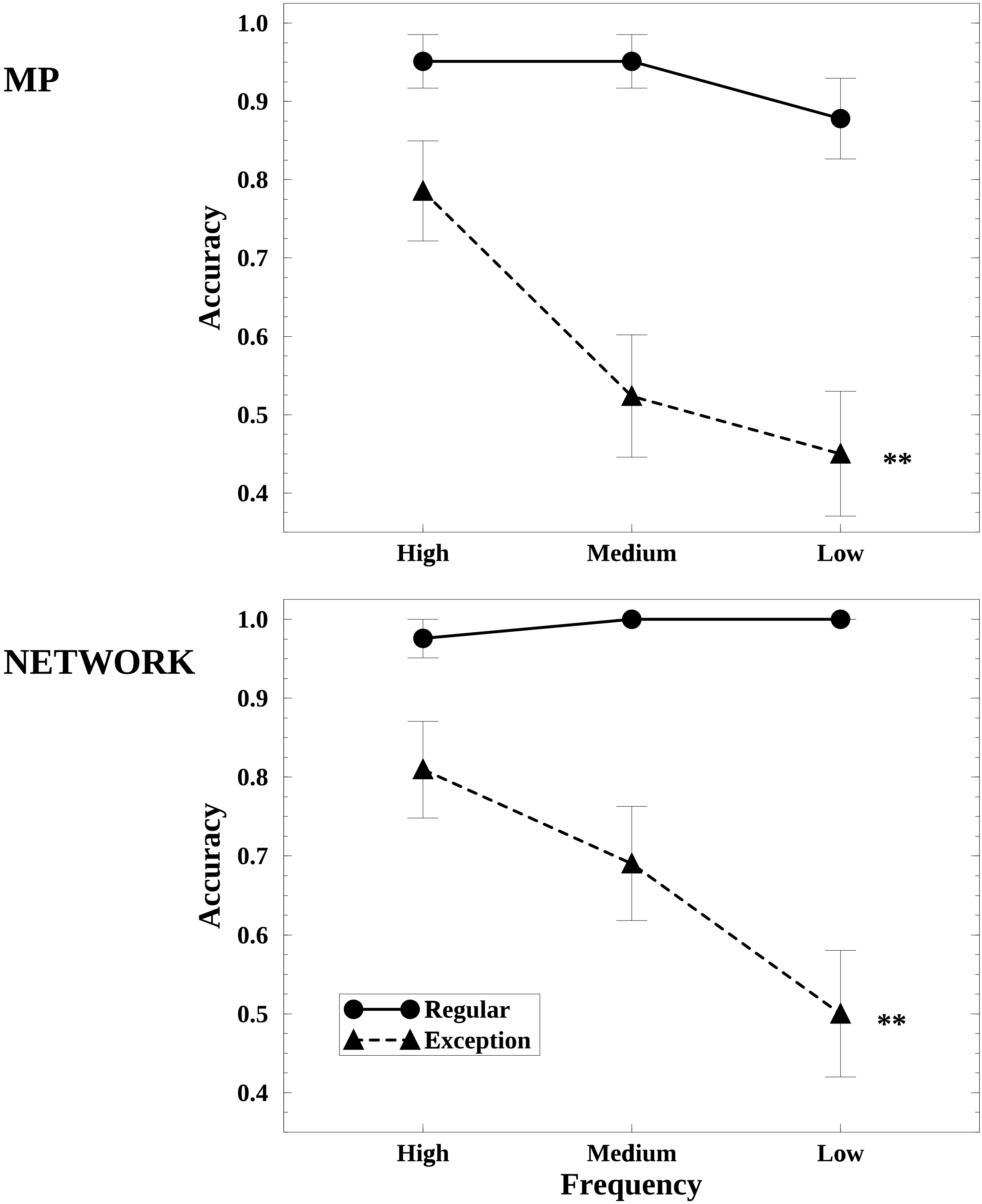
[c] From Behrmann and Bub (1992)

- **Results**
  - Incomplete training produces a better match to surface dyslexia than damaging network (also see Patterson, Seidenberg, & McClelland, 1989).
  - Consistent with view that surface dyslexia arises when the normal sublexical route, which masters some but not all exception words, is isolated from semantics (Patterson & Hodges, 1992).

Experiment 1: Surface List

This list (Patterson & Hodges, 1992) contains 252 monosyllabic monomorphemic words, made of 126 pairs of regular (REG) and exception (EXC) words matched for length, frequency and initial phoneme. REG or EXC is defined on the basis of (a) the vowel and final segment (e.g. POPE vs. DONE) or (b) the vowel alone (e.g. LEAF vs. HEAD). Strange words like YACHT or AISLE are excluded. Five trials were excluded from the analysis due to microphone failure.

Surface List: Results

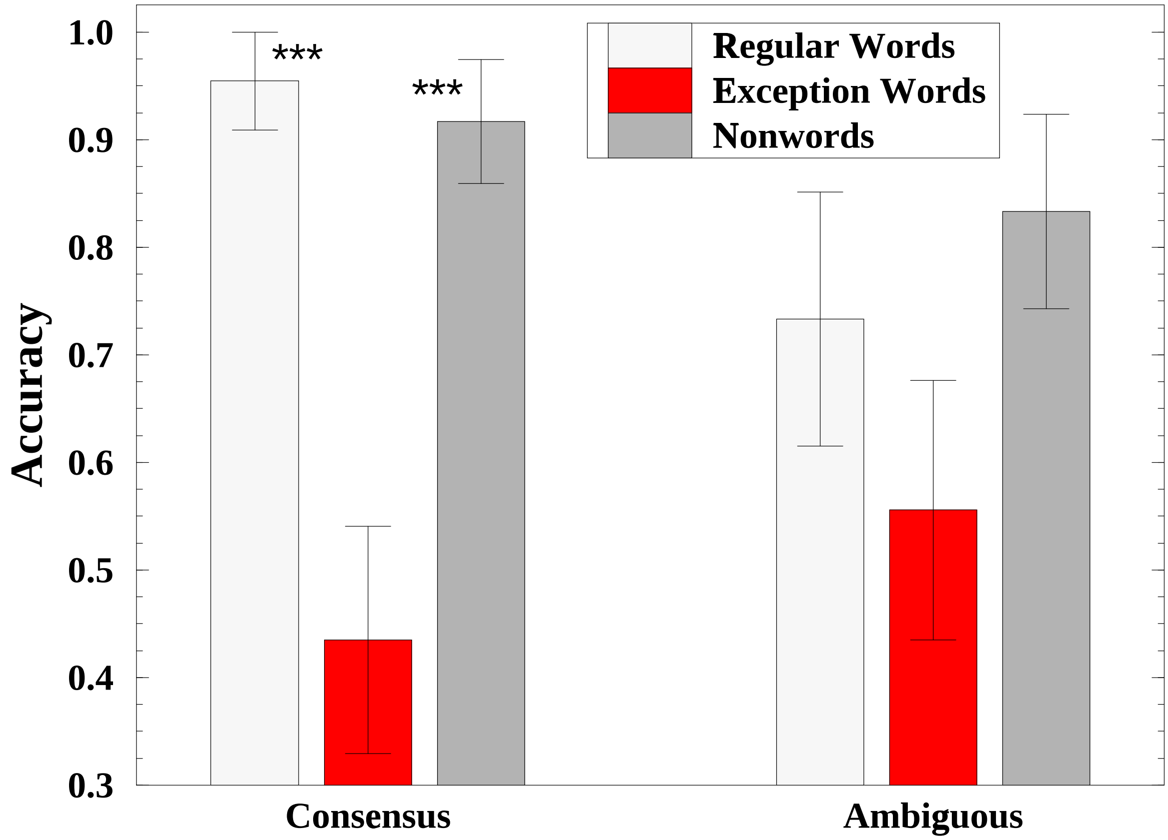


Experiment 2: Neighborhood List

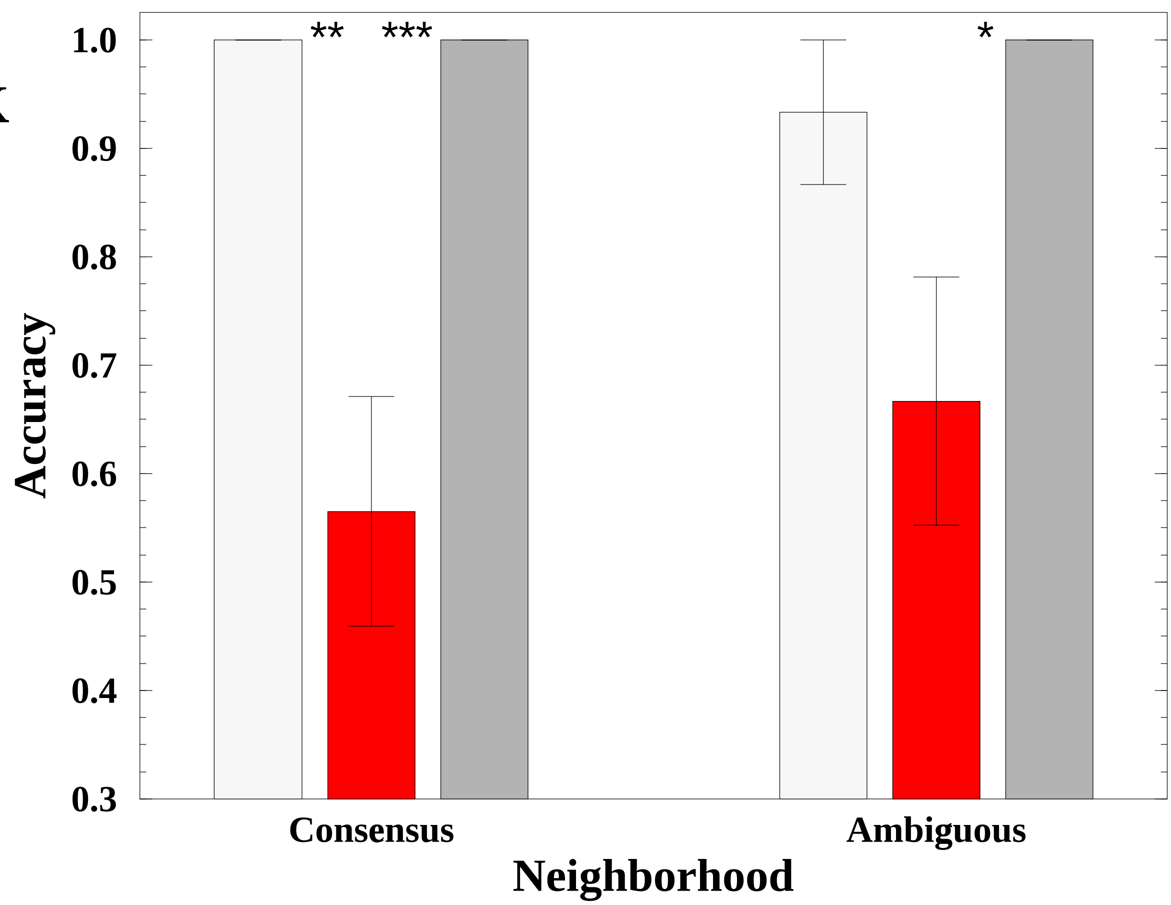
This list contains triplets of items, each consisting of a regular word, an exception word, and a nonword, sharing the same body. The triplets are drawn from two neighborhoods: (a) consensus: the large majority of pronunciations agree, with at most one exception (e.g. –AVE: 13 reg, e.g. SAVE; 1 exc, HAVE); (b) ambiguous: alternative pronunciations are about equally common (e.g. –ERE: 3 reg, e.g. HERE; 4 exc, e.g. WHERE). All items were randomized and presented as a single list. Accuracy is measured as a function of frequency and regularity.

Neighborhood List: Results

MP



NETWORK



Experiment 3: Nonword Reading

A list of 67 pronounceable monosyllabic nonwords was compiled for oral reading. Accuracy was measured as for the neighborhood list. Performance was also compared on a subset of Glushko's (1979) nonwords.

	MP	NETWORK
Nonword list	0.87 (58/67)	1.00 (67/67)
Glushko (1979)	0.95 (42/44)[a]	0.98 (43/44)

[a]From Behrmann and Bub (1992)

Regularizations of Exception Word Errors

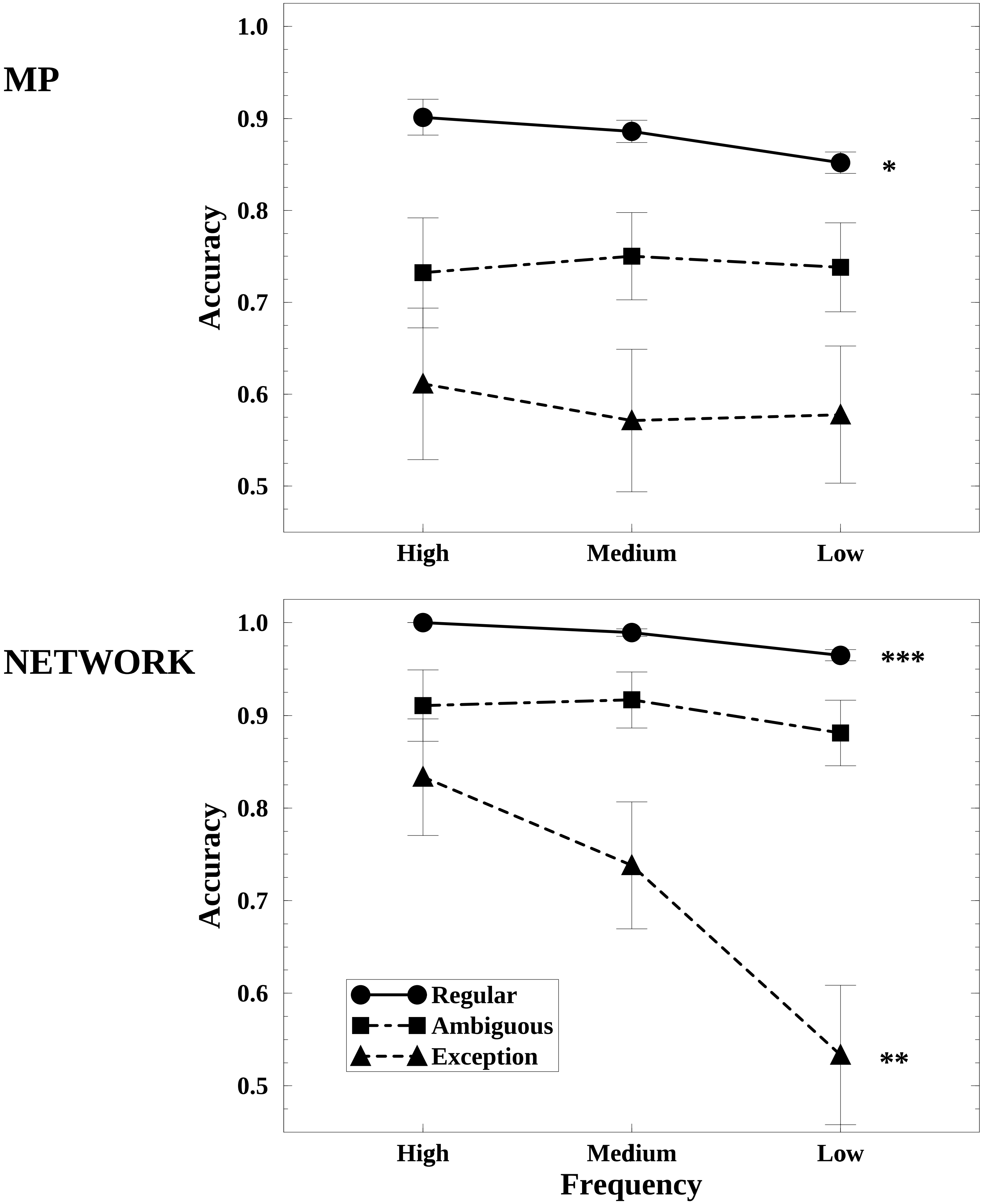
	MP	NETWORK
Surface List	0.90 (46/51)	0.93 (38/41)
Neighborhood List	0.91 (20/22)	1.00 (16/16)
SM89 corpus	0.80 (60/75)	0.85 (45/53)

Experiment 4: SM89 Corpus

The 2897 monosyllabic words of the Seidenberg and McClelland (1989, SM89) corpus were randomized and divided into blocks of 100 words. Each block was given to MP for oral reading. A full corpus of responses, however, is not available as MP read only 24 blocks and, of those, a number of trials were excluded because of microphone failure, leaving a corpus of 2395 responses. These data were collected over a four month period approximately two years after the data for Experiments 1–3 were collected.

Words with unique bodies (e.g. SOAP) were excluded from the analysis. The remaining 2184 trials were divided into three frequency bands (Kučera & Francis, 1967): high (>100 per million; n=325), medium (<=100 and >=10; n=792) and low (<10; n=1067). The trials were also classified according to neighborhood consistency (number of friends, F, and enemies, E): regular ((F+1)/E>=4; n=1837), ambiguous (0.5<(F+1)/E<4; n=224), or exception ((F+1)/E<=0.5; n=123). Accuracy is measured as a function of frequency and neighborhood consistency.

SM89 Corpus: Results

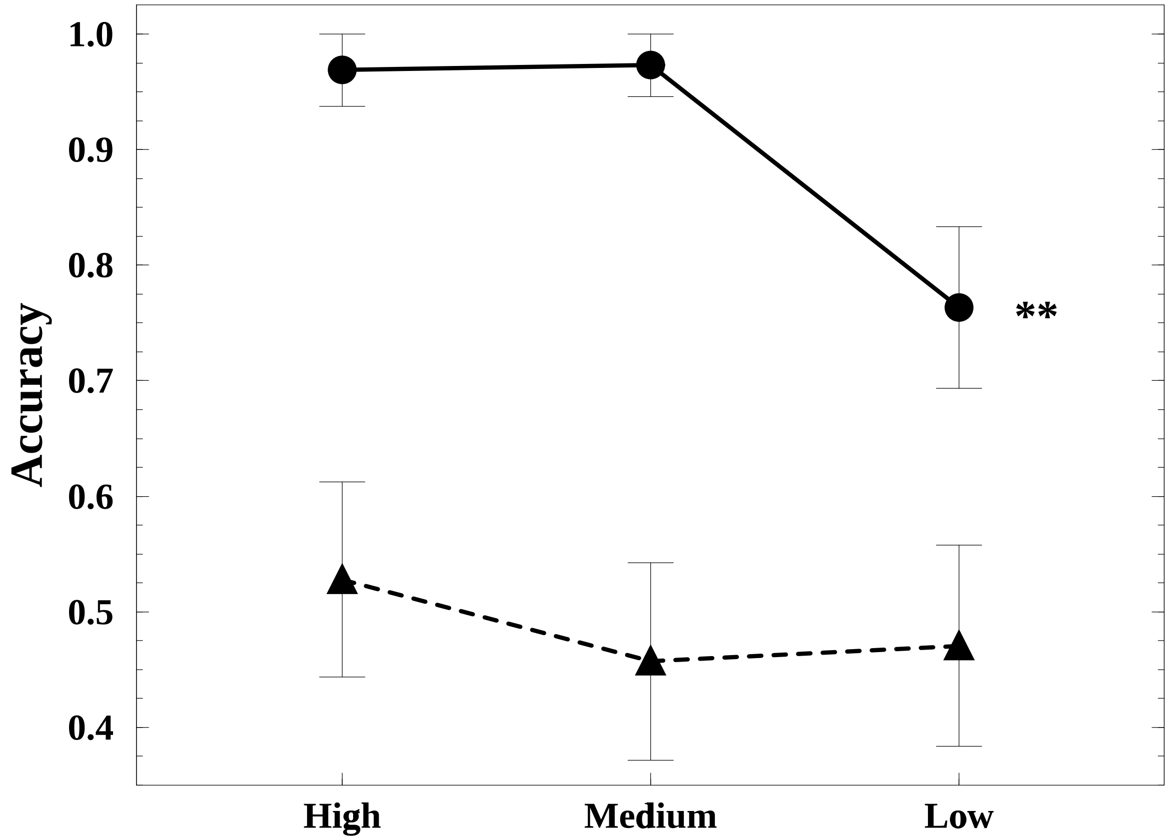


Experiment 5:
Surface List Within SM89 Corpus

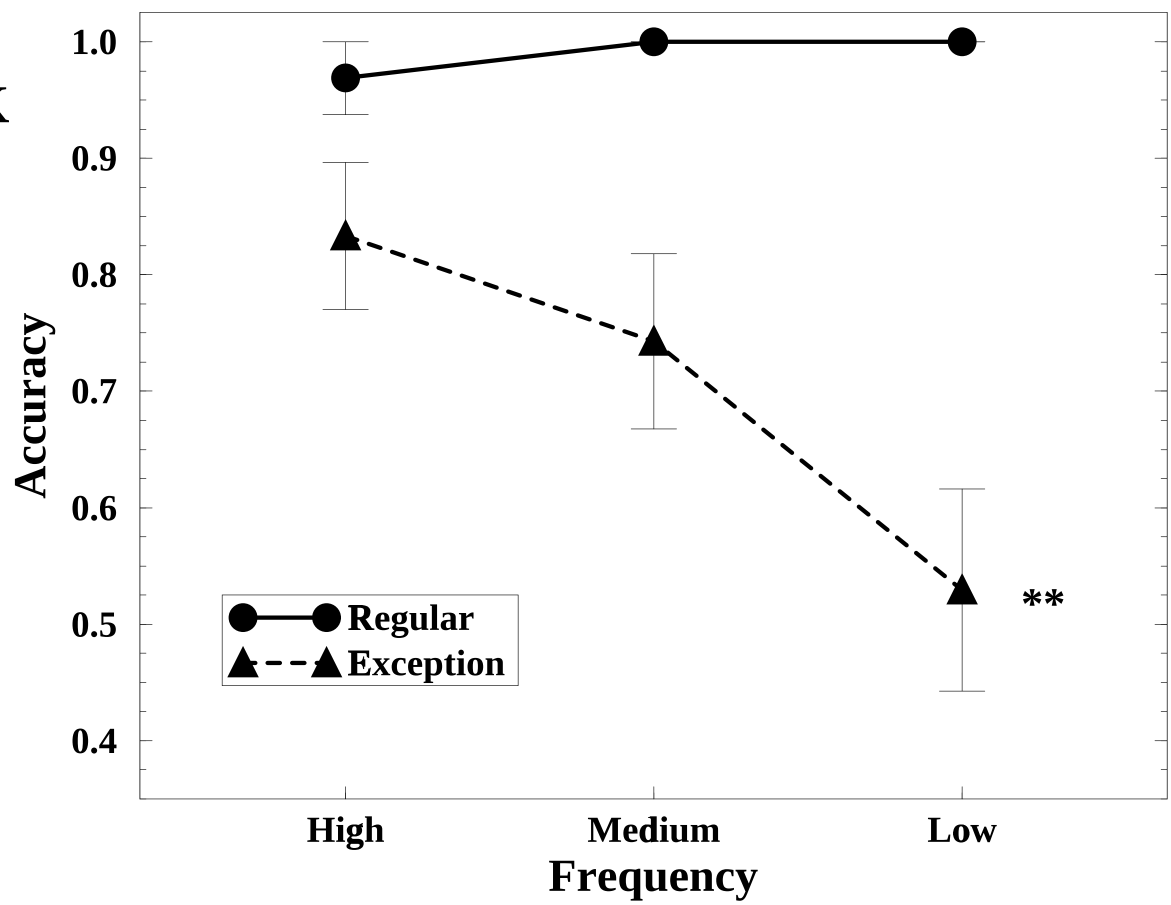
To better understand the absence of the expected frequency-by-consistency interaction in MP’s accuracy in reading the SM89 corpus, we selected out those items in the corpus that are also on the Surface List (Experiment 1). Data for 35 of the items in the initial analysis were unavailable, leaving 212 items for re-analysis. These items were analyzed in the same way as Experiment 1.

Surface List Within SM89 Corpus: Results

MP



NETWORK



Conclusions

- We believe that skilled reading involves the cooperative interaction of both the sublexical and lexical/semantic procedures.
- In surface dyslexic patients such as MP, the semantic system is severely impaired or disconnected from phonology, leaving only the sublexical procedure in operation.
- The sublexical procedure need not master all exception words because it can normally depend on the contribution of semantics.
- Such a sublexical procedure is approximated by a network that is only partially trained, capturing frequent and regular spelling-sound correspondences, but not those exhibited by low-frequency exception words.
- This view of the sublexical procedure contrasts with the claim that the sublexical procedure uses a system of rules that correctly pronounces all regular words and no exception words (e.g. Coltheart, Curtis, Atkins, & Haller, 1993).

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