DISRUPTION OF GRAPHEME-TO-PHONEME CORRESPONDENCE MAPPING DURING SINGLE WORD READING IN PATIENTS WITH EPILEPSY:

IMPLICATIONS FOR MODELS OF READING

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INTRODUCTION

The nature of the processes engaged during the oral reading of single words has long been a contentious issue in cognitive neuroscience, in part because it may presage much broader questions about the processing of high-level information. The two major classes of reading models, dual-route (Coltheart, et al., 2001) and connectionist (Harm & Seidenberg, 2004; Plaut, 1999; Seidenberg & McClelland, 1989), differ in their predictions about the processing of spelling-to-sound correspondence. Specifically, effects of the frequency of sublexical spelling-to-sound correspondences have been broadly taken to support connectionist models of reading (but see Coltheart, et al., 2001 for alternative explanations). Examining such frequency effects in patients with neural disorders might provide further tests of the generality of different models of reading, and contribute to our understanding of the neural representation of reading processes.

To this end, we tested two groups of patients with epilepsy on a single-word oral naming task using words that varied in the frequency of their spelling-to-sound correspondences. We compared our results to those reported previously for a non-patient population of normal readers (Brown, 1987).

EXPERIMENT

Materials

Participants were asked to name single printed words aloud as quickly and as accurately as possible; their reaction times and accuracy were recorded. Participants were tested on the Brown (1987) word list. Each word was classified as belonging to one of three categories:

Consistent words: the orthographic body of these words is common to many words in English, and the pronunciation of these words is consistent with the most frequent rime in the language.

Examples: SINK DRAIN BELT

Exception words: words with which other words frequently share the same orthographic body but a different rime; exception words were chosen to be the only words in the language with their rime.

Examples: SOUL DOUGH BOWL

Unique words: these words are the only words in English to have their orthographic word body; these words are thus consistent (in that the word body is always pronounced the same way), but the rime is infrequent in the language.

Examples: SOAP DOUBT BULB

All words were one syllable, of relative low frequency, and were matched across conditions on initial phoneme and on positional bigram frequency. The categories differ in terms of spelling-to-sound correspondence and along dimensions of sublexical frequency, as summarized below:

	Consistent	Exception	Unique
Regularity	High	Low	High
Consistency	High	Low	High
Ortho frequency	High	High	Low
Rime frequency	High	Low	Low
Neighborhood size (N)	6.33	3.24	1.86
Friends	High	None	None
Enemies	None	High	None

PARTICIPANTS

We tested thirty-four patients with epilepsy prior to resective surgery to diagnose and to ameliorate medically intractable seizures. All gave informed consent. For the purposes of data analysis, we subsequently divided the patients into three groups, based on the locus of the eventual brain resection (left-hemisphere, right-hemisphere, and other). Characteristics of the patients are provided in the table; the three groups did not differ significantly on any of the characteristics listed.

	LH (N = 23)			RH (N = 8)			Other (N = 3)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Age	31.57	12	49	29.63	11	43	32.33	22	44
Age of seizure onset	15.50	.25	42	7.00	1	14	14.00	7	19
Years of education	13.50	7	20	12.13	6	16	14.00	12	16
Pre-surgery FSIQ	96.19	73	125	93.75	73	105	90.67	82	97
Pre-surgery VIQ	95.33	72	124	93.00	74	111	96.67	93	100
% Right-handed	78%			100%			100%		
% Male	65%			38%			100%		

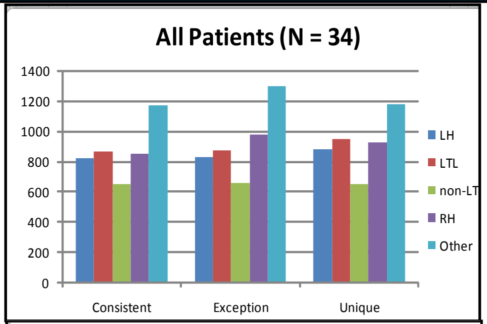
RESULTS

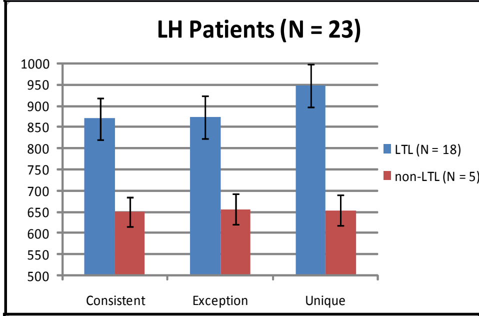
All Patients: There was a significant main effect of stimulus [F_1 (2, 62) = 5.841, p = .005, F_2 (2, 102) = 4.186, p = .018]. Planned comparisons indicated that participants were faster to name words in the Consistent condition, relative to words in the Exception condition [F_1 (1, 33) = 4.96, p = .033, F_2 (1, 53) = 10.771, p = .002] and the Unique condition [F_1 (1, 33) = 10.515, p = .003, F_2 (1, 53) = 2.420, p = .126], which did not differ significantly from each other [F_1 (1, 33) < 1; F_2 (1,53) = 1.340, p = .252].

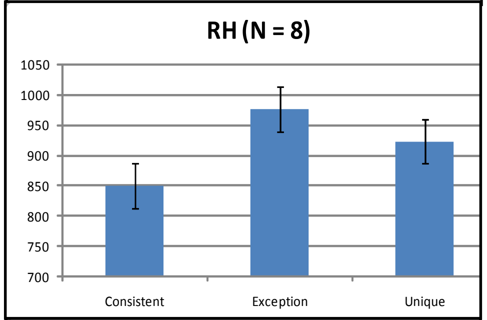
LH Patients: RTs were significantly faster to Consistent words [F_1 (1, 22) = 7.404, p = .012, F_2 (1, 17) = 7.136, p = .016] and to Exception words [F_1 (1, 22) = 7.419, p = .012, F_2 (1, 17) = 7.322, p = .015]. , relative to Unique words. RTs did not differ significantly between the Consistent and Exception conditions (Fs < 1). This pattern held true when the analysis was restricted to those patients whose eventual resection included the anterior left temporal lobe. This pattern did *not* hold true for the five LH patients whose eventual resection was outside of the left temporal lobe, whose RTs were overall faster (and less variable) than the LH LTL patients, and did not differ significantly by condition (all Fs < 1).

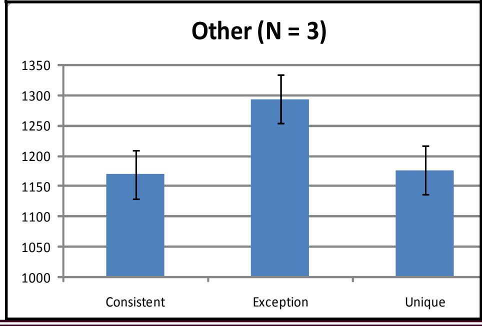
RH Patients: The RTs to words in the Consistent condition were generally faster than those to words in the Exception condition [F_1 (1, 7) = 3.058, p = .124; F_2 (1,17) = 19.196, p < .001] and in the Unique condition [F_1 (1, 7) = 2.866, p = .134, F_2 (1,17) = 4.016, p = .061], which did not differ from each other [F_1 (1, 7) = 1.619, p = .244, F_2 (1, 17) = 1.628, p = .219].

Other Patients: Patients in this group were generally much slower than patients in the LH and RH groups. For these patients, RTs to Exception words were the slowest [relative to Consistent: F_1 (1, 2) = 9.973, p = .087 ; F_2 (1,17) = 3.850, p = .066; relative to Unique words: F_1 (1, 2) = 7.645, p = .010, F_2 (1, 17) = 1.880, p = .188]. The other two conditions (Consistent and Unique) did not seem to differ from each other [Fs < 1].









DISCUSSION

Across all of our patients, there was no evidence of the primacy of spelling regularity or consistency per se in the determination of naming times. If this had been the case, we would have expected evidence in one of these groups that consistent and unique words (which are both high in regularity/consistency) were read faster than exception words. We did not observe this pattern. In normals (as shown by Brown, 1987), and in our group as a whole, reading times seemed to be determined primarily on the basis of rime frequency. This was also true of our RH patients.

We observed a different behavioral response from the LH/LTL patients. This group showed similar RTs to consistent and exception words, both of which were faster than unique words. This group, then, seems relatively more susceptible to the influence of orthographic body frequency, rather than rime frequency. Why would this group be less sensitive to phonological aspects of sublexical frequency and more sensitive to the orthographic aspects? It may be that an epileptic focus in the left temporal lobe results in less efficient functioning of this region. To the extent that this region is involved in the integration of orthography and phonology in typical cortical networks, this function may be disrupted in LTL epilepsy.

The LH/non-LTL patients, who showed the fastest RTs of our patient groups, did not show sensitivity to any of the features on which we characterized the words in the three conditions. This diverges from the sensitivity to rime frequency noted by Brown (1987) for normal adult readers. The patients in our Other group were much slower than the other patient groups tested; these patients showed a regularity or consistency effect. This group may thus have a greater reliance on GPC-type rules, and may not benefit from the type of whole-word processing that develops in normal readers with greater experience.

These results are relevant to the differential predictions of the two classes of reading models. It is difficult to see how orthographic body frequency and rime frequency effects could arise in a dual-route model, or how damage to the LTL would cause a greater influence of orthographic frequency on reading than rime frequency. Instead, the influence of sublexical frequency features such as rime frequency or body frequency on reading is more easily accommodated within the class of connectionist models, in which the influence of statistical regularities that are reflected in sublexical frequency features arise quite naturally through the design of the computational network.

WORKS CITED

Brown, G.D.A. (1987). *Journal of Memory & Language, 26*, 1-23.

Coltheart, M., et al. (2001). *Psychological Review, 108*, 204-256.

Harm, M.W., & Seidenberg, M.S. (2004). *Psychological Review, 111*, 662-720.

Plaut, D.C. (1999). *Cognitive Science, 23*, 543-568.

Seidenberg, M.S., & McClelland, J.L. (1989). *Psychological Review, 96*, 523-568.

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