

Distinguishing representation deficits and processing deficits in a case of acquired dysgraphia

Robert B. Katz & Toni Deser

To cite this article: Robert B. Katz & Toni Deser (1991) Distinguishing representation deficits and processing deficits in a case of acquired dysgraphia, The Quarterly Journal of Experimental Psychology Section A, 43:2, 249-266, DOI: [10.1080/14640749108400969](https://doi.org/10.1080/14640749108400969)

To link to this article: <http://dx.doi.org/10.1080/14640749108400969>



Published online: 29 May 2007.



Submit your article to this journal [↗](#)



Article views: 15



View related articles [↗](#)

Distinguishing Representation Deficits and Processing Deficits in a Case of Acquired Dysgraphia

Robert B. Katz and Toni Deser

*Aphasia Research Center, Department of Neurology, Boston
University School of Medicine, Boston, Massachusetts, U.S.A.*

The same acquired disorder of spelling may be due to deficits affecting lexical representations of word spelling or deficits affecting the mechanisms that process those representations. This study sought to distinguish these possibilities in a dysgraphic patient. The integrity of the patient's lexical orthographic representations was assessed by having him decide whether or not pairs of words presented auditorily rhymed. Although the patient was impaired on a variety of spelling tasks and with all types of stimulus material, he showed a normal effect of spelling on the rhyme task. Like normal subjects, he was faster at deciding that words rhymed when they were spelled similarly (e.g. *tool-cool*) than when they were spelled dissimilarly (e.g. *rule-cool*) and slower at deciding that words did not rhyme when they were spelled similarly (e.g. *toad-broad*) than when they were spelled dissimilarly (e.g. *code-broad*). Therefore, as the patient's lexical representations of word spelling seemed to be generally intact, his spelling problems were probably due to difficulty in processing those representations.

Names of syndromes in cognitive neuropsychology refer to families of impairments affecting a particular skill. For example, although surface dyslexia is thought to occur as a consequence of impaired lexical routes, leading to dependence on a non-lexical route for reading, Coltheart and Funnell (1987) noted seven different patterns of impairment to the lexical reading routes that could produce surface dyslexia. Therefore, terms such as "surface dyslexia" by themselves may not be particularly useful. Indeed, some investigators (e.g. Coltheart, 1987; Ellis, 1987) have called for the abandonment of the use of syndrome names, asserting that cognitive neuropsychologists should try to specify more precisely the deficits underlying patients' difficulty with a particular skill. The fundamental method used

Requests for reprints should be sent to: Robert Katz, Bell Communications Research, Room NVC 2X-413, 331 Newman Springs, Road, Red Bank, N.J. 07701, U.S.A.

This research was supported by NIH Grant NS06209. Some of the data were presented at the meeting of the Academy of Aphasia in October, 1989.

to specify the locus of impairment has been to administer a battery of tests that allows one to infer which storage and processing components are deficient; for example, an investigation of a spelling disorder might involve testing the patient on spelling to dictation, spontaneous spelling, written spelling, and oral spelling. In addition, it is relevant to examine the patient's performance on non-spelling skills that may share the same mechanisms as spelling. However, these techniques have not been very useful in dealing with one particularly thorny problem: how to distinguish between deficits that affect representations and deficits that affect the processing of those representations.

Distinguishing representation deficits from processing deficits is a particularly difficult problem because representations and the processes that apply to them are highly interdependent; they are so tightly tied together that they form a system (Anderson, 1978; Palmer, 1978). This point was highlighted in cognitive psychology several years ago during the debate as to whether visual imagery is more likely encoded by propositions or by pictorial representations. Anderson (1978) argued that no simple conclusion may be possible, as any body of behavioural data accounted for by a theory that uses pictorial representations can also be accounted for by a theory that uses stored propositions, and vice versa, provided that appropriate assumptions are made about the accompanying processes. Thus, differences in representations can be made up for by compensating differences in processes. In neuropsychology, a related problem exists in distinguishing between representation deficits and processing deficits. The same impairment may be accounted for either by a system with deficient representations and intact processing or by a system with intact representations and deficient processing.

When a patient can no longer perform a particular skill, this might be a consequence of degraded or deleted representations, of deficient processing, or of inability to access the appropriate representations. The reasons for inconsistent performance are also equivocal. Access deficits might cause inconsistent performance, as a representation would sometimes be accessed successfully and sometimes not, but processing deficits could also cause inconsistent success in processing representations. However, inconsistent performance might come from degraded representations, as the processing of degraded representations could sometimes yield correct responses and sometimes not. One might claim that error analyses can disentangle these possible sources of difficulty, but these analyses tend to be more helpful in ruling out access deficits than in deciding between representation and processing deficits. For example, on a spelling task, if a patient produces all of the correct letters of words but in the wrong order, it may be concluded that at least access to the correct representations was successful. However, production of partial information by itself does not indicate whether the main

problem is in the quality of the representations or in the processing applied to them. In the literature, both accounts have been given to explain this kind of spelling difficulty (Caramazza, Miceli, Villa, & Romani, 1987; Ellis, 1982).

Shallice (1987; see also Shallice, 1988) has described several techniques for ascertaining whether a deficiency lies in the quality of semantic representations or in access to those representations. Unfortunately, these techniques generally do not shed light on the distinction between representation and processing deficits. Effects that depend on analyses of response consistency or on manipulations of word frequency and rate of presentation could arise either from representation deficits or deficits in processing representations. One technique noted by Shallice seems to be relatively less vulnerable to criticism of this sort, however, and it may be generalizable to the analysis of several different skills. Applied to the semantic system, this technique involves the use of priming in the lexical decision task. If patients with semantic difficulty show an effect of semantic priming in deciding the lexical status of letter strings, then it is likely that their semantic representations are relatively intact. The patients' problem, then, would be in accessing or processing semantic representations in particular tasks. The priming paradigm was used by Milberg and Blumstein (1981), who found that Wernicke's aphasics were poor at making judgements of semantic similarity but showed an effect of semantic priming. It is important to note that this paradigm does not require subjects to make an analysis of the semantic relatedness of words. Rather, subjects simply decide whether or not stimulus items are words. There is no inherent reason why semantic factors must come into play under these circumstances, but they do. Thus, the integrity of semantic representations can be ascertained by having subjects perform a task that is not semantic in and of itself.

The purpose of this investigation was to test whether a task analogous to semantic priming could be applied to another domain of performance—in this case spelling—to determine whether a patient's impairment was more likely to be due to deficits affecting lexical representations or deficits affecting the processing of those representations. The patient had spelling difficulty on a variety of spelling tasks and with all kinds of stimulus materials. To examine whether he had generally disturbed representations or generally disturbed processing mechanisms for spelling, we used a task that did not require him to spell words but which, in normal subjects, is influenced by word spelling and presumably uses the representations necessary for accurate spelling. In this experiment, the patient had to decide whether or not pairs of words presented auditorily rhymed. Rhyme judgements are simple to make even by young children (e.g. Lenel & Cantor, 1981), and they can be made on the basis of phonological information alone. However, for literate adults it has been found that the spelling of the stimulus words influences the speed of the rhyme decision (Donnenwerth-Nolan, Tanenhaus, & Seidenberg, 1981;

Seidenberg & Tanenhaus, 1979). Adults are significantly faster at deciding that words spelled similarly (e.g. *bite-kite*) rhyme than that words that are spelled dissimilarly (e.g. *flight-kite*) do. Conversely, they are slower to decide that words do not rhyme when they are spelled similarly (e.g. *freight-height*) than when they are spelled dissimilarly (e.g. *date-height*). If our patient, who had a severe spelling disorder, performed normally on this task, then this would indicate that his lexical representations of word spelling were generally intact.

CASE REPORT

C.C. was a 61-year-old right-handed high school graduate who had worked as a meat cutter in a supermarket. Four years before testing began for the present study, he had a coronary artery bypass graft and awakened from surgery confused and agitated. CT scan revealed a left-hemisphere lesion involving portions of the posterior temporal lobe with superior extension into the region of the supramarginal and angular gyri and a large occipital lobe lesion. His neurological examination was essentially normal, except for a dense right homonymous hemianopsia. Two weeks later, his speech was fluent and empty and contaminated by literal paraphasias and neologisms. He also showed deficits in auditory comprehension, repetition, naming, reading, and writing. Two months later, his speech had improved, but it still contained literal and semantic paraphasias and frequent word-finding pauses. Repetition was good for one-syllable words but broke down on phrases. Comprehension was good for yes/no questions and two-step commands.

C.C. was given the *Boston Diagnostic Aphasia Examination* (Goodglass & Kaplan, 1983) two months post-onset and showed impairments on virtually every test. However, one month later his scores in auditory comprehension and repetition had improved, and his neuropsychological profile was consistent with Wernicke's aphasia. On the *Wechsler Adult Intelligence Scale-Revised* (Wechsler, 1981), he attained a performance IQ of 76. Praxis, map localization, and drawing and copying figures were intact. At the time of the present testing, four years post-onset, C.C. remained a cooperative and friendly subject. His speech and auditory comprehension had recovered to the point where he was able to discuss many everyday topics with little difficulty, but he still had problems with naming, reading, and writing.

On the reading (Level 2) subtest of the *Wide Range Achievement Test-Revised* (WRAT-R) (Jastak & Wilkinson, 1984), which requires oral reading of individual words, C.C. read the first 11 of the easiest test words without difficulty, but he was unable to read any words after the 28th item. Overall, he read only 23 words correctly, and his score corresponded to a fourth-grade level. We then asked him to read 12 regularly spelled and 12 irregularly

spelled words selected from the list of Coltheart, Besner, Jonasson, and Davelaar (1979). He was able to read 10 of the regular words and 7 of the irregular. His errors were mainly visual confusions. Next, we had him read 20 nouns and 20 functors matched in length and all of high frequency (greater than 100/million in the word count of Thorndike & Lorge, 1944). He read 19 nouns and all 20 functors correctly. C.C. was also given a list of 12 non-words to read. Of the six one-syllable items, he read three correctly, whereas of the six two-syllable items he was unable to pronounce any in a plausible manner. His errors on one-syllable non-words usually had only one phoneme wrong. His errors on two-syllable non-words had more incorrect phonemes, but at least the initial phonemes were usually read in a plausible way. Finally, C.C. had relatively little difficulty naming letters, as he scored 25 of 26 correct.

Spelling

As a first measure of C.C.'s spelling ability, we administered the spelling subtests of the WRAT-R, which require writing individual words to dictation. We first gave him the Level 2 subtest, but this was too difficult for him. He spelled the first two test words correctly, made an error on the third word (*arm*), spelled the fourth word correctly, then made errors on the next three words (*shout*, *correct*, *circle*). Thus, he was able to spell correctly only three of the first seven test words. We then administered the Level 1 spelling subtest. On this test, he spelled the first four words correctly but made an error on the fifth item (*and*). Altogether, before reaching ceiling level, he correctly spelled 14 of 23 words, which corresponded to a second-grade spelling level.

Letter Processing

When we asked C.C. to write letters to dictation, he scored 20 of 23 (87%) correct. Although this score was relatively high, it was below his performance in writing numbers to dictation. On both 1-digit and 2-digit numbers, he scored 10 of 10 correct. C.C. was also tested on his ability to change upper-case letters to lower-case and vice versa. All test items had visually dissimilar upper-case and lower-case forms (e.g. *Gg*, *Rr*). When changing lower-case to upper-case, he scored seven of eight correct; his one error was on *g*. When changing upper-case to lower-case, he scored five of eight correct; his errors were on *B*, *G*, and *H*. On a multiple choice version of this test, he made no errors.

Effect of Word Frequency and Length

To examine the effect of word length and word frequency on C.C.'s spelling, we had him write to dictation a list of words consisting of three, five,

TABLE 1
Number of Correct Responses as a Function of Word Frequency and Length

Length	Frequency Group							Total
	High			Low				
	I	II	III	IV	V	VI	VII	
3 letters	2	2	3	3	2	1	2	15
5 letters	3	2	2	0	1	3	0	11
7 letters	1	1	1	0	0	1	0	4
Total	6	5	6	3	3	5	2	30

Note: Max. = 5 in each frequency \times length cell.

or seven letters. Each word belonged to one of seven frequency groups. The lowest-frequency words occurred once in the corpus of Kučera and Francis (1967), whereas the highest-frequency words occurred more than 270 times. There were 5 words in each frequency \times length cell, making a total of 105 words. The results are shown in Table 1. From the table it can be seen that C.C.'s performance varied with word length, $\chi^2(2) = 8.7$, $p = 0.01$, and that his spelling accuracy was particularly poor on seven-letter words. Word frequency did not have an effect, $\chi^2(6) = 5.0$, n.s.

Although C.C.'s performance was affected by word length, he made the same types of errors on words of all lengths. Of his 75 errors, 22 came from a mistake affecting a single letter. Of these, 13 were substitutions (e.g. "rig" \rightarrow rag), 4 insertions (e.g. "roast" \rightarrow roaste), 3 deletions (e.g. "beard" \rightarrow bard), and 2 transpositions (e.g. "birth" \rightarrow brith). Most of C.C.'s errors, however, included mistakes that affected more than one letter. Of the 51 errors of this type, 26 were rated as generally similar to the correct spelling. These errors included at least half of the correct letters in approximately the correct position within the word (e.g. "monsoon" \rightarrow monsason; "mermaid" \rightarrow mewmaid). The other 25 errors represented the correct spelling less closely (e.g. "swallow" \rightarrow sweler) and in some cases had no clear relation at all to the stimulus word (e.g. "emerald" \rightarrow wholde). Some of these errors retained the pronunciation of the stimulus words, at least in part (e.g. "culture" \rightarrow coulocher). Finally, C.C. made two errors of a semantic nature ("treat" \rightarrow trick; "flame" \rightarrow llamp).

Although many of C.C.'s errors bore little resemblance to the correct responses, his errors were usually of the right approximate length. Of his 20 errors on three-letter words, 17 had three letters and the remaining 3 were off

by only one letter. Of his 24 errors on five-letter words, 10 had five letters and 11 were off by a single letter. Similarly, of the 31 errors on seven-letter words, 14 had seven letters and 13 were off by one letter. The correlation between the number of letters in the stimulus words and the number of letters in the error responses was highly significant, $r(73) = 0.86$, $p < 0.001$.

Effect of Part of Speech

To test the effect of part of speech, we asked C.C. to write to dictation sets of 20 nouns, verbs, adjectives, and functors. All of the words were of high frequency (greater than 100/million in the word count of Thorndike & Lorge, 1944) and were matched in length. No effect of grammatical class was found, as C.C. correctly spelled 12 nouns, 8 verbs, 8 adjectives, and 9 functors. In a later session we asked him to spell the same sets of words aloud. His accuracy level and errors were similar to those he had made in written spelling, and again no effect of grammatical class was apparent. He correctly spelled 12 nouns, 10 verbs, 13 adjectives, and 12 functors.

We presented the list of nouns to C.C. on a third occasion and asked him to assemble the spelling of the items using wooden tiles, each of which had a single letter printed on it. Although the tiles were arranged in alphabetical order on the table, C.C. had difficulty locating the tiles he wanted, making his performance quite slow. Nevertheless, his performance was close to that found in written and oral spelling; he successfully constructed the spelling of 9 of the 20 nouns. We also noted that he sometimes detected a spelling error that he had made; after assembling an erroneous response, he sometimes remarked that it was wrong. On these occasions, however, he did not know how to correct his responses, and he ultimately decided that his initial responses had been correct.

Effect of Concreteness

To examine whether the concreteness of words was related to C.C.'s spelling performance, we created two sets of nouns matched in frequency and word length. The abstract words had a concreteness rating below 3 in the norms of Paivio, Yuille, and Madigan (1968), whereas the concrete words had a rating above 6. The examiner spoke each word aloud, and C.C. spelled it aloud. The results showed no effect of concreteness. C.C. correctly spelled 7 of the 30 abstract words (23%) and 9 of the 30 concrete (30%).

Spontaneous Spelling

We showed C.C. a drawing of an outdoor scene and asked him to write a description of it. He wrote three sentences, consisting of 23 words (12 functors and 11 content words). The verb was omitted from one sentence,

and part of a second sentence was ungrammatical. Examining the spelling of the individual words, we found that 2 of the 11 content words were misspelled (*mother*→*month*; *picnic*→*pic*). All function words were used appropriately and spelled correctly.

Written Object Naming

We showed C.C. 11 pictured objects selected from the *Boston Naming Test* (Kaplan, Goodglass, & Weintraub, 1983) and 5 real objects and asked him to write their names. Before attempting to spell the object names, he always said them aloud. He named all 16 objects correctly, but we noted minor pronunciation errors on 4 items. In contrast, he correctly spelled only 4 of the 16 object names (25%). All of the errors except one had the first letter written correctly, and some errors included only one incorrect letter (e.g. *thumb*→*thump*). However, most errors were farther off (e.g. *volcano*→*vivioni*). In fact, in some errors only the first letter was correct.

Delayed Copy Transcription

We tested C.C. on delayed copy transcription by showing him a word for 5 sec, removing the word, and having him write it. He always read the word aloud as it was presented, and all but one of his 10 oral reading responses were accurate. Nevertheless, he wrote only 4 of the 10 words correctly. His errors were like his errors in spelling to dictation (e.g. *cheek*→*chicke*; *flame*→*frmer*).

Non-words

C.C. wrote to dictation 10 one-syllable non-words. He correctly spelled only 4 of the items. Of his 6 errors, 4 began with the correct letters (e.g. /sɔɪg/→*sove*). Two of these erroneous responses were words. The remaining two errors included mainly incorrect letters.

Summary

Although C.C. was a high school graduate, he scored at the second-grade level on a standardized test of spelling. Furthermore, he had difficulty with written spelling, oral spelling, spelling by arranging anagram letters, written object naming, spontaneous spelling, and delayed copy transcription. He made many errors on all types of words and on non-words. His spelling was affected by word length but not by word frequency, part of speech, or concreteness. Some of his errors came from a mistake affecting a single letter. However, most of his errors included mistakes affecting more than one letter, and many errors had little resemblance to the correct responses. Although his spelling difficulty did not conform to any particular type of pure spelling impairment noted in the literature, he clearly had a severe spelling problem.

The Rhyme Experiment

The question of concern here was whether C.C.'s spelling problem was due to generally disturbed representations or generally disturbed processing mechanisms for spelling. To examine this issue, we tested him on a rhyme task. The task did not require him to spell words but, in normal subjects, performance is influenced by word spelling. C.C.'s auditory and memorial abilities were sufficient to make use of this task possible. We reasoned that if he showed a normal effect of spelling on the rhyme task, then this would indicate that his lexical representations of word spelling were basically intact. Moreover, as the rhyme task, like spelling to dictation, requires using spoken words to access lexical orthographic representations, normal performance would suggest that C.C.'s lexical access ability was adequate for many spelling tasks.

Method

Control Subjects. In addition to C.C., a control group of eight normal men was tested. Their ages and educational levels were similar to those of C.C. They ranged in age from 56- to 69-years old, with a mean age of 62. All were high school graduates, and two had graduated from college.

Design. On each trial of the experiment, two words were presented in succession. The first word was the cue word and the second the target word. The subjects' task was to decide quickly whether or not the words rhymed. The two words either had similar spelling or dissimilar spelling. Thus, there were four conditions: (1) rhyming words with similar spelling (e.g. *tool-cool*), (2) rhyming words with dissimilar spelling (e.g. *rule-cool*), (3) non-rhyming words with similar spelling (e.g. *toad-broad*), and (4) non-rhyming words with dissimilar spelling (e.g. *code-broad*).

Stimuli. The procedure used to assemble the test stimuli was taken from Seidenberg and Tanenhaus (1979, Experiment 2). Stimuli for the two rhyming word conditions were created at the same time. First, we devised sets of three rhyming words, two of which were spelled similarly and one differently (e.g. *cool, tool, rule*). Next, one of the two similarly spelled words (*cool*) was chosen as the target word for both the "rhyme-similar spelling" condition and the "rhyme-dissimilar spelling" condition. The cue word for the "rhyme-similar spelling" condition was the word (*tool*) that was spelled like the target word. The cue word for the "rhyme-dissimilar spelling" condition was the word (*rule*) spelled differently from the target.

Stimuli for the two non-rhyme conditions were also assembled together. This process also began with sets of three words. This time two of the words in each set rhymed but were not spelled alike, whereas the third word did not

rhyme with either of the other two words but was spelled like one of them (e.g. *code*, *toad*, *broad*). The non-rhyming word (*broad*) was chosen as the target word for both the "non-rhyme-similar spelling" condition and the "non-rhyme-dissimilar spelling" condition. The cue word for the "non-rhyme-similar spelling" condition was the word (*toad*) spelled like the target word. The cue word for the "non-rhyme-dissimilar spelling" condition was the word (*code*) spelled differently from the target word.

Using this method, 30 trials were created for each of the four conditions. For each trial in the "rhyme-similar spelling" condition, there was a corresponding trial in the "rhyme-dissimilar spelling" condition that had the same target word. This was also true of the two non-rhyme conditions. As the stimuli were being assembled, care was taken to equate the conditions for the mean word frequency (Carroll, Davies, & Richman, 1971) of the target and cue words. To examine possible frequency differences, we computed an analysis of variance with rhyme (rhyme, non-rhyme) and word group (target word, cue word of similar spelling condition, cue word of dissimilar spelling condition) as between-groups factors. Neither main effect was significant ($F < 1$ in both cases), nor was the interaction ($F = 1.1$).

The 120 trials were randomized with these three constraints: (1) the first half of the test and the second half had an equal number of trials of each type; (2) no more than four consecutive trials consisted of either rhyming words or of non-rhyming words; and (3) trials with the same target word never appeared in the same half of the test. The words were then recorded on audiotape by a male talker. Each trial began with a ready signal, followed by the cue word and the target word. The interval between each element of a trial was 2 sec, and the interval between trials was 6 sec. Twelve practice trials constructed in the same manner as the test trials were recorded before the test trials. Next, a tone was recorded on the second track of the tape, synchronous with the beginning of the target word on each trial. During the experiment, the tone, which was inaudible to the subjects, triggered a digital millisecond clock. The clock was stopped when the subject made a key press. Due to error in placing the tone, one trial had to be omitted for every subject.

Procedure. The subjects' task was to decide as quickly and accurately as possible whether or not the two words in each trial rhymed. The words were presented binaurally through headphones. The subjects responded by pressing one of two keys, which were clearly marked YES and NO. As a reminder of the task, a card marked RHYME? was placed between the response keys. The subjects used the index finger of their preferred hand for responding. They were asked to keep their finger on a mark between the keys when they were not making a response. Before presentation of the practice trials, the examiner ascertained that the subjects could distinguish rhyming and non-rhyming word pairs and familiarized them with the response keys. The

TABLE 2
 Mean Percentage of Error as a Function of Spelling and Rhyme for
 Normal Subjects and C.C.

	<i>Similar Spelling</i>		<i>Dissimilar Spelling</i>	
	<i>Rhyme</i>	<i>Non-rhyme</i>	<i>Rhyme</i>	<i>Non-rhyme</i>
Normals	0.9	5.0	1.7	2.9
C.C.	6.7	20.0	3.3	20.0

subjects then completed the 12 practice trials and 60 of the test trials. After a rest period, the final 60 test trials were given. After each response, the examiner recorded the subject's decision and reaction time.

Results

Normal Control Subjects. The mean error percentages for the normal subjects are shown in Table 2. It can be seen that the mean percentage of errors was low, averaging less than 3% across conditions. The percentage of errors was examined in an analysis of variance with two within-groups factors (rhyme and spelling). No significant effects were found: rhyme, $F=1.7$; spelling, $F<1$; the interaction between rhyme and spelling, $F=1.0$.

Before the reaction times were analysed, for each subject we eliminated trials on which an incorrect response had been given. The mean reaction times are shown in Figure 1. The reaction times were examined in an analysis of variance with two within-groups measures (rhyme and spelling). A significant main effect of rhyme was revealed, $F(1, 7)=13.0$, $MS_e=20,217.4$, $p=0.0087$, as the subjects were faster on rhyming word pairs than on non-rhyming pairs. The main effect of spelling was not significant ($F<1$). Importantly, a significant interaction between rhyme and spelling was found, $F(1, 7)=11.5$, $MS_e=812.6$, $p=0.0116$. As expected, on rhyming word pairs the subjects were faster when the words were spelled alike than when they were spelled differently. On the non-rhyming pairs, the opposite was found: performance was faster when the words were spelled differently than when they were spelled similarly.

C.C. The mean error percentages for C.C. are listed in Table 2. Overall, his mean percentage of errors was 12.5. Thus, he made more errors than did the normal subjects. It is also clear that his error percentage varied with rhyme condition. Although the effect of rhyme condition was not statistically significant for the normal subjects, their mean error percentage was somewhat higher on the non-rhyme trials than on the rhyme trials. For C.C., this difference was much greater. On the rhyme trials he averaged 5% error, but

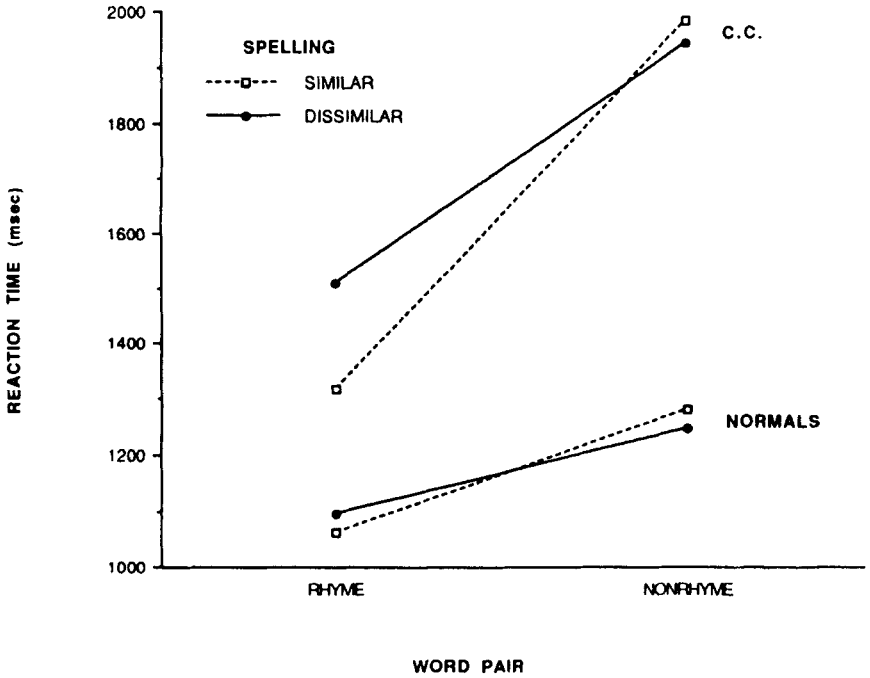


FIG. 1. Mean reaction time as a function of rhyme and spelling for normal subjects and C.C.

on the non-rhyme trials he averaged 20% error. Rhyme condition did not interact with word spelling, however; he made more errors on the non-rhyme trials than on the rhyme trials, whether the stimulus words were spelled similarly or dissimilarly. Possibly, C.C. made more errors on the non-rhyme trials simply because he had a bias to say that words rhymed.

Before examining C.C.'s reaction times, incorrect trials were eliminated. As fewer rhyme trials had to be eliminated, the reaction times in the rhyme condition were probably more reliable than those in the non-rhyme condition. C.C.'s mean reaction times are shown in Figure 1. Two features of his performance are immediately obvious: (1) He was generally slower than the normal subjects were; his mean reaction time was 1689 msec, compared with 1172 msec for the normal subjects. (2) The general pattern of his results conformed to that of the normal subjects. He, too, was faster on rhyming trials than on non-rhyming trials. More importantly, like the normal subjects, he showed a clear effect of spelling on his rhyme decisions. On rhyming word pairs, similarly spelled words had an advantage of 193 msec, but on non-rhyming pairs the mean reaction time for similarly spelled words was 40 msec longer than for dissimilarly spelled words.

Further examination of C.C.'s data revealed that he showed a reaction time advantage for similarly spelled over dissimilarly spelled rhyming words on both halves of the test. In the non-rhyme condition, however, dissimilarly spelled words showed an advantage over similarly spelled words only on the first half of the test. On the second half, the reaction times were equal. To see whether his mean reaction times had been skewed by a few extremely long reaction times, we examined C.C.'s data again, this time excluding trials with a reaction time one and a half standard deviations above the mean for its condition. We found that C.C. still showed the normal effect in the rhyme condition on both test halves, and he also showed the normal effect in the non-rhyme condition on both halves.

Thus, the results indicated that C.C., like the normal subjects, showed an influence of spelling on rhyme decisions. The question remained as to how well C.C. could spell the words used in the rhyme task. Accordingly, we asked him to write the stimulus words to dictation. He correctly wrote only 24 (40%) of the 60 target words. His accuracy level on the 120 cue words was similar, as he correctly spelled 46 (38%). We also determined that only 20% of the test trials had used both a stimulus word and a cue word that C.C. spelled correctly. When we examined his spelling errors, moreover, we found that 92% included a mistake affecting the vowel or post-vocalic consonants, which are the portions of the word whose spelling would be most likely to influence the speed of rhyme judgements. Thus, if C.C.'s spelling errors had been due to degraded lexical orthographic representations, then he would have usually been making rhyme decisions based on words spelled dissimilarly in his lexicon, and he should not have shown a normal effect of spelling on the speed of rhyme decisions.

We also examined C.C.'s reaction times from the rhyme experiment using only those trials with words he had trouble spelling. Trials were included in this analysis if C.C. had misspelled either the target word, the cue word, or both words. The results showed that C.C. still showed a reaction time advantage of 112 msec for similarly spelled words over dissimilarly spelled words in the rhyme condition. However, on the non-rhyme condition, similarly spelled words also had an advantage of 30 msec. When we examined the data of the normal subjects using the same trials (i.e. the trials selected on the basis of C.C.'s spelling errors), we found that, like C.C., three of the eight normal subjects also failed to show an advantage of dissimilarly spelled words in the non-rhyme condition. Two of the subjects showed essentially equal reaction times, and the third was 61 msec faster on similarly spelled words. A statistical comparison of the normal subjects' reaction times for these non-rhyme trials did not reach significance, $t(7) = 2.1$, $p = 0.0711$. Thus, the effect of word spelling shown by C.C. was within the range of normal performance.

As C.C.'s pattern of performance was like that of the normal subjects, it is apparent that his lexical orthographic representations were generally intact and accessible. Therefore, his difficulty with spelling was probably attributable to processing deficits.

DISCUSSION

Distinguishing representation deficits and processing deficits is difficult, as representations and the processes that apply to them are tightly bound. This can be seen by examining acquired disorders of spelling. Surface dysgraphia is a disorder in which lexical routes for spelling are unavailable. However, the lexical routes can be unavailable for several reasons: the lexical representations of word spelling may be generally degraded, the representations may be inaccessible, or the representations may be unusable because of faulty processing routines. Similarly, the occurrence of letter order errors in spelling could be due to degraded lexical representations or to weaknesses in processing relatively intact representations.

In the present study, we used a technique that we thought would be helpful in distinguishing representation and processing deficits. The technique required the patient to decide whether or not pairs of words presented auditorily rhymed. Although in theory this task can be done by using phonological information alone, reaction times for literate adults vary with the spelling of the words presented (Donnenwerth-Nolan et al., 1981; Seidenberg & Tanenhaus, 1979). Thus, reaction times show an effect of word spelling even though words do not have to be spelled. The patient we tested had difficulty on a variety of spelling tasks as a consequence of stroke. As his spelling errors usually included mistakes that affected the latter portions of words, if his errors had come from degraded lexical orthographic representations, then he would not have been expected to show a normal effect of spelling on the rhyme task. However, the results indicated that C.C. did show the normal effect when all of his data were used in the analysis as well as when extreme reaction times were excluded. Furthermore, when the analysis was restricted to trials with words he did not spell correctly, he continued to show an effect in the rhyme condition. Thus, it may be concluded that his lexical representations of word spelling were generally intact and his difficulty on tests of explicit spelling were not due to representation deficits.

If impaired lexical representations were not the source of C.C.'s spelling difficulty, did he have deficits in accessing lexical representations? As the rhyme task requires lexical access, C.C.'s normal performance on this task suggests that he could access lexical orthographic representations from words presented auditorily. Therefore, we would not expect access deficits to be the source of his spelling difficulty, at least for spelling to dictation, which begins with auditory input. Still, one could argue that the effect of

spelling in the rhyme task involves rapid, automatic lexical access, whereas ordinary spelling tasks require slow, controlled lexical access. On this argument, C.C.'s central problem was using auditory input for controlled access to orthographic information. However, C.C.'s high incidence of spelling errors that affected a single letter of the word indicated that he did not have a general problem with controlled lexical access. Moreover, a problem in accessing lexical representations from auditory input cannot account for the similarity in C.C.'s errors in spelling to dictation, spelling the names of objects, and writing a description of a scene. Therefore, his spelling difficulty probably did not come either from access deficits or from impaired lexical representations. His spelling difficulty was more probably attributable mainly to deficits in processing lexical orthographic representations.

If C.C.'s main problem in spelling was due to post-access processing deficits, it is relevant to ask what processing steps may have been impaired. As many of his spelling errors on words and non-words resembled those made by patients with impairment of the graphemic buffer (Caramazza et al., 1987; Miceli, Silveri, & Caramazza, 1985), this kind of impairment may have been a partial source of his spelling difficulty. Possibly, the graphemic buffer is necessary for spelling tasks but is not involved in the much more rapid task of making rhyme decisions. (Alternatively, even if the graphemic buffer becomes active when rhyme decisions are made, C.C.'s graphemic buffer could have had an abnormally fast decay rate, leading to impaired spelling performance but a normal pattern of rhyme performance.) Nevertheless, as many of C.C.'s spelling errors were not consistent with a graphemic buffer deficit, it is likely that he had other deficits as well. It may be that he also had deficiencies associated with the transfer of information to the graphemic buffer. Transfer of information to the graphemic buffer would require that lexical orthographic representations be maintained in an active state for a certain amount of time and that the processes for effecting the transfer be intact. Clearly C.C.'s orthographic representations could be activated, as this is why spelling had an effect on rhyme decisions. However, whereas orthographic representations activated briefly may influence rhyme decisions, transfer of information to the graphemic buffer may require relatively long activation times. Therefore, it is possible that one processing deficit C.C. had was in maintaining the activation level of lexical representations. A problem with this account is that it might have been expected that C.C. could activate lexical representations repeatedly until all orthographic information had been transferred to the graphemic buffer and used to spell words correctly. As this did not occur, we may suppose that the processes that effect the transfer of information to the graphemic buffer were themselves impaired. Conceivably, C.C. also had more peripheral deficits, which may have affected one form of spelling, such as written spelling, more than others.

We have interpreted the results of the rhyme experiment as indicating that C.C.'s representations of word spelling and access to them were relatively unimpaired. Therefore, his spelling difficulty came from processing deficits. It is necessary to point out that this interpretation assumes a model of reading and spelling with a single orthographic lexicon (e.g. Allport & Funnell, 1981), which subserves both reading and spelling. The results of the rhyme experiment suggested that C.C.'s orthographic representations were intact. Therefore, on a one-lexicon model, neither his spelling difficulty nor his less serious reading difficulty came from representation deficits; C.C.'s spelling difficulty and his reading difficulty were probably due to processing deficits. On a two-lexicon model, however, the interpretation of the rhyme experiment is ambiguous. This type of model (e.g. Morton, 1980) has two orthographic lexicons, an input lexicon (normally used for reading) and an output lexicon (normally used for spelling). Thus, the influence of word spelling on rhyme performance could have come from either of the two lexicons. If the output lexicon was the source of the spelling effect in the rhyme task, then our conclusion that C.C. had spelling difficulty because of processing deficits stands. If the input lexicon was the source, it does not, as the influence of spelling on rhyme decisions came from representations normally used for reading. That is, on a two-lexicon model, C.C. could have shown a normal effect of spelling on the rhyme task due to intact representations in the input lexicon but had spelling difficulty due to deficient representations in the orthographic output lexicon. However, in this case, C.C. must have had reading difficulty because of processing deficits. In this case, the rhyme experiment, by showing that the orthographic input lexicon was intact, actually distinguished representation deficits and processing deficits in reading. At present, the one-lexicon view and the two-lexicon view cannot be convincingly distinguished; some studies (e.g. Coltheart & Funnell, 1987) favour the one-lexicon view, and others (e.g. Campbell, 1987) favour the two-lexicon view. Therefore, on the grounds of parsimony, the one-lexicon view is preferable at this time, leading to the conclusion that C.C.'s spelling difficulty was due to processing deficits.

Recently, it has been proposed (Taft & Hambly, 1985) that the lexically stored phonological representations of words become modified by reading and spelling experience. On this position, literate people have a single representational store of amalgamated phonological and orthographic information, which is used for reading, spelling, listening, and speaking. If literacy produces orthographically influenced phonological representations, then the effect of spelling in the rhyme task comes from the same representations that are used to make the rhyme decisions themselves. If this is so, then all literate and formerly literate people who can decide whether or not words rhyme should show an effect of spelling in the rhyme experiment. Furthermore, whenever formerly literate people are dysgraphic but can still make rhyme

decisions, as was the case for C.C., processing deficits must be the source of their spelling difficulty.

In our study, the patient did poorly on explicit spelling tasks. Nevertheless, in the rhyme experiment, which did not require words to be spelled explicitly, word spelling had an effect. This is the first case in which a difference between explicit and implicit performance has been demonstrated for spelling. In other domains, several cases have been reported in which patients who performed poorly in explicit testing showed relatively good performance in implicit testing: vision (e.g. Weiskrantz, Warrington, Sanders, & Marshall, 1974), memory (e.g. Warrington & Weiskrantz, 1968), semantic ability (e.g. Milberg & Blumstein, 1981), face recognition (de Haan, Young, & Newcombe, 1987), and reading (e.g. Coslett & Saffran, 1989). These implicit/explicit differences may readily be interpreted as indicating intact representations in the face of processing deficits that affect explicit performance. A more difficult problem would be to interpret deficiencies in both explicit and implicit performance. This pattern could occur either from representation deficits or from intact representations with processing deficits for both implicit and explicit tasks. In fact, at this time it is not clear how one could ever convincingly demonstrate the existence of representation deficits.

In summary, the rhyme task can be helpful in distinguishing representation deficits and processing deficits by demonstrating that representations are intact. The rhyme task may be one case of a more general paradigm for examining implicit ability. It may be possible to devise analogous tasks to test the status of representations used in other domains.

REFERENCES

- Allport, D. A. & Funnell, E. (1981). Components of the mental lexicon. *Philosophical Transactions of the Royal Society of London*, *B295*, 397-410.
- Anderson, J. R. (1978). Arguments concerning representations for mental imagery. *Psychological Review*, *85*, 249-277.
- Campbell, R. (1987). One or two lexicons for reading and writing words: Can misspellings shed any light? *Cognitive Neuropsychology*, *4*, 487-499.
- Caramazza, A., Miceli, G., Villa, G., & Romani, C. (1987). The role of the graphemic buffer in spelling: Evidence from a case of acquired dysgraphia. *Cognition*, *26*, 59-85.
- Carroll, J. B., Davies, P., & Richman, B. (1971). *Word frequency book*. New York: American Heritage.
- Coltheart, M. (1987). Functional architecture of the language-processing system. In M. Coltheart, G. Sartori, & R. Job (Eds.), *The cognitive neuropsychology of language* (pp. 1-25). London: Lawrence Erlbaum Associates Ltd.
- Coltheart, M., Besner, D., Jonasson, J. T., & Davelaar, E. (1979). Phonological encoding in the lexical decision task. *Quarterly Journal of Experimental Psychology*, *31*, 489-507.
- Coltheart, M. & Funnell, E. (1987). Reading and writing: One lexicon or two? In D. A. Allport, D. G. MacKay, W. Prinz, & E. Scheerer (Eds.), *Language perception and production* (pp. 313-340). London: Academic Press.

- Coslett, H. B. & Saffran, E. M. (1989). Evidence for preserved reading in "pure alexia". *Brain*, 112, 327-359.
- de Haan, E. H. F., Young, A., & Newcombe, F. (1987). Face recognition without awareness. *Cognitive Neuropsychology*, 4, 385-415.
- Donnenwerth-Nolan, S., Tanenhaus, M. K., & Seidenberg, M. S. (1981). Multiple code activation in word recognition: Evidence from rhyme monitoring. *Journal of Experimental Psychology: Human Learning and Memory*, 7, 170-180.
- Ellis, A. W. (1982). Spelling and writing (and reading and speaking). In A. W. Ellis (Ed.), *Normality and pathology in cognitive functions* (pp. 113-146). New York: Academic Press.
- Ellis, A. W. (1987). Intimations of modularity, or, the modelarity of mind: Doing cognitive neuropsychology without syndromes. In M. Coltheart, G. Sartori, & R. Job (Eds.), *The cognitive neuropsychology of language* (pp. 397-408). London: Lawrence Erlbaum Associates Ltd.
- Goodglass, H. & Kaplan, E. (1983). *The assessment of aphasia and related disorders*. Philadelphia: Lea & Febiger.
- Jastak, J. F. & Wilkinson, G. S. (1984). *Wide range achievement test—revised*. Wilmington, DE: Jastak Assoc.
- Kaplan, E., Goodglass, H., & Weintraub, S. (1983). *Boston naming test*. Philadelphia: Lea & Febiger.
- Kučera, H. & Francis, W. N. (1967). *Computational analysis of present-day American English*. Providence, RI: Brown University Press.
- Lenel, J. C. & Cantor, J. H. (1981). Rhyme recognition and phonemic perception in young children. *Journal of Psycholinguistic Research*, 10, 57-67.
- Miceli, G., Silveri, M. C., & Caramazza, A. (1985). Cognitive analysis of a case of pure dysgraphia. *Brain and Language*, 25, 187-212.
- Milberg, W. & Blumstein, S. E. (1981). Lexical decision and aphasia: Evidence for semantic processing. *Brain and Language*, 14, 371-385.
- Morton, J. (1980). The logogen model and orthographic structure. In U. Frith (Ed.), *Cognitive processes in spelling* (pp. 117-133). London: Academic Press.
- Paivio, A., Yuille, J. C., & Madigan, S. A. (1968). Concreteness, imagery, and meaningfulness values for 925 nouns. *Journal of Experimental Psychology Monograph Supplement*, 76, 1-25.
- Palmer, S. E. (1978). Fundamental aspects of cognitive representation. In E. Rosch & B. B. Lloyd (Eds.), *Cognition and categorization* (pp. 259-303). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
- Seidenberg, M. S. & Tanenhaus, M. K. (1979). Orthographic effects on rhyme monitoring. *Journal of Experimental Psychology: Human Learning and Memory*, 5, 546-554.
- Shallice, T. (1987). Impairments of semantic processing: Multiple dissociations. In M. Coltheart, G. Sartori, & R. Job (Eds.), *The cognitive neuropsychology of language* (pp. 111-127). London: Lawrence Erlbaum Associates Ltd.
- Shallice, T. (1988). *From neuropsychology to mental structure*. Cambridge: Cambridge University Press.
- Taft, M. & Hambly, G. (1985). The influence of orthography on phonological representations in the lexicon. *Journal of Memory and Language*, 24, 320-335.
- Thorndike, E. L. & Lorge, I. (1944). *The teacher's word book of 30,000 words*. New York: Teachers College.
- Warrington, E. K. & Weiskrantz, L. (1968). New method of testing long-term retention with special reference to amnesic patients. *Nature*, 217, 972-974.
- Wechsler, D. (1981). *Wechsler adult intelligence scale—revised*. New York: The Psychological Corp.
- Weiskrantz, L., Warrington, E. K., Sanders, M. D., & Marshall, J. (1974). Visual capacity in the hemianopic field following a restricted occipital ablation. *Brain*, 97, 709-728.