Identity without form: Abstract representations of letters

RHONDA B. FRIEDMAN

*Department of Neurology, Boston University Medical School, Boston, Massachusetts 02130
and Boston V.A. Medical Center, Boston, Massachusetts 02130*

Subjects viewed single letters and orthographically regular pseudowords in a tachistoscope at threshold duration. The pseudowords were either all of one case (upper or lower) or they were of mixed case. Letter identity ("A") and case judgments were required for one letter on each trial. It was found that letter identity was often reported correctly when case was reported incorrectly, even for letters whose upper- and lowercase forms are physically dissimilar (e.g., G-g). This "case effect" was stronger for letters in pseudowords than for letters presented alone. It held across different type fonts, and it occurred even when the upper- and lowercase letters were of different sizes (gEaT) and when the instructions to the subjects stressed the greater importance of case reports over identity reports. The results are consistent with the view that letter identification is an automatic process, the product of which is an abstract representation containing no information about physical form.

The present investigation examines the representations upon which viewers base their responses when reporting tachistoscopically presented words and letters. One view is that orthographically regular stimuli are processed rapidly and automatically into an abstract representation on the basis of an initial letter identification process (Estes, 1975; McClelland, 1976). This representation leaves behind the visual features of letters; thus details of the type font (Adams, 1979) and letter thickness (Earhard, 1969) may be unavailable for conscious report. However, as McClelland points out, it is difficult to determine whether the inability to report such features indicates abstraction or simply a failure to perceive the features in the first place. The second possibility is quite likely in these instances, since neither type font nor line thickness contribute to the determination of letter identity.

In contrast, in the experiments reported here the visual information in question is the total form or shape of the letter—information that must have been used to determine the letter's identity. If such information remains available, then viewers should be

able to report on letter case (g vs. G) when they have correctly identified a letter ("G"). On the other hand, if viewers are reading out from a more abstract level, then case reports may be incorrect even when identity reports are correct.

There is already some evidence for the abstract representation of letter identities in reading. Coltheart and Freeman (1974) and McClelland (1976) have found that in certain circumstances subjects may be able to report an entire word or pseudoword correctly without being aware that the letters in the word are not all the same case. However, McClelland's subjects were required to report the identities of all four letters before giving case reports. Thus, it is possible that the case information was available immediately after viewing but was lost during the report of all of the letter identities. In the Coltheart and Freeman experiment the possibility of memory loss was even greater, since their subjects were not asked about the visual form of the words until after the experiment was over.

In addition to the possibility of memory loss, it is also possible to interpret the fact that subjects could often report the identity of the letters in a word without being sure of their case by supposing that they made use of redundant contextual information to infer the identity of letters not actually seen, thus increasing their chance of getting the letters correct, but not influencing their probability of correctly identifying the case of the letters.

To reduce the possibility of using redundant contextual information, the present experiment used pronounceable pseudowords rather than words, and subjects were tested only on letters that occurred in context capable of forming orthographically regular strings with at least 10 other letters. To reduce the memory load problem as much as possible, the sub-

This investigation was carried out while the author was a graduate student in the Department of Psychology, M.I.T., Cambridge, Massachusetts. It was supported by NIH Training Grant NIH-5-T01-GM01064 and by grants from the Sloan Foundation and the Spencer Foundation to the Department of Psychology, M.I.T. Preparation of this manuscript was supported by USPHS Fellowship 3-F32-NS06065 and USPHS Grant 07615. The author wishes to thank Mary C. Potter and James L. McClelland for their invaluable advice and James C. Johnston and William F. Ganong III for helpful comments and discussion. The results of Experiment I were presented at the 47th annual meeting of the Eastern Psychological Association, New York, 1976. Requests for reprints should be sent to Rhonda B. Friedman, Psychology 116B, Boston Veterans Administration Medical Center, 150 S. Huntington Ave., Boston, Massachusetts 02130.

jects reported on only one letter per trial, and the letter to be reported was indicated immediately after display offset by a position marker in the postdisplay pattern. In order to avoid any possible bias towards reporting identity before case, the subjects made their case reports simultaneously with their letter identity reports by writing the letter in the appropriate case.

Additionally, single letter controls were added to this experiment. If abstract representations are formed only for orthographically regular letter strings, then no instances of identity without case should be reported for the single letters, in contrast to the pseudowords.

EXPERIMENT 1

Method

Stimuli and Apparatus. A total of 576 different test items were used in the experiment, 288 pseudowords and 288 single letters. The test stimuli were made from 36 pairs of pseudowords generated by the author and checked by several judges (undergraduate students) for pronounceability and acceptability as English words. The two members of each pair differed by one letter, called the *critical letter*. For all of the pairs, at least 10 letters could occur in the critical letter position without rendering the string unpronounceable. Each of the 72 individual pseudowords appeared in four forms for a total of 288 pseudowords (see Figure 1). Two of the four forms were same-case items, one uppercase and one lowercase. The other two were mixed-case items in which the critical letter was not of the same case as the other three letters. In one of the mixed-case items the critical letter was lowercase; in the other it was uppercase. The uppercase letters were the same height as the lowercase letters, without ascenders or descenders, to minimize the extent to which case reports could be based on gross size cues.

The 288 single-letter items were simply the critical letters of each pseudoword with the remaining three letters deleted. Hence, the single letter could appear in any of four positions, depending upon which position it had occupied in the pseudoword from which it was taken.

In 24 of the 36 pairs of pseudowords, one of the two critical letters was drawn from the key letters A, D, G, and R (Figure 1). These four letters were rated by 10 subjects in a pilot study as having the greatest degree of physical dissimilarity between their uppercase and lowercase versions in the type font used for the present study. The critical letter for the other members of these 24 pairs and for the remaining stimulus pairs was always drawn

Aa Dd Gg Rr

FUEG fueg

FUEG fueg

Figure 1. The four key letters and the four forms of a pseudoword, Experiment 1.

Figure 2. The prestimulus mask, the stimulus (a pseudoword or a single letter), and the poststimulus mask with letter-position indicator.

from the remaining letters of the alphabet which did not have identical upper- and lowercase forms (b, e, f, h, . . .). Each key letter appeared equally often in three of the four positions. (Orthographic considerations prohibited the presentation of each letter in all four positions.) The set of three positions was different for each key letter so that, taken together, each of the four positions contained a key letter equally often. Each position was tested equally often when the critical letter was not a key letter.

A pre- and postexposure mask was made from pieces of the stimulus letters placed in a random pattern within a small rectangle. In addition, the postexposure field contained a position cue consisting of an exclamation point directly above the position of the critical letter and dashes above the other three letters (see Figure 2).

The stimuli were constructed of black letters on white index cards. The font used was Normatype Olive Demi-gras, 10-point for uppercase and 12-point for lowercase. The stimuli were presented in a three-field Iconix tachistoscope at a viewing distance of 91 cm. The four letters subtended a visual angle of .70 deg in width and .20 deg in height.

Design. Trials were divided into three sessions which took place on successive days. The first session was a practice session in which the subject became familiar with the procedure and the nature of the stimuli. Practice stimuli were generated in a manner analogous to the test stimuli. During the practice session, the exposure duration was adjusted until a duration was found at which the subject could report the letter identity correctly 50% of the time, averaging over pseudowords and single letters. The median exposure duration was 50 msec. The stimuli were blocked by material type (pseudoword vs. single letter) with blocks presented in alternation. Half the subjects saw a pseudoword block first; half saw a single-letter block first. There were eight blocks, four of each type, each containing 24 trials.

In each of the two test sessions, the subject saw six blocks of 24 pseudoword trials alternated with the corresponding six blocks of 24 single-letter trials. Thus, a total of 144 test trials of each stimulus type were presented per session. Block order was counter-balanced over subjects. An additional pair of blocks, presented at the beginning of each session, served as practice blocks in which the exposure duration was again adjusted to maintain the appropriate rate of error. Additional adjustments were made at the end of each pair of blocks if the subject was deviating substantially from the 50% level.

Of the four forms of each of the 72 pseudowords, two appeared in each test session, but not in the same block. The four different forms of stimulus items occurred equally often within each block. Each of the four key letters appeared twice as the critical letter in every block, once in each case, for a total of one-third of all trials.

Procedure. The subject was asked to fixate the center of the preexposure mask. After the experimenter had indicated that the next trial was ready the subject was free to begin the trial. This was done by pressing a button which caused the stimulus item to appear 500 msec later and to remain on for the predetermined exposure duration. Onset of the postexposure mask occurred concurrently with offset of the stimulus. The exclamation point above the postexposure mask indicated which letter the subject was to

report; the cue appeared after single-letter trials as well as pseudo-word trials. The subject wrote down the cued letter. Omissions were not permitted. The subject was instructed to write the letter in the perceived case, so that identity and case judgments were reported simultaneously. Confidence in the identity report was then rated on a scale of 1 (high) to 4 (low). The subject then indicated explicitly the letter's case (in case the handwritten letter was unclear) by marking "U" for upper and "L" for lower and rated his or her confidence in the case judgment on the same 4-point scale.

Subjects. The subjects were 18 male and female undergraduates who were paid for their participation in three 1½-h sessions. A subject was discarded if his or her accuracy on letter identity did not fall into the range of 30%-70% correct by the end of the practice trials of Session 2. A total of 19 subjects were needed, as one failed to achieve this criterion.

Results

Letter identity reports. Table 1 presents the percentage of letters correctly identified for all critical letters and for the key letters A, D, G, R. Overall accuracy for mixed-case pseudowords, same-case pseudowords, and single letters did not differ from one another [$F(2,34) = 1.7$]. Subjects were more accurate on uppercase than on lowercase letters [$F(1,17) = 16.2$, $p < .001$], and this was true for single letters, mixed-case pseudowords, and same-case pseudowords. The interaction between stimulus type and case was not significant [$F(2,34) = 2.47$, $p > .1$]. The same general patterns were obtained for the key letters; however, the effect of case was not statistically reliable.

Case reports. The data of central interest concern the accuracy of case reports *when the letter identity was reported correctly* (shown in Table 2). For the key letters, case was often reported incorrectly when identity was reported correctly, for both single letters (7.2%) and pseudowords (25.2%). These percentages are significantly above chance level and thus could not be the result of pure guessing.¹ (More will be said about guessing later.) Note that if we can assume these incorrect case reports to reflect trials on which case

was not known and was guessed incorrectly, then there should be an equal number of trials on which case was not known but was guessed correctly. Thus the actual number of correct-identity trials on which case was not known is about 14% for single letters and as high as 50% for pseudowords.

Analysis of variance indicated a main effect of stimulus type [$F(2,34) = 43.9$, $p < .001$]. Pseudowords showed a much larger "case effect" than single letters, despite equal identification accuracy, a finding that is consistent with the abstract code hypothesis. Newman-Keuls tests indicated that the cases of single letters were reported more accurately than were those of same-case pseudowords, which were, in turn, reported more accurately than the cases of letters in mixed-case pseudowords. Although some bias toward reporting the case of context letters in pseudowords may have occurred (hence a greater case effect for mixed-case than for same-case pseudowords), such a bias should work against committing a case error in same-case pseudowords. Thus, the larger case effect for same-case pseudowords compared with that for single letters occurred *despite* such a bias and not because of it.

Further analysis revealed a significant effect of case [$F(1,17) = 5.50$, $p < .05$], as well as Case by Stimulus Type interaction [$F(2,34) = 9.72$, $p < .001$]. For pseudowords, the case of uppercase letters was reported more accurately, whereas the reverse was true for single letters. These apparent biases, while somewhat puzzling, nevertheless do not appear to have any direct bearing on the main results of this study.

Accuracy of case reports for trials on which identity was reported incorrectly is reported in Table 3. Overall, case report accuracy was 50.0%, not greater than chance. Thus, when identity was not perceived, case information was unavailable as well. The same biases that occurred when identity was reported correctly (case and context) were also observed here, despite

Table 1
Experiment 1: Percentage of Correct Reports of Letter Identity for All Critical Letters and for the Key Letters (A, D, G, R)

Stimulus Type	All Critical Letters			Key Letters		
	Uppercase	Lowercase	Mean	Uppercase	Lowercase	Mean
Same-Case Pseudowords	60.4 (1296)	52.1 (1296)	56.3	63.4 (432)	57.9 (432)	60.1
Mixed-Case Pseudowords	53.9 (1296)	47.7 (1296)	50.8	56.7 (432)	52.8 (432)	54.7
Mean of Pseudowords	57.2 (2592)	49.9 (2592)	53.6	60.1 (864)	55.4 (864)	57.7
Single Letters	52.8 (2592)	49.2 (2592)	51.0	57.1 (864)	56.6 (864)	56.8

Note—Numbers in parentheses indicate trials per point.

Table 2
Experiment 1: Percentage of Correct Reports of Case When Identity is Reported Correctly for the Key Letters (A, D, G, R)

Stimulus Type	Uppercase Critical Letter	Lowercase Critical Letter	Weighted Mean
Same-Case Pseudowords	92.0 (274)	74.0 (250)	83.4
Mixed-Case Pseudowords	76.3 (245)	53.5 (228)	65.3
Weighted Mean of Pseudowords	84.6 (519)	64.2 (478)	74.8
Single Letters	89.7 (493)	95.9 (489)	92.8

Note—Numbers in parentheses indicate trials per point.

Table 3

Experiment 1: Percentage of Correct Reports of Case When Identity is Reported Incorrectly for the Key Letters (A, D, G, R)

Stimulus Type	Uppercase Critical Letter		Lowercase Critical Letter		Weighted Mean
Same-Case Pseudowords	67.1	(158)	60.4	(182)	63.5
Mixed-Case Pseudowords	39.6	(187)	35.8	(204)	37.6
Weighted Mean of Pseudowords	52.2	(345)	47.4	(386)	49.7
Single Letters	28.8	(371)	71.5	(375)	50.3

Note—Numbers in parentheses indicate trials per point.

the rather different overall pattern of results. (There were fewer case errors for same-case pseudowords than for single letters when identity was reported incorrectly, but the opposite result was seen when identity was reported correctly.)

Confidence ratings. Basically, the confidence rating data paralleled the identity and case accuracy data, supporting the conclusions reached thus far. They are summarized briefly below.

The confidence ratings have been grouped for simplicity into those rated as 1 or 2 (very confident and somewhat confident) vs. those rated 3 or 4 (vaguely confident and no idea). The percentage of times the subject reported a rating of 1 or 2 for letter identity is given in Figure 3; the percentage of times the subjects reported a 1 or 2 for his case report is given in Figure 4.

The *letter confidence* data (Figure 3) indicate that subjects were more confident about correctly identified letters than about incorrectly identified letters, given that they reported the case of the letter correctly [$t(17) = 3.60$ for pseudowords, 3.70 for single letters; $p < .001$]. The more interesting finding, though, is that for letters in pseudowords, subjects were more confident of their correct letter-identity reports than of their incorrect letter-identity reports, even when they misreported the case [$t(17) = 3.31$, $p < .001$]. This supports the view that, for letters in pseudowords, subjects sometimes reported from an internal representation that captured the identity of the presented

letter, but not its form. For single letters, we see only a hint of the same pattern of results [$t(17) = .80$, $p < .1$].

The *case confidence* results (Figure 4) reinforce the conclusion reached on the basis of the accuracy data that subjects never had any information about the case of the critical letter when they lacked information about its identity. For letters in pseudowords as well as single letters, when identity was reported incorrectly, confidence in the case reports did not vary as a function of the accuracy of that response [$t(17) = .37$ for single letters; $t(17) = .37$ for letters in pseudowords, $p > .5$].

When the letter was reported correctly, however, there was a significant difference in confidence of case, depending upon whether or not the case was, in fact, correctly reported [$t(17) = 3.6$, $p < .005$, for single letters; $t(17) = 2.75$, $p < .02$, for pseudowords]. The fact that when they reported identity correctly, subjects could distinguish those trials in which they knew the case from those in which they did not know the case strongly suggests that the correct case reports in these instances were not simply the result of guessing.

Discussion

The results of Experiment 1 indicate that subjects have considerably more trouble reporting the case of correctly identified letters contained within orthographically regular pseudowords than they do with correctly identified letters presented alone. For single

Figure 3. Percentage of letter confidence judgments rated as 1 (very confident) or 2 (somewhat confident) on a 4-point scale, as a function of accuracy of letter and case reports, Experiment 1.

Figure 4. Percentage of case confidence judgments rated as 1 (very confident) or 2 (somewhat confident) on a 4-point scale, as a function of accuracy of letter and case reports, Experiment 1.

letters, subjects identified the case of the letter correctly on 93% of the trials in which they correctly identified the letter. For letters in pronounceable pseudowords, however, they identified the case correctly only 75% of the time when they correctly identified the letter. Even when critical letter and context letters were of the same case (and context was maximally helpful), subjects reported case correctly on only 83% of the trials on which they correctly identified the letter.

As mentioned earlier, the key letters for which this finding held were chosen because their upper- and lowercase forms are physically dissimilar. Indeed, closer inspection of these letters reveals that the featural information necessary to accurately distinguish any of these letters from all other letters is also sufficient to distinguish the two forms of the letters from each other. In light of these characteristics of the key letters, the finding of accurate letter identification in the absence of correct case identification is rather extraordinary. Replication of the results therefore seemed desirable.

EXPERIMENT 2

Some factors in the method of Experiment 1 may have exaggerated or underestimated the tendency to misrepresent case. The use of upper- and lowercase letters of equal size may have confused the subjects. Also, the use of mixed-case stimuli in which *all three* context letters were of the opposite case may have provided an unduly strong bias. Perhaps the results, and some of the observed biases, were particular to the type font used; this font did have ascenders and descenders that were shorter than most, for example. And the insistence upon reporting case and identity simultaneously, while intended to eliminate any bias created by reporting one before the other, may have, instead, defeated this purpose. Since case is ordinarily less important than letter identity, when both judgments were required the subjects may have opted to identify the letter identity first. Experiment 2 was designed to control for all of these possible objections while replicating the original main result.

In this experiment, a new type font was used, the mixed-case stimuli now contained two uppercase and two lowercase letters, and the upper- and lowercase letters were not equated for size. Furthermore, emphasis was now placed upon the case response.

GEAT

geat

geAT

gEaT

Figure 5. The four forms of a pseudoword, Experiment 2.

Method

Stimuli and Apparatus. A new set of the 288 pseudowords and the 288 single letters of Experiment 1 was prepared. The new stimuli were made of Century Schoolbook 18-point lettering. Each stimulus appeared on a piece of photographic film as black lettering on a white background. The piece of film was pasted on the center of a white index card. The uppercase letters subtended a visual angle of .33 deg in height; lowercase letters were .22 deg high, without ascenders or descenders. A pseudoword was approximately 1.02 deg in length. The stimuli were presented in a Gerbrands Harvard Model T4A four-field tachistoscope at a viewing distance of 84 cm. The background luminance was about 7.7 cd/m², as measured by a Honeywell light meter. The contrast was .80. A sample stimulus set is presented in Figure 5.

Procedure. The procedure was the same as that used in Experiment 1, with the following exceptions: The subject did not write the answer, but spoke it aloud to the experimenter, who recorded the answer. No confidence ratings were obtained. The subject was required to report case first. The instructions to the subject emphasized several times that the case judgment was more important than the identity judgment.

Subjects. The subjects were 16 male and female students, who were paid for their participation in the three-session experiment.

Results

Letter identity reports. On pseudoword trials, 49.8% of all letter identities were reported correctly; on single letter trials, 48.9% of all letter identities were reported correctly. The difference is not significant [$F(2,30) < 1$]. (See Table 4 for a complete breakdown.) Overall, the subjects performed better on uppercase items [$F(1,15) = 105.6, p < .001$]. The interaction between stimulus type and case was significant [$F(2,30) = 11.3, p < .001$]; the mixed case pseudowords showed less of a superiority for uppercase items than did the same-case pseudowords or the single letters. The general pattern was, once again, similar for the key letters; the main effect of case and the Case by Stimulus Type

Table 4
Experiment 2: Percentage of Correct Reports of Letter Identity for All Critical Letters and for the Key Letters (A, D, G, R)

Stimulus Type	All Critical Letters				Key Letters			
	Uppercase		Lowercase		Uppercase		Lowercase	
Same-Case Pseudowords	63.8	(1152)	36.5	(1152)	50.1	72.1	34.4	53.3
Mixed-Case Pseudowords	55.7	(1152)	43.1	(1152)	49.4	59.1	38.3	48.7
Mean of Pseudowords	59.8	(2304)	39.8	(2304)	49.8	65.6	36.4	51.0
Single Letters	62.1	(2304)	35.7	(2304)	48.9	74.3	33.9	54.1

Note—Numbers in parentheses indicate trials per point.

Table 5

Experiment 2: Percentage of Correct Reports of Case When Identity is Reported Correctly for the Key Letters (A, D, G, R)

Stimulus Type	Uppercase Critical Letter		Lowercase Critical Letter		Weighted Mean
Same-Case Pseudowords	84.5	(277)	75.0	(132)	81.4
Mixed-Case Pseudowords	77.1	(227)	69.4	(147)	74.1
Weighted Mean of Pseudowords	81.2	(504)	72.0	(279)	77.9
Single Letters	87.2	(571)	88.1	(260)	87.5

Note—Numbers in parentheses indicate trials per point.

Table 6

Experiment 2: Percentage of Correct Reports of Case When Identity is Reported Incorrectly for the Key Letters (A, D, G, R)

Stimulus Type	Uppercase Critical Letter		Lowercase Critical Letter		Weighted Mean
Same-Case Pseudowords	61.7	(107)	62.7	(252)	62.4
Mixed-Case Pseudowords	52.2	(157)	44.7	(237)	47.7
Weighted Mean of Pseudowords	56.1	(264)	54.0	(489)	54.7
Single Letters	42.6	(197)	64.4	(508)	58.3

Note—Numbers in parentheses indicate trials per point.

interaction both reached significance [$F(1,30) = 91.3$, $p < .001$, and $F(2,30) = 7.6$, $p < .01$, respectively].

Case reports. The percentage of trials in which case was reported incorrectly *when identity was reported correctly*, for the key letters, was 22.1% for pseudowords and 12.5% for single letters. As in Experiment 1, these percentages are significantly above chance level [$t(15) = 9.43$, $p < .001$, and $t(15) = 4.92$, $p < .001$, respectively].

The main effect of stimulus type was significant [$F(2,30) = 10.0$, $p < .001$]. (See Table 5 for a breakdown of the results.) Subsequent analysis indicated greater accuracy for single letters vs. same-case pseudowords [$F(1,15) = 5.02$, $p < .05$] and greater accuracy for same-case pseudowords vs. mixed-case pseudowords [$F(1,15) = 6.92$, $p < .025$].² There was an uppercase advantage for both mixed- and same-case pseudowords, as in Experiment 1, but no lowercase advantage for single letters.

The percentage of times in which case was reported correctly *when identity was reported incorrectly* is presented in Table 6. As before, when the identity was incorrectly reported, the case reports were at chance level [$F(1,15) < 1$].

GENERAL DISCUSSION

Experiment 2 replicated the main finding of Experiment 1: Subjects reported the abstract identities of letters more accurately than they reported the case of those same letters. This effect was obtained even for letters whose upper- and lowercase forms were physically dissimilar.

The use of different type fonts in Experiments 1 and 2 ruled out the possibility that the effect was specific to a particular type font. Mixed-case pseudowords constructed of two upper- and two lowercase letters provided less "pull" from the context letters; indeed, the effect occurred even for same-case pseudowords. Furthermore, the effect survived attempts to subvert

it by emphasizing case over identity in Experiment 2. And it appeared despite the gross physical cue to case provided by the large difference in absolute size between the upper- and lowercase letters in Experiment 2.

The inability to report letter case was surprising to viewers themselves; as one subject said, "I know it was a G, but I don't know whether it was upper or lower. How can I not know?! They don't look anything alike!"

What might account for these results? Two possibilities come to mind: (1) The letter identity is not really perceived when the case is misperceived but is correctly guessed; (2) the letter's physical form is correctly perceived, and hence both identity and case are available at some level, but they are not always available at the time of report. These two possibilities will be explored in the discussion that follows.

Models that attribute the above results to guessing will be considered first. According to one possible account, the pseudoword trials in which identity is correctly reported while case is missed represent those trials in which both identity and case were guessed, the former correctly, the latter incorrectly. As the case effect is greater in pseudowords than in single letters, an implicit assumption of the model is that there are more instances of correct guessing of the identity among pseudowords than among single letters. This superior performance is often attributed to the contextual cues provided by the orthographically regular pseudowords.

The non-key stimuli which differed from the key-letter stimuli by only the critical letter provide a means of assessing the amount of guessing of the key letters. If contextual information did facilitate correct guessing of the critical letter in pseudowords, then the probability of guessing a key letter, given presentation of its paired stimulus, should be higher for pseudowords than for single letters. The obtained probabilities for Experiment 1 were .034 for letters in pseudowords and

.030 for single letters. For Experiment 2, they were .029 and .034, respectively. These proportions did not differ reliably [$t(17) = .89$, $p > .1$, and $t(15) = -.76$, $p > .1$, respectively], yielding no support for the hypothesis that subjects simply guessed the identity of letters correctly more often for letters in pseudowords than for letters presented alone.

While these results rule out a guessing explanation of the case effect based upon context alone, another model to be considered is a sophisticated guessing model which assumes that guesses are based upon contextual information that is combined with partial visual information picked up from the stimulus (Rumelhart & Siple, 1974). According to this hypothesis, subjects pick up enough feature information from the critical letter to constrain the set of possible letters to a small number, but not to a single letter. They then attempt to identify the letter from among this set, using contextual information extracted from other letters when possible. Like the previous model, this interpretation can account for a greater probability of correctly guessing letter identity for letters in pseudowords compared with single letters. If the partial information leading to the correctly guessed letter-identity report was frequently not sufficient to determine which of the two versions of the critical letter was presented, then this model would lead to the prediction of an increased likelihood of case errors given correct letter reports for letters in pseudowords. However, several arguments make this account implausible. (1) A number of studies of accuracy of tachistoscopic perception have failed to find any evidence of the postulated benefits of contextual constraints (Estes, 1975; Johnston, 1978; Smith & Haviland, 1972). (2) As noted above, there is no hint of a difference between pseudowords and single letters in the proportion of times a key letter was guessed when its paired stimulus was presented. Although this sophisticated guessing model might predict less of a difference than the guessing model previously discussed, some difference would be expected. (3) The pseudowords used in these experiments were deliberately constructed to provide as little contextual constraint as possible. Even if all three noncritical letters had been correctly identified, there still would have been at least 10—often more—possible alternatives for the critical letter. (4) If enough featural information were picked up to significantly reduce the number of letter possibilities, then, at least for the key letters, this information should also be sufficient to discriminate between cases. Therefore, given the magnitude of the differences between pseudowords and single letters in the probability of correct case report on correct letter identification trials, a sophisticated guessing model must stretch very far to account for these results.

Since the results of these experiments cannot be readily explained away as artifact, it is reasonable to assume that the visual forms of the letters in question really were perceived by the viewers. But, at least

for the key letters (A, D, G, R), it is difficult to see how the visual information necessary to identify a given letter would be insufficient to determine the case. The memory loss explanation discussed earlier in connection with the McClelland (1976) study postulates that subjects did have access to both identity and case on the trials under consideration, but memory overload caused the case information to be lost during the reports of identity. This explanation is less convincing for the present experiments since only one letter, not four, was to be reported on each trial. Indeed, it is difficult to see how such an explanation could be applied to Experiment 2, in which case reports were made *prior* to identity reports.

A more likely explanation of the case effect is that, although the information needed to make both identity and case determinations is available at some level, the encoding of abstract identity is superior to that of case for some reason. Before attempting to describe a model based upon this supposition, it would be helpful at this time to reiterate the findings that such a model should be able to account for: (1) For both pseudowords and single letters, case was often reported incorrectly when letter identity was reported correctly. (2) The case effect was significantly greater for pseudowords than for single letters. (3) Despite the difference in accuracy of case report between pseudowords and single letters, the two groups did not differ in accuracy of letter-identity reports.

The model outlined here attempts to deal with all of the above findings. According to the model, subjects initially extract feature information from the stimulus that allows the determination of each letter's identity (and its case, as well, for letters which are very different in the two cases). Letter identities are determined rapidly, automatically, and in parallel once a sufficient number of features have been extracted (LaBerge & Samuels, 1974), and are encoded in some abstract form which contains no visual information. For pseudowords, a further level of encoding takes place automatically, perhaps at a phonological level (McClelland & Johnston, 1977; Spoehr & Smith, 1975). These abstract codes serve as the basis for the overt responses given by subjects with regard to letter identity.

Unlike the determination of letter identity, which presumably is very well practiced in the normal reader and has thus become automatic (LaBerge & Samuels, 1974), the determination of case does not occur automatically. When a case response is required, then, as in the present experiments, *attentional activation* (LaBerge & Samuels, 1974) must be called upon to process the information. Since it is assumed that attention can only be directed to one letter at a time, as the number of letters increases, the time required to process the letters increases as well. By the time the mask and indicator appear, if case has not been encoded, it is lost.

Such a model accounts for the three main results

outlined above as follows. Since the activation of attention required for case processing requires more time than the automatic processing of identity to an abstract level, on some trials identity, but not case, will have been encoded when the mask appears. On these trials, identity will be reported correctly; case will be reported at chance level.

Secondly, the case effect should be stronger in pseudowords than in single letters, according to the model. This is so because only one case (hence one unit) need be encoded for single letters, while four cases (hence four units) must be encoded for pseudowords (since the subject does not know in advance which letter will be probed). Finally, since letter identity and letter case are encoded separately, it is quite plausible to find that the difference in accuracy of identity reports for pseudowords and single letters is not equal to the difference in accuracy of case reports. The finding that there was no difference at all in accuracy of identity reports for pseudowords and single letters is consistent with the notion that a pseudoword, like a single letter, is encoded as a single abstract unit.

The results presented here, then, suggest that visual letter information is processed automatically to an abstract level which serves as the basis for identity reports. They further suggest that once this abstracting process is completed, given certain time constraints, only the final result of this process is available for report. Information that must have been used to achieve the final result—that is, the visual form of the letter—becomes inaccessible. Since a small but significant case effect was found for single letters as well as for pseudowords, it seems that abstract representations are not limited to orthographically regular letter strings, as some have suggested (Johnston, 1978; McClelland, 1976; McClelland & Johnston, 1977). Finally, contrary to the claim by LaBerge and Samuels (1974) that the subject can “choose to pay attention to the curved lines in the familiar *a* if he chooses” (p. 300), subjects in this study could not pay attention to case (despite gross size cues) at the expense of identity, even when instructed to do so.

REFERENCES

- ADAMS, M. J. Models of word recognition. *Cognitive Psychology*, 1979, **11**, 133-176.
- COLTHEART, M., & FREEMAN, R. Case alternation impairs word identification. *Bulletin of the Psychonomic Society*, 1974, **3**, 102-104.
- EARHARD, B. Perception and retention of familiar and unfamiliar material. *Journal of Experimental Psychology*, 1968, **76**, 584-595.
- ESTES, W. K. The locus of inferential and perceptual processes in letter identification. *Journal of Experimental Psychology: General*, 1975, **104**, 122-145.
- JOHNSTON, J. C. A test of the sophisticated guessing theory of word perception. *Cognitive Psychology*, 1978, **10**, 123-153.
- LABERGE, D., & SAMUELS, J. Toward a theory of automatic information processing in reading. *Cognitive Psychology*, 1974, **6**, 293-323.
- MCCLELLAND, J. L. Preliminary letter identification in the perception of words and nonwords. *Journal of Experimental Psychology: Human Perception and Performance*, 1976, **2**, 80-91.
- MCCLELLAND, J. L., & JOHNSTON, J. C. The role of familiar units in perception of words and nonwords. *Perception & Psychophysics*, 1977, **22**, 249-261.
- RUMELHART, D. E., & SIPLE, P. Process of recognizing tachistoscopically presented words. *Psychological Review*, 1974, **81**, 99-113.
- SMITH, E. E., & HAVILAND, S. E. Why words are perceived more accurately than nonwords: Inference versus unitization. *Journal of Experimental Psychology*, 1972, **92**, 59-64.
- SPOEHR, K. T., & SMITH, E. E. The role of orthographic and phonotactic rules in perceiving letter patterns. *Journal of Experimental Psychology: Human Perception and Performance*, 1975, **104**, 21-34.

NOTES

1. Chance level, the probability that a key letter's identity was accidentally guessed correctly and its case then guessed incorrectly, was estimated by the number of times the key letters were reported when they were not presented. This occurred on 5.8% of the single-letter trials and on 4.6% of the pseudoword trials. Since there are two cases, upper and lower, it is expected that case will be guessed correctly half of the time. Therefore, it was estimated that the key letters were guessed correctly and their case guessed incorrectly on 2.9% of the single-letter trials and on 2.3% of the pseudoword trials. The obtained values of 7.2% case errors for correctly identified single letters and 25.2% for pseudowords were both well above the chance level [$t(17) = 3.59$, $p < .01$; $t(17) = 8.14$, $p < .001$, respectively].
2. The main effect of case and the interaction of case with context for identity reports, for the key letters, were both significant in this experiment. Since the number of correct identity reports serves as the denominator for the proportions concerning case reports, the use of these unweighted proportions in an F test is less than desirable. Consequently, weighted proportions for the upper- and lowercase items were used in testing differences between (combined upper and lower) mixed-case pseudowords, same-case pseudowords, and single letters. In Experiment 1, in which there was no effect of case for the key letters, the use of such weights was deemed unnecessary.

(Received for publication July 26, 1979;
revision accepted January 18, 1980.)