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PRONOUNCEABILITY. STUDIES OF ORAL READING, II.

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VERBAL REACTION TIMES TO WORD FORMS THAT DIFFER IN THEIR PRONOUNCEABILITY WERE ASSESSED FOR SIGNFICANCE OF CORRELATION. SINGLE PSEUDOWORDS OF VARYING PRONOUNCEABILITY WERE SHOWN TO 36 THIRD AND FOURTH GRADERS, AND THEIR REACTION TIMES FOR ORAL RESPONSES WERE MEASURED. THE RESPONSES WERE TAPE RECORDED, AND THE PERIOD OF TIME FROM THE EXPOSURE OF THE WORD TO THE ONSET OF THE FINAL PRONUNCIATION WAS MEASURED. CORRELATIONS WERE ACQUIRED BETWEEN MEAN RESPONSE LATENCIES AND RATED PRONOUNCEABILITY PER WORD BY GRADE LEVEL AND WORD LENGTH. THE CORRELATIONS WERE ALL SIGNIFICANT AND CLEARLY INDICATED THAT THE HARDER A WORD WAS TO PRONOUNCE, THE LONGER WAS THE INTERVAL FROM THE EXPOSURE OF THE WORD TO THE VERBAL RESPONSE. (GD)

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Studies of Oral Reading[1]

II. Pronounceability

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In an earlier study (Levin and Biemiller, 1965) we hypothesized that the reaction time period in reading a word aloud was taken up by the processes of translating the written symbols to sounds, matching these sounds to an auditory schema and saying the sounds. The schema, we suggested, was the memory for English-like sound sequences. There was some evidence, especially from an analysis of reading errors, that subjects rehearsed the decoded sounds in an attempt to bring them into line with the schema.

Verbal reaction time, to adopt Fraisse's (1964) term, will increase as a function of the difficulty of decoding the print to sound and of the acceptability of the sounds so generated. In practice, these two processes are inter-twined although it should be possible to disentangle them experimentally. For example, a series of letters predictable in their correspondences to sounds may decode to an odd sound sequence or a rare sequence of letters may yield familiar sounds.

The present experiment is concerned with verbal reaction times to word forms that differ in their pronounceability. We assume that the more unpronounceable words yield less familiar sound patterns. At the same time, the letter sequences of unpronounceable words violate the

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spelling pattern for English and so create decoding difficulties. In other words, the variation of pronounceability confounds both the ease of decoding and the predictability of sounds. Either process singly or in combination with the other should increase verbal reaction times.

Unpronounceable word forms require higher thresholds for perception (Gibson, Pick, Osser and Hammond, 1962). We have argued that perceptual measures also involve decoding to sound, although the evidence is only inferential. Fraisse (1964) argues categorically that the measurement of thresholds for words and the verbal reaction times to words are part of the same process. He reports a correlation of .81 between the two measures. When the familiarity of the words are held constant, the correlation is still a substantial .55. In fact, a correlation as high as .81 means that the two measures are practically interchangeable. More important, the degree of relationship implies that in the determination of the threshold at which the word is recognized, some central processing is taking place.

Specifically, we postulate that to a literate person, an array of letters (such as a word) is an automatic instigation to saying that word to one's self. As a case in point, in an experiment in which consonant sequences were presented visually and the recall was written, errors were predicted by acoustic confusability (Conrad, Freeman, and Hull, 1965) which means that Ss said the letters to themselves. Likewise, even in short term tachistoscopic exposures of letter groups, the viewer says them to himself. The pronounceable groups are decoded more easily, stored and retrieved more efficiently. The process is the same as verbal reaction time and hence the similarity of findings.

Our speculation that the decoded sound is matched against an auditory image gains support from two studies by Smith (1965 a, and b). Recognition of words as sequences of digits is facilitated when the correct response is heard prior to the visual display. We interpret these findings to mean that the auditory input creates a schema against which the decoded visual stimulus is matched. Smith (1965b, p. 158) puts it "Present results support the interpretation that the facilitation of recognition found is due to a perceptual interaction effect, namely, an effect of hearing on seeing."

Method

Subjects. 36 children, nine boys and nine girls from a third and a fourth grade were randomly selected.[1,2] Each of the classes had children with a range of abilities.

Stimulus Materials. Twenty-four pseudo-words were taken from a study by Gibson, et al. (1962). These words had been generated from spelling patterns described by Hockett (1960). Each of the words had been rated for pronounceability by Underwood and Shultz's (1960) method. The words and their pronounceability ratings are given in Table 1.

Procedure. Each child was informed that he would be shown words on a screen and asked to read them. He was told that the words had been made up so he did not have to feel bad if he did not know them. The words were projected on a screen three feet from the S. The projected words were about six inches long by two inches high. After the child gave his response, there was a two second interval before the next word was presented. If

[1]We wish to thank the staff of the Belle Sherman School, Ithaca, N.Y., for their help.

[2]Non-native speakers of English were eliminated before selection.

Table 1. Stimulus Words with Pronounceability Ratings, Adult Mean Errors, and Mean Latencies in Seconds by Grade.

	Pronounceability[1] Rating	Number[2] Written Errors	Latency 3rd & 4th Grades
Number of Ss	165	25	36
Stimulus Words			
DINK	1.1	7	1.3
CODS	1.3	18	1.2
CLATS	1.[illegible]	34	1.6
VUNS	1.5	15	1.9
GLOX	1.6	8	1.8
GRISP	1.6	12	1.8
FUNTS	1.6	6	2.2
SLAND	1.7	5	1.6
SULB	1.9	30	2.5
TILMS	2.2	28	2.9
BLORDS	2.3	71	1.7
BESKS	2.3	46	1.8
FRAMB	2.4	13	1.8
PREENT	2.9	69	3.0
BLASPS	2.9	58	2.9
GLURCK	2.9	74	3.0
BRELP	3.0	34	2.8
QUEESK	3.0	80	2.5
KLERFT	4.2	88	3.0
TIRPTH	4.5	83	3.2
PRILTHS	4.6	97	3.3
JRILFTAS	5.3	112	3.9
SMAWMP	6.2	122	3.2
DRIGHK	6.3	89	4.2

1, 2) From Gibson, E.J., et. al. (1962).

the child made no response to a word in 15 seconds, he was asked if he would like to go on to the next one. He invariably did. Similarly, if the child suggested going on, the next word was displayed.

The Ss' responses were tape recorded and, for analysis, the tapes were played through a rectifier connected to a pen-writing recorder. The pen was deflected by sound on the tape so that we measured the period of time from the exposure of the word to the onset of the final pronunciation given by the S. That is, repetitions, false starts, stutters, etc., were included in the reaction time period.

Results

The 24 words were divided at the median of pronounceability and an analysis of variance calculated according to the classifications, pronounceability, sex of Ss, and grade level.[1] The means are given in Table 2.

Table 2. Mean Latencies in Seconds by Rated Pronounceability, Grade and Sex.

	(N)	More Pronoun. 12 Words	Less Pronoun. 12 Words	All Words
All Grades and Sexes	36	1.58	2.37	1.98
Third Grade, all	18	1.93	3.26	2.60
boys	9	1.75	2.70	2.22
girls	9	2.12	3.83	2.97
Fourth Grade, all	18	1.70	2.85	2.28
boys	9	1.41	2.05	1.73
girls	9	1.99	3.65	2.85

[1] The observations were transformed for this analysis according to the formula, $Y = \log (X-0.4)$, Y is the transformed score and X = latency in seconds. This transformation is discussed in Woodworth and Schlosberg (1954, p. 39).

The single significant source of variation was pronounceability ($F = 35.2$; $df = 1, 32$; $p < .001$). No other main effects or interactions are significant. It is clear that children take longer to read the less pronounceable words.

The main hypothesis of this study concerns the correlations between the latencies to the various words and their pronounceability. Latencies were calculated for each word, across Ss. The results appear in Table 3.

Table 3. Correlations (rho) between Mean Response Latencies and Rated Pronounceability per Word by Grade and Word Length.

		Grade		
	(N)	3rd	4th	Combined
All words	24	.89	.92	.87
Four and five letter words	13	.65	.74	.61
Six, seven and eight letter words	11	.89	.93	.88

The correlations are all significant and clearly indicate that the harder a word is to pronounce, the longer is the interval from the exposure of the word to the verbal response. However, the less pronounceable words tend also to be longer (see Table 1). To control for length, separate correlations were calculated for short and long words. As can be seen in Table 3, the association between pronounceability and latency holds even when word length is controlled.

The comparisons between the latency data and the error scores for these words reported by Gibson, et. al. are interesting, especially in light of Fraisse's findings. First, though, the differences in the experiments should be clear. Gibson and her co-workers exposed two groups of pseudo words: 25 pronounceable (P) and 25 unpronounceable (U) items. We are using her P list which itself includes a range of pronounceability as can be seen from their ratings in Table 1. Each list was tachistoscopically presented five times at exposure speeds 30, 50, 100, 150, 250 m. sec. The S wrote what he saw. The number of correct reproductions was summed for each word across Ss and exposures.[1]

In our data the mean latency for each word was tabulated across Ss. The correlations (rho) between the two scores from the two experiments are given in Table 4. The overall correlation is .86. However, note the

Table 4. Correlations (rho) Between Mean Response Latencies and Mean Errors (Gibson, et. al., 1962) per Word.

		Grade		
	(N)	3rd	4th	Combined
All words	24	.79	.80	.86
Four and Five letter words	13	.36	.08	.27
Six, seven and eight letter words	11	.75	.84	.79

differences in the degree of relationships which are a function of the length of the words. For the shorter, four and five letter words the correlation between errors and reaction times is negligible, whereas, for longer words the correlation is substantial, rho = .79. It is tempting to think that length of word influences the relationship between the measures of accuracy of recognition at the threshold and reaction time. However, it is more likely that the differences in the two sets of cor-

[1]For simplicity in exposition we have calculated the number of errors rather than the number correct from Gibson, et. al's data. (Compare their Table 1 with our Table 1).

relations is due to the restricted range of errors scores to the shorter words. The range of errors to the four and five letter words is 41; to the longer words, 83.

Fraisse (1964), it will be recalled, reported a correlation of .81 between verbal reaction time and recognition threshold. This correlation is very close to the .86 which we find. His stimuli were 25 real words representing a range of frequency in French. The words contained 5 or 6 letters. His correlation is between the median recognition threshold and reaction time to reading the word. Both measures were taken on the same Ss.

It appears that there are a complex of responses which are highly interrelated. The correct recognition of words at threshold, the level of the threshold and the time it takes to read a word when the stimulus is available ad lib. all correlate highly. These findings hold regardless of whether the Ss are adults or children, whether the stimulus words are real or nonsense. The correlation of any of the measures varies with the pronounceability of the word.

Pronounceability is a measure of the ease or difficulty with which the groups of letters can be sounded. We have argued in this and an earlier study that all of these measures have a common process at their base: the decoding to sound and in the case where the procedure requires a verbal response, the private rehearsal of the decoded sound sequence against an experience-generated schema of "acceptable" sounds.

We agree with Gibson that the results are not a reflection of response biases, in the usual sense. The various measures we have discussed are not primarily reflections of experiences with letter or sound sequences (frequency), but of experiences with the relationships between letters and sounds and further a superordinate development which we might call a language sound schema. Such a schema should predict whether a speaker will accept a novel sound sequence as belonging to a language; that is, as being congruent with the schema.

Summary

Thirty-six third and fourth grade children read a list of 24 pseudo words which varied in pronounceability. It took the children longer to read the less easily pronounceable words. In addition, the errors in reproducing these words after rapid tachistoscopic exposures correlate highly with the reaction times to read the words.

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