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Relationships Between Written Spelling, Motor Functioning and Sequencing Skills

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The research was carried out on a representative sample of normal third-grade school children to investigate whether or not there were any meaningful relationships between spelling ability, motor functioning, balance, handedness, visuo-spatial ability (independent of motor activity), and various auditory and vocal (articulemic) skills.

The results reported in this paper and the subsequent discussion refer mainly to the relationship between spelling, psycholinguistic skills and motor functioning. The latter term is used here in its widest meaning in that it includes balance, vocal activity, writing and to some extent handedness. Obviously, kinesthetic sensory feedback is essential to muscular action and therefore it, too, is implicated.

SAMPLE OF CHILDREN

The sample consisted of a representative group of 50 third-grade, eight-year-old children comprised of 30 boys and 20 girls. Although the sample contained one or two learning disability cases, it is to be emphasized that the vast majority of the sample more or less coped with regular third-grade school work. Some of the children may have been slightly 'socially disadvantaged' and very few could be classified as upper-middle-class. The higher number of boys was partially determined by availability of subjects and also by the fact that boys are poorer spellers than girls, (Maccoby, 1966, pages 336-337).[1]

The mean I.Q. (Stanford-Binet) for the boys was 99.8 and for the girls 101.5, a negligible difference. The mean I.Q. (Stanford-Binet) for the 25 worst spellers was 100.2 and for the 25 best spellers 100.8 (product moment correlation r = +.059) a result which suggests that in this study at least intelligence and spelling skills are unrelated. Therefore, in the reported results and discussion below any significant finding cannot be attributed to sex differences in overall intelligence or I.Q. differences between the spelling ability groups.

DESIGN OF THE RESEARCH

The 50 children were given a battery of tests, the results of which were analyzed by means of product-moment correlations (see Table I). Other results were obtained by calculating 't'-tests to discover if there were significant

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TABLES OF RESULTS

Table I - Correlations Between Written Spelling and Selected Variables

	1	2	3	4	5	6	7	8	9	10	11
1. Word Spelling (Written)	1.0										
2. BVSMT Simplification	-.29*	1.0									
3. Balancing on one leg	.33*	.00	1.0								
4. Unlearned ambidexterity	.42**	-.14	.28*	1.0							
5. MFD Test (very accurate design score)	.33*	.01	.08	.03	1.0						
6. Sound-Blending ITPA	.40**	-.15	.16	.25	.37**	1.0					
7. Auditory Closure ITPA	.11	-.05	.08	.05	.13	.37**	1.0				
8. Auditory Sequencing ITPA	.21	.07	.27	-.14	-.13	.02	.22	1.0			
9. Visual Sequencing ITPA	.06	.07	.10	-.09	.09	-.01	-.22	-.08	1.0		
10. PERC Auditory Discrimination	.25	.21	.19	.05	.19	.02	.20	.26	.03	1.0	
11. Letter span memory	.17	.11	.24	.09	.02	-.01	.16	.66**	.24	-.12	1.0

N = 50
** r = 0.273 (.05 level of probability)*
*** r = 0.354 (.01 level of probability)*

NOTE: Correlation between Written Word Spelling and:
a) MFD very accurate drawn reproduction of designs, r = +.33
b) BVSMT selection (visuo-spatial) of correct originals, r = +.16
This suggests a motor-kinesthetic factor is partially operating even in the unit memory-for-designs aspect of spelling.

differences between the means for (a) boys vs. girls and (b) good spellers vs. poor spellers (see Table II).

A Verimax factor analysis was made of the total correlation matrix even though the battery of tests was not selected to cover evenly a wide area of psycho-physical functioning. Seven factors were extracted, one of which meaningfully related to spelling (see Table III).

The total number of variables taken from the tests for statistical analysis was 47, most of which one would not predict would be intercorrelated. The sets of statistical data demonstrate the same relationships, being simply different ways of looking at those relationships.

DESCRIPTIONS OF TESTS

The battery of tests used was as follows. Unfortunately, only brief descriptions are possible here.

BVSMT: The Bannatyne Visuo-Spatial Memory

Table II – Differences Between Means

Significant 't'–test Differences for ––

Test Variable	Boys (30)	Girls (20)	t-value	Significance
	Means (N = 50 unless otherwise specified)			
No. BVSMT Rotated Design Choices	.47	1.05	2.101	.05
No. BVSMT Complicated Design Choices	.70	.30	2.024	.05 level
Also Note: Spelling (Correct) Score (N = 32)*	24.62	34.36	1.937	Not sig.@.05 level Sig.@.07 level
Balancing on toes, both feet, eyes closed &	4.38 secs.	12.00 secs.	2.430	.05 level

Significant 't'–test differences for ––

Test Variable	Poor Spellers(25)	Good Spellers(25)	t-value	Significance
	Means (N = 50 unless otherwise specified)			
ITPA Auditory Closure	19.80	22.08	2.111	.05 level
ITPA Sound Blending	17.84	23.92	3.38	.01 level
No. BVSMT Simplified Design Choices (N = 32)*	.81	.25	2.38	.05 level
No. M-F-D-drawings of accurate original	3.64	4.80	2.07	.05 level
Balance on one foot (N = 32)*	19.44 secs.	54.56 secs.	2.41	.05 level
Total Balance Score	31.48	56.04	2.02	.05 level
Unlearned Handedness - ambidextrous	.72	1.24	2.88	.01 level

**NOTE: When N = 32, it indicates that eighteen children who were in the middle of the spelling distribution were excluded from a second complete series of t-tests on all variables. This was done to see if two 'extreme' groups of the distribution would increase the number of significant t-tests but only the two per table indicated were added (and one or two subtracted). Therefore, increasing the mean differences between groups is largely counteracted by the overall reduction in numbers (group size).*

Test was devised to assess a person's visuo-spatial memory-for-designs in a 'pure' way without involving motor activity. Each of fifteen separate stimulus designs is presented in turn for four seconds. After the presentation of each design, a blank page is turned, an operation taking one second, its purpose being to help eliminate after-images. This reveals a page of eight designs, the subject being required to select one design (in a multiple choice situation) as the exact equivalent of the original stimulus design. The eight designs, which are randomized on the page, are all slight variants of the stimulus design and they include the original design, a simplified version of it, a mirror image, a 90-degree rotation, a fragmentation, and out-of-proportion version of it, a complicated version, and a symmetrical version. The subject is told beforehand that one design is the same as the original design and that he must select that particular one. On the above sample of 50 eight-year-old, third-grade school children, the distribution of correct answers and the scatter of item difficulty were near-normally distributed.

ITPA: The Revised Illinois Test of Psycholinguistic Abilities (Kirk, 1968) cannot be described in detail here. The visual closure sub-test requires the subject to search for and identify objects and parts of objects within a series of pictures. The auditory sequencing sub-test is a digit span memory test similar to that in the WISC but with half-second intervals between digits, the subject being required to repeat back the series of numbers which have been dictated by the experimenter. The visual sequencing sub-test requires the subject to remember the order in which a series of almost non-meaningful geometrical designs on little cards have been placed, the subject having to sequence the designs in the correct order from memory. The auditory closure sub-test requires the subject to correctly say words which have been spoken by the examiner, but which have phonemes or even syllables missing from them. For example, on the stimulus word 'ingernail' the subject must reply 'fingernail.' The sound-blending sub-test requires the subject to synthesize into normal speech, words which are presented with intervals of silence between phonemes. Only these five out of a total of twelve sub-tests were given.

Table III — Verimax Factor Analysis

NOTE: This research was not primarily designed as a factor analytic study. The author, after much experience with the statistical techniques, has reservations about the value of (a) orthogonal factors, (b) the subjective selection of original tests and variables, (c) subjective factor rotation if it is part of the process and (d) subjective factor interpretation. Most of the Verimax factors were difficult to interpret but Factor 4 had a very high loading on spelling.

Factor 4 (Significant loadings)	
Spelling Score (Correct Words)	*.80*
Total Balance Score (Seconds)	*.63*
Balance on one foot, eyes open (Seconds)	*.56*
Balance on both feet (toes), eyes closed (Seconds)	*.55*
Sound Blending (Correct Blends)	*.54*
Handedness: Unlearned Ambidexterity	*.54*
Sex of child (Girls High)	*.34*
Simultaneous Writing: mirror imaging with non-dominant hand.	*31*

Spelling: The written spelling test was a simple standardized graded word spelling test ranging from very simple three-letter words to quite complicated ones (Schonell, 1960). Much of the orthography in this test is irregular.

Balance: The balancing test required the subject to stand on one foot with his eyes open and arms folded for as long as possible, the score being the number of seconds this posture could be maintained without undue 'wobbling.' A prior sub-test using two feet with eyes closed was included, and the results of both sub-tests separately and combined were included in the analysis.

Simultaneous writing: The mirror writing score was obtained from the simultaneous writing test in which the subject has to write the numbers 1 through 12 down the page as quickly as possible using both left and right hand simultaneously. The mirror writing score was obtained by counting up the number of mirrored numbers in the column written by (a) the dominant hand, and (b) the non-dominant hand. For the purposes of this test, hand dominance or laterality was decided on the basis of the learned handedness test described below.

Laterality of handedness: The unlearned handedness test consisted of three items, folding arms, clasping hands together with meshed fingers, and touching the left ear with a particular hand. A very careful analysis was made of the results of these three sub-tests to insure there was a commonality of handedness across all three in terms of laterality. An ambidexterity score was obtained if an item was performed in an ambidextrous way or if one item was performed with the right hand and another with the left hand. The latter preferences were still used to contribute to the right and left scores. When both measures of ambidexterity occurred, the results were combined.

The learned handedness test was composed of (a) which hand the child could best write with, (b) which hand could pile ten cards more quickly, and (c) which hand was uppermost when the child clapped hands. It could be argued that the latter is untrained, but I think it is a reasonable assumption that most children are deliberately taught to clap hands in infancy by parents and siblings. Ambidexterity was calculated in the same manner as for the unlearned handedness test.

Note that in a sample of third-grade children there will be a higher proportion of less well lateralized subjects than would be the case with older children or adults since lateralization is a function of maturation, (Hecaen and Ajuriaguerra, 1964).[2]

M – F – D: The Graham-Kendall Memory-For-Designs test requires the child to look at each of fifteen cards in turn. After the five-second presentation of each design, it is removed from sight, and the subject has to try to accurately reproduce that design from memory by drawing it on blank paper. All the fifteen drawings are usually done on one sheet of white paper. Thus, the test has a strong motor element as well as visuo-spatial memory. By contrast, the BVSMT to which the MFD is closely equivalent involves no motor activity other than pointing.

Letter span: The letter span memory test was devised to parallel the digit span test (ITPA) but using consonants instead of numbers. The correlation between the two tests was high, (r = +.66).

PERC Auditory Discrimination: This test which is very similar to Wepman's requires the subject to discriminate whether or not pairs of similar sounding words are the same or different. The test was tape-recorded for standard administration and sixty pairs of words were used.

DISCUSSION OF RESULTS

There was a significant tendency (from the t-tests results) for poor spellers (the lower spelling half of the sample) to choose the simplified versions of the original stimulus of the BVSMT designs. There were no significant differences on this test between poor spellers and good spellers on the choice of mirror-image designs, rotated designs, fragmented designs, disproportionate designs, complicated designs, or designs which had been made more symmetrical. Rotation was the next in line but the difference between the means was not significant.

Posture or balance requires visual, vestibular and proprioceptive information and it is an "essential function of the cerebellum to combine vestibular information and visual information about equilibrium with the state of contraction from the muscle spindles concerned and to so integrate these data as to be able to send out over the motor fibers a coded message which will maintain the upright posture over the desired period of time." (Woodburne, 1967).[3] This quotation is included to make the point that balance requires the integration of visual, proprioceptive and muscular information. The ability to balance on one leg with the eyes open is positively correlated with spelling achievement (r = +.33) a result which, though not a high correlation, suggests that overall coordinated motor control, eye-motor coordination, etc., (possibly involving the cerebellum) is necessary to good spelling. Even though the spelling test was written in form, it should be stressed here that the quality of the writing was ignored. Therefore, this correlation was not predisposed, so to speak, by a built-in motor score.

It is not suggested, of course, that balance itself contributes to spelling ability. It is rather that an efficient motor/kinesthetic/vocal/visual/vestibular system is very likely to effect good balance and high quality vocal-motor activity and manual dexterity each as separate functions.

A fascinating result was the highly significant correlation (r = +.42) between unlearned ambidexterity and spelling achievement. In the whole survey, the unlearned and learned laterality tests were separately significantly correlated with many of the other test variables, but on almost all laterality variables the two tests were uncorrelated with each other. The smaller but significant correlation (r = +.28) between unlearned ambidexterity and balance (the only laterality score correlated with balance), would seem to indicate a superior motor coordination between the two sides of the body and between these two variables and the eyes. In other words, the inference is that the superior speller possesses superior visuo-motor coordination and it is not stretching the evidence too far in the light of Luria's (1966)[4] remarks on motor planning, to suggest that spelling as an encoding function is heavily dependent on automatized motor/kinesthetic/praxic processes. The relatively high correlation between spelling and unlearned ambidexterity, also suggests that spelling is less dependent on the activity of one (verbal) hemisphere. This is supported by the low correlations of spelling with auditory sequencing, auditory discrimination and auditory closure. This pattern of relationships is reflected in the correlations of Table I and the variables listed as contributing to Factor 4 (Table III).

Certainly, the unit memory-for-designs when motor-encoded as a drawing is seen to be an important variable in the significant correlation (r = +.33) between the very accurate reproduction score of the Graham-Kendall Memory-For-Designs Test with the written word spelling test. When not motor-encoded (drawn) as in the BVSMT, unit design is less important to spelling. It is not very surprising that the ability to remember and reproduce single designs is significantly correlated with written spelling, because when one is involved in it, one is continuously remembering letter designs and even, perhaps Gestalt word patterns. The two (MFD and BVSMT) memory-for-designs correlations just quoted strongly suggest that motor/kinesthetic, manual-dexterity configuration patterns (writing) in the relevant areas of the brain contribute as much to unit-design 'visual' memory as does vision. Strangely, the ITPA visual (design) sequencing sub-test, which does not involve motor encoding to any extent, had almost no correlation (r = +.06) with written spelling or any other variable for that matter. It would seem that visual sequencing of designs makes no contribution to written spelling. This finding will be referred to again later in the paper.

The sound-blending test (ITPA) on the other hand is significantly correlated (r = +.40) with the spelling test. It is interesting that sound-blending is also correlated significantly with the Graham-Kendall memory-for-designs, 'very accurate' score. This suggests that sound blending, also an important aspect of reading, has in it, so to speak, a considerable element of the motor/kinesthetic and visuo-motor aspects of reading and writing, even when the stimuli are presented orally. It is self-evident that sound-blending as a function of speech involves the operation of motor and kinesthetic vocal processes. These results from this and the previous paragraph would seem to support those educators who claim that reading and spelling is best learned through an active motor writing and spelling curriculum, (e.g., Fernald, 1943[5]; Spalding and Spalding, 1957)[6] especially if one concedes that spelling and reading are interdependent skills (see below).

Although the ITPA sub-test auditory closure is significantly correlated (r = +.37) with sound-blending, it is not itself significantly correlated with spelling. This would seem to suggest that through the exclusion of motor, kinesthetic and visual functions, auditory closure is far more of an auditory, temporal lobe, type of test than is sound–blending as a whole, a conclusion which fits in with auditory closure being largely a recognition sensory decoding operation – which is one aspect of reading.

Variables 7, 8, 9, 10 and 11 (Table I) were included in the matrix to illustrate that they are of less importance in spelling, even though they are obviously highly auditory in modality. Of course, this lesser importance in spelling does not mean that they are not important in the reading process. Even the letter memory-span test (variable 10) which, because it is a process of remembering sequences of letters one would expect to be correlated with spelling ability, was not so correlated. It is highly correlated with the auditory sequencing digit span sub-test on the ITPA (r = +.66) which was also not significantly correlated with written spelling.

The general conclusion from the above results is that spelling as a written test, and perhaps as an oral test (because of the importance of sound blending), is very much (but not entirely) determined by the efficiency of the motor/kinesthetic/praxic/visuo-spatial output or encoding processes, the sequential memory influence in these processes, and the degree of automatization or habituation which has or has not been achieved in that output. After all, it is self-evident that spelling is in large part a rote memory (automatized) process.

The importance of unit-design memory in spelling is further supported by another variable correlation, namely the significant negative correlation between success in spelling and the choosing of the simplified design version in the BVSMT. The correlation is not very high but it could still be argued that an appreciation of unit-configuration or design complexity in terms of visuo-spatial maturation is necessary to an accurate encoding memory for letter designs in spelling. Thus, poor spellers are not so much simplifying designs as they are unable yet to appreciate or memorize the complexity of letter designs. A corollary conclusion is that a visuo-motor (writing) memory for complex unit designs is much more important to written spelling than remembering the purely visual sequence of designs, (ITPA visual sequencing/spelling correlation r = +.06). As will be suggested below as a result of the evidence from this and other research, it is very likely that the sequencing aspect of spelling is primarily determined by the vocal-motor habitual patterns involved in sound-blending, that is, the vocal-motor sequencing of articulemes.

PREVIOUS RELEVANT RESEARCH

It is worthwhile to compare the above results on spelling with those found by Kass (1962)[7] in her investigation of the psychological correlates of severe reading disability. She found the sample of 21 reading disability cases to be similar to the normal reader in understanding questions (auditory decoding, ITPA), describing familiar objects (vocal encoding, ITPA), digit span memory (auditory-vocal sequential, ITPA), 'conceptual communality' picture association (visual-motor association, ITPA), and answering with gestures (motor encoding, ITPA). In Kass' study, the reading disability cases had significant deficits in (a) a controlled association analogies test (e.g., "father is big, baby is _____," auditory-vocal association, ITPA); (b) memory for a series of pictures or geometrical designs, (visual-motor sequential, ITPA); (c) sound-blending (Monroe); (d) memory for designs (Graham-Kendall); (e) mazes (WISC); and (f) perceptual speed (PMA) – a rate of recognition test. Although the children had no known auditory or visual impairment, Kass does note that the tested deficiencies may be related to neurological dysfunctions which limit symbolic storage. The results indicate disabled readers are deficient in 7 out of 8 abilities at the automatic-sequential psycholinguistic level but in only 1 of 6 representational (meaningful) level abilities. Some of Kass' results (e.g., normal auditory-vocal sequential-digit span memory-scores) do not tally with other findings, namely McLeod (1965)[8] and Wolf (1967)[9], and her sample was almost certainly heterogeneous. (By contrast in the present research report, the children were a representative sample of local third-grade children attending public school.) Wolf's group were carefully screened to exclude neurological dysfunction cases and McLeod's review covered many research studies and samples. Nevertheless, one main conclusion which Kass has come to and which other authors have investigated or noted (e.g., Whiting, Schnall and Drake, 1966)[10] is the number of reading disability cases who fail on tests involving automatized functions in the various sensory and motor modalities.

Yedinack (1949)[11] found that second-grade children with functional articulation defects are significantly inferior in both oral and silent reading to children with normal speaking ability. Thus, speech patterns may not be fully automatized.

Anyone reviewing the extensive literature on reading and spelling disabilities can hardly help but come to the conclusion that the inability to automatize (that is, rote memorize) auditorially, visually, motor-kinesthetically or praxically is central to the problem. Inasmuch as motor-kinesthetic encoding is very often an habituated or automatized memory task (Adams, 1967), [12] as for example in typing or writing, it is not surprising to find it is a large element of the spelling process.

SPELLING AS AN ENCODING TASK

When we write spontaneous prose, it is our conceptualizing and thought processes which are the major stimulus of the content, which means that the letters of the words we must spell have to be remembered as designs and sequenced solely from recall. Usually, in such a situation, there is no external cueing which acts as a stimulus to facilitate spelling. Thus, the spontaneous composition of prose is a slightly different spelling situation to the one in which the child is cued by a list of words dictated to him orally which he must then reproduce correctly in writing. This slight cueing, which comes from the spoken word, can help the more verbally gifted child because he may be able to discriminate the phonemes which comprise the various words, and through his habitual phoneme/grapheme letter imaging and sequencing associations, automatically sequence the written symbols in the correct order.

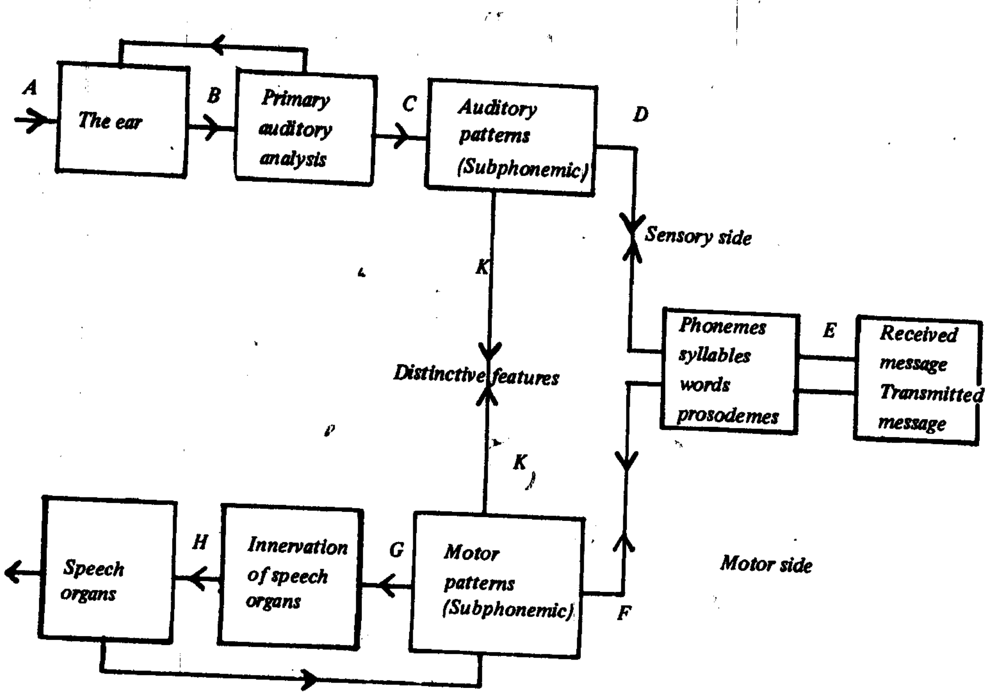
In a like manner, even when the child is working solely from conceptualizing processes and not the spoken word, he must hear (in phonetically written languages) his phonemic inner language in order to encode the correct graphemes which are associated with the internalized phonetic-auditory word. This occurs because the child, long before he learns to read and write, has associated the objects and concepts with the spoken word, many of these associations being firmly established prior to school entry. When he does eventually learn to read and write, the new visual symbols and their sequences are phonetically associated with the extensive auditory-vocal language which is already present. It would seem highly likely that those children who have auditory or vocal shortcomings of one kind or another (not necessarily always caused by neurological dysfunctioning) may not be able internally to 'hear' or vocally process phonemic elements of words in a sufficiently discriminatory and analytical way to provide the inner speech cues for satisfactory spelling output. It is likely that poor sound-blending (and by implication a lack of phonics training) is the problem because from Tables I and III, it is apparent that sound-blending is a more important variable in spelling than is auditory closure, auditory sequencing or auditory discrimination. It will be remembered that in Kass' study of reading disability, sound-blending and auditory-vocal association were the only auditory-vocal types of tests which significantly discriminated between the two ability groups. In a study on the influence of certain reading methods on the spelling ability of junior school children, Peters (1965)[13] came to the conclusion that, "Though spelling attainment is not affected, perceptual training (in learning to read) is transferred to spelling techniques, with important implications for remedial teaching." Peters found that children who were taught by the phonics methods, although equal to the other children in many categories of error, were superior in the remaining categories of fewest transpositions, fewest substitutions of vowels, and the greatest number of reasonable phonic alternatives. Since phonics training includes a large amount of sound-blending (vocal-motor) training in synthesizing words from their phonemic elements, it would seem that the synthesis which is involved in blending sounds during the reading process in some way assists in the reverse situation, namely the analysis of a unit word in inner speech into its component parts which are then encoded (spelled) either vocally or in handwriting. This is an interesting confirmation of the study by Sommers (1961) that a training in articulation significantly improves the performance of children in reading. Thus, the facilitation process between reading and spelling is a two-way one which is in considerable part engendered by a training in single-phoneme articulation and in phoneme or sound-blending, both being vocal-motor activities.

THE NATURE OF SOUND-BLENDING

The fusion of sound into a smooth utterance, or the analysis of an utterance into its component sounds (phonemes or distinctive features) is rather obscure. The spectrographic analysis of speech (Fant, 1967)[14] demonstrates how complex the speech waves are. He says, "Distinctive feature analysis applied to speech does not require an initial stage of segmentation in terms of sharply time limited portions of the speech wave. Some features appear and fade out gradually, and the tendency of segmental structuring to be observed in spectrograms is such that one phoneme is often characterized by cues from several adjacent segments and that one segment may carry some information on the identity of two or more successive phonemes." Although much more work will have to be done on the nature of speech and speech perception in terms of their elemental units before the nature of sound-blending is fully understood, Fant quotes Penfield and Roberts (1959)[15] to support the notion that the brain has two separate locations for motor units (for words) and sensory units (for words). Penfield and Roberts say, "This strongly suggests that the motor units for words and phrases are separated somehow, spatially, from the sensory units. But it is also clear that they are both located in the general region of the cortico-thalamic speech areas of the left side, where they are closely inter-related in function.". This work has led Fant to construct a hypothetical model of brain function in speech perception and production (see Diagram I). The model closely follows the work of Luria (1966) and the many others. It also parallels the psycholinguistic diagrams of Osgood, Wepman and others inasmuch as the distinctive features correspond to unit automatism whereas the phonemes, syllables, words and prosodemes correspond to sequencing automatism of various hierarchical 'ranks'.

From the sound-blending aspect, the important part of Fant's model is the two-way feedback or rather 'feed-around' K F D K and K D F K which would account for the reinforcement which articulatory motor patterns lend auditory patterns and vice-versa. In the spelling situation, E F G H I, the loop F K K D F if automatically activated, would reinforce the breaking down or analysis of the motor patterns into phonemic and unit letter sequences. However, Fant's model is of neuropsychological functions in oral speech perception and production and is not primarily intended to hypothesize the mechanisms involved in reading, spelling or writing. Even so, the blending of separate phonemes could and would on Fant's model take place in the F G box of motor patterning. This takes us back to Luria's work (1966) in which he says, "Expressive (motor) speech always requires the presence of a kinetic system (or chain) of articulatory movements with constant inhibition and modification (depending on the order of the sounds to be articulated) of preceding articulation...The pronunciation of any sound or syllable is possible only if an articuleme can be inhibited at the right time and the articulatory apparatus can be transferred to the next articuleme. It follows that a disturbance in the kinetic system (or the specific motor programs) of the whole word

DIAGRAM I: HYPOTHETICAL MODEL OF BRAIN FUNCTIONS IN SPEECH PERCEPTION AND PRODUCTION (after Fant, 1967)



and the inability to promptly inhibit each link of this system inevitably leads to a profound impairment of the pronunciation of words." Luria goes on to describe how in patients who have lesions in Broca's Area (area 44), "...cannot pronounce a syllable or a whole word, for the ability to inhibit individual articulatory impulses and to shift from one articulation to another is extremely limited. The patient has to make a separate, special effort for each sound and therefore cannot articulate a complete word smoothly. As a rule, the pronunciation of an articuleme reveals pathological inertia, and the patient cannot move on to the next sound." Such patients have similar difficulties when they try to write because the integral kinetic structure of writing is disturbed.

If, as Luria suggests, the motor patterning and innervation of speech organs (as in Fant's model) depends on Broca's pre-motor area, it is reasonable to suggest that children who find blending difficult in reading, or letter reproduction and sequencing difficult in spelling, have a less efficient encoding vocal-motor programming of articulemes (probably involving Broca's Area) than do their peers, an hypothesis supported by the present research data. (It should be made clear that this statement in no way implies lesions or neurological dysfunctions. The assumption is that almost all 'normal' physiological and neurological functions in the population as a whole can each be ranged along a relatively normal continuum with many intact individuals falling at the lower end of the distribution. Thus, many persons, particularly males [Morley, 1965][16] will exhibit articulatory hesitancies, slight mispronunciations, etc., even though their speech production falls within normal limits. Such children can no more be said to be 'brain damaged' than can those individuals who have I.Q.'s of under 90.)

Broca's Area, while it may regulate the facilitation and inhibition of articulemes, is not necessarily responsible, so to speak, for assembling, kinetic distinctive features into those articulemes, but this is of minor importance here because blending in reading is essentially a process of fusing the articulemes on the basis of the original template formed from a phoneme analysis of the word as represented in inner perceived speech – one must have experienced hearing a word to pronounce it. The child who cannot blend when reading may sound out the parts of the phonemic structure of the word successfully but be unable to run these sounds together in the conventional pattern. If the inner speech hypothesis is correct then a child's problem when reading is one of (a) running the sounds together smoothly enough to approximate to a normally spoken word, and (b) matching this word approximation against both the auditory patterns and the already learned relevant vocal-motor patterns of inner speech. The quality of the two latter patterns will determine the quality of his word-identification in reading.

THE ANATOMY OF SPELLING

Written word spelling is significantly correlated with,

a) unlearned ambidexterity,
b) sound-blending,
c) accurate visuo-motor drawing of memorized unit designs,
d) balancing on feet,
e) visual memory for complex unit-designs.

Written word spelling is not significantly correlated with,

a) auditory closure,
b) auditory memory for letters or digits in sequence,
c) visual memory for sequences of designs,
d) auditory discrimination (a borderline variable),
e) visual memory for unit designs when they are not drawn (motor activity).

Therefore, in the light of the reported results and the above discussion, it would seem that the spelling process is structured as follows:

1. Spelling is facilitated by an overall intact functioning of the motor and kinesthetic aspects of the C.N.S., not because all motor-kinesthetic functions are involved in the spelling process, but because those which are involved function well in an integrated way.
2. Because sound-blending is a sequential vocal-motor multi-articulatory process, spelling as a sequencing skill must (on the basis of this research) be dependent on vocal-motor activity of a sequential type.
3. Spelling does not involve the visual sequencing of designs and thus the sequencing element in spelling is very much more determined by the vocal-motor sequencing patterns of multiple articulatory sound-blending than by the visuo-spatial sequencing memory for letters. In other words, the sequencing element of spelling (i.e., writing down the correct sequence of letter shapes) is primarily determined by the sequence of articulemes occurring in the neuropsychological motor speech areas than it is on remembering the particular sequence of unit-designs. These articulemic sequential motor/kinesthetic patterns are obviously habitual (or overlearned) in competent spellers but, even they may have to 'sound out' an unusual word in order to spell it correctly. True it may be visually checked, too, but I suspect it is more likely as a gestalt than a sequence.
4. Even the remembering of unit-designs seems as dependent on motor/kinesthetic activity (drawing designs or the writing of letters) as it is on visual functions (M-F-D Original/Spelling, r = +.33; BVSMT Original/Spelling, r = +.16).

Collectively, these findings may help explain why Conrad (1962, 1964) and Conrad and Hull (1964),[17] in experimenting with acoustic similarity and visual similarity of visually presented letter-sets in a short term memory recall experiments, found that the error rate for aurally similar 'letter-sets' was twice that of the visually similar letter sets. In other words, the subjects were more confused by the auditory-vocal similarity of the unspoken visually presented letter-sets (which the subject recorded in writing) than they were by their visual similarities. Conrad also found that errors in an auditory discrimination test correlated highly (r = +.64) with mistakes in the short term recall of visually presented letters. Auditory factors in memory for both letter-sets and letters appear to override visual factors.

5. The visual memory element of spelling is not concerned with any form of sequencing. It would seem from the results of the present research that only a memory for unit-designs is important and that the ability to remember (relatively) complex unit-designs during a brief exposure is crucial. Therefore, visually it is the pattern-design of the individual unit letters, or grapheme groupings of letters, which is important in written spelling, not their visual sequence. I include the possibility of graphemes as unit configurations because they have some constancy from word to word within those sets of words which utilize them (e.g., night, fight, sight, right, but not kite).

IMPLICATIONS FOR TEACHING SPELLING

It would seem imperative if the above research is valid that children being taught to spell should concentrate on these points.

Step 1: There should be considerable deliberate and careful articulation of the words to be learned, and this articulation should emphasize: (a) the individual articulemes, (b) their blending into word sections, and (c) then into whole words. This should be done initially in the absence of the visual presentation of the word. The process should include breaking down the whole word into its phonic elements as well as blending them.

Step 2: The visual patterns of the letters in the words should be individually presented in turn without naming them. Then they should be grouped into their respective graphemes for a given word and these finally grouped as a whole word. This step should not take up too much time unless a particular child has a visual neurological dysfunction.

Step 3: The visual grapheme patterns should then be integrated, matched with or fused into the correctly articulated sequence of articulemes in a rhythmic way. This achieved, first, by having the children articulate them slowly as the teacher points to the graphemes on the board or the children point to them in their books, the graphemes being slightly spaced apart. Note that the alphabetic letter names should not be repeated unless being specifically referred to as individual letter configurations for denotation purposes. Second, and this is the major part of the whole learning process, the children should write the graphemes as slightly spaced units as they articulate them in rhythmic sequence, a grapheme and its equivalent articuleme coinciding. Coincidental (matched) writing and articulation should fix a word into the rote memory store more quickly than any other technique. This step should include copying and tracing -- especially so in severe learning disability cases.

Step 4: Test and repeat Step 3 for unlearned words until overlearned.

This series of teaching steps is based on the research findings that unit designs are sequenced in words on the basis of articulemic-motor encoding with an emphasis on the blending aspects of that process. Color coding the vowel phonemes may further facilitate the above spelling learning method. (Bannatyne, 1966).[18]

FURTHER RESEARCH

The findings of this research can be validated by further research into the specific hypotheses implied above concerning the neuropsychological nature of spelling. The articulemic/unit-configuration method should be tested against traditional letter spelling methods.

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GLOSSARY

ARTICULEME, ARTICULEMIC: An articuleme is the spoken or vocal single sound equivalent of a phoneme (which is heard) or a grapheme (which is printed or written). Most people use the term phoneme to indicate the separate sounds in both heard *and vocalized words, but Luria prefers the term articuleme for the latter group.*

CLOSURE: Closure is a process of completing an uncompleted set of stimuli which, through past experience, suggest a correct 'missing piece' fill-in. Closure may occur in any sensory modality. Visual closure occurs when a missing piece of a design or series is filled in. Auditory closure occurs when we hear a slightly mispronounced or accented word and yet identify it correctly.

GRAPHEME, GRAPHEMIC: A grapheme is the written or printed (letter or letters) equivalent of the auditory/speech unit of sound the phoneme. If the orthography of the language is irregular, the matching of phonemes to graphemes is not consistent. For example, the phoneme /eye/ can be written as the graphemes, eye, i, I, igh, ei, ie, uy, y.

HAND LATERALIZATION: Traditionally, this term refers to the hand which is used for writing and other everyday functions as the 'dominant' hand which in most people is the right one. In this paper, unlearned handedness is a new concept. It refers to the hand which appears to be 'dominant' in certain tasks which are thought to be unlearned. Each hand is 'controlled' or motorically activated by the appropriate motor and kinesthetic areas of the motor cortex on the opposite side of the body to the hand in question, e.g., right hand control is in the left hemisphere.

HEMISPHERIC DOMINANCE: In most people, the left hemisphere of the brain (and in particular the left cortex) processes language functions even though the right hemisphere may also be involved, particularly motorically. In some few people language functioning may take place in the right hemisphere. The side of the brain which processes language in any given individual is called the dominant hemisphere.

ORTHOGRAPHY: The matching or correspondence of phoneme to grapheme (auditory sign to printed symbol) in phonetic languages. The matching may be nearly exact in some words (e.g., handedness) or very irregular (e.g., one, cough).

PHONEME: A class or family of closely related heard speech sounds (phones) regarded as s single sound and represented in phonetic transcription by the same symbol, as the sounds of /r/ in bring, red and round. The discernible phonetic differences between such sounds are due to the modifying influence of the adjacent sounds. A spoken phoneme is called an articuleme by Luria.

PRAXIA, PRAXIS: This is an ability to perceive, organize, construct or assemble objects out of parts in a correct manner in either two or three dimensions. Putting on one's clothes, building an erector set bridge and even drawing objects or designs are praxic activities all of which are heavily dependent on visuo-motor skills. Praxic disabilities are referred to as apraxia.

VISUO-SPATIAL and VISUO-MOTOR: Visuo-spatial refers to the neuropsychological ability of an individual to perceive and manipulate objects in space. In this context, it does not refer to motor activity or dexterity for which the term visuo-motor is used. (See also: praxia).

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