Span Ability: A Theory of Intelligence

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This paper represents a "new look" at the concept of intelligence. The theory provides a conception of intelligence couched in terms of stimulus and response that falls in the mainstream of psychological thought bridging the gap between S-R and cognitive psychology and leading to an analysis of a wide variety of complex human behaviors in terms of span.

We make a considerable number of closely related points about intelligence in connection with the concepts of span ability (a capacity notion), response string (sequentially cued responses, as in a span test), and complexity of stimulus control (task complexity). The chief integrative concepts in our analysis are span ability (as typically measured in an immediate memory span test) and complex stimulus control or cueing (as borrowed from the animal learning literature). This conceptual framework leads to a view of intelligence that is quite different from the usual checklist or agglomerate strategy common to most IQ tests.

The complexity of stimulus control, the number of relevant stimuli that jointly elicit a response at one brief point in time, is the key concept in specifying task complexity and assessing span. Here, it is important to stress that the critical cues are jointly relevant for the total target response; that is, each of the cues is essential for correct responding. We are not, in other words, referring simply to an increase in the number of controlling stimuli when any one of them is sufficient to elicit the target response. This would only mean that the cues are redundant and that the situation is, if anything, less, rather than more complex, facilitating rather than complicating performance.

Much of what we are going to discuss flows rather directly from a definition of intelligence that a number of investigators in the area of mental retardation would be inclined to endorse (Denny, 1975). This definition approximates an operational definition of intelligence better than "that which

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the IQ test measures" because it operationalizes, at least potentially, what is mainly involved in constructing such tests: When the operation of special sense receptors or motor systems have been excluded from consideration, intelligence is the total set of individual difference variables that interact with difficulty (complexity). That is, the more complex the task the more intelligent one needs to be to perform the task; and when the task is extremely simple, intelligence is not a relevant variable.

Age-scales like the Stanford-Binet clearly incorporate the notion of difficulty in their construction, especially as difficulty is defined by relative levels of performance. IQ-test items are selected for increasing difficulty by testing them with various age groups.

From the perspective of span theory, intelligence is somewhat different from the ability to think abstractly or the ability to adapt. Intelligence need not be thought of in evaluative terms; that is, intelligent behavior need not always be correct or adaptive. A high level of intelligence is only expressed under certain conditions, namely, conditions of complex stimulus control. An intelligent person does not behave intelligently except as situations demand. At other times his behavior is no different from a person with lesser intelligence.

In an immediate memory test a series of stimuli, such as digits, is presented, and the subject attempts to repeat them in the order of presentation. The largest string which the subject can repeat reliably is called his memory span. The characteristics of span scores are similar to those of the concept of general intelligence in a variety of ways.

Like IQ scores, span measures are highly reliable, above .95, if the tasks are properly constructed; and they are highly correlated with each other across many variations in stimuli, responses, task requirements, and procedures used to test for span.

To the extent general intelligence is conceived as a basic capacity it is usually assumed to be insensitive to practice, that is, practice produces new behaviors or associations but does not affect native ability, per se. Similarly, span appears to be relatively insensitive to practice effects. The few studies which have been done indicate that practice effects are either nonexistent or quite small, specific to the stimulus-response sequences used in training, and temporary. Research at Western Carolina Center has consistently failed to find even minimal improvement with practice when the sequential auditory word span test is used.

Even so, Heber & Garber did find in the Milwaukee project that the inner city children who received the extensive intervention program beginning soon after birth and lasting several years had significantly higher digit span than the control group which was only tested periodically. While several reasons can be advanced to account for this effect including that span is modifiable during these early years, the most reasonable interpretation, to our way of thinking, is based on the nature of the materials effect in span tasks. Digit spans are typically larger than word spans, and word spans seem to be a truer measure of span ability than digit span. For instance, my Doctoral Research (1970) examined the relation between digit span and word span in borderline and retarded adults and showed that the difference between the two measures for individual subjects ranges from 0 to 2 and that this difference correlates .36 ($p<.01$) with IQ. Digit spans were never less than word spans which was interpreted to reflect the extensive experience subjects are likely to have with specific digit sequences as compared with experience with specific random noun sequences as used to measure word span. In other words, the more experience a subject has with specific digit sequences, such as phone numbers, arithmetic, ages, etc., the more likely he is to chunk pairs of digits and thus increase his digit span with no change in true span ability.

The difference in digit span between the two groups of the Milwaukee study was about 1 digit, very much like the average materials effect already mentioned. Since, in the Milwaukee project, the experimental group had much more experience with digits than the control group this can explain the one digit difference. In other words the two groups should have identical word spans if span ability is unmodifiable.

General intelligence is conceived to increase regularly throughout the developmental period and reach a plateau in early adulthood; span measures follow the same developmental sequence. This is true even with a group that differs widely in intelligence.

Span measures are more highly related to measures of intelligence than commonly supposed. Among retarded and borderline institutionalized adults Bachelder has found the correlation between digit span and IQ is .79 and in another study that word span and IQ correlate .66. The correlation between WISC digit span and the WISC full scale IQ (minus digit span) ranges between .60 and .70 when corrected for attenuation. For the WAIS test this correlation is .75. The ability to repeat two digits at age 2 1/2 correlates .62 with Stanford-Binet IQ. The WAIS digit span subtest has a loading of .63 (.80 corrected for attenuation) with the factor g for the age group 18-19 and the digit span and the vocabulary subtest on the WAIS correlates .60 (or .73 corrected for attenuation) for the normative group. In addition, college students have larger spans than average adults (Bingham, 1916; Humpstone, 1917; Bachelder, Note 1).

Just as measures of intelligence are positively related to academic performance there is evidence that span is also. Students at the bottom of their class (by teacher evaluation) have smaller spans than students at the top of their class (Jacobs, 1887; Johnson, 1895). In the same vein, the best predictor in a comprehensive battery of subtests for first grade performance among "high risk", learning problem, kindergarten children is digit span. It also seems relevant in this context to point out that the digit spans of autistic children correspond to their chronological rather than their mental age which reflects the notion that these children are not basically retarded.

Finally, it can be argued here that the digit span yields a rather unbiased "culture-free" estimate of intelligence as compared with the score on an IQ test. Digit span and IQ correlate significantly in middle- and upper-class children but not in lower-class children. If, to a sizable extent, IQ reflects achievement in school, then those who have a maximum educational opportunity should achieve their potential, as indexed by digit span, and produce the full range of individual differences. On the other hand, children of lower socio-economic status who probably do not have an adequate educational opportunity to achieve their potential, would be less differentiated by school and home experiences and therefore show a nonsignificant correlation between digit span and IQ. In this same vein it has been shown that black children and white children are not different in digit span even though the IQs of the black children show the usual 15 point difference in favor of the white children (Clark, 1923; Jensen, 1970).

Joint relevance of stimuli. It has been customary to analyze behavior into S-R units or chains with the implicit assumption that the subject observes one stimulus at a time, responds appropriately, observes another stimulus, and so on. These stimuli are classified as relevant or irrelevant according to whether or not they provide the basis for appropriate responding. A key concept of span theory is that two or more stimuli may be jointly relevant; that is, a number of stimuli taken together may be necessary or sufficient to specify consistently correct responding. In the span tasks, for example, all the stimuli in subspan strings must be jointly relevant because the subject must attend to them all to produce the correct target response string. Other tasks involve joint relevance also. In the two-choice discrimination learning experiment one of two stimulus objects is designated correct and either cue is all that is needed for correct responding (approach to the positive cue or avoidance of the negative cue). In a conditional discrimination problem, however, at least two cues are relevant on each trial. For example, the circle is correct when the background is red and the square is correct when the background is blue. Correct responding is dependent on joint attention to background color and form. In an oddity problem the subject views three stimuli and must choose the one which is different from the other two. In such a situation no one stimulus can serve as the basis for correct response, nor can any pair. Only the three stimuli considered jointly can specify the correct response in an oddity problem.

Task complexity. We assert that the complexity of a task increases with the number of stimuli that are jointly relevant for correct responding. Thus, according to our analysis, the oddity problem is more complex than the conditional discrimination problem which in turn is more complex than the two-choice discrimination problem. In a span task, no learning or practice is required. Thus it follows, given that the stimuli are all familiar and can be readily imitated, that the complexity of a span task is equal to the number of stimuli in a stimulus string. On occasion, in complex stimulus situations, it may be rather difficult to assess the joint relevance of a cue or whether it is a discrete stimulus element. Such decisions must await experimentation.

Span ability. Span is defined as the highest level of stimulus complexity that yields a consistently high level of accurate performance. Whatever makes it possible to achieve a particular level of span is called span ability. In any test of span, the operation of specific practice effects must be minimized; a subject is not scored for response sequences with which he is highly familiar. For example, the digit string 12345 and the date 1976 are obviously inappropriate test sequences.

Span ability conforms to our definition of intelligence since it interacts with task complexity. Low-span subjects perform as well as high-span subjects on simple stimulus strings, but only high-span subjects perform well on complex stimulus strings.

The traditional immediate memory test is a particularly good measure of span ability because the number of jointly relevant stimuli are nicely specified and the test items can be selected so as to be comparable across subjects of widely differing ages, abilities, and backgrounds. For example, most subjects, including retardates, have had extensive experience with familiar single-syllable nouns such as dog, cat, tree and shoe. Thus errors in the immediate memory test cannot readily be ascribed to lack of familiarity with the target responses; rather, difficulties in performance can be attributed to limitations in span ability.

Relative task difficulty. Relative task difficulty is defined as the ratio of task complexity to span ability. A value of 1.0 means that task complexity is equal to the subject's span ability; values less than 1.0 mean the task is less complex than span ability (theoretically an easy task) and values greater than 1.0 mean that the task is more complex than span ability (a difficult task). This concept permits taking into account both task complexity and individual span abilities for predicting performance. Later, we will present evidence that relative difficulty values are highly predictive of actual performance in the absolute judgment task.

Response string. The term response string is used to differentiate response sequences produced under complex stimulus control from response chains developed through conditioning or chaining. Superficially, the response string and response chain are identical. They are functionally different, however, in that the occurrence of a response string is dependent upon an antecedent complex stimulus string while the occurrence of a response chain is not. A response chain can be initiated by a single cue, as when the rat resumes barpressing on an FR schedule after ingesting the food pellet. Response chains require a definite and frequently extensive training history, while response strings do not. The individual, component S-R associations of a string, e.g., saying "nine" after hearing the digit 9, have had to be developed through practice, but the specific sequence of a response string needs only to be elicited, not learned. Ongoing behavior is doubtless a combination of response strings and response chains, making analysis complex.

In the following section span theory is extended to a variety of behavioral phenomena; data which support this extention as well as the implications span theory has for many areas of performance are cited.

Absolute judgment. In this type of experiment, the experimenter selects a pool of stimuli for judgment by the subjects, say, a pool of black squares differing in size. The experimenter also defines a set of appropriate responses, usually arranged on an ordinal scale (such as all numbers from 1 through 14), with which the subject judges the stimuli. A long series of randomized test trials is then given, with one stimulus presented at a time, and the subject attempts to identify each stimulus with the correct response.

In absolute judgment, if the pool of stimuli is small performance is essentially perfect once the responses have been specified for the subject. As the number of stimuli is increased, however, a point is reached beyond which the subject can no longer correctly judge all of the stimuli. The number of stimuli at this transition point is called the span of absolute judgment and is approximately 7±2 in college students. The size of span and the range of individual differences for the absolute judgment paradigm seem to be equivalent to the other measures of span ability; and the average span of absolute judgment for educably retarded adolescents is about 5 rather than 7 (Spitz, 1973).

The role of joint relevance in the absolute judgment task is not so clear as in other tasks. Garner (1962) points out, however, that it is unfortunate that the absolute judgment experiment has been so named because in fact the judgments are not absolute. He points out (p. 77) "all judgments are made with respect to the total range of stimuli in a particular experimental situation." We argue that if the judgments were not relative judgments then each stimulus must be eliciting a particular response. But if each stimulus is associated with a specific response then there should be no particular span effect, that is, the subject should be able to learn each association and respond correctly on all stimuli regardless of the number of stimuli in the experiment. In fact, Garner states that there is some evidence that such associations form with extended practice but it appears that in the common experimental situation such associations play a small role. It appears to us that the subjects produce correct responses through implicit comparison of the target stimulus with the entire pool of judgment stimuli, which is to say all stimuli are jointly relevant for correct responding on any given trial.

At Western Carolina Center we have found rather direct support for the relation between span ability and absolute judgment. The subjects were 60 adults in three groups; 20 institutionalized retardates ($\overline{IQ}$=47.8), 20 normal cottage staff, and 20 college students. The subjects judged squares varying in size and encountered problems of increasing complexity as the number of squares in the judgment pool increased from 2 to 8. Twelve subjects failed to meet the criterion of 95% correct on the 3-stimulus problem, 25 failed on the 4-stimulus problem, 15 on the 5-stimulus problem, 7 on the 6-stimulus problem, and 1 on the 7-stimulus problem (Fig. 1). The mean word span scores for these groups were 2.65, 5.23, 5.87, 5.76, and 6.1, respectively. The difference among these means was highly significant ($p<.0005$). Thus there was a clear relation between span and how complex a problem could be successfully handled. The same relation was revealed through correlation of span with the information transmitted which is a statistic approximately equal to the $\log_2$ of span of absolute judgment when the tasks are supraspan. The three simplest problems were unique among the many presented in the experiment because all 60 subjects performed on them, that is, even the low-span subjects performed on these before they failed to meet criterion on more complex problems. The information transmitted was calculated for each of the three problems and then these values were averaged for each of the subjects. The mean information transmitted correlated .78 ($p<.0005$) with word span.

In order to study the effect of relative task difficulty, theoretical complexities were assigned to each of the three problems discussed above. With 60 subjects and three problems each there were 180 complexity-span combinations from which we calculated 180 relative task difficulty values. Relative task difficulty correlated well with the number of correct responses on the respective subject-problem combinations; $\underline{r} = -.68$, $\underline{p} < .0005$. The relation is negative because the greater the relative difficulty, the smaller the number correct. When mean relative difficulties and mean spans were used for the same subjects grouped into 12 relatively homogeneous span groups with five subjects each, the correlation increased to $-.86$, $\underline{p} < .0005$ (Fig. 2).

Span of apprehension. In these experiments the subject briefly observes a number of simultaneously and randomly presented visual stimuli such as dots on a plain background and responds to indicate the number of items shown. For small numbers of stimuli, up to about six items, performance is easy and essentially perfect for normal adults. Much beyond this point performance is imperfect, and the subjects seem simply to estimate the number of stimuli. The stimuli are presented too briefly to be counted but all stimuli must be perceived (jointly relevant) when their number is accurately apprehended. According to Spitz (1973), spans of apprehension for educable retardates are about 4 - 5, that is, lower than the spans of apprehension of college students as predicted by span theory.

Language behavior. It has long been a truism that language behavior and intelligence are interrelated, but a common theoretical foundation in stimulus-response terms has been lacking. We propose that both can be seen as expressions of the same fundamental ability to cope with complex stimuli (span ability). An analysis of language as sets of response strings elicited by complex stimuli makes it possible to handle characteristics of language that do not fit the usual S-R model that sentences are response chains in which each word elicits the next. For example Lashley (1951) has argued that the relations among words of a sentence are so variable and complex that a given word cannot be acting as an eliciting stimulus in the usual sense. He gives this example: "The mill-wright on my right thinks it right that some conventional rite should symbolize the right of every man to write as he pleases"(p. 116). In this example the meaning of the various "rites" is not clear except in the context of other words. That is, word meaning typically depends upon the joint relevance of two or more words or morphemes (stimuli).

Similarly, the meaning of most sentences is determined by most of the words considered jointly. One need only leave a key word out of a sentence or change a key word to drastically obscure or change the meaning. For example, "The boy is smart." or "The boy is missing." In a similar vein, the meaning of connected discourse invariably is conveyed by a number of sentences considered jointly. Difficult logical or philosophical points are typically developed by means of long sequences of related sentences; and the omission of any sentence makes correct comprehension difficult or impossible for the relatively naive listener.

The meaning of a sentence may vary with nonverbal context and thus the appropriate response (meaning) requires joint attention to contextual stimuli as well as the words in the sentence. For example, "That was wrong, try again." has no specific meaning except in context.

Critics of S-R and operant analyses of language point out that language is generative; that is, speakers produce sentences which they have not heard or practiced before (Chomsky, 1959). Since the component responses (words) of such generative sentences must have been part of the speaker's learned repertoire, any creativity or novelty in the sentence must be novelty of combination and sequence. This type of novelty is inherent in the response string whose content, word sequence, and combination with other strings is determined by the total stimulus complex. It is not at all unusual to elicit novel verbal response sequences (from the point of view of the speaker's verbal history) by presenting novel stimulus strings or complexes. Novelty in language production resides in the novelty and complexity of the stimulus situation, and span ability allows this novelty to be expressed in response strings (language). To bolster this point the next section of the paper will show that the complexity of sentences that are imitated or generated is in both cases limited by size of span.

Language development. One clear dimension of language development in young children is the number of words in a sentence or utterance. Brown and Fraser (1963) suggest a strong relation exists between span ability and language development: "A basic factor causing the child's reduction of adult sentences is surely an upper limit of some kind of immediate memory span for the situation in which the child is imitating and a similar limit of programming span for the situation in which the child is constructing the sentences. A comparison of the mean lengths of utterances produced as imitations with the mean lengths of spontaneously produced utterances from the same children shows that the paired values are very close and that neither is consistently higher" (p. 193).

At Western Carolina Center the relation between span and sentence imitation in retarded subjects has been studied (Notes 2 & 3). Ten retarded adolescents with mean IQ = 59.2 imitated meaningful sentences varying in number of words in a fairly typical span paradigm. The correlation between word span and sentence span was .79, $p<.005$. In another study with 17 subjects very similar to those in the first study the correlation was .81, $p<.0005$. This relation between span and sentence imitation helps clarify the developmental sequence of language. As children grow older they are able to imitate longer and longer sentences under conditions of increased stimulus complexity. Through practice many of these sentences become a stable part of their verbal repertoire. Similarly, those deficient in span have difficulty augmenting their verbal repertoire by imitation and show delayed language development.

We also have conducted several studies of the relation between span and the complexity of sentences generated in a free speech situation. In these studies the subject views pictures and is asked to talk about them. Their speech is tape recorded and then for analysis fed into a heat writing oscillograph which provides a visual record of the pattern of speech production. From these records the pattern of output can be observed directly, a group of words followed by a pause, followed by another group of words, etc. The number of words in each "burst" (between pauses) is counted and averaged for each subject. For a group of 19 retarded adolescents with a mean IQ of 61.37 the correlation between word span and number of words in a burst was .62, $p<.005$ (Note 4). Ten college students in a quite similar study produced a correlation of .73, $p<.01$ (Note 5). These findings remain somewhat tentative while we improve our measure of the complexity of sentence generation.

Reading. Reading involves jointly relevant stimuli in several ways. If a child is attempting to learn to read words by the whole word method, then all of the letters of the word are jointly relevant for the correct response. If the phonetic approach is taken and the student has acquired a working repertoire of letter sounds, then he can begin to sound out new words, a process which clearly benefits from high span ability. The smooth production of a sequence of letter sounds is directly controlled by the sequence of letters that makes up the words. Thus, young, inexperienced readers sound out small words much more readily than long words.

Reading skill is improved if a student can determine the meanings of unfamiliar words through context. As already mentioned, the use of context to establish the specific meaning of words involves the use of several cues at once. Thus we should expect the ability to determine the meaning of unfamiliar words through context to be related to span. In general, comprehension of what we read requires joint attention to several words at a time.

IQ subtests. Good performance on some subtests of several IQ tests seems definitely to involve joint stimulus relevance. The WAIS Arithmetic subtest presents problems orally and they must be solved without pencil and paper. An example is: "If a man buys seven two-cent stamps and gives the clerk a half dollar, how much change should he get back?" To produce the correct answer the subject must consider several words and values jointly, for example, seven, two-cent, half dollar, and change. In the WAIS Block Design test the subject reproduces designs of increasing complexity requiring from four to nine cubes. This task clearly seems to involve a number of stimuli jointly relevant for the target response. Thus performance should be a direct function of span ability. It is entirely possible for a subject to look at just one element (block) in relation to another (in the model) and slowly assemble the design but the person who can perceive larger numbers of elements in configuration should be able to construct the design much more rapidly. Thus, high span is not necessary for performance but it is sufficient for superior performance. It is interesting to note that the items on this test range in difficulty from four to nine blocks with the most difficult test falling at the upper edge of the 7 ± 2 range of span for college students. In the WAIS Picture Arrangement test the subjects arrange a number of pictures in proper sequence so as to tell a story. Obviously the subject's main task is to discern the relevant story. No one picture considered in isolation can convey this information accurately. All of the pictures must be considered jointly before the subject can construct the proper sequence. In this test, also, the number of pictures increases as difficulty increases.

Intelligence and learning. The empirical relation between learning and intelligence as measured by IQ tests is not simple or staightforward. For example, gain scores, which have high face validity as a measure of learning, have been shown repeatedly to be unrelated to intelligence. While span theory cannot as yet account for the bulk of the results that have been found to date, the implications of span theory for this state of affairs are quite clear: Intelligence as defined herein, and learning as defined as a change of behavior as a function of practice are two distinct processes which become related only under certain conditions. On the other hand, the traditional belief in a relation between intelligence and learning follows from the theory when the implications that span has for performance are adequately exploited.

A study done at Western Carolina Center is suggestive of just such a theoretical clarification (Note 6). Ten high-span retarded adolescents (mean word span = 4.78; $\overline{IQ}$=70.1; and $\overline{CA}$=13.2) and 10 low-span retarded adolescents (mean word span =2.5; $\overline{IQ}$=49.3; $\overline{CA}$-15.1) attempted 16 trials in a free recall paradigm. High-span subjects performed significantly higher than low-span subjects (p<.05) and all subjects improved across trials (p<.0005). Span ability did not interact with trials (F=1.12), that is, all subjects regardless of span improved in a similar way with practice. The more intelligent subjects performed better than the less intelligent subjects; but these differences were apparent from trial 1 onward. Span ability was not related to gains but was related to performance. Had the dependent variable been trials to a predetermined criterion the high-span subjects would have reached criterion faster, not because they learned faster but because they started higher.

The relation of span to learning requires that we consider a basic principle of learning, namely, that what is learned is what is elicited in a situation (Denny, 1966). Because span ability can limit the complexity of the behavior elicited under complex stimulus presentation we expect a similar limitation on learning. Under complex stimulus conditions, high-span subjects should learn faster than low-span subjects because at early stages of training a relatively large proportion of the target behavior can be elicited directly by the complex stimuli. Low-span subjects are at a relative disadvantage either because the requisite behavior cannot be elicited at all under given stimulus procedures or because only relatively small components of the target sequence can be elicited at any brief point during learning. This state of affairs is illustrated in the learning of a telephone number. A person with a high span can listen to the entire digit string and imitate it perfectly from the first presentation. Immediately he can begin practicing the number several times and thus learn it. The low-span individual who hears the entire digit sequence cannot repeat it in its entirety on early presentations and will take longer to acquire the entire sequence. In fact, the best way to teach such a sequence to a low-span person is to break it into smaller sequences that can be readily imitated and then chain them together to achieve the target response.

References

Bachelder, B. L. The memory span paradigm: Its use for the analysis of mental retardation. (Doctoral Dissertation, Michigan State University, 1970). Dissertation Abstracts, 1971, 32(1), 576B-577B. (University Microfilms No. 71-18,158)

Bingham, W. V. Some norms of Dartmouth freshmen. Journal of Educational Psychology, 1916, 7, 129-142.

Brown, R., & Fraser, C. The acquisition of syntax. In C. N. Cofer & B. S. Musgrave (Eds.), Verbal behavior and learning: Problems and processes. New York: McGraw-Hill, 1963.

Chomsky, N. Verbal Behavior by B. F. Skinner. Language, 1959, 35, 26-58.

Clark, A. S. Correlation of the auditory digit memory span with general intelligence. The Psychological Clinic, 1923, 15, 259-260.

Denny, M. R. A theoretical analysis and its application to training the mentally retarded. In N. R. Ellis (Ed.), International review of research in mental retardation (Vol. 2). New York: Academic Press, 1966.

Denny, M. R. Overview and synthesis. In N. R. Ellis (Ed.), Aberrant development in infancy. Hillsdale, N. J.: Lawrence Erlbaum Assocs., 1975.

Garner, W. R. Uncertainty and structure as psychological concepts. New York: Wiley, 1962.

Humpstone, H. J. Some aspects of the memory span test: A study in associability. (Doctoral Dissertation, University of Pennsylvania, 1917). Philadelphia: The Psychological Clinic Press, 1917.

Jensen, A. R. A theory of primary and secondary familial mental retardation. In N. R. Ellis (Ed.), International review of research in mental retardation (Vol. 4). New York: Academic Press, 1970.

Lashley, K. S. The problem of serial order in behavior. In L. A. Jeffress (Ed.) _Cerebral mechanisms in behavior: The Hixon symposium_. New York: Wiley, 1951.

Spitz, H. H. The channel capacity of educable mental retardates. In D. Routh (Ed.), _The experimental psychology of mental retardation_. Chicago: Aldine, 1973.

Reference Notes

1. Bachelder, B. L. *Memory span and absolute judgment in normal and retarded adults*. Paper in preparation. Western Carolina Center, Morganton, N. C. 28655, 1976.
2. Bachelder, B. L., Harris, C. R., Doss, J. L., & Roberto, N. J. *Span ability and imitation of random words, meaningless sentences, and meaningful sentences in retardates*. Unpublished brief report. Western Carolina Center, Morganton, N. C. 28655, 1973.
3. Bachelder, B. L. *Sentence imitation by retardates as a function of memory span and memory load*. Paper in preparation. Western Carolina Center, Morganton, N.C. 28655, 1975.
4. Bachelder, B. L. *Memory span, memory load, and sentence generation in retardates*. Paper in preparation. Western Carolina Center, Morganton, N. C. 28655, 1975.
5. Bachelder, B. L. *Memory span and sentence generation in college students*. Paper in preparation. Western Carolina Center, Morganton, N. C. 28655, 1975.
6. Bachelder, B. L. Span ability, word frequency, and free learning among retarded adolescents. *Western Carolina Center Papers and Reports*, *4* (16), Sept., 1974.