

Span theory: A theory of mental retardation and intelligence

Bruce L. Bachelder
Psychological & Educational Services
Morganton, NC

Preface¹

Span theory arose from early efforts (Denny, 1964, 1966) to bring basic data and theory to bear on the challenge of developing effective teaching methods for students with severe mental retardation. I was a graduate student trainee at Michigan State University in the late '60s working in a project developed by M. Ray Denny (1966). Ray is a learning theorist in the S-R neobehavioral tradition whose work integrates and extends that of Clark L. Hull, Edward Chace Tolman, Edwin R. Guthrie, Kenneth W. Spence, and B. F. Skinner (Denny, 1991b, p. 199).

Ray's interest in mental retardation is closely related to his *elicitation theory* (Denny, 1966, 1967, 1971a, 1971b; 1986; 1991; Denny & Adelman, 1955; Denny & Ratner, 1970, pp. 12-16, 601-658, 718-773; Ratner & Denny, 1964, pp. 7-10, 566-673; see also Estes, 1970, pp. 121-124; Maatsch, 1954; Marx & Cronan-Hillix, 1987, pp. 355-357; Mercer & Snell, 1977, pp. 142-177; this book). Elicitation theory is an S-R learning theory with broad application. I spent my graduate school years learning to bring the theory to bear on the challenge of understanding the learning problems of people with mental retardation.

When I reached ABD status, I left campus for a full-time position with a residential facility where I "discovered" the Digit Span subtest of the Wechsler IQ tests. It was second nature to view the span phenomenon from the point of view of elicitation theory. I reinterpreted "memory span" as "elicitation span" ($S_1S_2 \dots S_n - R_1R_2 \dots R_n$) and hypothesized an *elicitation span ability* to account for individual differences in memory span tasks. The basic memory span task seemed to indicate that one is able to elicit more-complex response sequences from higher-span subjects than from lower-span subjects. The elicitation span concept is much closer to the behavioral concept of stimulus control and to Ray's concept of complex cues than it is to the cognitive concept of memory. Thus, my first span theory research (Bachelder, 1970/1971) evolved quite naturally from the intellectual foundation laid down by Ray.

Span theory, taking the lead from elicitation theory, "avoids positing hypothetical concepts or intervening variables and depends upon a continual, detailed analysis of stimulus and response for the explanation and prediction of behavior" (Denny, 1966, p. 2; Denny, 1971, p. 235). Elicitation theory asserts that learning is by contiguity of S and R, not by reinforcement as in the law of effect. In Ray's analyses, the principle of reinforcement is important, but it is subordinate to, and derives from the principle of contiguity because learning through reinforcement can always be seen to be learning through consistent contiguity of S and R.

¹This is a working draft of the Preface of a book to be entitled, *Span Theory*. Comments are invited: Please do not quote without permission. Bruce L. Bachelder, 306 West Union Street, Morganton, NC 28655-3729, Bruce@BruceBachelderPhD.com 828-430-0421. Copyright 2000, 2001 by Bruce L. Bachelder. [E:\NBDATA\SPANBOOK\PREF1000.NBW] (3/19/01 update;file name changed to PREF1000.NB on 2-7-08; file name changed to Bachelder_2000_Preface.nb, 11-12-08)
Minor edits in November 2008

Reinforcers mediate learning because they arrange for consistent elicitation of the response classes involved in learning. The implication for the development of span theory was that I “grew up” thinking less in terms of arranging consequences so as to shape operant behavior and more in terms of detailed analyses of configurations of relevant stimuli and the responses which occur in their presence. According to span theory, developmental and individual differences in the ability to cope with complex stimulus control (now called *span load*) are central to understanding intellectual development and intelligence.

A basic principle of elicitation theory is: *what is learned is what is consistently elicited*. This follows from the contiguity principle, that is, responses which are consistently elicited in a situation are what is learned in that situation. The elicitation span interpretation of span tasks suggests that a critical difference in people with retardation is their restricted ability to respond to numbers of stimuli. What can be elicited from them is constrained, so their learning ability is constrained. Everything else held equal, in a single trial one can elicit more from a higher-span individual than from a lower-span individual. In other words, the new notion of elicitation span combined with elicitation theory suggests an explanation of the learning and performance limitations of both young normally developing children and people with mental retardation. Higher-span individuals (older or more intelligent) learn faster because at any moment more can be elicited from them.

In his books with Stanley C. Ratner (Denny & Ratner, 1970; Ratner & Denny, 1964) Ray took principal responsibility for a chapter entitled “Learning with complex cues.” That chapter makes the point that type of cue has substantial impact on rate of acquisition: *learning varies inversely with cue subtlety or complexity*. Cue complexity interacts with both phylogenetic and ontogenic level in impact on acquisition. Organisms of lower phylogenetic or ontogenic levels cope adequately only with cues of lower complexity. Organisms at higher levels cope effectively with both lower and higher cue subtlety/complexity.

There is little doubt that having been steeped in these two points of view, the centrality of analysis of stimulus control and the role of stimulus complexity in phylogeny and ontogeny, fostered the development of the central concepts of span theory, *span ability* and *span load* (previously called *stimulus complexity*). According to span theory, tasks vary in span load, defined as the number of stimuli jointly relevant for the target response. Individuals vary in their ability to cope with span load and that ability is called span ability. Higher-span individuals perform well with both higher and lower loads, while lower-span individuals perform well only with lower loads. Individual differences in span ability interact with span load and practice to give rise to the complex behavioral repertoires we call intelligence.

Span ability is a *g*-like construct because the *empirical* characteristics of the *raw scores* of span tests closely parallel the characteristics we attribute to the constructs of intelligence and *g*. Measured span abilities increase during the developmental period, closely paralleling the development of mental age. At each age there is a range of individual differences in measured span ability. Span ability is a general ability, that is, stimuli and responses of a great variety can be used in testing, all producing similar scores. Measured span abilities are larger in non-retarded people than in those with mental retardation. Up to about age 8 measured span abilities covary closely with language level. Higher-performing regular secondary students have generally higher

measured span abilities than their lower-performing classmates. Measured span abilities correlate positively and surprisingly strongly with IQ. Measured span *ability* is highly resistant to improvement with practice or training. Of course, practice and training result in nice improvements in specific repertoires in almost all people, with or without retardation. See Bachelder & Denny (1977a, 1977b) and later chapters in this book for reviews of supporting data.

As a mentor, Ray has fostered the development of span theory in several general ways. With Ray there is always a sense that anything in psychology is a fascinating object of study and fair game for analysis in elicitation theory terms. His wide-ranging interests encouraged a broad outlook, exploration of diverse subdisciplines of psychology, and the search for theoretical integration. When cognitivism was on the ascendancy, Ray asserted the merits of behaviorism (see, for example, Denny, 1986). With Ray it was “ok” to be a theorist when theorizing was actively discouraged in much of behavioral psychology. Ray does not “put down” other approaches and psychological traditions in an attempt to promote his point of view. While putting down other approaches has its advantages as part of a strategy to promote one’s career (Amsel, 1989, p. 9), it can handicap a student who may ignore findings deriving from different traditions. Ray has encouraged my work, contributed to it, and coauthored papers with me (Bachelder & Denny, 1977a, 1977b). It was gratifying to learn that he had incorporated the span theory point of view at numerous points in his introductory psychology text book (Denny & Davis, 1982) and that in Denny (1980, Chapter 14) he had rewritten, from the point of view of span theory, his chapters on complex cues (Denny & Ratner, 1970; Ratner & Denny, 1964).

I am inclined to agree with Ray: Cognitivism, despite its obvious successes, could be a setback for the development of the science of psychology (Denny, 1986, p. 35; see also Kimble, 1994a, 1994b). Tolman’s notions of behaviorism (1967/1932, pp. 2-3) are central to the metatheory of span theory: “All that can ever actually be observed in fellow human beings and in lower animals is behavior” (p. 2); and “‘Mental processes’ are, for the behaviorist, naught but inferred determinants of behavior, which ultimately are deducible from behavior” (p. 3).

Some are put off by a behavioral approach, believing, perhaps, that cognitivism “won out” in a clash of paradigms. But behaviorism did not “lose” to cognitivism, it just descended to second place as cognitivism rose to first place (Amsel, 1989, 38-39). Amsel (Figs. 1, 2, pp. 38, 39) suggests the ascendancy of cognitivism is only the current state of a seemingly endless spiral of points of view, rotating among radical behaviorism, cognitivism, S-R neobehaviorism, and cognitive neobehaviorism. Recent papers by Gregory A. Kimble (1994a, 1994b) urging a return to behaviorism and the edited book by O’Donohue & Kitchener (1999) may indicate behaviorism is slowly spiraling again toward ascendancy.

One of the main virtues of cognitivism is its demonstrated ability to foster the investigation of the fascinating and important phenomena which in lay theory and cognitive theory are called “mental” or “higher cognitive functions.” Ray makes a similar point (Denny, 1986, p. 42) when he acknowledges the value of cognitivism’s focus on a wide range of important stimulus and response classes, previously ignored by behavioral approaches. The so-called cognitive phenomena are all but ruled out by a strict *radical* behaviorism which does not admit “private events” into an “objective behavioral analysis.” Neobehaviorism, through the

use of intervening variables, relaxes a bit the radical behavioral proscription of so-called “private” or “mental” phenomena.

Elicitation theory admits a vast array of “cognitive” and “mental” phenomena to a behavioral analysis by conceiving them as Rs in the sense of inferred response classes which “obviate the need for intervening variables and hypothetical concepts and simply dictate the use of a detailed analysis of objective data--the stimulus situation and response occurrences” (Denny, 1986, p. 36). Elicitation theory also undermines the notion that radical behaviorism is somehow more objective and scientific than neobehaviorism. Ray (1966, 1986) makes the subtle but important point that typical behavioral analyses confuse two quite different uses of the terms *stimulus* and *response*. Ray uses the terms *stimulus occurrence* and *response occurrence* to refer to Ss and Rs as data-level events. He uses the terms *stimulus class* and *response class* to refer to inferred theoretical constructs. It is this latter meaning of S and R which enter into lawful statements about behavior. Both thinking and operant bar pressing, for example, have the same logical status. Both are theoretical response classes inferred from specifiable stimulus and response occurrences. To illustrate, when we present a problem (stimulus occurrence) and observe the subject produce an answer (response occurrence) we infer thinking (response class). Similarly, when we observe a rat approach and press (response occurrences) a bar (stimulus occurrence) we infer an operant (response class). Ray’s conception of the stimulus and response as inferred theoretical constructs admits “higher cognitive functions” into behavioral analyses as objectively inferred response classes. No reference to intervening variables is needed because the function of such constructs is taken over by the abstract response class. This conception of response class meant for me that “intelligence” phenomena are amenable to a behavioral analysis of certain types of inferred response classes. Since cognitivism suggests that one cannot effectively study the so-called “higher mental functions” via a behavioral approach, Ray’s way of viewing things removed the roadblocks of both radical behaviorism and cognitivism.

Elicitation theory liberates both neobehaviorism and radical behaviorism by asserting the stimulus class and the response class as fundamental units of theoretical analysis. Span theory continues that liberating trend by taking the *task* to be the fundamental unit of analysis. Just as the S and R of elicitation theory are abstract theoretical concepts, so is the task in span theory. Behaviorists and cognitivists can readily agree at the level of the task, that is, at the level of our procedures and observations. We disagree at the level of theory, that is, in the way we talk about our procedures and observations. Span theory proscribes few or no phenomena and incorporates seemingly diverse phenomena comparatively easily. If an experimenter can devise a task to study a phenomenon, presumably that task can be analyzed in terms of span theory because span theory is a theory of tasks, not of hypothetical underlying processes.

While Ray’s work has largely been basic research and theory development, he has been well aware of the practical implications of his work. He has “tried to bridge the gap [between theory and practice] by writing and getting students involved” (Denny, 1977, p. iii). His 1991 edited book updates basic research and theory of aversive events and behavior. Ray points out that understanding aversive events and behavior is important because much of clinical psychology (anxiety, phobias, neuroses, aggression, and conflict) have their roots in these phenomena, and basic data and theory could help solve “many of the behavior problems that beset human beings” (Denny, 1991a, p. ix). His chapter within that book (Denny, 1991b)

presents elicitation theory and his concepts of relief and relaxation as explanations of key phenomena in aversive learning and conditioning. In Denny (1976) he brought the concepts and principles of elicitation theory to bear on understanding generalized anxiety disorder and he pointed out implications for behavior therapy. In his 1964 review chapter he summarized basic learning research with people with mental retardation and concluded, "it should be possible to develop appropriate motivational procedures and special training techniques to overcome an appreciable portion of the retardates' difficulties" (p. 136). In his 1966 chapter he presented elicitation theory in a formal way as a foundation for teaching concepts to students with severe mental retardation. He co-authored a booklet (Evans & Denny, 1974) with Sharon Evans (now Sharon Bradley-Johnson) which brings elicitation theory to bear on teaching reading to students with IQs of 50 and below. Mercer & Snell (1977) incorporate elicitation theory into their book on teaching students with mental retardation.

Undoubtedly, Ray's combined basic and applied interests nurtured my strong interests in both areas. One of my studies (Bachelder, 1978, Part 3) used span tests as an alternative to IQ tests to evaluate institutional adolescents with mental retardation. They were unable, through physical and verbal disability, to take standard IQ tests. We developed individualized span tests capitalizing on individual S-R repertoires (the ability to hear spoken words and point to corresponding pictures). The simple span tests quickly and effectively discriminated the students by span ability levels. We assessed construct validity by investigating the relation of span scores to measures of language. Measured span ability covaried closely with length of utterance in natural language samples of symbol-board language as well as formal assessment of language comprehension. The research effectively answered institutional questions bearing on class placement for the students of our study.

The original presumption underlying the development of span theory was and continues to be that this theoretical work will prove highly useful to parents, teachers, psychologists, and other specialists working with people with mental retardation. Happily, the theory also appears to apply nicely to intellectual maturation and individual differences among normally developing children and adults and promises to be useful with them.

The intellectual discipline required to observe both Tolman's notion of the nature of behaviorism and Ray's careful distinction between stimulus and response occurrences and stimulus and response classes ultimately gave rise to one of my working metatheoretical propositions: *All's fair in love, war, and scientific research*. The point of this proposition is there is no *a priori*, "proper" type of theory, either behavioral, cognitive, neurophysiological, or mathematical. All theories are *fair* in the game of science, but some theories are more effective than others at explaining data and stimulating basic and applied research. The tendency for behaviorism to *proscribe* cognitivism and for cognitivism to *proscribe* behaviorism directs the contest to the wrong issue. The all's-fair proposition aims to shift discussion from holy war rhetoric to a direct comparison of the efficacy of competing theories. Some theories work better than others, not necessarily because they are behavioral or cognitive, but because they clarify better, are more heuristic, resolve conflicts of interpretation, resolve anomalous findings, obviate pseudoproblems, integrate diverse subdisciplines, stimulate technological development, and solve practical problems.

Perhaps I am especially sensitive to this issue. It has long seemed to me that cognitivists dismiss span theory because it is behavioral and behaviorists dismiss it because it seems cognitive. I want to shift the discussion to a more useful question: Does the theory work well to explain and integrate data and generate useful basic research and practical applications? I believe span theory does those things well.

Bruce L. Bachelder
Morganton, NC
October 2000

References

- Amsel, A. (1989). *Behaviorism, neobehaviorism, and cognitivism in learning theory: Historical and contemporary perspectives*. Hillsdale, NJ: Erlbaum.
- Bachelder, B. L. (1970/1971). The memory span paradigm: Its use for the analysis of mental retardation. (Doctoral Dissertation, Michigan State University, 1970). *Dissertation Abstracts International*, 32(1), 576B-577B.
- Bachelder, B. L. (1978, March). Span Theory: Laboratory and classroom applications. Paper presented at the Eleventh Annual Gatlinburg Conference on Research in Mental Retardation, Gatlinburg, TN.
- Denny, M. R. (1964). Research in learning and performance. In H. Stevens & R. Heber (Eds.), *Mental retardation*. Chicago: University of Chicago Press.
- Denny, M. R. (1966). A theoretical analysis and its application to training the mentally retarded. In N. R. Ellis (Ed.), *International review of research in mental retardation*. New York: Academic Press.
- Denny, M. R. (1967). A learning model. In W. C. Corning & S. C. Ratner (Eds.), *The chemistry of learning*. New York: Plenum Press.
- Denny, M. R. (1971a). Relaxation theory and experiments. In F. R. Brush (Ed.), *Aversive conditioning and learning*. New York: Academic Press.
- Denny, M. R. (1971b). A theory of experimental extinction and its relation to a general theory. In H. H. Kendler & J. T. Spence (Eds.), *Essays in neobehaviorism: A memorial volume to Kenneth W. Spence*. New York: Academic Press.
- Denny, M. R. (1976). Post-aversive relief and relaxation and their implications for behavior therapy. *Journal of Behavior Therapy & Experimental Psychiatry*, 7, 315-321.
- Denny, M. R. (1977). Foreword. In *Learning theory research in mental retardation: Implications for teaching*. Columbus: Charles E. Merrill.
- Denny, M. R. (1986). "Retention" of S-R in the midst of the cognitive invasion. In D. F. Kendrick, M. E. Rilling & M. R. Denny (Eds.), *Theories of animal memory*. Hillsdale, NJ: Erlbaum.
- Denny, M. R. (1991). Relaxation/relief: The effect of removing, postponing, or terminating aversive stimuli. In M. R. Denny (Ed.), *Fear, avoidance and phobias: A fundamental analysis*. Hillsdale, NJ: Erlbaum.
- Denny, M. R. (Ed.). (1991). *Fear, avoidance and phobias: A fundamental analysis*. Hillsdale, NJ: Erlbaum.

- Denny, M. R., & Adelman, H. M. (1955). Elicitation theory: I. An analysis of two typical learning situations. *Psychological Review*, *62*, 290-296.
- Denny, M. R., & Ratner, S. C. (1970). *Comparative psychology*. Homewood, IL: Dorsey Press.
- Estes, W. K. (1970). *Learning theory and mental development*. New York: Academic Press.
- Evans, S., & Denny, M. R. (1974). *Reading achievement program*. Danville, IL: The interstate printers & publishers, Inc.
- Kimble, G. A. (1994a). A frame of reference for psychology. *American Psychologist*, *49*(6), 510-519.
- Kimble, G. A. (1994b). A new formula for behaviorism. *Psychological Review*, *101*(2), 254-258.
- Maatsch, J. L. (1954). Reinforcement and extinction phenomena. *Psychological Review*, *61*, 111-118.
- Marx, M. H., & Cronan-Hillix, W. A. (1987). *Systems and theories in psychology* (4th ed.). New York: McGraw-Hill.
- Mercer, C. D., & Snell, M. E. (1977). *Learning theory research in mental retardation: Implications for teaching*. Columbus: Charles E. Merrill.
- O'Donohue, W., & Kitchener, R. (Eds.). (1999). *Handbook of behaviorism*. San Diego: Academic Press.
- Ratner, S. C., & Denny, M. R. (1964). *Comparative psychology*. Homewood, IL: Dorsey Press.
- Tolman, E. C. (1967/1932). *Purposive behavior in animals and men*. New York: Irvington.