Span Theory: An overview

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Span theory (Bachelder, 1970/1971; 1974; 1977a, b, c; 1978; 1980; 1981; 1999; 2001a,b; 2003; 2005a,b; 2007; Bachelder & Denny, 1976; 1977a, b; Denny, 1980, Chap. 14) is a theory of intelligence which got its start in the late '60s in a program (Denny, 1966) which aimed to bring the findings of basic and applied mental retardation research to bear on the challenge of teaching concepts to adolescents with moderate to severe mental retardation.

The theory blends critical features of behaviorism, cognitivism, and psychometrics in an account of developmental and individual differences in diverse tasks. It rigorously avoids mentalism. Each of us has a *span ability* defined in terms of the behavioral concept of stimulus control and measured by the *standard staircase span test.* *Task analysis of span load* (*TASL*) is a type of task analysis which links span ability with the ability to perform in specific tasks. Span theory focuses on traditional tasks of cognitivism including the three span limits and individual and developmental differences in diverse "cognitive" tasks and "mental" abilities and "intelligence."

The original goal of span theory, to understand individual differences in intelligence and learning in a way which will lead to more effective teaching and training, is still a central concern. Eventually, however, it became clear that (a) the theory could be a full theory of intelligence, apply to delayed, normal, average, and bright individuals; and (b) span theory is a Kuhnian (Kuhn, 1970) *paradigmatic* alternative to both cognitivism and behaviorism as an approach to scientific psychology.

Span theory is grossly similar to two theories from the cognitive and cognitive science traditions. These are, respectively, Pascual-Leone's neo-Piagetian *M-space theory* (e.g. Case, 1972; 1974; Pascual-Leone, 1970; 1987) and *working memory capacity theory* (e.g. Case, 1978; Engle & Kane, 2004). Span theory developed independantly of either of these theories and work from these alternative points of view has made little reference to span theory. All three approaches aim to account for developmental and individual differences in diverse tasks via a capacity notion which has to do with coping with task demands. All three use variations on task analysis to assess task demand for capacity. All emphasize the link between their capacity notions and "cognition" and "intelligence."

Span theory has had far ranging utility. It proposes an unitary answer to the *spans question* (Bachelder, 2005a), which asks, "What is the nature of the curious span limits in human performance?" It accounts for diverse data of children and adults, both normally developing and developmentally delayed (e.g. Bachelder, 1970/1971; 1974; 1977a, b; 1978; 1979; 1980; Bachelder & Denny, 1977a, b). It offers an account of "intelligence,"

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combining the behavioral repertoire notion with an empirically derived ability construct defined in terms of the behavioral concept of stimulus control. It provides the scientific base for the development and application of new psychometric assessment and prescription techniques (Bachelder, 1978, Pt. 3; 2003) which are useful with people who can't take standard IQ tests or who have moderate to severe mental retardation. It bridges and integrates cognitivism and behaviorism.

This diverse applicability stems in large part from a departure from both cognitivism and behaviorism; span theory uses a different unit of theoretical analysis. Cognitivism uses the structure and processes of the mind; behaviorism uses the *response*, the *S-R bond*, or the *operant*; ***span theory uses the task.*** The generic nature of the *task* means the theory lends itself readily to analysis of the tasks of both behaviorism and cognitivism but without mentalism. Since IQ scores are derived from performances on subtests and since subtests are complex *tasks*, the theory is also a theory of IQ scores and, therefore, of intelligence.

Span theory can be distilled to a single statement:

$$\mathbf{P_{task} = f(span\ ability,\ 1/span\ load,\ acquired\ repertoire,\ other\ variables).}$$

As is typical of well developed scientific theories, a statement like this is incomprehensible without a good bit of background in the meanings of terms and experience applying it in diverse situations (Kuhn, 1970, pp. 46-47).

P_{task} refers to performance in a specified task or task family, assessed as the probability of a correct response and ranging from 0.0 to 1.0. *Span load* is a characteristic of a task or task family. It is a count of the number of stimuli conjunctively relevant for a target response. Loosely, in mentalistic terms, it is the number of stimuli which must be kept in mind as a basis for correct responding. *Span ability* is a developmental and individual differences variable, defined as the ability to cope with *span load* and measured with a psychometric span test.

Tasks. Both cognitivism and behaviorism view tasks as *tools* to explore theoretically important *hypothetical processes*. For example, cognitivism has tasks to measure memory and attention; behaviorism has tasks to measure learning, conditioning, and stimulus discrimination. In span theory the task is not a tool to measure hypothetical processes, it is a ***molar unit of behavior,*** the ***central unit of theoretical analysis,*** the ***object of a behavioral taxonomy.***

A *task* has seven defining characteristics: (a) the stimulus pool, (b) the response pool, (c) the relevant stimulus set, (d) the procedure, (e) the S-R rule, (f) the counting rule, and (g) the task equation. This is not so esoteric as it first appears. All characteristics except the counting rule and the task equation are standard parts of the methods sections of both cognitivism and behaviorism. The concept of the task is critical in both traditions, but it is not usually thought of that way.

Stimulus pool, *response pool*, *relevant stimulus set*, and *procedure* need little explanation. The *S-R rule* is an explicit statement of the relation between stimuli and responses and is often implicit in methods sections. In many experiments the *S-R rule* is the basis for scoring a response right or wrong. In other experiments, such as those in operant conditioning chambers, it is the rule specifying the occurrence of a target response and is built into the equipment. In a bar-pressing situation the bar provides much of the stimulus function as participants orient to, approach, and press the bar. Subjects can't behave coherently without stimuli to specify correct responses. The S-R rule is essentially a statement of *stimulus relevance*. For the subject stimuli are *necessary* as a basis for correct or coherent responding; for the observer they are necessary for prediction responses.

The *counting rule* is the method of counting *conjunctively relevant stimuli* to assess *span load. Span load* is the number of stimuli *conjunctively relevant* for a target response. Stimulus relevance refers to situations in which a particular stimulus is necessary or sufficient for the prediction of a target response. *Conjunct or joint relevance* refers to situations in which two or more stimuli are conjunctively or jointly relevant. That is, situations in which two or more stimuli are singly *necessary* and collectively *sufficient* to specify a correct target response. Conjunct relevance translates roughly to the cognitive notion of the number of stimuli which must be kept in mind as a basis for correct responding. Conjunct relevance stands in contrast to *redundancy* in which any *single* stimulus of a group is *sufficiently* relevant for the target response. In cognitive terms, redundancy refers to situations in which attention to any *single* stimulus of two or more stimuli enables reliable correct responding.

The *task equation* is a mathematical expression of the form, *Performance=f(span load, span ability).*

The goals of span theory research include:

(1) Exploration of the role of individual and developmental differences in psychometric span ability in the performance of diverse tasks

(2) Development of methods of task analysis (collectively, *Task Analysis of Span L*oad or *TASL*) which will lead to testable hypotheses concerning the relation between performance and span load and span ability.

(3) Development and validation of applications of span theory, and

(4) Development of a *taxonomy* of tasks.

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