Reprinted from AMERICAN PSYCHOLOGIST, Vol. 40, No. 2, February 1985
Printed in U. S. A.

The Evolution of Mental Metaphors in Psychology: A 90-Year Retrospective

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ABSTRACT: It seems plausible that the conception of the mind has evolved over the first hundred years of psychology in America. In this research, we studied this evolution by tracing changes in the kinds of metaphors used by psychologists to describe mental phenomena. A corpus of metaphors from 1894 to the present was collected and examined. The corpus consisted of all metaphors for mental phenomena used in the first issue of Psychological Review *in each decade, beginning with the inception of the journal in 1894 and continuing with 1905, 1915, and so on through 1975. These nine issues yielded 265 mental metaphors, which were categorized according to the type of analogical domain from which the comparison was drawn.*

The chief finding was that the nature of the mental metaphors changed over time. Spatial metaphors and animate-being metaphors predominated in the early stages, then declined in favor of systems metaphors, often taken from mathematics and the physical sciences. A secondary finding was that the numbers of mental metaphors varied. Metaphors for mental phenomena were more prevalent in the early and late stages of the corpus than in the middle stages (1935 to 1955). These patterns are interpreted in terms of conceptual evolution in psychologists' models of the mind.

In this article we examine historical changes in the metaphors used by American psychologists to describe mental processes. Our aim is to use changes in metaphoric language to trace changes in the models of the mind that psychologists have held.

It is by now accepted that researchers bring to their field of study a theoretical framework—which may be more or less explicitly conscious—in terms of which they construe the phenomena they observe (Koestler, 1964). Moreover, these frameworks change over history, sometimes quite rapidly (Kuhn, 1962). Cognitive psychology during the past hundred years seems a prime example of a field in which conceptual change has been rapid and extensive. The turn-of-the-century dialectic between structuralism and functionalism was followed by the schools of Gestalt psychology, behaviorism, and still later by information processing. Some of these changes are recorded in major position papers or books, such as Titchener's (1915) primer. Yet such position statements are not always available, and when we do find them they may constitute later codifications of principles rather than reflections of the actual development of the ideas. It would be useful to have a more immediate method for tracing changes in the zeitgeist. The kinds of metaphoric language used in articles through this period of history in psychology may provide just such a measure.

To infer underlying models from the metaphors used in writing about psychology requires making the assumption that metaphorical language reflects underlying metaphoric thought, that is, that it reflects a genuine mapping of significant relationships from the analogical domain to the target domain (the domain to be explained; e.g., Lakoff & Johnson, 1980; Reddy, 1979). Certainly some caution is warranted here. The mere existence of metaphorical language cannot be taken to indicate an underlying conceptual model corresponding to the metaphor. Nevertheless, studies of the history of science have produced persuasive evidence that scientists use metaphor in the invention and organization of ideas (e.g., Darden, 1980; Hesse, 1966; Hoffman, 1980; Hofstaedter, 1981; Koestler, 1964). More importantly, the firsthand introspective reports of working scientists also stress the importance of metaphor in their creative thinking (e.g., Glashow, 1980; Kepler, 1620/1969; Oppenheimer, 1956). Further, there are experimental demonstrations that the inferences people draw in problem-solving tasks are affected by the analogies they bring to the domain (Gentner & Gentner, 1983; Gick & Holyoak, 1980).

More specifically, it has been argued persuasively that metaphors from other domains have played a role in the shaping of psychological theory. Roediger (1979, 1980) noted several distinct metaphors for human memory, such as Freud's (1952) house model

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and Atkinson and Shiffrin's (1968) storage box model. He argued that commonalities among these metaphoric models can reveal deep-seated intuitions of the research community. Hearst (1979) suggested that the structuralist effort to isolate and characterize the "basic elements of the mind" was put together by Titchener using the analogy of chemistry. As a related point, Zwicky (1973) traced the widespread use of a similar molecular combination metaphor in linguistics.

If indeed the metaphors used in psychology reflect the way that researchers have conceived of the domain, then changes in the kinds of metaphors used to describe the mind may provide an unobtrusive measure of changes in the conceptual paradigms used in American psychology. With this in mind, we undertook to collect a representative sample of metaphors of the mind. We chose as our source the journal *Psychological Review*, because it has a history of broad representation of major work in psychology that dates back to 1894. Thus, our project was designed (a) to sample *Psychological Review* systematically from 1894 to the present for mental metaphors, (b) to classify the resulting metaphors according to their base domain (their analogical domain or domain of origin), and (c) to note any changes in the numbers or types of metaphors used across time.

Methods Used

Corpus

For each decade since the inception of the journal, we examined all articles in the first issue of one volume. The years selected were 1894 (Vol. 1), 1905 (Vol. 12), 1915 (Vol. 22), 1925 (Vol. 32), 1935 (Vol. 42), 1945 (Vol. 52), 1955 (Vol. 62), 1965 (Vol. 72), and 1975 (Vol. 82). Although each article was examined, not all of them yielded metaphors for the mind. Out of a total of 68 articles, 48 contained metaphors of relevance to this study. The articles containing mental metaphors were numbered and appear in Table 1, along with the number of mental metaphors found in each.

Method of Selection

All mental metaphors were recorded on their first occurrence in a given article. A *mental metaphor* was defined as a nonliteral comparison in which either the mind as a whole or some particular aspect of the mind (ideas, processes, etc.) is likened to or explained in terms of a nonliteral domain.[1] Preferring to err on the side of inclusiveness, we included in the initial collection everything that seemed a possible metaphor, including many frozen or conventionalized metaphors, such as "mental health" or "intellectual level." Only one instance of each metaphoric term or phrase was collected from a given article. Thus the count of metaphors represents the number of types, not the number of tokens in each article. This was done to avoid extraneous effects of article length. However, when more than one term or phrase occurred in connection with a particular extended metaphor, all of the terms were collected. An example of such a system occurs in James (1905): The phrases "an idea encountering a resisting idea," "an idea moving under its own momentum," and "ideas overcoming an obstacle" (pp. 6, 7) were each recorded, although they are clearly part of the same extended metaphor.

Method of Categorization

After the set of metaphors was assembled, we sorted them into groups of three or more that seemed drawn from a common domain. Most of these groupings cut across decades, because the sorting was guided by the content of the metaphors themselves rather than by decade of origin. The next phase was to combine these small groups into meaningful larger categories. We arrived at four major content categories, further described in the Results section. The final product of the selection and categorization is a list of metaphors used in each decade, categorized according to the analogical domain from which each metaphor is drawn.

Where more than one category or subcategory might apply, we used the central features of the metaphór to select among alternatives. If two categories seemed equally applicable, we assigned the metaphor to the most specific of them. This issue arises particularly with the spatial category (see below), because many metaphors assigned to other categories involve spatial information (Roediger, 1979, 1980). Thus, metaphors like "a find-and-compare operation" or "control structures" (Carpenter & Just, 1975) were categorized as computer systems metaphors rather than as spatial metaphors,

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The study on which this article is based was done for a seminar headed by George Mandler at the University of California at San Diego. Support was provided in part by the National Institute of Education under Contract Nos. HEW-NIE-C-400-80-0031 and HEW-NIE-C-400-81-0030.

We thank George Mandler, Don Norman, and Ed Smith for their comments on the study and Henry Roediger III for his detailed and insightful comments on an earlier draft. We also thank Natalie Dondekar, Margaret McClennan, Ben Teitelbaum, and Yvette Tenney for their help with the research and Cindy Hunt for preparing the manuscript.

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[1] We did not include metaphors in general, only mental metaphors. For example, a metaphor in which an experimental apparatus was compared to a factory assembly belt would not have been included.

Table 1
Psychological Review *Articles Containing Metaphors*

Article	No. of metaphors
Volume 1 (1894)	
Ladd, G. T. President's address before the American Psychological Associates	1
Dewey, J. The psychology of infant language	1
Strong, C. A. Mr. James Ward on modern psychology	5
Starr, M. A. Psychological literature: Aphasia	9
James, W. Psychological literature: Hysteria paramnesia	3
Bryan, W. L. Psychological literature: Experimental	1
Warren, H. C. Psychological literature: Experimental	2
Fullerton, G. S. Psychological literature: Epistemological	1
Dewey, J. Psychological literature: Ethical	2
Volume 12 (1905)	
James, W. President's address: The experience of activity	29
Haines, T. H., & Williams, J. C. The relation of perceptive and revived mental material as shown by the subjective control of visual after-images (with two color charts)	18
Brand, J. F. The effect of verbal suggestion upon the estimation of linear magnitudes	1
Manchester, J. S. Experiments on the unreflective ideas of men and women	1
Volume 22 (1915)	
Woodworth, R. S. The revision of imageless thought	15
Brown, W. Practice in associating number names with number symbols	1
Brown, W. Practice in associating color names with colors	1
Brown, W. Incidental memory in a group of persons	2
Volume 32 (1925)	
Myers, C. S. Conceptions of fatigue and adaptation	1
Peterson, J. A. A functional view of consonance	1
Dashiell, J. F. A physiological-behavioristic description of thinking	3
Melrose, J. A. A method for organic problems	1
Weiss, A. P. One set of postulates for a behaviorist psychology	3
Volume 42 (1935)	
Peterson, J. Aspects of learning	12
Buel, J., & Ballachey, E. L. Limiting factors in the effect of reward in the distribution of errors in mazes	2
Tolman, E. C., & Brunswick, E. The organization and causal texture of the environment	7
Hunt, W. A., & Landis, C. The present status of abnormal psychology	1
Gray, J. S. An objective theory of emotion	9
Dennis, W. Goal gradient or entrance gradient?	5
Volume 52 (1945)	
Heidbreder, E. Toward a dynamic psychology of cognition	4
Howells, T. H. The obsolete dogmas of heredity	7
Arnold, M. B. Physiological differentiation of emotional states	4
Lerner, E. A reply to Wyatt and Teuber	3
Volume 62 (1955)	
Brunner, J. S., Mater, J., & Papanek, M. L. Breadth of learning as a function of drive level and mechanization	3
Restle, F. A. A theory of discrimination learning	1
Goss, A. E. A stimulus-response analysis of cue producing and instrumental responses	1
Gibson, J. J., & Gibson, E. J. Perceptual learning: Differentiation or enrichment	9
Osgood, C. E., & Tannenbaum, P. H. The principle of congruity in prediction of attitude change	6
Simon, H. A., & Guetzkow, H. A model of short and long run mechanisms involved in pressures toward uniformity in groups	4
Wishner, J. The concept of efficiency in psychological health and psychopathology	5

(*table continued*)

Table 1 (continued)

Article	No. of metaphors
Volume 72 (1965)	
Zwicker, E., & Scharf, B. A model of loudness summation	8
Moltz, H. Contemporary instinct theory and the fixed action pattern	6
Peterson, D. R. Scope and generality of personality factors	2
Bahrick, H. P. The ebb of retention	4
Minard, J. G. Response-bias interpretation of "perceptual defense": A review and evaluation of recent research	7
Volume 82 (1975)	
Klinger, E. Consequences of commitment to and disengagement from incentives.	14
Stokols, D. Toward a psychological theory of alienation	2
Zajonc, R. B., & Markus, G. B. Birth order and intellectual development	7
Carpenter, P. A., & Just, M. A. Sentence comprehension: A psycholinguistic processing model of verification	30

despite the fact that the components of a computer are generally distributed in space. In general, if the focus of a metaphor was on a lawfully constrained interaction of a set of elements, the metaphor was classified as a systems metaphor. If the focus was on particular spatial interactions of objects or simply on their distribution in space, the metaphor was classified as a spatial metaphor.

Results

Categories of Metaphors

We found a total of 265 metaphors for mental phenomena. The initial sorting into groups yielded 20 groups of 3 or more metaphors, which combined into four major categories of metaphor: *animate-being* metaphors (23 instances), *neural* metaphors (16 instances), *spatial* metaphors (61 instances), and *systems* metaphors (80 instances). In animate-being metaphors, ideas or aspects of the mind are likened to creatures. These are sometimes reminiscent of homunculi, as in "my ideas may have no prevision of the whole of [my plan]" (James, 1905, p. 11); but in other cases they are clearly nonhuman creatures, as in "through lying, the mind grows wary or strong from swimming against the stream" (Dewey, 1894, p. 109). In neural metaphors, the analogical domain is some version of the physical nervous system, as when a disturbance of thought is likened to "shortcircuiting too large an amount of excitation" (Arnold, 1945, p. 47), or more elaborately, when it is stated that word meanings are stored as

> mental images acquired through different senses, located in different regions of the gray cortex of the brain, and joined together in a unit by a series of association-tracts which pass in the white matter under the cortex. (Starr, 1894, p. 89)

Spatial metaphors have as their analogical domain the distribution or movement of objects in space, as in thoughts "on or below the sensory surface" (Woodworth, 1915, p. 15) or "things active against a background of consciousness" (Strong, 1894, p. 79). Systems metaphors are those that liken some mental phenomenon to a system of lawfully constrained interactions among elements. Often they draw on a physical or mathematical system[2] or on an artificial device as their analogical domain: for example, "fusion of ideas" (Peterson, 1935), "the variance of the distribution of associative strength" (Bahrick, 1965, p. 61), or critical band behaving "like a variable band-pass filter" (Zwicker & Scharf, 1965, p. 24). Instances from each of these categories are given in Table 2 for early, middle, and recent periods.

In addition to the four major categories described, there were two other categories. The first was a *conventional* category for terms that seem to have some metaphoric basis but whose metaphoric associations may have been lost. Examples of items in this category are "mental health," "intellectual growth," and "mental state." Of the 265 total metaphors, 71 were classified as conventional metaphors.

[2] Although some would argue that the use of mathematical systems is not actually metaphoric, we have included such usage as one subcategory of systems metaphors. This is chiefly because, as the use of the term *mathematical model* itself suggests, equations and variables have the essential characteristics of analogical representations; that is, they convey that the relational structure of the target domain is much like that of an analogical domain (in this case, a mathematical system), which is otherwise quite different from the target domain. Furthermore, as is described below, the pattern of distribution of mathematical models is similar to that of other systems metaphors. In any case, the exclusion of this subcategory would not change the overall pattern of distribution among the four major categories.

Table 2
Examples of the Four Major Categories of Metaphors by Tridecade

Early (1894–1915)	Middle (1925–1945)	Recent (1955–1975)
	Animate-being	
Through lying, mind grows wary or strong from swimming against stream (Dewey, 1894)	Reaction arcs block each other, varying in tension, until one waxes strong enough (Dashiell, 1925)	Super discriminating preperceiver who selectively prevents recognition (Minard, 1965)
Ideas struggle with one another (James, 1905)		Ego defenses (Minard, 1965)
	Neural	
Associations among images, like white matter connecting regions of gray matter (Starr, 1894)	Thinking is neural impulses shifting along associative fibers from one area to another (Dashiell, 1925)	Inhibitory processes (Zwicker & Scharf, 1965)
Wider ideas shortcircuit smaller ideas (James, 1905)	Anger shortcircuits excitation into the parasympathetic system (Arnold, 1945)	Loudness perhaps proportionate to number of mental impulses (Zwicker & Scharf, 1965)
	Spatial	
Anything hiding in the background is not mental activity (James, 1905)	Habitual connections between ideas (Peterson, 1935)	Critical band is formed (Zwicker & Scharf, 1965)
Tracing is to a photograph as memory is to immediate attention (Woodworth, 1915)	Fear inundates the sympathetic nervous system (Arnold, 1945)	Reservoir model for fixed action pattern (Moltz, 1965)
	Systems	
A body moves in empty space by its own momentum as when our thoughts wander at their own sweet will (James, 1905)	Nervous system is like a switchboard mechanism (Gray, 1935)	$\theta = r/r + i$, where r = no. of relevant elements, i = no. of irrelevant elements, and θ = conditioning constant (Restle, 1955)
Associative force (Woodworth, 1915)	Goal gradient: positive/negative transfer (Dennis, 1935)	Serial iterative operations (Carpenter & Just, 1975)

The remaining category was that of *idiosyncratic* metaphors. This category was included to allow for metaphors that resisted categorization; 14 metaphors were placed in this group. An example of an idiosyncratic metaphor is the comparison of cognition to respiration, in that each has a typical, dominant form plus variations (Heidbreder, 1945; it should be noted that Heidbreder commented on the limits of the analogy).

Patterns of Distribution

The patterns of metaphor use change across time in two distinct ways. The most important finding is that there was a change in the kinds of mental metaphors used from the beginning of the survey to the end. This shift is discussed in detail below. A second chronological pattern is that the overall number of metaphors used shows a U-shaped distribution, with a decline in the middle tridecade relative to the first and last tridecades of the survey. The mean numbers of mental metaphors used per issue are 31.0 in the first tridecade (1894 to 1915), 21.0 in the middle tridecade (1925 to 1945), and 36.3 in the last tridecade (1955 to 1975). This variation in overall number of metaphors is significant by a chi-square test, $\chi^2(2, N = 265) = 12.35, p < .01$.

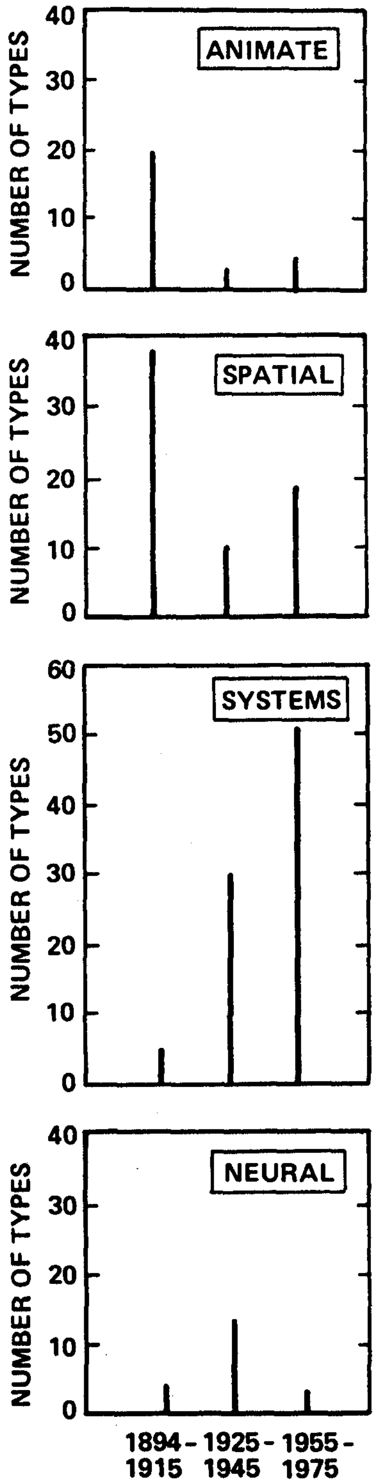
Analyses

As noted above, the major finding is a shift in the categories of metaphoric domains used over time. To verify this shift, we examined the data in three different ways.

In the first analysis, we compared the number of metaphors used in each of the four major categories in each of the three tridecade blocks, as shown in Figure 1.

In the early samples, spatial metaphors and animate-being metaphors dominate. There is a sharp

Figure 1
Numbers of Metaphors in Each Tridecade for each of the Four Major Categories



drop across time in the number of animate-being metaphors, along with a less severe reduction in the use of spatial metaphors. Systems metaphors show the opposite trend: Starting as an unimportant category, with five members in the first tridecade, systems metaphors gradually come to predominate. They are largely responsible for the overall rise in metaphor use in the last tridecade. A 3 (tridecades) × 4 (categories) chi-square test verified that there are significant variations in the frequency of use of the four major categories across the three tridecades, $\chi^2(6, N = 180) = 77.47, p < .0001$.

To examine the shift more specifically, separate chi-square comparisons were performed for the six metaphor categories. For animate-being, spatial, and systems metaphors, the three tridecades differ significantly, $\chi^2(2, N = 23) = 21.48, p < .001$; $\chi^2(2, N = 61) = 20.69, p < .001$; and $\chi^2(2, N = 80) = 52.08, p < .001$, respectively. Idiosyncratic metaphors, which are prevalent only in the early decades, also show a significant drop, $\chi^2(2, N = 14) = 8.71, p < .05$. Neural metaphors and conventional metaphors remain constant in number. Unlike the other three major categories, neural metaphors show no decrease in the intermediate tridecade (1925–1945) and no shift in frequency of use across time, $\chi^2(2, N = 16) = 3.88$, *ns.* The possibly metaphoric conventional expressions show a similar pattern, remaining at a constant level throughout, $\chi^2(2, N = 71) = .37$, *ns.* Thus, the individual analyses confirm a significant decrease in the numbers of animate-being, spatial, and idiosyncratic metaphors and a significant increase in the number of systems metaphors, with no change in neural metaphors or conventional metaphors.

A second way of looking at the pattern is to categorize each article according to its predominant type of metaphor. Thus, an article with five animate metaphors and two spatial metaphors would be categorized as animate. Table 3 shows the numbers of articles per tridecade in each of the four major categories. The patterns are virtually identical to those shown in Figure 1, indicating that the results are not dependent on a particular method of analysis. The chi-square analysis for the 3 × 4 matrix of the major categories across tridecades was strongly significant, $\chi^2(6, N = 35) = 30.64, p < .0001$. When we extend the analysis to include the general and idiosyncratic metaphors, the results are the same, $\chi^2(10, N = 48) = 36.23, p < .0001$.

A third way to trace the shift in preferred analogical domains is to record the most frequently used categories in each decade. Table 4 shows the two categories containing the greatest numbers of metaphors in each decade. It can be seen that the shift from the early dominance of animate-being and spatial metaphors to the eventual dominance of

Table 3
Number of Articles per Tridecade with a Majority of Their Mental Metaphors in Each Category

	Category			
Tridecade	Animate-being	Spatial	Systems	Neural
1894–1915	4	7	0	0
1925–1945	0	0	5	3
1955–1975	0	3	12	1

systems metaphors and spatial metaphors is a steady progression. Only during the middle tridecade, when metaphor use in general was at its lowest, did neural metaphors achieve relative prominence.

Subcategories

Two of these categories, spatial metaphors and systems metaphors, have subcategories whose membership is large enough to warrant discussion. The subcategories of spatial metaphors are *container* metaphors, *image* metaphors, and a *general spatial* category. The subcategories of systems metaphors are *mechanical systems, physical science systems, mathematical systems, symbol systems, computer systems,* and *general systems* metaphors.

Among the subcategories of spatial metaphors, the one clear change occurs for image metaphors, which are prominent in the early decades (1894–1915) and become relatively infrequent afterward. Within systems metaphors, the earliest prominent subcategory is mechanical systems. Beginning in 1935, a number of other subcategories came into use, notably mathematical, physical science, and symbol systems. In 1975, computer systems metaphors appear in large numbers. The distribution of metaphors across subcategories over the three tridecade periods is shown in Table 5.

Discussion

Reprise of Phenomena

Two central patterns emerge from the examination of these mental metaphors. The major finding is the long-term shift in the content domains from which the metaphors were drawn. The domains that dominate in the first tridecade are supplanted by new categories by the end of the century. A second finding is the U-shaped pattern in the overall numbers of metaphors used in different periods. Metaphors for the mind are abundant at the outset of our sample (1894–1915), drop sharply from approximately 1925 to 1945, and rise to even greater numbers during the most recent tridecade (1955–1975). We will discuss the second pattern first, because its explication seems fairly straightforward.

Table 4
Numbers and Proportions of Metaphors in the Two Major Categories for Each Decade

Decade	Chief category	Number	Proportion	Second category	Number	Proportion
1894	Spatial	10	.40	Animate	3	.12
1905	Spatial	18	.37	Animate	15	.31
1915	Spatial	7	.37	Systems	1	.05
1925	Neural	2	.22	An/Sys[a]	1	.11
1935	Systems	18	.50	Spatial	5	.14
1945	Systems	3	.17	Spatial	1	.06
1955	Systems	17	.59	Spatial	9	.31
1965	Systems	7	.26	Spatial	5	.19
1975	Systems	32	.60	Spatial	6	.11

Note. Proportions were obtained relative to the total number of metaphors.
[a] In 1925, animate-being and systems metaphors each had one member.

Table 5
Numbers of Spatial and Systems Metaphors Within Each Subcategory and Tridecade

	Spatial			Systems					
Tridecade	General	Container	Image	General	Symbol	Computer	Mechanics	Physics	Math
1894–1915	17	6	12	0	0	0	5	0	0
1925–1945	5	1	0	2	3	0	5	2	7
1955–1975	13	5	2	4	13	10	15	3	11

Variation in Overall Numbers

The decline in the use of mental metaphors during the middle third of our survey (1925–1945) probably reflects the influence of behaviorism. Articles from this period tend to be straightforward reports of data, devoid of any discussion of the internal workings of the mind. Mental metaphors, like other mentalistic language, are rare.[3] Those metaphors that did occur during the middle decades often reflect mathematical models of the behavioral phenomena: for example, "goal gradient" (Dennis, 1935). The other class of metaphoric domain that is represented is neural metaphors: for example, "neural flux" (Gray, 1935). We will return below to the issue of why neural metaphors withstood the general moratorium on mental metaphors.

Shift in the Content of Metaphors

The major pattern that emerges from the collection is the shift in the kinds of domains from which metaphors were drawn. Animate-being metaphors were used frequently in the early period, around the turn of the century, yet this category virtually disappeared by the middle tridecade. Spatial metaphors show a similar though less severe overall drop. They declined from their position as most dominant category at the turn of the century through a sharp depression in the middle tridecade, and although their numbers increased in the recent tridecade, they failed to reach their initial levels. However, it should be noted that many systems metaphors have a spatial substrate. As Roediger (1979, 1980) pointed out, a large proportion of mental metaphors draw on spatial knowledge. Indeed, spatially organized domains are a particularly favored source of metaphoric models in general (Lakoff & Johnson, 1980; Reddy, 1979). This is perhaps because perceptual space is among our most familiar and best understood areas of well-structured knowledge. Thus, the decline in the spatial category does not necessarily indicate a decline in the importance of spatial information but rather an increased reliance on analogies based on systems properties that go beyond the purely spatial. For example, the spatial notion of moving ideas into consciousness may be further specified in a computer systems metaphor as fetching and loading programs into working memory.

As spatial metaphors declined, systems metaphors increased from an extremely minor early role to become the dominant form. Further, within systems metaphors, there was a marked proliferation in the kinds of systems that appeared. The early mechanical systems metaphors were joined by metaphors drawn from mathematics, various branches of physics, and finally computer sciences.

This shift in the kinds of metaphors seems a particularly inviting place to look for clues to the development of the psychology of thought. However, before drawing conclusions about conceptual evolution in psychology, we must consider a less interesting possibility. It could be that the changes in metaphor usage are attributable simply to a general tendency to use new technology as a source for metaphor. If this were true, then (a) psychological metaphors should reflect *any* major new technology and/or (b) the metaphors found in psychological writing will occur equally in other fields—economics, biology, and so on. We will consider these in turn.

Jaynes (1976) noted that the most complex objects in our environment are often used as metaphors for the mind. Certainly we found evidence for the impact of technology in the metaphors used by psychologists. The concentration of spatial image metaphors in the early decades of the study (1894–1915) may be linked to the development of photography in the second half of the nineteenth century. The metaphors in this category include an explicit photography metaphor (Woodworth, 1915; see Table 2) as well as a number of references to such terms as "memory image" (Bryan, 1894) and "mental picture before the mind's eye" (Haines & Williams, 1905). Later, a parallel is drawn between the nervous system and a "switchboard mechanism" (Gray, 1935; see Table 2), and still later an analogy is made between mental processing and a computer flowchart (Carpenter & Just, 1975).

Some of these examples suggest a tendency to use newly available technology as a basis for constructing analogies. Yet the influence of new technology does not adequately explain the changes in analogical domains. For example, it is not until 1935 that we find the influence of mathematics and physics, with terms like "learning coefficients" (Peterson, 1935) and "neural flux" (Gray, 1935). Yet mathematics and the physical sciences were formal systems well before psychologists made use of them in this way. Thus, newness of technology is not *necessary* for the use of a system in mental metaphors. Further, other new technologies besides computer technology have grown up in the last hundred years, such as aviation, nuclear power, and television. Yet we find few metaphors from these domains, indicating that newness of technology is also not *sufficient* to guarantee use of a system in mental metaphors. There is selectivity in the choice of mental metaphors.

Nor does it seem plausible that the shift in metaphors used in psychology simply reflects a general shift toward new technology metaphors across all abstract domains. In politics and economics, for

[3] This is not to say that those articles contained no metaphoric language, merely that they contained few metaphors for the mind.

example, contemporary writing makes heavy use of metaphors drawn from sports, hydraulics, and other domains but rarely from computer systems. Thus, the shift in preferred domain in psychology cannot be merely the result of indiscriminate borrowing of concepts from new technology.

We wish instead to advance the possibility that the shift in the types of metaphors is related to changes in schools of thought in psychology. For example, the neural flux metaphors used in the middle tridecade may reveal the influence of Gestalt psychology; the mathematical systems metaphors may be linked to the advent of information processing in cognitive psychology. Thus, there does appear to be a correlation between changes in metaphoric domains and changes in the dominant schools of psychology. In the remainder of this article we use the historical patterns of change in mental metaphors to gain insight into the changes in schools of psychology—or more precisely, the changes in the way in which psychologists thought about their subject matter.

We turn now to an examination of the reasons that psychologists chose particular types of metaphors and the nature of the explanatory goals these metaphors were intended to serve. To begin with, we pose three questions that will serve to organize the discussion: (a) What is the function of metaphor in scientific explanation? (b) Are some explanatory metaphors better than others? and (c) If so, have the mental metaphors in psychology improved over time?

The role of metaphor. Metaphor can serve a number of functions, and not all authors may have the same intent in introducing an analogy. One purpose a metaphor may serve is to convey an overall sense of complexity or potential richness without necessarily specifying precise mappings between objects and relations in the analogical domain and the target domain (the topic being explored). In such metaphors, the affective complex conveyed may be more important than any set of enumerable assertions that might be derivable from the metaphor. It can be argued that this expansive function of metaphor, emphasizing richness perhaps at the expense of precision, underlies much of the use of metaphor in literature (Gentner, 1982).

In scientific exposition, the communicative purpose of metaphor is often conceived of more stringently. An analogy or metaphor can allow the formulation of precise predictions in an unknown domain on the basis of known relationships in a familiar domain (Gentner, 1983). For example, Rutherford's comparison of the hydrogen atom to the solar system allowed a number of predictions concerning the structure of the hydrogen atom: that there is a smaller object that is peripheral to a larger object, that the smaller object revolves about this larger object, that the space between them is large relative to the size of the objects, and so on. (See Hanson, 1958, pp. 128–129. For a fuller discussion of the role of metaphor in scientific reasoning, see Gentner, 1979, 1982, and Gentner and Gentner, 1983).

Differences in quality of metaphors. When a metaphor is used in an explanatory or predictive fashion, we may legitimately inquire whether it is a useful piece of explanation. There seem to be implicit criteria for judging the quality of an explanatory metaphor (Gentner, 1982). At least three principles seem to be involved: whether the object correspondences between domains are rigorously defined and preserved (precision); whether the immediate predictions derived from these correspondences seem correct (plausibility); and, if both of the above conditions hold, whether the consequences are interesting and powerful. This last condition is in large part a matter of whether the predictions derivable from the metaphor form a coherent set of interrelated assertions,[4] that is, whether the metaphor is systematic. In general, an explanatory metaphor conveys a set of "attempted predications" (Ortony, 1979). In a systematic metaphor, these attempted predications form a mutually constraining set of interrelated propositions from which further, perhaps quite unexpected, predictions can be derived. Systematic metaphors tend to be more valued as explanatory-predictive devices than as unsystematic metaphors, whose immediate predictions, even if demonstrably true, are not concatenatable and are thus unproductive of new inferences.

Have psychology metaphors improved? The change in the kinds of analogical domains from which the metaphors are drawn is perhaps the most striking aspect of the data. The spatial and animate-being metaphors that dominate the early period are gradually supplanted by systems metaphors. This change occurs despite the considerable appeal of some of the early metaphors, which often seem livelier and more inventive than later metaphors. What underlies this change?

A remark by William James in his *Principles of Psychology* (1890) suggests a possibility: "At a certain stage in the development of every science a degree of vagueness is what best consists with fertility" (p. 6). It seems likely that psychologists were gradually becoming uneasy with James's "degree of vagueness" and were seeking out explicit, systematic domains. Analogies to familiar phenomena serving a local descriptive purpose gave way to more precise analogies involving systems that, even if not univer-

[4] Such interrelations between lower order inferences can be represented as higher order propositions that take the lower order propositions as their arguments.

sally familiar, offered greater possibilities for explication and prediction.

James and other earlier writers may have used metaphor in the expansive, less precise sense described above. Certainly some of the early animate-being metaphors seem to lack systematicity: for example, "through lying, the mind grows wary or strong from swimming against the stream" (Dewey, 1894, p. 109) or "memory moves more easily from a name to a person [its referent] than the reverse, as a fish swims more easily from upriver down to the ocean" (Starr, 1894, pp. 91, 92). Neither of these seems to offer much beyond what is given; the derived predictions for the target domain (mental processes) are rather shallow. (Indeed, in the first example, it is not clear just how to set up a precise enough set of correspondences to allow an unambiguous set of predictions.)

In contrast, when the analogical domain is a mathematical or physical system, the predicates imported into the target domain may participate in a tightly interconstrained predicate structure such that concatenations of immediate predictions into new predictions are possible. An example is the learning theory equation (Restle, 1955). $\theta = r/r + i$, where θ is the conditioning constant, r is the number of relevant elements, and i is the number of irrelevant elements. The systematicity of the analogical domain of algebra is such that one can go beyond the immediate inferences. We can predict, for example, that θ should rise with the number of relevant elements and decrease with the number of irrelevant elements; that the ratio of relevant to irrelevant elements should be $\theta/1 - \theta$; and that, as the numbers of relevant and irrelevant elements approach equality, θ should approach 0.5, and so on.

This is not to say that animate-being metaphors are always less clear or systematic relative to systems metaphors. The structure conveyed by a metaphor depends not only on the degree of systematicity in the analogical domain but also on the precision and aptness of the particular correspondences set up. It is certainly possible to find cases in which an early animate-being metaphor has served as a more systematic metaphor than some of the later systems metaphors. For example, James (1905) used a metaphor of an animal driver with his yoked animals to describe a hierarchical system of higher order ideas controlling, but depending on, lower order thought processes. In the course of this prescient analogy, "long-span activities" are described as "yoking," "encouraging," and "steering" "short-span activities" (p. 12). This metaphor conveys a number of complex concepts: the notions of hierarchies of goals with nested scope, the notion of an interdependent system of partially autonomous units, and so forth. Its precision and systematicity seem at least as high as in such later systems metaphors as "action-specific energy" (Moltz, 1965) or "efficiency as a function of the ratio of focused to diffuse activity" (Wishner, 1955, p. 79). Nevertheless, the overall pattern suggests that psychologists' criteria for explanatory metaphor, or perhaps their conception of appropriate standards for their profession, have altered in favor of more systematic, explicit metaphors.

Neural Metaphors: Vigilance and Quality

At this point a subtle yet important question arises of the degree to which a particular metaphor is used as an intentional metaphor, as opposed to being invoked unconsciously. Without denying the usefulness of a serendipitous, initially unconscious metaphorical association in creativity or discovery, as described by Koestler (1964) and others, the advantages of recognizing a metaphor at the time of writing seem clear. The writer can ensure that the metaphor is precise, that concepts and relations in the base domain are mapped clearly to the corresponding items in the target domain, and that there is no confusion of the two domains or unwarranted assumption of causality.

Conscious scrutiny of an explanatory metaphor is an important aspect of productive usage because, as one of the authors surveyed in this study noted, "analogies are too tricky to be given free reign" (Heidbreder, 1945, p. 5). Analogies commonly begin as imprecise feelings of likeness and are made precise only through careful, often sustained, analysis (Gentner, 1982; Polya, 1973). An unaware user of a metaphor may be unable to follow Lewontin's (1981) warning that "the price of metaphor is eternal vigilance" (p. 245). Indeed, Boyd (1979) has pointed out that the analysis and explication of scientific metaphors are taken to be the shared enterprise of the scientific community (much more so than with literary metaphor).

All of this suggests that, aside from the degree of potential aptness of a given metaphor, an important determinant of the success of an analogical enterprise is the conscious analysis of the analogy. In this connection, one may speculate that a metaphor is most dangerous when it possesses a false credibility. The example that arises here is the neural metaphor. There is, of course, a legitimate, rigorously correct way to use a neural metaphor for a mental process: namely, to convey the position that the same principles of organization hold within the mental domain as within the neural domain. However, one suspects that the fact that the neural domain forms a causal substrate for the mental domain tends to give metaphors drawn from neurophysiology a spurious authority. It may be that neural metaphors are particularly likely to go unexamined. The causal connection between physiological organization and the organization of the mind, though irrelevant from the point of view of the metaphor, may lead to a decrease in vigilance. This would mean first, that neural metaphors should be less detectable as metaphors, and second, that neural metaphors should be less subject to the kind of analytical scrutiny that leads to precision and systematicity.

The patterns found here accord with these suggestions. The steady presence of a small number of neural metaphors, even in the antimentalistic middle tridecade, suggests that these metaphors had a respectability that allowed them to be used even when most mental metaphors were avoided. Further, it seemed to us that, in general, the neural metaphors were particularly careless. We find metaphors such as "gray matter as images or concepts, with white matter as associations between them" (Starr, 1894, pp. 88–89); "neural impulses shifting along associative fibers from one area to another" (Dashiell, 1925, p. 55); and "shortcircuiting too large an amount of excitation" (Arnold, 1945, p. 47). It may indeed be that the closeness of the base and target domains for neural metaphors effected a decrease in vigilance in analyzing the analogical structure.

Conclusions

The mental metaphors of psychology have changed rather strikingly in the past 90 years. The early animate-being metaphors have virtually disappeared, and the spatial metaphors that also flourished in the first 30 years of American psychology have receded to a minor category. In their place we find steadily increasing numbers of systems metaphors, and most recently of computer systems metaphors in particular. American psychology appears to be converging on a common framework of explanation for cognitive phenomena. This convergence is further marked by a decrease in the numbers of idiosyncratic metaphors.

What makes computer systems metaphors so popular? Certainly the adoption of these computer systems metaphors does not guarantee either rigor of application or interestingness of results. Use of the computer metaphor does not even guarantee avoidance of animism. Terms like "retrieving," "detecting," and "searching" can all describe human behaviors as well as machine operations, and this ambiguity is sometimes exploited in vague analogizing. It has been observed that an entire homunculus can be concealed within one processing box in a flow diagram (Mandler, 1978). Nevertheless, a computer analogy can represent a genuine simplification, if the powers of the individual processors are sternly limited. As Dennett (1978) put it, "if one can get a team or committee of *relatively* ignorant, narrow-minded, blind homunculi to produce the intelligent behavior of the whole, this is progress" (p. 123). Further, the potential breadth and systematicity of these systems make them powerful tools with which to work. Sacrificed, perhaps, is the sense of richness that is possible with metaphors that are not fully specified, that retain a degree of vagueness. Metaphors like "through lying, the mind grows wary or strong from swimming against the stream" (Dewey, 1894, p. 109) and "striving itself had drawn or pulled them [words] into actuality" (James, 1905, p. 13) have an almost literary wealth of connotative possibilities.

It is tempting to conclude that there has indeed been a change in the degree of vagueness tolerated in modeling and that the current analogies are more conducive to progress in understanding the mind. According to the thesis assumed here, though, our judgments must be cautious, because we see through the metaphors of our time. Our own frameworks remain to be evaluated.

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