1. PRESIDENTIAL ADDRESS

Graphics in psychology: Pictures, data, and especially concepts

DARRELL L. BUTLER
Ball State University, Muncie, Indiana

Over the last 50 years, psychologists have included numerous graphics in their journals and textbooks. The textbooks have contained mostly pictures, whereas the journals have contained mostly data graphs. Surprisingly, conceptual graphs (such as a network chart of the relations among types of memory) have been very infrequent. There are two main reasons for this absence of conceptual graphs: a lack of awareness of the important role that they have played in the history of our discipline, and a lack of knowledge about how to make them. Four types of conceptual graphs are presented here: mathematical graphs (e.g., Fechner's law), geometric models (e.g., Henning's smell prism), networks (e.g., Atkinson and Shiffrin's STM-LTM model), and Euler-Venn graphs (e.g., Shiffrin and Schneider's model of control and automatic processes). Suggestions are offered for *heuristics* that can be used to facilitate the perception of conceptual relations in these graphs. It is argued that appropriate conceptual graphs can help researchers and theorists communicate the "big picture" relevant to their ideas, can help educators more effectively communicate with students, and may help clinical psychologists communicate their ideas to clients better.

Once when I returned from a trip, a friend who had never been to the place I had visited asked me what it was like. I told him that it was so big, it filled my eyes in every direction and made me weak with awe. The colors—the oranges, browns, and yellows—were far more intense than I had ever expected. I kept trying to describe it. I made the best comparisons I could by pointing out how different it was from the places we had both been to. But in the end, I could tell that my friend had only the vaguest idea about what the Grand Canyon was like. He simply needed to see it himself.

Recently, Glenberg and McDaniel (1992) argued that human communication "really requires an admixture of language and visuospatial formats." According to Glenberg and McDaniel, language cannot be an accurate surrogate for experience. Humans need the organized, detailed representations made available by their perceptual apparatuses. Although Glenberg and McDaniel may have slightly overstated their case, they are not alone in

arguing that visuals add something to communication (see, e.g., Guri-Rozenblit, 1988; Lambiotte, Dansereau, Cross, & Reynolds, 1989; Larkin & Simon, 1987).

A look through recent textbooks and journals in psychology provides some anecdotal support for the hypothesis that graphics are useful in communication. Psychologists' efforts to communicate include a substantial number of sentences and many graphics.

GRAPHICS IN THE PSYCHOLOGY LITERATURE

To develop a better idea of the types of graphics used by psychologists, I surveyed a variety of introductory psychology textbooks¹ and some of the most respected psychology journals² published during the last 50 years or so. I looked for figures that could not be created with an electric typewriter or a simple word processing program. In my survey, I identified some major types of graphics that could not be produced by machines designed to create or edit only language. Although several variables were involved in the determination of these types, one of the most important factors affecting my decisions on how to categorize figures comprised the kinds of computer software that would probably be used today to create each graphic. Another major factor was the concreteness of the graphic.

Figure 1 shows the results of my survey on textbooks. The solid line in the figure refers to the types of graphs I call *pictures*. Generally, pictures are graphics of objects

I would like to thank my wife, Leah Ruth-Butler, who provided insights and encouragement as I worked on this project. I would also like to thank several colleagues at Ball State who provided feedback on various ideas presented in this paper, as well as some of the characteristics of the graphics: Carl Summers, William Clark, and Paul Biner. Thanks also to the anonymous individual at the SCIP conference who recommended that I refer to the last type of conceptual graphic as Euler graphs, not Venn diagrams. Correspondence should be sent to D. Butler, Department of Psychological Sciences, Ball State University, Muncie, IN 47306 (e-mail: 00dlbutler@bsuvax1).

Figure 1. Frequency per page of pictures, data graphs, and conceptual graphs in introduction to psychology textbooks from 1939 to the present (mean $SE = .02$; range, .002-.08).

and their spatial relations, although some rather abstract creations, such as Rorschach figures and gestalt stimuli, were included in this category. Textbooks show pictures of people (such as famous psychologists or participants in research), animals, research equipment, parts of anatomy (such as brains and the sense organs), stimuli for visual perception experiments, and a variety of miscellaneous objects including art reproductions. As you can see in Figure 1, textbooks contain many more pictures today than they did at the earlier times investigated. One other difference, which cannot be seen in Figure 1, is that recent pictures are much more likely to be in color.

The second most common type of graphic found in textbooks consists of *data graphs*, which are shown in Figure 1 with a dashed line. Data graphs are visual analogies. They are created by quantifying variables and depicting numbers. Viewers are able to determine something about the variables they are interested in by examining the spatial information in the depicted numbers. There are many types of data graphs, including variations of line charts, bar charts, scatterplots, and maps. I use the term *maps* here to refer to data graphs such as PET images and eye-movement records in which data that have a spatial variable are mapped into some congruent spatial form such as the shape of a brain or a visual scene. As can be seen in Figure 1, textbooks show that most areas of psychology have been reasonably data oriented over the past 50 years. However, there were more data graphs in the 1950s-1970s than there were before or have been since. Part of the reason for this variation across years is the prevalence of chart recordings of animals during the 50s, 60s, and 70s. Part of the variability also appears to represent a recent shift from reporting individual research studies to reporting trends across many studies.

I refer to the third type of graphic found in textbooks as *conceptual graphs*. Conceptual graphs indicate relations among ideas or concepts, but the individual ideas or objects are simply represented as boxes or some other simple shapes. The conceptual graphs in textbooks included flow charts and various other types of network charts, Venn diagrams (overlapping circles), and some

geometric solids (such as Guilford's model of intelligence, which is represented as a cube, and Henning's smell prism). As can be seen in Figure 1, there has been no major change in the low frequency of use of conceptual graphs over the last 50 years. However, there have been changes in the specific graphs reported. For example, none of the texts in 1939 included a flow chart. Virtually all modern texts have at least one flow chart that indicates the relations between STM and LTM.

Figure 2 summarizes similar data obtained from psychology journals. I specifically chose journals that are considered the best in our field, such as the *Psychological Review* and the *Journal of Experimental Psychology*.

In contrast to the textbooks, journals have more data graphs than other types of graphics. Interestingly, the number of data graphs per page has increased over the past 50 years, but the types of data graphs have not changed much.³ The only substantial noticeable change was the addition of neural activity maps such as PET scans. I found this particularly surprising, given the software tools presently available to create such a wide variety of data graphs. Castellan (1991) made a similar observation when he pointed out that exploratory data analysis is not really showing up in our literature.

In our journals, picture graphics are used most commonly to represent stimuli, apparatuses, and laboratory animals. As can be seen in Figure 2, they are relatively rare in our journals, but, as is also found with textbooks, there has been an increase in their use. However, there are several reasons for believing that the 1990s datum should be judged somewhat cautiously, rather as we judge undergraduate data collected in the last week of the semester. The most important reason is that this datum includes an article published by Biederman on his geon theory. This article contained an explosion of pictures; it had more than any other article I found. Thus, although the trend is easy to demonstrate, it may not be quite as extreme as is indicated in this figure.

As found for textbooks, there really has not been much change in the low frequency with which conceptual graphics are used in journals. There has been some change in the kinds of conceptual graphs. Although there were

Figure 2. Frequency per page of pictures, data graphs, and conceptual graphs in some of the most respected psychology journals from 1939 to the present (mean $SE = .02$; range, .004-.066).

no flow diagrams in the journals 50 years ago, nearly all of the conceptual graphics that I found in recent journals were flow diagrams.

CONCEPTUAL GRAPHICS

I was surprised to find out how infrequently conceptual graphics occurred in both psychological journals and textbooks. I have developed several hypotheses to explain this lack.

One possibility is that conceptual graphs do not serve any purpose. This seems unlikely. Although unaware of Glenberg and McDaniel's (1992) hypothesis that human communication requires both language and graphics, psychologists who have produced some of the most significant books and papers written in our field have used conceptual diagrams to help communicate their ideas. I shall name only a few here. In the last century, Titchener, an important historical figure in the history of psychophysics, provided conceptual graphs of the elements of sensation (see Guilford, 1939). Lewin (1938), the father of social psychology, used conceptual graphs to communicate his ideas about social interaction. Atkinson and Shiffrin (1968) used a conceptual graph to communicate the theoretical relations among sensory memory, short-term memory, and long-term memory. Maslow (1943) even named his theory of motivation, the hierarchical theory, after the shape used to depict it.

Another possibility is that conceptual graphs are infrequent because, unlike more concrete images, they are difficult to understand or remember. This too is unlikely; there is a growing literature suggesting that conceptual graphs can facilitate comprehension and memory. Heine and Rohr (1986) provided some evidence that conceptual graphs (in this case Venn diagrams) can aid students' comprehension, even when students are given no prior training on using conceptual graphs. Guri-Rozenblit (1988) provided evidence that conceptual graphs (of sequential and hierarchical relations) helped students understand social science essays. One of the students in my lab, Kelly Creek, has been running extensions of Bower, Clark, Lesgold, and Winzenz's (1969) study. This study, which is relatively well known, demonstrated that organized information was recalled much better than unorganized information. In Kelly's extensions, recall was found to be better for information presented in a conceptual graph (an organization chart) than for the same information presented in an outline.

Another hypothesis is that conceptual graphs are infrequent because psychologists are uninterested in working through the logic of their theories or the relationships among their concepts. I believe that this hypothesis is false, but refuting it requires one to show that other motives cannot explain the psychologists' behavior. For example, I could offer data showing that psychological faculty are not motivated very much by money; I could use academic salaries as evidence. But I suspect you already know the salary data. I could also provide evidence showing that most researchers get students to run the sub-

jects and in many cases do the data analysis as well as many other relatively mechanical aspects of research. After we account for everything the students do, there really is not much left for researchers to do. Either researchers must be involved in the conceptual aspects of doing research or they are the laziest group of Type A personalities in history.

Although I could offer other possibilities to explain the low frequency of conceptual graphs, I suspect that the major reasons are that psychologists have not really been made aware of the value of various kinds of conceptual graphs and that they do not know efficient ways to create and edit them. Thus, my task is pretty well defined. In this paper, I am going to show some of the value of conceptual graphs and describe some of what I have learned over the last few years about creating and editing conceptual drawings.

MAIN TYPES OF CONCEPTUAL GRAPHS

I have tried several different ways to conceive of the similarities and differences in conceptual graphs. I have experimented with categorizations based on such factors as the number of dimensions discriminating the concepts and visual similarity. The typology I present comprises four main types of conceptual graphs: 1) mathematical graphs, 2) geometric models, 3) network models, and 4) variations of Venn diagrams. Some examples of each type are described below. However, it is very easy to mix these types in conceptual graphs. Thus, the categories should not be thought of as rigid classes.

Mathematical Graphs

The interplay between mathematical equations, drawings of mathematical equations, and psychological constructs goes back (at least) to the beginnings of our discipline. One of the first achievements of psychophysics was to approximate the function relating sensation to stimulus energy. This function is known as Fechner's law or the Weber-Fechner function and has been depicted graphically nearly everywhere it is mentioned.

The depiction of mathematical functions is still used in theory development and communication today. For example, van der Maas and Molenaar (1992) have argued that the Piagetian concepts such as conservation can be understood with reference to a mathematical graphic of catastrophe theory. Figure 3 shows a theoretical behavior surface that is a function of the variables x and y . Note that Path A shows gradual behavioral changes over the range of x , whereas Paths B and C show abrupt changes and different modes of behavior over the middle range of x . According to van der Maas and Molenaar, if the behavior surface represents the degree to which a child demonstrates conservation, various paths represent children who differ in various ways—as, for example, in cognitive capacity.

Although mathematical graphs have been and will continue to be important in our discipline, one problem is that many psychologists have not learned enough mathe-

Figure 3. A depiction of a response set or response surface as a nonlinear function of two variables as conceived in catastrophe theory. (From "Stagewise cognitive development: An application of catastrophe" by H. L. J. van der Maas and P. C. M. Molenaar, 1992, *Psychological Review*, 99, p. 397. Copyright 1992 by the American Psychological Association. Adapted by permission.)

Figure 4. The five elements of somesthetic experience are depicted here as a square-based pyramid. This conception was originally proposed by Titchener. (Adapted from Guilford, 1939.)

matics to feel comfortable enough to develop them on their own. The other types of conceptual graphics do not have this disadvantage.

Geometric Models

Geometric models use analogies to geometry to communicate something about conceptual relations. There are numerous geometric models in psychology, such as Guilford's intelligence cube and Henning's smell prism.

Although geometric models have been valuable in sciences such as chemistry, they have not been as successful in psychology. This is mainly because they do not really aid our understanding, even if they may help memory. One from Titchener (see Guilford, 1939, p. 127), the somesthetic pyramid, is shown here in Figure 4. Here, the analogy to geometry just does not seem to add anything to a list of the elements. For example, does the line connecting ache and tickle imply something different from what is implied by the lack of a line between ache and neutral pressure? Probably not. This structural model is rarely published anymore. Another geometric model

(shown here as Figure 5) was provided by Henning (see Guilford, 1939, p. 116). Again, the analogy to geometry just does not seem to add any useful information about the relations among the six hypothetical primitives. However, enough researchers still rely on the six primitives, so that this model is still shown in many books. However, the geometric aspects of the model are not even discussed. Another example is Maslow's (1943) need hierarchy. Although hierarchies need not be presented as geometrical objects, Maslow chose to employ it as a type of geometric model (see Figure 6). This geometry implies something Maslow wanted to communicate—that needs lower in the figure were somehow more basic or important and had to be satisfied before the "higher" needs affected motivation. However, most modern theorists do not believe that this structural relationship is reasonable. With the exception of some physiological needs, motivation is determined by an interaction of needs, not one particular, unmet, most basic need (e.g., Buck, 1988, p. 33). In Figure 7, I have tried to rework Maslow's theory, creating a graphic form that is more consistent with present ideas about motivation. In this model, a variety of needs affect motivation, but their influence is moderated by an attenuator that has cognitive input.

There may be some cases where geometric models have been and will be useful in psychology. However, I be-

Figure 5. The six elements of olfactory experience as conceived by Henning. (Adapted from Guilford, 1939.)

Figure 6. A version of Maslow's need hierarchy. Over the last 45 years, the number of needs included in the hierarchy has varied, but the basic hierarchical shape is typical.

Figure 7. This graph shows an alternative depiction of needs. In this diagram, the various needs are drawn at the same height, except in the instance of physiology. The arrangement is meant to imply that all the needs are equivalent, except for some physiological needs. A second important characteristic of this graph is that an attenuator can reduce the effect of various potential needs on motivation.

lieve that the approach is fundamentally flawed. Structuralists developed the first geometric models, and these models are consistent with their view of psychology. Just as we have evolved different approaches to psychology, we need to evolve different kinds of conceptual graphics.

Network Models

A third type of conceptual graphics consists of network models. These basically represent concepts as rectangles or other shapes, which are then connected by lines. Some theorists have argued that nets can be very generalizable and can depict a tremendous variety of ideas. Spreading activation models (e.g., Collins & Loftus, 1975) provide one very general solution. In these models, the strength of a relationship between two concepts is depicted as the length of the line between two simple shapes. Even more general are semantic nets that are used most commonly by researchers in English. They use verbal labels on the connecting lines, rather than vary the line length. This allows one to depict extremely complex, multidimensional models. However, sometimes these networks are not very visual because they do not take advantage of visual analogies. The net you see in Figure 7 was not too complex, so I was able to use a simple coding. The arrows imply the direction of influence and the widths of the lines indicate the amount of influence.

One special kind of net is the *hierarchical* chart (also sometimes called the *organizational* chart, as a result of its common use in depicting organizations). A hierarchical chart attempts to show subordinate and superordinate relations among concepts or ideas. There are a number of different varieties of hierarchical charts, such as organization charts, tree diagrams, and in some cases, pie charts. These charts have been used in a variety of ways in psychology, such as, for example, to illustrate phenotypes and genotypes, to depict the relations among the sciences, and to diagram sentence structure.

Recently, Squire (1992) used a hierarchical chart to discriminate various types of memory. Figure 8 is taken from Squire, but the bottom layer has been truncated. Squire's article summarizes physiological data that justify the discriminations provided in the chart. I have used similar charts in courses to provide a framework for discussing kinds of memory, the types of visual depth cues, and other sets of hierarchically related concepts. In general, the only major issue to be decided as one creates a hierarchical chart is the level of detail to present in the graph. If many concepts are presented on many levels, the graph can begin to lose its advantage in promoting comprehension.

Another special kind of net is the flow chart. Flow charts were created by von Neumann and his associates in the 1940s (Goldstine & von Neumann, 1947). Of course, flow charting has evolved dramatically in 45 years. However, this history is not particularly important to our discipline, because psychologists do not usually create flow charts that follow all of the rules of modern flow-charting. Models such as Atkinson and Shiffrin's (1968) model of memory, Lewinsohn's (1974) depression model, or James-Lange's theory of emotions can be depicted by using very simplified charts.

Flow charts are often better when they use spatial relations in ways that help a person "see" relationships in the graphic. I have observed that when the axes of the graph have references (e.g., the horizontal axis refers to time), then differences and similarities in the graph with

Figure 8. A hierarchical chart of types of memory. (From "Neuropsychological investigations of memory and amnesia: Findings from humans and nonhuman primates" by S. Zola-Morgan and L. R. Squire, 1990, in A. Diamond, *The development and neural bases of higher cognitive functions*, p. 437. New York: New York Academy of Sciences. Copyright 1990 by the New York Academy of Sciences. Adapted by permission.

Figure 9. A simple flow chart summarizing the James-Lange theory of emotions.

Figure 10. A simple flow chart illustrating the Cannon-Baird theory of emotions. Note that the x-axis reference of time permits one to quickly "see" the parallel process characteristic of this theory.

Figure 11. A simple flow chart of the main ideas of the Schachter-Singer theory of emotions.

respect to that axis can be interpreted easily. The idea I am proposing is the same as what is done in data graphs with labeled x- and y-axes and also as the vertical "hierarchical" dimension implied in organization charts.

To illustrate the idea of reference axes in flow charts, I created a series of graphics that depict theories of emotions. The first diagram shows the James-Lange theory of emotions (see Figure 9). Here I chose to refer to time as the x-axis. Note that the basic theory is very sequential. The next diagram shows the ideas of Cannon and Baird (see Figure 10)—especially the idea of parallel processes, or two or more events happening at the same time. The third diagram is an attempt to show Schachter and Singer's theory of emotions (see Figure 11). Note that it is a modified version of Cannon and Baird's theory, in that there are two parallel processes. However, it is debatable whether this picture has remained true to the axis labeling. This drawing makes it appear as if it takes no time for appraisal of an event to lead to autonomic arousal. Although there are several ways to solve this problem, one is to abandon the choice of time as the reference axis. Figure 12A shows a flow diagram referenced to the part of the nervous system that can become active, rather than to time. Although this model looks very dif-

ferent, it is only a slight variation on Schachter and Singer's theory.

Once the time axis is eliminated, a major issue is how to demonstrate the temporal process in the model. There are several ways, one of which is to use motion. This is simulated in Figure 12. First, events produce inputs (Figure 12B). Next, the thalamus is excited (Figure 12C). The thalamus sends information to the cortex and (at least under some circumstances) influences the limbic system (Figure 12D). The process now becomes more complex: The limbic system produces emotional responses, while perception and appraisal of the events can lead to emotional experience and modify the activity in the limbic system (Figure 12E). (Note that if we accept James's definition of emotion, the "spread" to emotional experience must be delayed until behavior is perceived.) The behavior, of course, produces new sensory input (Figure 12F). We could continue to track the effect of this new sensory input as it modified the activity of various parts of this network.

If this diagram became much more detailed (something that could be easily done by adding additional feedback, elaborating the input, output, and processing components) it would soon begin to resemble a kind of neural activity map, like a PET scan. The concept graph is purposely kept simpler for purposes of communication. There is research suggesting that schematic depictions such as the one I have used here can be extremely valuable in communicating the "big picture." For example, in a recent article, Winn (1988) reported that students who studied circuit diagrams with all specific circuits replaced by squares remembered the pattern of the relationships better than did students studying more traditional circuit diagrams with detailed symbols. In other words, it is important to adopt an appropriate level of detail in a conceptual graph in order to facilitate communication.

In addition to keeping the symbols reasonably simple, Bohm and Jocopini (1966) have demonstrated ways to move between complex flow charts and simpler ones. They showed that flow charts of all procedures can be written by using only three primitives (the linear primitive, the alternate primitive, and the repetitive primitive). All of these primitives have a simple graphic representation. These are shown in Figure 13. Some procedures can begin to look complicated when written with these primitives; this is simulated in Figure 14. This complexity can be reduced by recognizing the hierarchical structure of complex procedures and depicting higher order units. An illustration of this is shown in Figures 15 and 16. Note that we can substitute a box for a simple linear sequence and another for repetition. Finally, we can replace an alternative with a box. Note that when all primitives have been replaced, all procedures appear as sequences! Thus, if we are willing to simplify (at least to get the big picture), we can often communicate by using simple and clear conceptual graphs. Note too that this process can be done in reverse to provide more and more details about a process. This can be quite helpful when a theorist needs to

Figure 12. A revised (and slightly modified) version of the Schachter-Singer theory of emotions. This figure is drawn with reference to position in the nervous system (y-axis) instead of time as done in Figures 10 and 11. Figures 12B-12F simulate the inclusion of a temporal variable.

Figure 13. This graphic shows three primitives of flow charts. Bohm and Jocopini offered them as an alphabet of flow diagrams. (From "Flow diagrams, Turing machines, and languages with only two formation rules" by C. Bohm and G. Jacopini, 1966, *Communications of the ACM*, pp. 366-371. Copyright 1966 by the Association for Computing Machinery, Inc. Adapted by permission.)

Figure 14. A somewhat complex flow chart. (From "Flow diagrams, Turing machines, and languages with only two formation rules" by C. Bohm and G. Jacopini, 1966, *Communications of the ACM*, pp. 366-371. Copyright 1966 by the Association for Computing Machinery, Inc. Adapted by permission.)

use the diagram as a mirror for working through some of the complex aspects of a theory.

Euler-Venn Diagrams

Sometimes, concepts are not mutually exclusive. Yet the standard network drawings that I have been using imply that they are. When the mutually exclusive quality seems inappropriate, variations in nets are required. I think of these variations as making the diagrams look more like the Euler diagrams that were used by Venn and are still often used to depict simple syllogisms. I often think of these Euler-Venn diagrams as top views, whereas organization charts, flow charts, and other nets are front

views. For example, Figure 17 shows a redrawn version of Squire's (1992) hierarchy of memory using the Euler-Venn or top-view approach. Once we have the top view, we can eliminate the implied mutually exclusive quality by allowing the shapes defining individual concepts to have crossing boundaries. For example, if a theorist hypothesized that episodic and semantic memory were not completely independent or that dispositions and nonassociative learning were related in some important way, he/she would depict these concepts as overlapped or having crossing boundaries. This is shown in Figure 18.

I would like to illustrate one area of psychology in which this transformation to using Euler-Venn diagrams has already begun: the STM-LTM literature. Figure 19 shows the relations among SR, STM, and LTM as conceived by Atkinson and Shiffrin (1968). Note that this is a fairly

Figure 15. This figure shows the substitution of superordinate boxes for the primitive linear and repetition subsections of the flow chart shown in Figure 14.

Figure 16. This figure shows another substitution of a superordinate box, this time for a primitive alternate subsection. Note that after the substitution, the flow chart is a simple sequence.

Figure 17. This figure shows a revision of Figure 8. This is a top-view or Euler-Venn graph.

standard flow diagram (although neither axis is an obvious axis of reference). It explicates the processing differences in these three types of memory. Figure 20 (based on Shiffrin & Schneider, 1977) shows a dramatic change in the relations among SR, STM, and LTM. Note that STM is now within LTM (i.e., it is a subset). If I am interpreting this graphic correctly, SR is also now a part of LTM, as is the motor production system. Several theorists, such as Anderson (1983, 1991) and Baddeley (1986) have gone even further. I have attempted to capture their arguments about the nature of the relations among types of memory in the following graph (Figure 21). Note that in this graph the active aspects of memory are STM; the LTM is

divided into basic subareas, including sensory and motor areas; and the behavior affects the perceptual input. This graph is not Anderson's or Baddeley's and thus may certainly depict my own ideas as much as theirs. For example, both Baddeley and Anderson prefer to use the term *working memory* instead of STM.

Allowing concepts to be subsets and to interact is an important way to communicate psychological concepts. We could follow the logic of Boole and simply partition concepts until they did not overlap. However, such a solution would ignore the fundamental difference in the purposes to which logicians put diagrams and the purposes for which I am suggesting we use them. Our goal in using

Figure 18. This figure shows a further modification of Figure 8. In this figure, the mutually exclusive quality of concepts is removed by overlapping the boundaries of the concepts that are not mutually exclusive. Note that this modification is for illustrative purposes; it is not meant to provide a new theoretical statement about memory.

Figure 19. A simplified version of the well-known memory model provided by Atkinson and Shiffrin (1968). (From "Human memory: A proposed system and its control processes" by R. C. Atkinson and R. M. Shiffrin, 1968, in *The psychology of learning and motivation* (Vol. 2, pp. 89-195, Figure 1). Orlando, FL: Academic Press. Copyright 1968 by Academic Press. Reprinted by permission.)

conceptual graphics is not to derive methods for verifying whether arguments are logical; our goal is to provide depictions of theories that further the scientific understanding of human thought, emotion, and behavior. Many of the concepts we use are not mutually exclusive, and our depictions of these ideas should permit us to characterize these concepts appropriately.

I have one other example of a Venn-like concept chart that I have used to help students get some idea of what psychology is all about (Figure 22). This figure is quite different from one that I would create if I were attempt-

ing to depict the view of Descartes, in which cognition would not be a subset of physiology; the two concepts would intersect. If I were to create this figure for different psychologists in the history of our discipline (e.g., Skinner), differences in conception would be obvious. Undoubtedly psychologists will need to alter it in the future to make it adapt to the evolution of our discipline.

Unfortunately, when we use these Euler-Venn graphics, we eliminate some of the devices that we use in the apprehension of other types of graphs. For example, it becomes difficult to label axes meaningfully, even though we may still be able to label implied ones as is done here. One alternative that can help simplify complicated Euler-Venn graphs is to include animation. I illustrated this above by using a model of emotion. Others have also found value in using animation. For example, Tweedie and Barnard (1992) have argued that animation helps them communicate their "complex psychological model."

CONCLUSION

Geoffrey Loftus (1985, 1991), a former president of the Society for Computers in Psychology, has warned psychologists about some potential problems associated with using computers in our discipline. One of his concerns is the use of computers to crunch through complex psychological models with thousands (or more) of small, computable parts. Loftus argues that this activity probably has not helped us create better theories, because it conflicts with the search for simple, elegant, parsimonious theories.

In contrast, I believe that the creation and modification of conceptual graphs (especially when the goal is to facili-

Figure 20. This figure is a slight modification of the diagram of automatic and controlled processing offered by Shiffrin and Schneider (1977). (From "Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory" by R. M. Shiffrin and W. Schneider, 1977, *Psychological Review*, 84, p. 162. Copyright 1977 by the American Psychological Association. Adapted by permission.)

Figure 21. An Euler-Venn graph of memory that attempts to integrate many modern ideas.

tate communication) is very consistent with the goal of developing elegant theories. Computers can be helpful to psychologists as they create, reflect upon, and edit various kinds of images of their ideas. For mathematical graphs, Mathematica and Maple V can be quite helpful. Many packages are available to assist in the creation of flow diagrams, organization charts, and some other kinds of nets (ABC Flowcharter, RFFlow, and SemNet). Although these network drawing packages can be quite useful, I have not located any that also permit the creation of easy-to-edit Euler-Venn graphics. There are drawing packages that are more general and thus allow one to create many different kinds of conceptual graphs. I used one, Intellidraw, to create and edit all the conceptual graphics presented in this paper.

Although the present state of drawing packages is adequate, I have hopes that psychologists will encourage the development of better conceptual drawing tools and interfaces. Good tools can help researchers, educators, and practitioners more effectively work through and communicate their theories and ideas. This can have a clear and positive impact on theory development in our field, the education of our students, and the practice of clinical psychology.

REFERENCES

- ANDERSON, J. R. (1983). *The architecture of cognition*. Cambridge, MA: Harvard University Press.
- ANDERSON, J. R. (1991). *Cognitive psychology and its implications*. New York: W. H. Freeman.
- ATKINSON, R. C., & SHIFFRIN, R. M. (1968). Human memory: A proposed system and its control processes. In K. Spence & J. Spence (Eds.), *The psychology of learning and motivation* (Vol. 2, pp. 89-195). NY: Academic Press.
- ATKINSON, R. L., ATKINSON, R. C., SMITH, E. E., & BEM, D. J. (1990). *Introduction to psychology*. San Diego, CA: Harcourt Brace Jovanovich.
- BADDELEY, A. D. (1986). *Working memory*. Oxford: Oxford University Press.
- BOHM, C., & JOCOPINI, G. (1966, May). Flow diagrams, Turing machines, and languages with only two formation rules. *Communications of the ACM*, 366-371.
- BORING, E. G., LANGFELD, H. S., & WELD, H. P. (1939). *Introduction to psychology*. New York: Wiley.
- BOWER, G. H., CLARK, M. C., LESGOLD, A. M., & WINZENZ, D. (1969). Hierarchical retrieval schemes in recall of categorical word lists. *Journal of Verbal Learning & Verbal Behavior*, 8, 323-343.
- BUCK, R. (1988). *Human motivation and emotion*. New York: Wiley.
- CASTELLAN, N. J., JR. (1991). Computers and computing in psychology: Twenty years of progress and still a bright future. *Behavior Research Methods, Instruments, & Computers*, 23, 106-108.
- COLLINS, A. M., & LOFTUS, E. F. (1975). A spreading activation theory of semantic processing. *Psychological Review*, 82, 407-428.

Figure 22. An Euler-Venn graph that depicts a view of humans that is compatible with many modern definitions of psychology.

- CROOKS, R. L., & STEIN, J. (1991). *Psychology science: Behavior and life*. Forth Worth: Holt, Rinehart & Winston.
- DEMBER, W. N., & JENKINS, J. J. (1970). *General psychology: Modeling behavior and experience*. Englewood Cliffs, NJ: Prentice-Hall.
- GLEITMAN, H. (1992). *Basic psychology*. New York: Norton.
- GLENBERG, A. M., & MCDANIEL, M. A. (1992). Mental models, pictures, and text: Integration of spatial and verbal information. *Memory & Cognition*, **20**, 458-460.
- GOLDSTINE, H. H., & VON NEUMANN, J. (1947). *Planning and coding problems for an electronic computing instrument* (Vols. 1-3). New York: van Nostrand.
- GUILFORD, J. P. (1939). *General psychology*. New York: van Nostrand.
- GURI-ROZENBLIT, S. (1988). The interrelations between diagrammatic representations and verbal explanations in learning from social science. *Instructional Science*, **17**, 219-234.
- HEINE, S., & ROHR, G. (1986). Human-computer interaction (HCI): A problem of cognitive ergonomics. In H. P. Willumeit (Ed.), *Human decision making and manual control* (pp. 115-124). Amsterdam: North-Holland.
- KENDLER, H. H. (1968). *Basic psychology*. New York: Appleton-Century-Crofts.
- LAMBIOTTE, J. G., DANSEREAU, D. F., CROSS, D. R., & REYNOLDS, S. B. (1989). Multirelational semantic maps. *Educational Psychology Review*, **1**, 331-367.
- LARKIN, L. H., & SIMON, H. A. (1987). Why a diagram is (sometimes) worth ten thousand words. *Cognitive Science*, **11**, 65-99.
- LEWIN, K. (1938). *The conceptual representation and the measurement of psychological forces*. Durham, NC: Duke University Press.
- LEWINSOHN, P. (1974). A behavioral approach to depression. In R. Friedman & M. Katz (Eds.), *The psychology of depression: Contemporary theory and research* (pp. 157-186). Washington, DC: Winston/Wiley.
- LOFTUS, G. R. (1985). Johannes Kepler's computer simulation of the universe: Some remarks about theory in psychology. *Behavior Research Methods, Instruments, & Computers*, **17**, 149-156.
- LOFTUS, G. R. (1991). Postdictions of 20-year predictions about the state of computer technology in psychology (and one or two other matters). *Behavior Research Methods, Instruments, & Computers*, **23**, 112-113.
- MASLOW, A. H. (1943). A theory of human motivation. *Psychological Review*, **50**, 370-396.
- MCKEACHIE, W. J., & DOYLE, C. L. (1970). *Psychology*. Reading, MA: Addison-Wesley.
- MORGAN, C. T. (1956). *Introduction to psychology*. New York: McGraw-Hill.
- MYERS, D. G. (1992). *Psychology*. New York: Worth.
- RATHUS, S. A. (1990). *Psychology*. Orlando, FL: Holt, Rinehart & Winston.
- SHIFFRIN, R. M., & SCHNEIDER, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review*, **84**, 127-190.
- SQUIRE, L. R. (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys, and humans. *Psychological Review*, **99**, 195-231.
- TWEEDIE, L., & BARNARD, P. (1992). The interactive talk: A new tool for presenting complex theory. *Psychology Software News*, **3**, 43-45.
- WICKENS, D. D., & MEYER, D. R. (1955). *Psychology*. New York: Dryden.
- WINN, W. (1988). *Journal of Research in Science Teaching*, **25**, 375-386.
- VAN DER MAAS, H. L. J., & MOLENAAR, P. C. M. (1992). Stagewise cognitive development: An application of catastrophe theory. *Psychological Review*, **99**, 399-417.

NOTES

1. There were 12 textbooks: R. L. Atkinson, R. C. Atkinson, Smith, & Bem, 1990; Boring, Langfeld, & Weld, 1939; Crooks & Stein, 1991; Dember & Jenkins, 1970; Gleitman, 1992; Guilford, 1939; Kendler, 1968; McKeachie & Doyle, 1970; Morgan, 1956; Myers, 1992; Rathus, 1990; Wickens & Meyer, 1955. The total number of pages searched was 7879.
2. The journals were the *Psychological Review* (1940, 1969, 1992), the *Psychological Bulletin* (1941; 1969, Vol. 72; 1992, Vol. 111), the *Journal of Experimental Psychology* (1939; 1969, Vol. 79, Pt. 1; *Journal of Experimental Psychology: General*, 1992, Pts. 1, 2, and 3), and *Psychological Sciences* (1992). The total number of pages searched was 6524. Removing *Psychological Sciences* from the last group has little effect on the 1990s data points, but inclusion of this journal slightly lowered the means.
3. There have been changes in size of pages, size of print, and other changes as well. No attempt was made to control for these variables.

APPENDIX

Software Mentioned in Text

- ABC Flowcharter (Micrografx, 1303 Arapaho, Richardson, TX 75081; 214-234-1769).
- Intellidraw (Aldus Corp., 411 First Ave. South, Seattle, WA 98104; 206-628-2320).
- Maple V (Waterloo Maple Software, 160 Columbia St. West, Waterloo, ON, Canada N2L 3L3; 519-747-2373).
- Mathematica (Wolfram Research, 100 Trade Center Dr., Champaign, IL 61820; 800-441-6284 or 217-398-0700).
- RFFlow (RFF Electronics, 1053 Banyan Ct., Loveland, CO 80538; 303-663-5767).
- SemNet (SemNet Research Group, 1060 Johnson Ave., San Diego, CA 92103; 619-232-9334).