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# Things done

*Cosas hechas*

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## Abstract

This paper proposes a new interpretation of basic operant research. The practice of operant research is distinguished from the intepretation. The practice has three key features, which are summarized. The usual interpretation of operant research is discussed in relation to the ambiguity of the word behavior. Some examples of data analysis based on a conceptual analysis of the events directly represented by the data are presented. The paper concludes that the traditional interpretation of operant research neither guided these data analyses nor is implied by the resulting visual-representations of the things done by participants.

Key words: behavior, data, visualization, difference scores, behaviorism

## Resumen

Este trabajo propone una nueva interpretación de la investigación operante básica. Se distingue a la práctica de la investigación operante de su intepretación. La práctica tiene tres rasgos claves, que se resumen. Se discute la interpretación usual de la investigación operante en relación con la ambigüedad de la palabra conducta. Se presentan algunos ejemplos de análisis de datos basados en un análisis conceptual de los eventos representados directamente por los datos. El artículo concluye que la interpretación tradicional de la investigación operante no guió estos análisis de datos ni es implicada por las representaciones visuales resultantes de las cosas hechas por los participantes.

Palabras clave: conducta, datos, visualización, puntajes de diferencia, conductismo

In this paper, I propose the beginnings of a new interpretation of operant research. I use the phrase operant research to refer to the tradition initiated by B. F. Skinner in the 1930s. Operant research continues in modern psychology in behavior analysis, and it underpins radical behaviorism, Skinner's philosophy of the science of psychology.

At the heart of radical behaviorism is an argument about the subject matter of psychology. Skinner argued psychology should be conceptualized and pursued as the science of the behavior of the organism. Skinner defended his argument by pointing to operant research. He interpreted operant research as demonstrating the environmental control of the behavior emitted by the organism.

I recommend we should explore a new interpretation of operant research. To explain my recommendation, I begin by clarifying what I mean by operant research, and I discuss the usual interpretation of *operant research*. I next return to the data, and I develop a new interpretation of them. I do this by exploring how data visualization software can cast light on the things participants do during operant experiments.

## Operant research

It is important to distinguish the practice of doing operant research from the interpretation of this research. The practice of doing operant research includes the things experimenters do to acquire data. I now consider three elements of these data acquisition practices to clarify what I mean by *operant research*.

First, data are collected as a participant acts on a key, button, touch screen, and or some other device. In operant research, such a device is known as an operandum. A device is an *operandum* if a participant can bring about changes at it and if an experimenter can arrange for the automatic detection and recording of these changes. The word *change* means a transition in the state of something (e.g., the depression of a button as defined by the closure of a switch).

The data represent things done. Things done are changes at an object or in a medium (e.g., air) that would not occur without the physical efforts of an individual and the one or more things that are changed. For example, a button release (by a participant) is a thing done. It is a change in the state of the button, from its down state to its up state, that depends on the button and on the participant.

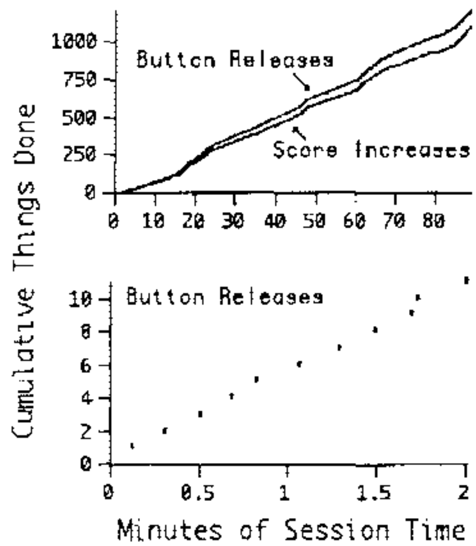


Figure 1. Cumulative button releases and score increments across session time in minutes (top graph), and cumulative button releases across the first two minutes of session time (bottom graph).

To clarify these events, Figure 1 shows some data from my laboratory. Among other things, the human participant repeatedly depressed and released a button. As a result, he occasionally had an opportunity to depress a key to increase his score. The top graph in Figure 1 shows cumulative button releases across session time in minutes. It also shows cumulative score increases. The data paths contain many dots or points (1217 for button releases and 1104 for score increases) spread across almost 39 min of session time. The points are so densely packed that the data paths look like lines. The composition of the data paths is clear in the bottom graph in Figure 1. It shows the 11 button releases that occurred during the first two minutes of the session. The reduced degree of compression makes evident that each event is represented by a point and therefore should be conceptualized as a momentary event (consistent with its description as a transition).

It is important to be clear about what the data do not represent. They do not represent bodily activities (e.g., the motions of body segments around the joints). Things done depend on bodily activities and would not occur without them. They also would not occur without the thing changed (e.g., the button). But things done are not themselves bodily activities.

It is easy to think that *thing done* is synonymous with *response*. In fact, the data do not represent responses, whether responses are conceptualized as parts of behavior (e.g., Catania, 1991) or as units that conjoin bodily activities and a thing done (Glenn & Madden, 1995). Responses are inferred from the data and not represented by them. The data *represent* (i.e., directly correspond to) only changes (i.e., transitions) that depend on a biophysical agent and on the object that is changed. (Incidentally, the data do include representations of score increases (Figure 1), and, in this experiment, score increases were things done. They were changes at the score display that depended on the individual and on the score display, and also on the button and on the causal connections that linked changes at the button to changes at the score display.)

Second, experimenters arrange causal connections, traditionally called *contingencies*, between changes at an operandum and changes at one or more other objects. An example of a statement of such a contingency is the following: Provided the button is released at least 2.5 s after permission to release is given, then the release produces an opportunity to increase the displayed score by depressing a key. This contingency conditionally relates a change at the button to a change at the score display. As explained elsewhere (e.g., Findley, 1962; Sidman, 1986a, 1986b; Weingarten & Mechner, 1966), contingencies are open to endless elaboration. They are not restricted to simple examples of this kind.

Third, experimenters change contingencies during an experiment. They investigate how changes in the contingencies (i.e., causal relations among things done) affect what the participant does at the operandum. For example, initially the experimenter might require button releases at least 2.5 s after the instruction to release the button, but later button releases must occur at least 3.5 s after this instruction. The contingency between button releases and score increases has been changed, and the experimenter investigates how this change affects the button releases (and therefore also the score increases).

## Usual Interpretation of Operant Research

The usual interpretation of operant research follows Skinner's interpretation of it. Skinner interpreted the subject matter of operant research as the *behavior* emitted by an organism under the control of environmental variables. Skinner's interpretation depends on the word behavior. Throughout psychology's history, critics (e.g., Coulter, 1982; Hamlyn, 1953; 1986; Kitchener, 1977; Parmelee, 1924, p. 1; Roback, 1923) have persistently noted the ambiguity of this word. Underlying the ambiguity, the word behavior has two incompatible meanings, which are usually glossed over. These meanings need to be distinguished to make sense of Skinner's interpretation of operant research.

*Behavior as things done.* The word *behavior* can mean conduct. Conduct consists of the things people do that we make judgments about; judgments of good or bad, successful or unsuccessful, right or wrong, effective or ineffective, satisfactory or unsatisfactory, competent or incompetent, and so on. Examples of conduct include getting to one's office on time, giving the sum of a column of digits, getting a letter signed (rather than omitting to sign it), getting a window closed before the rain starts, and getting an assignment graded consistent with a set of publicized criteria. Getting a button depressed or released, getting a score display to increment, getting a message to appear on a computer screen, and getting a key depressed are examples of things done by participants in operant experiments.

When we talk about conduct, we are interested in the impact (Jacobs, Blackburn, Buttrick, Harpur, Kennedy, Mana, et al., 1988) an individual has on something. For example, when we talk about an individual planting seeds in a garden, we are concerned with whether the seeds get planted, with where and when they get planted, and with what further results. We are interested in the things done; in the results or effects of the individual's efforts. At this level of organization, we are not concerned with the movements of the individual's body parts, with the biochemistry of his or her blood, with the beating of his or her heart, and so on. Operant data (e.g., Figure 1) represent things done (e.g., button releases) and nothing else. The data imply an interest in whether the participant does the thing at all, under what conditions, and with what other things also get done as a result. The data do not imply an interest in the organism as a biophysical entity or in the operandum as a physical entity.

The things an individual gets done depend on the individual's body and on other things as well. For example, the outcomes of an individual planting seeds in a garden depend on the quality of the seeds, the time and place in which they are planted, and other conditions as well as on the individual's body. Similarly, a button depression by an individual depends on the individual's body and on the physical properties of the button.

The idea that a thing done depends on its constituents physically and is separable from them conceptually is hard to grasp. The difficulty arises because the principle of levels is uncommon in psychology. The principle of levels states that nature comprises nested levels of organization. Items that are units at one level of organization contain constituents and are themselves constituents of other units. For example, molecules contain atoms, which are units at a more fine-grained level of organization and which also contain constituents (e.g., quarks), and molecules are constituents of compounds which are units at a less fine-grained level of organization.

The idea of nested levels of organization in nature casts light on the conceptualization of things done. Things done have a unity such that we can point to them, count them, and represent them visually (Figure 1). Things done also have constituents, which are the biophysical agent and the object changed. Things done depend on their constituents: Things done have no physical existence apart from their constituents. But things done are separable conceptually, as it is possible to count, visually represent, and theorize about things done, without also having to count, visually represent, and theorize about their biophysical and physical constituents, even while these constituents are always implied.

Ordinary usage of the word behavior implies behavior in this sense of conduct or things done. For example, when we say people should improve their behavior, we mean they should improve their act or change what they get done and how they get it done. As Roback (1923) put it, for most people outside psychology, the word behavior means "conduct of the normative kind" (p. 111). Behavior in this sense is the subject matter most of us entered psychology to study.

*Behavior as phenomena. Behavior* has another meaning that makes it synonymous with *phenomenon*. Technologists and scientists use behavior in this way. For example, they speak of the *behavior of a computer program, the behavior of a mathematical equation, the behavior of a quark, or the behavior of the universe.* Suppose we carry over this meaning to our understanding of behavior in psychology. Then the expression the behavior of the organism is synonymous with the expression the *phenomena of the organism* which reduces without loss of meaning to the phrase *the organism*.

The implication that psychology is about the organism seems absurd. However, it is consistent with the assumption that the individual is the psychological unit or where psychology's subject matter is to be found. This is one of psychology's central assumptions, as noted by Lee (1995). This assumption has two central implications. First, if the individual is the unit of interest, then many sciences contribute relevant information. For example, to describe and understand the structure and function of a human body, we need information from genetics, biochemistry, physics, neurology, movement science, optometry, and so on. It is hard to identify a role for psychology. Second, if the individual is the psychological unit, then the distinction between organism and environment is fundamental to psychological thought. Organism implies environment, and vice versa. As long as the individual is accepted as the psychological unit, it is hard to imagine psychology without this classification of the observables (i.e., classes of organismic or behavioral and environmental events).

The behavior (i.e., phenomena) of the organism is not what most of us entered psychology to study. Psychology is intuitively about conduct, or the impact of an individual. Intuitively, psychology is not properly characterized as a science concerned with the individual's body. However, the ambiguity of behavior has led many psychologists to think otherwise.

*Skinner's interpretation.* Operant data represent things done or changes brought about by a participant. They represent behavior in the sense of conduct. However, Skinner interpreted things done as evidence of the behavior of the organism, and he claimed the behavior of the organism as his subject matter. This interpretation depends on acceptance of three of psychology's central assumptions, which have already been implied earlier in this paper.

The first assumption is that the individual is the primary psychological unit or the item psychology is obliged to explain. In contrast, operant data imply that the thing done is the primary unit.

The second assumption is that psychology's subject matter is found at the organism. The stated subject matter is then either the organism's behavior (behaviorism) or the internal properties that explain the organism's behavior (cognitivism). In contrast, operant data imply a subject matter abstracted from a conglomerate comprising a biophysical agent and the objects and media the agent changes or contributes to changing.

The third assumption is that psychology's subject matter divides into behavioral and environmental parts. This implies all items of interest to psychologists are classifiable as either of the organism or of the world outside the organism. In contrast, operant data imply only things done. These units have two constituents. These *constituents* are not *parts* of psychology's subject matter. The constituents are the biophysical agent and the thing the agent changes. Other sciences, including physics, biochemistry, and movement science, investigate these constituents.

Skinner assumed that the subject matter of psychology is a subset of the bodily activities of the organism. On the basis of his experiments, Skinner reasoned that psychology was about behavior that has effects on the environment and that is maintained or changed as a result. He called this operant behavior. An organism can get a thing done using different parts of its body on different occasions. For example, a rat can depress a lever with its right paw, its left paw, and so on. Because of this plasticity of the bodily constituents, Skinner introduced the idea that his subject matter comprised classes of bodily activities defined by their effects. He called these classes *operants*. Skinner's conceptualization of the data assumed that the subject matter comprises some bodily activities of the organism. Without that assumption, neither the concept of the operant nor the concept of operant behavior nor the distinction between organism and environment are required.

In making sense of this, it is essential to notice that things done are abstractions. Suppose we point to a participant working on a task. It will not be immediately obvious what we are pointing to. We could be pointing to the participant, to the computer, to a key, to a depression of a key, to a motion of one of the participant's body segments, to movements of the participant's eyes, and so on. If we say we are pointing to the button pressing response, it will remain unclear what we are pointing to. We could be pointing to the movements of the participant's body segments (e.g., rotation of the shoulder) or to the things done by the participant (key depression, key release) or to both.

If we think about the data (e.g., Figure 1), we can develop clarity concerning what we intend to point to and therefore concerning the subject matter we intend to theorize about. The data themselves imply that we intend to point only to a particular aspect of the total conglomerate that we see as unaided observers. In the present example (Figure 1), when we point to the data, we point to representations of the button releases and score increases. We abstract out these things done, these ways in which the participant makes a difference. We abstract them out conceptually when we talk about them without also talking about the movements of the participant's body, the contractions of the participant's muscles, the beating of the participant's heart, the computer, and the other constituents on which the things done depend.

Things done are what the data represent. For theorizing to be empirical, the events represented by the data are what we should conceptualize, even if doing so offends the basic assumptions of traditional psychology.

## Data

I now return to the data to explore something of what they reveal about the subject matter they represent. Figure 2 shows another view of aspects of the same data file used to construct Figure 1.

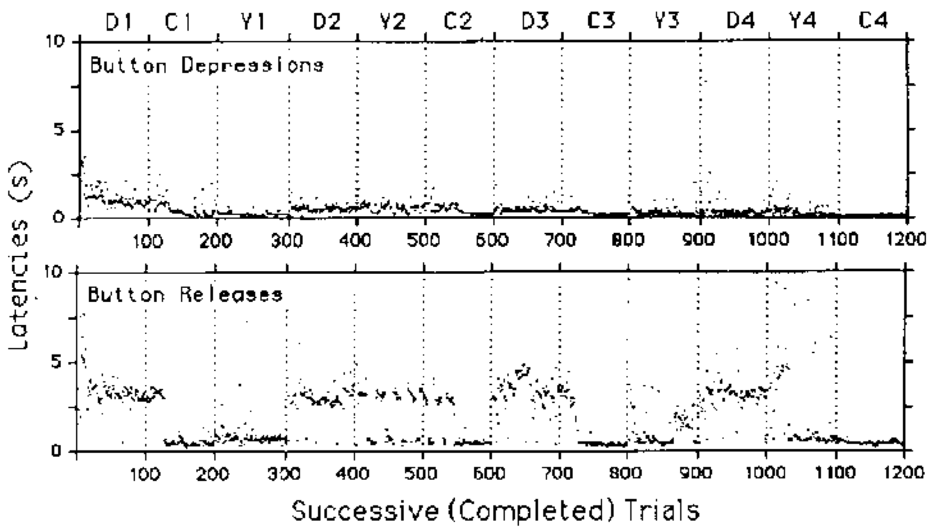


Figure 2. Latencies of button depressions and button releases across successive completed tasks. Each dot represents one latency. Condition indicators ("D1", "C1", etc.) represents repetitions of three kinds of conditions: (a) differential reinforcement conditions in which latencies 2.5 s or greater were successful, (b) yoked intermittent reinforcement conditions with the series of successes and failures yoked to the preceding differential reinforcement condition, and (c) continuous reinforcement conditions in which every button release was successful.

To explain: The data in Figures 1 and 2 are from an experiment comprising 1200 completed trials. On each trial, the participant was told to depress a button. After a variable interval of time, provided the button was still down, permission was given to release the button. If the button was released before this permission message was given, the trial was not completed. Consequences of button releases depended on the latency of the button release and on the operating conditions of the experiment at the time. The latency of the button release was timed from the permission message. Each successful latency produced a message to depress any key to increase the score. Each unsuccessful latency produced a message to depress any key to continue to the next trial. Figure 2 is like Figure 1, except it represents button releases and button depressions from completed trials and the latencies of these things done. Figure 1 shows the distribution of button releases and score increases across session time.

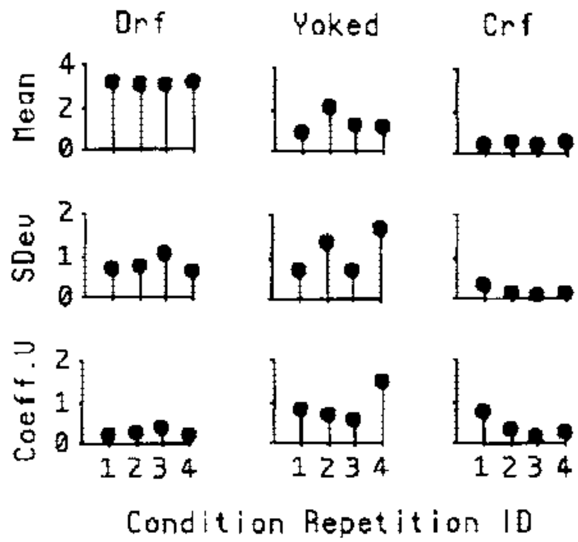


Figure 3. Means, standard deviations, and coefficients of variation (standard deviation divided by mean) for the four repetitions of each kind of condition: differential reinforcement ("Drf"), yoked intermittent reinforcement ("Yoked"), and continuous reinforcement ("Crf").

A first step in trying to understand the subject matter of this experiment is to develop a dot plot to represent key aspects of the data. Dot plots (e.g., Figure 2) are a first step in visualizing the data. They let us grasp the overall progress of an experiment and inspect its details. For example, Figure 2 indicates that latencies in the second yoked condition ("Y2") fell mostly into two bands, one band comprising latencies of less than one second, and the other comprising latencies of around three seconds.

Dot plots are rare in behavior analysis. For example, a review (Lee, in preparation) of research on intra-individual variation found only two articles that included dot plots (Millenson & Hurwitz, 1961; Notterman, 1959). Typically, large blocks of data, sometimes containing hundreds of data points (e.g., Lachter & Corey, 1982; Saslow, 1968), were summarized by means and other measures of central tendency, by standard deviations and other measures of dispersion, and by histograms. These statistics did not supplement dot plots. They supplanted them.

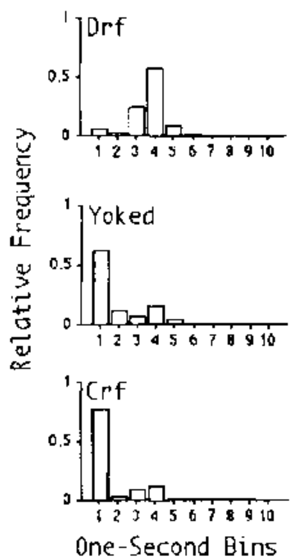


Figure 4. Relative frequencies of release latencies in each of 10 one-second bins for four differential reinforcement conditions, the four yoked intermittent reinforcement conditions, and four continuous reinforcement conditions.

It pays to reflect on what such statistics do to the data. Figures 3 shows examples for the data from Figure 2. Figure 3 shows means, standard deviations, and coefficients of variation. Several comments need to be made.

First, the statistics add nothing new. They provide only a quantitative statement of what the dot plot (Figure 2) already shows.

Second, in some cases the statistics misrepresent the data. For example, the standard deviations for Y2 and Y4, respectively, are 1.3 and 1.6, suggesting more variability in Y4 than in Y2. However, visual inspection of the dot plot (Figure 2) for release latencies indicates Y4 consisted of systematically increasing latencies followed rapidly by almost consistently short latencies with occasional outliers across the condition. In contrast, Y2 consisted of persistent alternation between two bands of latencies. For practical purposes (e.g., for shaping longer latencies), Y2 is more variable than Y4, despite what is implied by the standard deviation (and coefficient of variation).

Third, descriptive statistics put black boxes around large segments of the data. Black boxes make sense when they enclose the constituents of a subject matter. For example, in an investigation of the relations among things done, it

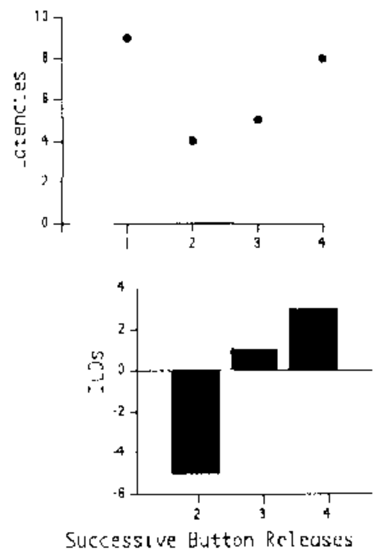


Figure 5. Latencies of four successive button releases (top graph) and the three corresponding interlatency differences (bottom graph). The first button release in a series has no interlatency difference.

makes sense to put a black box around the motions of a participant's body segments. Black boxes make no sense when they enclose parts of the subject matter, because they hide the analytic and conceptual demands of the subject matter.

Use of descriptive statistics seem unremarkable when the subject matter is conceptualized as the behavior of the organism. The statistics then facilitate the stated goal of operant research. It is to show that environmental variables control the behavior emitted by an organism. For example, in the present case, when reinforcers required longer latencies (Figure 4, Graph 1), latencies were longer and more dispersed. When all button releases were successful (Figure 4, Graph 3), latencies were shorter and less dispersed. This approach to data analysis seems concerned with maintaining a particular outlook rather than with using the data to learn about the subject matter represented by the data.

*Interlatency differences.* Suppose the data are accepted as representing the subject matter (rather than as evidence of the subject matter). Then, it seems reasonable to return to the dot plot (Figure 2) and to think about the particulars it represents. Data visualization software makes it easy to zoom in on segments

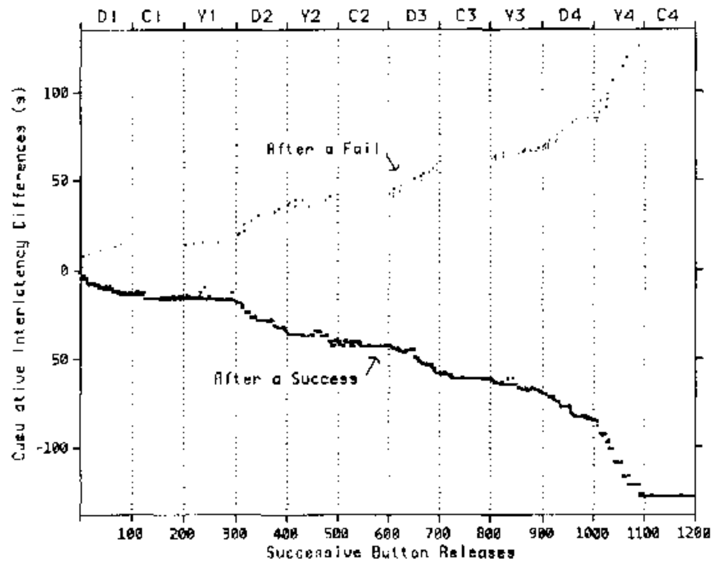


Figure 6. Cumulative interlatency differences across successive button releases. Vertical dotted lines indicate condition changes. Condition indicators are as in Figure 2. The data path in the top half of the figure represents interlatency differences after fails. The other data path represents interlatency differences after successes. When interlatency differences are cumulated, the data path moves upward when positive interlatency differences predominate, downward when negative interlatency differences predominate, and horizontally when interlatency differences vary narrowly around a local median of zero.

of a dot plot, as shown in Figure 1. Suppose we take four successive latencies as shown in the top graph in Figure 5. This display implies a property of the subject matter difficult to see in the more compressed version (Figure 2).

Each button release except the first has a latency (top graph, Figure 5) and an interlatency difference (bottom graph, Figure 5). An interlatency difference is the difference between a latency and its predecessor. For example, given two successive latencies of 2.5 s and 1.5 s, the successor latency has an interlatency difference of -1.0 s relative to its predecessor. Interlatency differences can be positive, zero, or negative. They are positive when the successor latency is longer than its predecesssor, zero when it is the same, and negative when it is shorter than its predecessor. The first thing done in a series does not have an interlatency difference, because it does not have a predecessor.

Another feature of the data is also not immediately apparent in Figure 2. It is whether a particular button release followed a success or a failure. A success

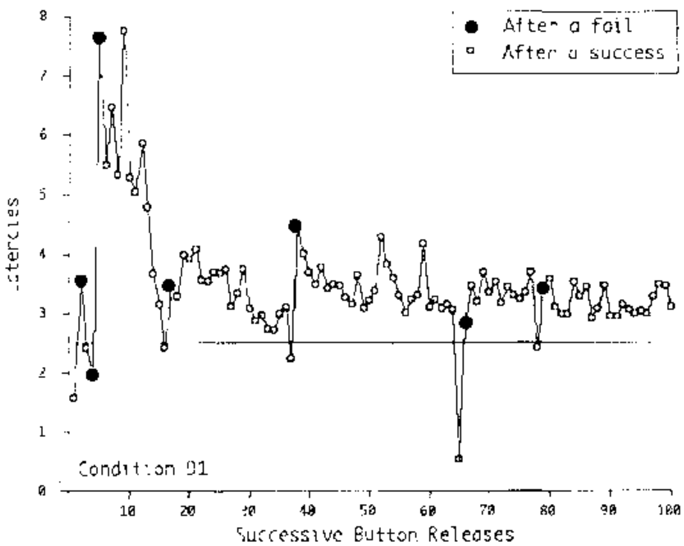


Figure 7. Latencies of successive button releases in the first condition. Filled circles represent latencies after a fail. Open circles represent latencies after a success. The data points are joined to highlight the difference between each successive pair of data points.

in this experiment was a score increase. A failure was a mere continuation to the next trial. Suppose we classify interlatency differences according to whether they followed a failure or a success and then plot them cumulatively to make visible any differences between the two classes of interlatency differences. Figure 6 shows the result. The two datapaths pull apart early in the experiment. Interlatency differences after a failure cumulate positively overall, and interlatency differences after a success sometimes cumulate negatively and sometimes vary narrowly around a local median of zero (i.e., horizontal sections of the bottom data path).

To check how this worked in a particular case, latencies from the first condition ("D1") are shown (Figure 7). The horizontal line on the graph indicates latencies of 2.5 s. Latencies below this line were failures. Each filled circle represents the latency of a button release that followed a failure. Each open circle represents the latency of a button release that followed a success. In all but one case, each latency after a fail was longer than its predecessor. Latencies after successes that followed the third, fourth, and fifth failures gradually decreased until the next fail occurred. Following the sixth failure, with one

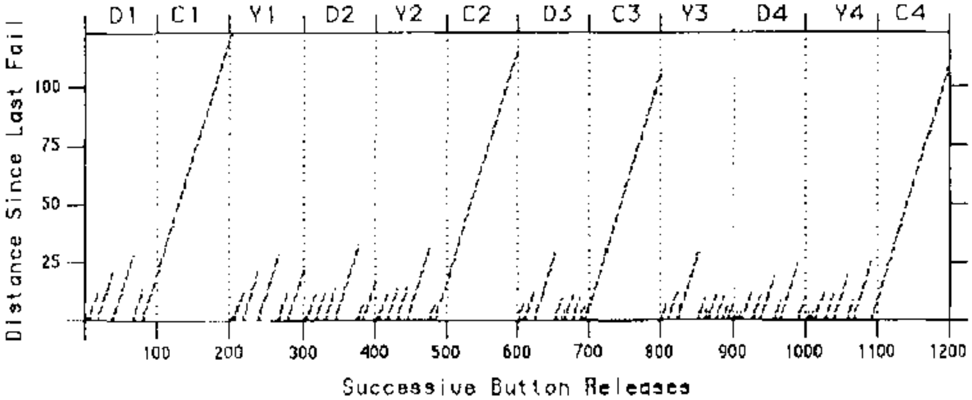


Figure 8. Distances since the last fail across successive button releases. Distance accumulates (1, 2, 3, 4, . . .) until a fail occurs, when the next thing done has a distance of one since the last fail.

exception, latencies after successes varied narrowly without an overall decrease being evident. To speculate: These data suggest participants who adjusted to this contingency waited longer after a fail and desisted from waiting increasingly shorter across successive successes. This is what such participants did, or, alternatively, these are the things done that adjustment to these contingencies consists of. This interpretation implies that an upper limit criterion (e.g, latencies less than 0.5 s) should have the opposite effect: Participants who eventually make few errors should wait shorter after a fail and desist from waiting increasingly longer across successive successes.

An interlatency difference, or more generally, a difference score, is a relational property of each thing done except the first in a series. Distance since the last failure is another relational property of each thing done; more exactly, of each thing done after the first failure. In the present experiment, if the immediately preceding button release failed, then distance since the last failure was one. If the immediately preceding button release was successful but preceded by a failure, then distance since the last failure was two, and so on. Figure 8 shows distances since the last fail across successive button releases. The lines are cumulative because distance since the last fail is a cumulative value. Distance accumulates (1, 2, 3, 4, 5, 6, . . .) until a failure occurs, when the next thing done has a distance of one since the last fail.

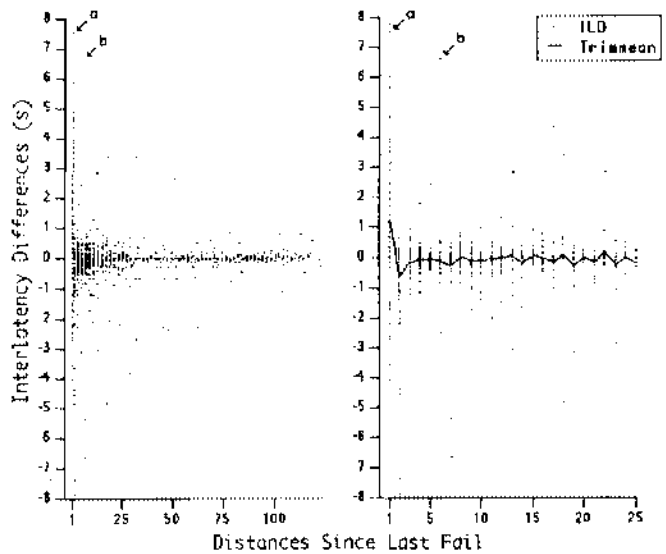


Figure 9. Interlatency differences plotted against distances since the last fail for all distances (left graph) and for distances from one to 25 (right graph). The arrows point to the same two data points in each graph to indicate relative data compression. Each interlatency difference is represented by a point. The line represents the trimmean (mean excluding the top and bottom 10 percent of the data).

Each button release except the first has an interlatency difference, and each button release except those before the first fail also have a distance since the last fail. The left graph in Figure 9 shows these properties plotted against each other for each button release that had both these properties. Interlatency differences were more dispersed at smaller distances since the last fail. They became less dispersed as distance increased. The right graph in Figure 9 is an expanded view of a segment of the same data. It shows dispersion of interlatency differences for distances from one through 25. The line drawn on the graph represents the trimmean of interlatency differences for each distance since the last fail. The trimmean was the mean excluding the top and bottom 10 percent of each set of data. On average, interlatency differences immediately after a failure were positive. Interlatency differences after a success that immediately followed a failure were negative. Trimmeans of interlatency differences at subsequent distances were typically close to zero.

Figure 9 is interesting because it implies a subject matter that consists of particulars (i.e., things done) that have properties (e.g., difference scores) that

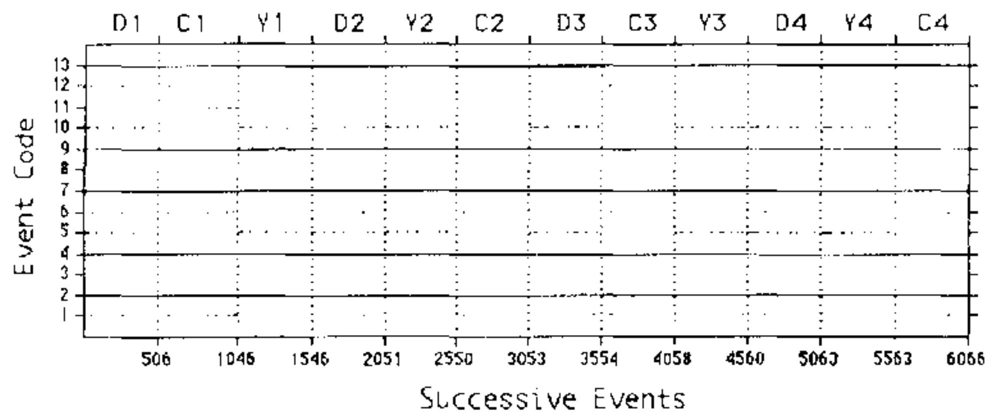


Figure 10. Event code plotted across successive events with condition changes indicated by the dotted vertical lines. Each point represents an event. The density of some classes of events gives the appearance of a line (e.g., event ID #13). Event classes were as follows: (1) reprimand message on, (2) button down message on, (4) key depression when reward message on, (5) key depression when continue message on, (6) key depression when neither reward nor continue message on, (7) button up message on, (9) reward message on, (10) continue message on, (11) button down while reprimand message on, (12) button down while reward or continue message on, (13) button depression in compliance with hold down message.

define classes (e.g., class of difference scores) that interact in, or relate to one other, in interesting ways. Figure 9 shows the interaction of two classes; the class of interlatency differences, and the class of distances since the last fail. The figure represents only things done, two relational properties of things done, and the relation between classes of these properties.

## Discussion

We should give up the central assumptions of traditional psychology. They are that the individual is the psychological unit, that the individual gives psychology a biological subject matter, and that psychology's subject matter therefore divides naturally and inevitably into behavioral and environmental parts.

We should replace these assumptions with three alternative assumptions. First, the thing done is the primary psychological unit. Second, the basic con-

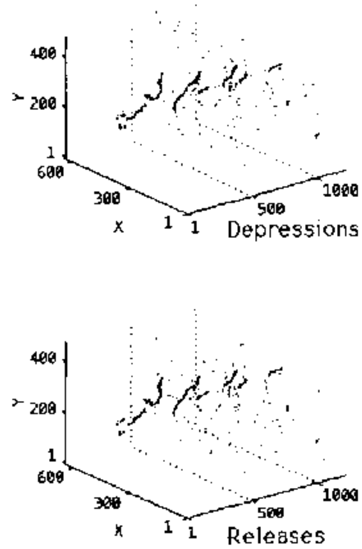


Figure 11. Horizontal (x) and vertical (y) coordinates of the cursor on the computer screen at each button depression (top graph) and button release (bottom graph).

stituents of a thing done are the individual and the thing the individual changes, which can be a part of the individual's body or an object (or a medium such as air or water) outside the individual. Third, the subject matter is a vast, densely-populated, and complex domain that contains things done, properties of things done, classes of these properties, and relations among these classes. These assumptions follow from the data, whereas the traditional assumptions follow from other considerations.

We should look at the data and conceptualize the items that the data represent. We should do this without feeling obliged to distort our conceptualization to make it compatible with traditional assumptions about psychology.

The data files show records of things done and include other information (e.g., current condition) useful for classifying things done. For example, the data files used to construct the present figures included records of the following events: button depressions, button releases, key depressions, the horizontal and vertical coordinates of the cursor at each button depression and button release, and the appearances of various messages on the computer screen. The experiment was designed so that all the recorded events, except the first message, depended on the biophysical agent (i.e., the participant) and on the computer

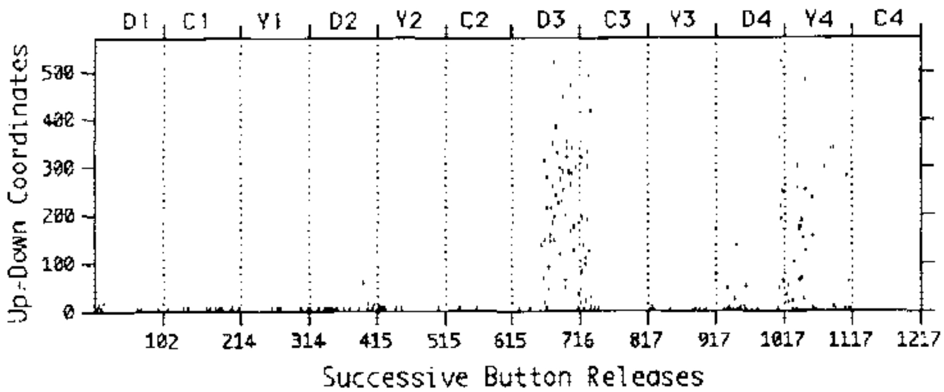


Figure 12. Absolute distance in pixels between the coordinates of the cursor when the button was depressed ("down") and when the button was next released ("up"). Horizontal and vertical coordinates were combined in calculating distances as follows (in pseudocode): distance = square root((absolute(xUpxDown)).^2 + (absolute(yUp-yDown)).^2).

hardware and software. For example, each button release depended on the participant and the button. Each change in the cursor location depended on the participant, the mouse, and the software that related changes in the physical location of the mouse to changes in the physical location of the cursor. Each increment in the displayed score depended on a key depression in the presence of the instruction to increase the score which depended in turn on a button release which depended in turn on the participant and the button.

Including contingent score increases and contingent changes in the cursor location as things done is difficult to understand from a traditional perspective. A button depression is usually classified as evidence of a behavioral event. A change in the cursor location and an increment in the displayed score are classified as environmental events. In fact, each example is an environmental change that depends, ultimately at least, on the participant and on the object changed. The change in the cursor location and the increment in the displayed score differ from the button depression only in having greater causal distance from the physical efforts of the participant. They involve a causal chain of things done (e.g., score increase contingent on key depression contingent on button depression) rather than only one thing done.

As already noted, the data files imply a subject matter that is vast, densely-populated, and complex. A first step in getting a handle on this subject matter is to develop preliminary visualizations of the data. A visualization should *compress*, rather than *summarize*, the data. Data compression produces abstract pictures of aspects of the things done during the experiment, whereas data summaries place black boxes around large segments of the data. The abstract pictures produced by data compression (e.g., Figures 6 & 8) make it easier to think about the subject matter in ways that have a logical, rather than only an intuitive, connection to the data and, therefore, to the abstracted events.

Figure 2, which shows the latencies of button depressions and button releases, is an example of a preliminary visualization. It compresses records of 2400 events. Figures 6, 7, 8, and 9 were developed by reasoning about features of the data implied by Figure 2 but not immediately visible in it.

Another example of a preliminary visualization is the event record in Figure 10. It shows all recorded events tagged by their time of occurrence. Like Figure 2, Figure 10 is a starting point for further data analysis. In this context, it illustrates the density and complexity of the things done in an operant experiment. The event record contains 6066 events across almost 89 minutes of session time.

Figure 11 is another preliminary data visualization. It shows the coordinates of the cursor across successive button depressions and button releases across session time. The figure is a starting point for further data analysis, as illustrated in Figure 12. Figure 12 shows the distance between cursor locations at a button depression and at the next button release across successive button releases. Each distance greater than zero represents a change in the cursor location that depended on the participant (i.e., a thing done). Figure 12 provides another starting point for further data analysis. In this context, the figure shows how data visualization software can make visible some of the things done during an experiment that otherwise go unnoticed.

The present figures use a fraction of the capacity of data visualization software (e.g., MATLAB(D). This software is powerful. It allows investigators to take a virtual walk through large sets of data. Investigators who try to use data visualization software with operant data face two problems. First, there are few precedents. Extant methods of data analysis in operant research are limited to cumulative records, now rarely used, descriptive statistics, and regression analysis. Second, the traditional framework has an intuitive, and not a logical, connection to the data. In fact, the traditional framework barely sees the data. It accepts as data only records of those things done (e.g., button depressions) that it interprets as evidence of responses. The traditional framework makes it difficult to do the thinking required to use data visualization software to see the subject matter of operant research.

I have argued we need a new conceptual framework. We need a framework that begins in a conceptual analysis of the abstractions represented by operant data. These things done are transitions that depend, ultimately at least, on a biophysical agent and on the thing or things changed. Things done, and not classes of the activities of an individual's body defined by things done, comprise the subject matter of operant research. This subject matter consists of intra-individual and inter-individual variation across successive things done. It includes the effects of successes and failures on what is done next. We need new analytic and conceptual tools to help us see and think about this subject matter. Identifying the abstractions represented by the data as things done is a first step. It has been objected that changing the way we talk about (and therefore think about) our subject matter will do nothing to advance the science of the behavior of the organism. There is no defence against this objection. However, changing the way we talk about, think about, and consequently look at our subject matter will advance a science of things done. And that is the only science warranted by the data.

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