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THE INSTRUMENTAL ROLE OF APPARATUS IN THE HISTORY OF PSYCHOLOGY

EL PAPEL INSTRUMENTAL DE LOS APARATOS EN LA HISTORIA DE LA PSICOLOGÍA

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Abstract

Apparatus has been, and continues to be, instrumental in the growth of psychological science. It has allowed both the control and measurement of things that otherwise could not be studied. Conceptually, it provides the basis for operational definitions of terms and constructs, and the data it generates is the impetus for both further experimentation and the articulation of organizing principles. Although its effects on a science are largely positive, it also can constrain scientific progress when it becomes simply a path of least resistance in generating data, or when it becomes an end for the activity of scientists, as opposed to the means to the end of advancing the science. Even when apparatus becomes obsolete, it remains a tangible reminder of the scientific practices and values of psychology of its time in the journey from 1879 to the present.

Key words: apparatus, control, measurement, apparatus and concepts, history of apparatus

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Resumen

El aparato ha sido, y continúa siendo, instrumental en el crecimiento de la ciencia psicológica. Ha permitido tanto el control como la medición de cosas que de otra forma no podrían estudiarse. Conceptualmente, provee las bases para las definiciones operacionales de los términos y los constructos y los datos que genera provén el ímpetu para realizar más experimentos y para articular principios organizadores. A pesar de que sus efectos son enormemente positivos, también puede limitar el progreso científico cuando se convierte simplemente en el camino con menor resistencia en la generación de datos o cuando se convierte en un fin de la actividad científica en oposición a ser un medio cuyo fin es avanzar la ciencia. Incluso cuando los aparatos se vuelven obsoletos, se mantienen como un recordatorio tangible de las prácticas y los valores de la psicología en su momento, en un viaje de 1879 a la fecha.

Palabras clave: aparatos, control, medición, aparatos y conceptos, historia de los aparatos

Apparatus has been a part of psychology since the first converts from experimental physiology brought with them into the new science their brass instruments of the time. Apparatus has been as humble as a piece of paper and a pencil or an inflatable Bobo doll (Bandura, Ross, & Ross, 1961) and as technologically sophisticated as a supercomputer. Its description in its own special section, institutionalized by the *Publication Manual of the American Psychological Association* (2009), in virtually every research article published attests to its importance. *How* it is important is the subject of this review.

Control and Measurement

Apparatus is like the starship Enterprise – it allows psychological science to go boldly where it has not gone before, to control variables that otherwise could not be controlled, and to measure things that otherwise would be either unmeasurable or measurable only with great difficulty. Controlling variables simply means arranging independent variables to occur in a systematic repeatable way across time. It is hard to imagine, for example, arranging many of the complex schedules of reinforcement that are used in the experimental analysis of behavior without absence of apparatus – most recently, digital computers – that can keep track of all of the nuances of programming reinforcers in time and in relation to behavior, and record the latter. The history of psychology is replete with other examples, from presenting visual stimuli for only milliseconds at a time to arranging systematic subtle differences in the brightness, hue, pitch, or chemical composition of a stimulus to delivering micro-amounts of a neurochemical to a specific brain location. Although apparatus enables scientific investigation, the best apparatus doesn't necessarily equate to the best science. There are many historical examples of technologically cutting edge labs where the scientific output has been below expectations. Great scientific work can be done with cutting edge technology, certainly, but it also is the case that such great work occurs with Rube Goldberg-like assemblages of instruments. Apparatus doesn't have to be elaborate or at the frontier. It merely needs be sufficient to allow the levels of control and analysis appropriate for the problems under investigation.

A major function of control apparatus is its role in demonstrating the direct and systematic replication (Sidman, 1960) of phenomena, by which the reliability and generality of behavioral phenomena are established. A question arises as to how similar apparatus needs to be across laboratories or experiments to yield reliability and generality of data. Similar or different effects obtained with repeated uses of the same apparatus can be telling evidence of the apparatus's reliability. If different effects are obtained with variations of apparatus while other variables are held constant, then there is reason to question the generality of the phenomenon under study. If, on the other hand, similar effects are obtained despite considerable variability in apparatus, then apparatus as a constraint on generality is ruled out, and, in fact, the generality of the phenomenon is expanded.

Constructing similar apparatus for studying similar problems contributes to the likelihood of reliability, as noted above. Structural consistency of apparatus can be achieved in different ways. The most common way is for investigators to either see the apparatus they wish to replicate or construct it based on the kind of written descriptions that appear in the scientific articles that have used such apparatus. Written descriptions of apparatus are quite variable in that section of research articles. Some contain commendable amounts of the detail needed to duplicate the apparatus, but all too often apparatus sections are superficial and rote, merely cut and pasted from previous reports with little attention to the need for apparatus replication. Using commercially manufactured apparatus is another way of achieving consistency across laboratories, but, even here, when described in apparatus sections information like model numbers are omitted.

Measurement also is a fundamental activity in science, and the complement to control. Like control systems, measurement systems range in complexity from counting on one's fingers to MRIs and beyond. One of psychology's first precision-measurement instruments, the Hipp chronoscope (Schraven, 1984), was used extensively in physics and ballistics testing before being imported into experimental physiology and from there to experimental psychology. In early psychology experiments, it was used to record reaction times occurring on the order of milliseconds, a precision obviously not achievable by human recorders. Recording the errors and speed of completion as rats moved through the Hampton Court maze introduced by Small (e.g., 1901) or as cats learned to escape Thorndike's (1898) puzzle boxes probably were sufficiently accomplished with a stopwatch and paper and pencil. Measurement of the speed of maze navigation, however, became far more precise, and perhaps even more objective, with the adoption of photocells combined with Hunter-type electronic timers.

A final observation with respect to control and measurement apparatus is that these items sometimes breaks down (cf. Skinner, 1956). Malfunctioning apparatus can be a terrible problem, for it means that data have been lost, time has been wasted, and advancement in understanding the problem under study is impeded. It also is the case, however, that a malfunctioning apparatus can reveal new dimensions of a problem and new insights as to the nature of the psychological processes under investigation not apparent when things were working normally. The significance of data generated when apparatus fails often depends on the investigator. If the failed data are considered an obstacle to the investigation, then they likely will be ignored and discarded. If, however, the investigator can see in apparatus failure the opportunity to learn something more about the behavioral processes under study, then such failures hold out at least the possibility of advancing the science in new and previously unconsidered directions.

Apparatus and the Shaping of Constructs

Apparatus often seems to be considered to be a passive participant in the research process, just sitting there spewing out data for researchers to ponder, crunch, and debate. An alternative view is that apparatus assumes a more active role in the shaping of a science. Apparatus is a part of an environment in which scientists work. If we assume, as behavior analysts do, that science is the behavior of scientists, and that behavior is shaped by the environment, then the apparatus, and thus the data it generates, assumes a far more active role in determining the shape of the science.

One way that this happens is through the definition of psychological terms and constructs. Before something can be studied, it has to be defined, whether the something is angst, learning, problem solving, play, prejudice, or self-awareness. One can't get very far in scientific analysis with a layperson's definition of these constructs, because such definitions lack the precision required to quantify them. A widely accepted way of defining a psychological concept is in terms of how it is measured. Boring's (1923) observation that "intelligence is what the intelligence test tests" illustrates the point. His proposal for an operational definition came at the end of a time when there was much confusion and many missteps in trying to identify what intelligence was, and is. Instruments are sometimes described as means to ends, as ways of tapping into the concepts that interest scientists. Thus conceived, the memory drum and its digital-technology offspring become tools for unravelling human memory. But what is this memory that the instrument is allowing us to study? The most common definitions are operational ones. Memory defined operationally thus becomes not a psychic or ethereal thing, but the outcome of the set of operations by which it is measured. Which places apparatus in a truly instrumental position. If memory is defined by its measurement, then, in a sense, the memory is the memory drum. Memory, then, isn't in the head, it is in the apparatus used to measure it – historically, the memory drum.

Science is organized around principles and concepts that either originate or terminate in observations of data, data collected via apparatus. Thus apparatus also is an important, often essential, link in the connections between data and concepts. It has been suggested that data are constrained by the world view or conceptual framework of the science. The very apparatus used in collecting those data are similarly constrained. Jenkins (1979), for example noted that "[i]t is hard to overestimate the influence of experimental arrangements on the shape of a learning theory. The maze, runway, and puzzle box do not suggest shaping, which is the operationalization of response-selection by reinforcement" (p. 200). The concept of the operant as a functional unit of behavior developed from Skinner's (1935) observations that different lever-press topographies could have common functional outcome – producing a reinforcer. Early psychophysical studies of mental life in the form of the relation between physical events and the psychological experience of those events were formulated based on the apparatus used to measure physiological reactions to stimuli by physiologists.

By the last quarter of the 20th century, digital computers were employed widely in psychological research of all types (cf. Chapanis, 1984). These computers were especially influential in the conceptualization of human cognition, where they provided a general organizing framework for such activity. Like early psychophysical research, many computer models were concerned with creating, or re-creating, the form or structure of human cognition based on the computer's structure. Thus, terms like hard-wired, core memory, storage, and the like became common concepts in discussions of human memory. Functional examples, however, also were derived from analogues with computer software. One was the distributed-parallel-processing model, by which a human's ability to concurrently process several lines of thought was conceptualized in terms of concurrent activities of digital computers (e.g., Rumelhart, McClelland, & the PDP Research Group, 1986).

It could be argued that there can an issue of primacy here: Which comes first, the apparatus or the world view? Apparatus determines the very data that the scientists use in constructing their particular view of the world. And the world view shapes the construction of the apparatus that is the lens through which the world is observed. Rather than considering one as the cause of the other, it may be more productive to consider the two as operating in an inseparable dynamic such that both evolve together over time. Dinsmoor (1988) noted this relation as follows: "(t)he abstract category 'response' serves an integrative function at the theoretical level, and in a somewhat different fashion the concrete instance of a switch closure serves to integrate the data at an empirical level" (p. 288). This symbiotic relation between apparatus and conceptual development in a science suggests that, far from being a passive, data-generating participant in scientific activity, apparatus plays a fundamental role in creating the very constructs that define the science.

Apparatus as Constraint

Few research areas in the history of psychology have advanced far in the absence of apparatus of some kind. Contrasting to this crucial, positive, effect of apparatus in advancing research are some constraining consequences of apparatus, what might be called the darker side of apparatus. One constraint associated with apparatus is its design. Apparatus often goes through a number of iterations before it is perfected to the point that it yields the desired data. Skinner (1956), for example, documented the evolution of his free-operant method from a runway for rats to his operant conditioning chamber. One could say that the research environment shapes the apparatus created by the scientist. A potential problem with commercially developed and manufactured apparatus is that it is not always under the control of the same contingencies that control the behavior of scientists. Keeping costs low, for example, is often a priority over quality and durability of a piece of apparatus. More importantly, many of the nuances of apparatus design requirements are not always available to commercial manufacturers in the same way that it is to bench scientists, as suggested above. In fact, some of the best psychological research apparatus has come from manufacturers with long histories of interacting directly with laboratory scientists. Two such companies that historically were exemplary in this regard were the Ralph Gerbrands Company and the Grason Stadler Company. The leaders of both of these companies had extensive experience in the psychological laboratories at Harvard University, working with the likes of B. F. Skinner and S. S. Stevens, respectively.

Apparatus can be detrimental to the conduct of scientific inquiry when the apparatus becomes not a means to an end, but the end itself. One way that this happens is when scientists settle into what might be labeled a comfortable routine once the scientific value of an apparatus has been established. A potential outcome of this is that there can be over-reliance on a single method of investigation, often involving one or just a few types of apparatus. Indeed, such reliance could be an extreme example of what Kuhn (1970) labeled normal science. Many contingencies converge to produce data, and data are quickly and efficiently produced with well-established methods by simply substituting new independent variables and examining their effects. There is much to be said for such an approach because it allows for a thorough analysis of the problem under investigation. There are costs, however, such as a narrowing of the field of inquiry and a slowing or abandonment of efforts to develop other apparatus that might be even more efficient and effective in scientific progress.

Another way that apparatus can constrain scientific progress is when the apparatus becomes more important than the question it is employed to investigate. Many a good scientist has been lost to the Lorelei of technology, the fascination with electronics or computers or whatever other apparatus might draw the scientist away from the scientific questions the apparatus was developed to study. Obviously, scientists require the technical skills to create and maintain the apparatus needed for their research, requiring a balance between technical and scientific acumen. Many scientists successfully maintain this balance to the advantage of advancing scientific knowledge, but others falter under the allure of the technology itself.

Apparatus as Living History

Lattal (2008) described a selectionist view of the life cycle of apparatus, which begins with the selective pressure to solve a problem related to scientific inquiry. The cycle ends with extinction, when either the problem that the apparatus was designed to control or measure falls out of vogue for whatever reasons, or more technologically sophisticated apparatus is developed to better control or measure than did the obsolete version. The path leading from psychology's past to the present is littered with abandoned apparatus. Indeed, much of it has been discarded, in the spirit of early-20th century American industrialist Henry Ford's famous quip about eschewing the past (which included the memorable phrase, "history is bunk") to focus on the present.

When they are preserved, these obsolete pieces of apparatus often are described as "historical artifacts," and regarded as physical by-products of times gone by in a science. Such a description seems a misnomer in light of the analysis presented herein. Given the important role of apparatus in the shaping of both data collection and analysis, and in the construction of concepts derived from the former activities, old apparatus seems ill-characterized as simply quaint, old-fashioned, or even oddball, "things." Rather, such apparatus seems more realistically, and usefully, considered as living evidence of the practices and values of the science of its times – a reflection of where the science was, both methodologically *and* conceptually, when the apparatus was "alive." Apparatus, old and new, is the physical embodiment of the trials, tribulations, failures, and successes of psychological science. As such, it is an instrumental element in the journey from 1879 to today.

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