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"Learning to stand tall: Idiopathic scoliosis, behavioral electronics, and technologically-assisted patient participation in treatment, c. 1969–1992."

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Abstract: Basing itself on the archives of American learning psychologist Neal E. Miller, this article investigates the role of instrumentation in the expansion and diversification of the behavior therapy domain from the 1960s to the 1980s. Through the case Miller's research on the biofeedback treatment of idiopathic scoliosis, it argues that the post-World War II adoption of electronic technology by behavioral psychologists contributed to extending their subject matter to include physiological processes and somatic conditions. It also enabled a technologically-instrumented move outside the laboratory through the development of portable ambulatory treatment devices. Using the example of the Posture-Training Device that Miller and his collaborators invented for the behavioral treatment of idiopathic scoliosis, this paper finally considers how electro-mechanical psychological instrumentation illustrated a larger and ambiguous strategic shift in behavior therapy from an orientation toward external control to one of self-control.

Key words: behavior therapy; electro-mechanical psychological instrumentation; biofeedback; portable training device; behavioral treatment of idiopathic scoliosis.

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1. Introduction

There is a well-noted paradox in the history of behavioral psychology: the downfall of the American tradition of objectivist psychology, behaviorism, during the 1960s and 1970s coincided with the growing implantation of behavioral approaches in various practical fields (Parot, 2008, p. 75; Baistow, 2001, p. 309). At the same time as the behaviorist conception of psychology was losing ground to cognitivism in academia, behavior therapy was gaining a foothold in clinical settings, especially in the United States and Great Britain. Subsumed under that heading were a host of diverse intervention techniques directed at changing "maladaptive" conducts, which were based on learning paradigms initially derived from Ivan Pavlov's conditional reflex research and the work of B. F. Skinner on operant conditioning. Despite the controversial aura of behavior therapy, which has often been equated with behaviorism (Amouroux, 2017), clinical psychologists and psychiatrists gradually integrated its techniques into their practices, first and foremost for the treatment of anxiety-related disorders (Buchanan, 2003). More significant, perhaps, was the gradual and parallel extension of behavior therapy beyond the confines of mental health institutions (Rutherford, 2003). In the United States, it spread from psychiatric hospitals, first into prisons and "therapeutic communities" for treating addictions, then, from the mid-1970s onwards, into the subject's "natural environment", including special education schools, households and the workplace.

Historical and sociological studies have started to analyze this dual, apparently paradoxical movement wherein the reach of behavior therapy extended into the everyday life of the sick and the well in spite of behaviorism's lost position as a dominant perspective in U.S. academic psychology. Karen Baistow, in particular, has pointed out that the enlargement and diversification of the domain of behavior therapy was made possible by a shift in its "social project" (Baistow, 2001, p. 315). From the late 1960s onwards, the social meliorism of behavioral psychologists shifted away from expertise claims to dispense "direct social control services" to that of helping people to help themselves (Buckley, 1989, p. 175 quoted in Ehrenberg, 2018, p.93; Smith, 1996). The tone was famously set by George A. Miller in his presidential address to the American Psychological Association in 1969, in which he suggested that, to have a social impact, and change, like Freudian psychology, the "public conception of what is humanly possible and humanly desirable", psychologists had to enable lay persons to practice psychology for their own benefit (G. A. Miller, 1969, p. 1066). In the context of a burgeoning cultural practice of psychodynamic psychotherapies, which, as pointed out by sociologist Alain Ehrenberg, was opening "the horizon of ideals" to "well-being through self-understanding" (Ehrenberg, 2018, p. 107), Miller's call to "give [positive psychology] away to the people who really need it" also echoed a more general wave of distrust of vertical and hierarchical patterns of power and authority (G. A. Miller, 1969, p. 1071).

As outlined by Karen Baistow, this strategic innovation was supported by theoretical renewals in post-World War II American behavioral psychology. Under the aegis of the "psychopharmacological revolution" and renewed interest in brain-behavior relationships, some psychologists trained in the tradition of behaviorism were moving closer to nervous-system scientists, while also opening up to the cognitive perspective on learning. Deviating from Skinner's radical variant of behaviorism, they extended the subject of learning psychology beyond overt behaviors and physical stimuli, to include motivation, beliefs and internal bodily processes, as well as social stimuli. In the process, some learning theorists,

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such as Alan Bandura, emphasized the "mutually shaping, transactional nature of the person-environment relationship" (Baistow, 2001, p. 312). These theoretical renewals supported an ongoing, broader and ambiguous shift in emphasis in the behavior therapy discourse from "external control" to "self-control". Historian Alexandra Rutherford and sociologist Nikolas Rose have both pointed out that the latter term did not necessarily entail a belief in one form or another of internal determinism (Rose, 1989, p. 241; Rutherford, 2009, chap. 5). In its most cautious uses, "self-control" referred to configurations in which the external variables supposed to control behavior were manipulated by the individual him/herself, rather than by the practitioner. At any rate, it was a manifestation of behavioral psychology's growing concern with "people's ability to control their personal environment", and with its supportive role in assisting personal change and self-management (Baistow, 2001, p. 311).

By articulating cultural history and intellectual history, historians and sociologists have convincingly demonstrated the strong parallelism between the expansion and diversification of the behavior therapy domain, the relative emancipation of behavioral discourses from the social project and methodological strictures of behaviorism, and the ability of psychologists to seize shifting cultural opportunities, such as changes in public attitudes toward expert-knowledge and technology or in the ideals defining American individualism. Within this landscape, the actual practices of behavioral psychologists have received scant attention (see however: Rutherford, 2003). Yet it can be claimed that the domain of behavior therapy was defined as much by its techniques and apparatus - media, paper-and-pencil instruments, scientific instrumentation and training devices - as by its underlying principles and representations. The growing applications of the techniques of "self-control" to personal problems in the 1970s, for example, have involved training the individual, either directly or through self-help books, in the use of self-monitoring techniques, such as recording the frequency of a behavior and its controlling factors and plotting the data collected on graphs. The price of the attention received to what psychologists said is too often the little attention paid to what they did, and through what material means.

This article aims to explore the role played by material practices and instrumentation in the shifting objects, settings and aims of behavioral psychology from the 1960s to the 1980s. Focusing on the psychological reception of advances in electronics, it examines how the development and use of electro-mechanical instruments have been involved in the invention of new ways of intervening on behavior. A central focus is "behavioral engineering". For mid-twentieth century American psychologists, this expression was not only metaphorical (Lemov, 2005). It was the name given to a technologically instrumented approach to the control of behavioral problems, whose defining characteristic was that psychological treatment was to be delivered in the patient's "natural environment" through portable training devices. From the late 1960s onwards, this original treatment modality has been applied, through prototypes or commercially available devices, to problems as diverse as stuttering, smoking, toilet training, and "bad" posture.

Based on the archives of learning psychologist Neal E. Miller, who developed a portable "Posture-Training Device" for the behavioral treatment of idiopathic scoliosis in the mid-1970s, this article examines the role of instrumentation in extending the domain of behavior therapy on three levels. First, I will relate behavioral psychologists' inroads into somatic medicine to changes in their material culture and instrumental practices. In tracing the origins of Miller's posture- training device to his experimental and clinical research on

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biofeedback, I will show that the post-World War II adoption of electronic technology by behavioral psychologists contributed to extending their subject matter to include physiological processes and physical health problems. Second, I will consider the expectation of psychologists to deliver behavioral treatment to patients in daily life settings. Here, I will focus on identifying some of the difficulties and hopes which have driven a technologically-instrumented move outside the laboratory. I will show that, for Miller, portable treatment machines came to embody a technological fix to remedy the relative lack of clinical efficacy of biofeedback by increasing the duration of training. Third, I will ask whether, and to what extent, behavioral instrumentation answered the shifting aims of psychology, especially the ideal of involving people in the process of learning to do something for themselves. Below the meta-discourse on self-control in the biofeedback field, the historical trajectory of Miller's Posture- Training Device reveals a configuration in which the responsibility for behavioral change was practically distributed between the patient, the apparatus and the experimenter.

I begin by outlining the field of "behavioral electronics" that emerged in the United States during the 1960s, to which biofeedback training and the related invention of this Posture-Training Device contributed. I move on to consider two phases in the development of this device: the design and construction of a pilot model by Miller and his collaborators at the Rockefeller University in the middle of the 1970s, and its reconfiguration during field trials conducted in the following years. Both moments serve to highlight and discuss some of the ambiguities and tensions underlying technologically-assisted behavior change discourses and practices: the equivocal meaning of the term "self-control" used in biofeedback training; the discrepancy between expected and scripted uses of behavioral devices and patients' representations and appropriations of them; the individualistic model of learning incorporated into hardware and the interpersonal context in which behavior modification actually took place. I conclude by suggesting that the Posture-Training Device was a technological embodiment of an ambiguous transition in behavioral psychology from "external control" to "self-control".

2. "Behavioral Electronics"

In the United States, the rapid advances in solid state electronics, telemetry and media technology in the mid-twentieth century caught the attention of some behaviorists and neuroscientists, leading to both instrumental developments and the formation of a psychotechnological imaginary (R. L. Schwitzgebel & Schwitzgebel, 1973). To designate this trend, we can borrow an expression coined in 1964 by Harvard-based behavioral psychologists and twin brothers Ralph and Robert Schwitzgebel: "behavioral electronics", which they defined as "the application of electronics to the understanding, maintenance and modification of human behavior" (R. K. Schwitzgebel, Schwitzgebel, Pahnke, & Hurd, 1964, p. 233).

In a programmatic paper, they called on their fellow psychologists to keep abreast of technical developments in the electronics and communication branches of electrical engineering. To them, it was around these technologies, rather than the pencil-and-paper one, that the "future of psychological instrumentation" was taking shape (Baker, 1968). In the two decades that followed the end of World War II, the miniaturization of electronics, the invention of the integrated circuit and the commercial availability of transistors had led to the development of improved hearing aids, the implantable pacemaker and wildlife radio tracking (Serlin, 2004). Like medicine, psychology would benefit from gaining an "engineering dimension" (Burnham, 2015, pp. 316–317): the ability to build smaller, lighter and cheaper instruments, capable of protracted measurements of bio-behavioral data and remote deployment, promised to open new fields of investigation, and a host of practical applications.

Moving away from mundane examples of behavioral electronics in laboratory settings to improve and automate experimental control (On the use of electro-mechanical technology by Skinner in the 1950s, see: Escobar, 2014; Escobar & Lattal, 2014), the Schwitzgebel brothers expanded the notion to include the use of electronics as an "aid to observation", but also in psychotherapy in the form of "interventional or prosthetic devices" or in "the direct control of behavior by restricting voluntary actions or by eliciting involuntary ones" (R. K. Schwitzgebel et al., 1964, p. 233). Contemporary uses of closed-circuit television and video-tape replay to observe the psychotherapeutic encounter fell within this domain (Lindsley, 1969), as did teaching machines (Rutherford, 2003, pp. 7–12), and the stimoceiver. The latter device was developed in the 1960s at Yale University by neurophysiologist José Delgado to search for correlations between electrical brain patterns and spontaneously occurring or provoked alterations of behavior and emotions. It combined a multichannel radio stimulator, which delivered electrical impulses to selected targets in the brain through surgically implanted electrodes, with a telemetry receiver connected to an EEG recorder. With the stimoceiver, exploration of the brain could be conducted outside the EEG recording room, in "the relatively normal environment of the hospital ward and during spontaneous social interactions" (Delgado et al., 1968, p. 339). Delgado further argued that the small size of the device ensured that it could be "worn comfortably and permanently by the patient", making her "continuously available, day and night, for intracerebral recording or treatment" (ibid., p. 339)

Delgado's neurotechnology hinted at what the Schwitzgebels conceived to be behavioral electronics' most promising potential, namely its ability to extend the spatial and temporal reach of observation and intervention beyond the confines of the laboratory or the hospital. This was the path they took in their own venture into psychological instrumentation development. In the 1960s, the brothers designed a "Behavior-Transmitter Reinforcer" to experiment with the supervised monitoring of parolees. Seeking to provide an alternative to incarceration for "adolescent delinquents", they conceived a belt-worn device capable of transmitting information about the offender's whereabouts to recording equipment placed in a laboratory base station (R. L. Schwitzgebel & Bird, 1970, p. 99). They considered that continuous remote monitoring would bring both a parolee rights gain and an epistemic gain (Nellis, 2012; Chamayou, 2014). Offenders would be allowed to live with their kin, while scientists would be able to amass data on the day-to-day behavior of individuals to study it. But the purpose of electronic surveillance was primarily "assisting behavioral change" (R. K. Schwitzgebel et al., 1964, p. 235). A second functionality of the device was that the psychologist could communicate with the wearer by sending him/her audio signals from the base station. "[A]rranged into 'behavioral feedback' systems" (ibid., p. 233), these signals could be used either to warn the wearer for signs of risky behavior or to reward him for positive behavior. Feedback of information to the wearer, it was hoped, would result in a smoother and more sustainable mode of behavior modification than more coercive interventions.

In the 1960s, similar devices were on the engineering drawing boards of behavior therapists. Following the early example of the bedwetting alarm, a device invented in the late 1930s for the behavioral treatment of nocturnal enuresis in children (Doroshow, 2010), they were experimenting with the use of small, portable electromechanical devices to deliver therapy to patients in ambulatory settings. Psychiatrist Joseph Wolpe, for instance, used a portable shock apparatus with electrodes attached to the wrist to assist the conditioned inhibition of craving in drug addiction (Wolpe, 1964). Likewise, behavioral psychologist Nathan H. Azrin designed a cigarette case incorporating operant conditioning principles to reduce smoking (Powell & Azrin, 1968). Ear- and wrist-worn devices that produce a rhythmic beat were developed to reduce stuttering (Meyer & Mair, 1963). This approach to behavior change by portable training apparatuses became known as "behavioral engineering" (Azrin, Rubin, O'Brien, Ayllon, & Roll, 1968).

This electronic-based "psychotechnology" was "an innovative intellectual enclave straddling the border of behaviourism and neuroscience" (Nellis, 2012, p. 166). Compared to the flourishing field of medical electronics, which by the mid-1960s had already established a network of laboratories, national and international professional forums, and was lavishly funded by the monies of philanthropies and industries, behavioral electronics was little developed. The boldest visions of behavioral engineers were hampered by the state of technology, and their realizations mostly consisted in prototypes and speculative experimentations. Yet, these prototypes incorporated and materialized innovative ideas about how to intervene on behavior, including behavior related to physical rather than mental health problems.

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3. Visceral Learning: Neal E. Miller's Venture into Behavioral Electronics

The development of behavior therapy and applications of electronics coalesced in the laboratory of prominent learning psychologist Neal Elgar Miller's (1909-2002) in the 1960s, when he undertook a program of experiments on the acquired control of the autonomic nervous system. From that point, and way beyond retirement, Miller would dedicate a substantial part of his work to relating learning psychology with physiology and medicine. Thus doing, he contributed to the emergence and development of a new interdisciplinary field of inquiry and clinical intervention that, by the 1970s, became known as "behavioral medicine", whose first therapeutic incarnation was biofeedback training.

The starting point of Miller's late research venture was a program of experiments conducted under the heading of "visceral learning" first at Yale, then, from 1966, at the Rockefeller University, in which he used instrumental or operant conditioning procedures to teach animals to make changes in vital life processes that are ordinarily regulated by the autonomic nervous system, such as salivation or heart rate. These glandular and visceral responses were reputed to be subject only to classical "Pavlovian" conditioning. Miller hypothesized that they could, in fact, be trained like any other behavior mediated by the somatic nervous system through trial-and-error learning to become goal-directed responses.

In tackling the problem of operant conditioning of visceral responses, Miller was pursuing an old hunch of his, that there was "a fundamental unity in the learning process" and its neurophysiological bases.[1] In keeping with the research program of neo-behaviorist thinker Clark L. Hull, his teacher while he was a graduate student at the Yale Institute of Human Relations in the 1930s, Miller was convinced that all types of learning paradigms obeyed similar laws, spanning different domains of "behavior", including psychomotor behavior and mental acts pertaining to thinking, understanding and remembering (Coons & Leibowitz, 2010, p. 102). This belief underlied his attempt to bring learning theories to bear on thought processes and behavior relevant to psychotherapy. After having spent a year as a postdoctoral fellow in the Psychoanalytic Institute in Vienna in 1935, he joined forces with sociologist John Dollard to examine and ultimately explain Freudian phenomena, such as conflict and frustration, from a learning perspective (Dollard & Miller, 1950).

Miller's visceral learning experiments extended this dual quest to medically relevant physiological response, and further built on the psychophysiological turn taken by his investigative style in the 1950s. At that time, research in his laboratory was directed toward testing the drive-reduction hypothesis of reinforcement. Originally formulated by Hull, the strong version of this hypothesis held that needs, such as hunger, sex, pain and fear, drive or motivate the organism to action, and that drive-reduction was the only kind of reinforcement through which learning occurred (N. E. Miller, 1957, p. 1271). To test this hypothesis, Miller and his students started combining behavioral techniques with physiological techniques, including electrical stimulation of the brain. Based on the assumption that reactions elicited by electrical stimulation in hypothalamic structures could have "all of the functional properties" of a drive and motivate the learning and performance of instrumental responses (N. E. Miller, 1957, p. 1276), they teamed up with Delgado, and committed to learn the ins and outs of physiological electronics (Delgado, Roberts, & Miller, 1954). As recalled by Miller, they learned the hard way how to solve "petty but crucial problems, such as keeping the skull absolutely dry, making a small but rigid straight electrode, insulating it effectively, and plugging it into a cable to the stimulator" (N. E. Miller, 1992, p. 291). In his laboratory, the apparatus thus more and more revolved around transducers, amplifiers, physiological monitoring apparatuses and solid-state programming equipment.

In the early 1960s, these various strands of research coalesced in "visceral learning" experiments. Having read the English translation of *The Cerebral Cortex and the Internal Organs*, in which Russian physiologist Konstantin M. Bykov summarized his work on the classical conditioning of the autonomic system (Bykov, 1957), Miller undertook to demonstrate that laboratory animals could also learn to increase or decrease their heart rate to obtain a reward, just as they learned how to press a bar to get food (N. E. Miller, 1961, pp. 834–835). First conducted on dogs, then on rats paralyzed by curare and maintained under artificial respiration, these experiments involved the monitoring of the targeted autonomic function, as well as reinforcement for every change in the desired direction, either by stimulation of a "pleasure center" in the brain or by escape from electrical shocks to the tail. As the rewarding of small spontaneous fluctuations was repeated, the rat, it was hoped, would learn to make larger changes, until, eventually, a continuous low heart rate was achieved.

In 1967, Miller and his collaborators started reporting that rats could indeed learn to make bigger and bigger changes in various bodily functions- ranging from heart rate and blood pressure to intestinal contractions, that this learning could persist, without further training, over a period of three months, and that it could be quite specific (N. E. Miller & Carmona, 1967; N. E. Miller & Dicara, 1967; DiCara & Miller, 1968a, 1968b). A singular example of this specificity was that rats, which had been rewarded for differences in the vasomotor responses in the two ears, had learned to blush in one ear and blanch in the other at the same time (DiCara & Miller, 1968c).

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Miller quickly drew out the implications of these striking results, not only for learning theory, but also for the analysis and treatment of psychosomatic symptoms and organic malfunctions. In an article published in *Science* in 1969, he suggested that a technique similar to that developed during the experimental work on animals "should be well worth trying" with patients suffering from "any symptom, functional or organic, that is under neural control, that can be continuously monitored by modern instrumentation, and for which a given direction of change is clearly indicated medically - for example, cardiac arrhythmias, spastic colitis, asthma, and those cases of high blood pressure that are not essential compensation for kidney damages" (N. E. Miller, 1969, p. 444).

Even through, as early as 1971, investigators in Miller's and other laboratories encountered difficulties in replicating results[2], their research, which received widespread media coverage (Ched, 1971; Luce & Peper, 1971; Jonas, 1972), and secured funding from the National Institute of Mental Health, lent a measure of scientific legitimacy to biofeedback (fig. 1). Subsumed under that heading was a group of procedures already under development, in which electronic equipment was used to monitor the ongoing activity of a bodily function, amplify and process the input signal, and display the resulting information to the human subject. Through exposure to this usually unavailable biological information, and additional training, individuals were expected to gain direct or voluntary control over bodily processes commonly thought to be involuntary.

From the late 1960s onwards, biofeedback struck the imagination of behaviorally inclined psychologists, clinicians, unorthodox healers and lay persons alike. To some, as outlined by historian Anne Harrington, it was an offshoot of research conducted in the learning psychology laboratory. To others, it rather was an outgrowth of body-control techniques mastered by Yogis and Eastern mystics for centuries, or a revolutionary breakthrough in the field of parapsychology (Harrington, 2008, pp. 166–167). Regardless of the emphasis, it was seen as a "powerful research tool" to manipulate and study "specific physiological processes"(Schwartz & Beatty, 1977, p. 2), which also held strong clinical potential, and was indeed tried as an experimental treatment in an ever-expanding range of medical conditions.

Clinical applications of biofeedback also coincided with its definition and popularization among the public as a *self-control* technique (Barber et al., 1971). What precisely that term meant to its different users was far from clear. Its meanings and connotations varied depending on whether the mechanisms underlying biofeedback were interpreted in mentalist or behaviorist terms, as involving some internal process reflecting the persons' will, aims, and intentions, or conditioning by the environment (Black, Cott, & Pavloski, 1977). There was, however, an ethical sense of the word on which most promoters of biofeedback agreed early on. According to them, one of its main merits was that the patient would no longer be the passive recipient of treatments dispensed but become an agent of his or her own health status. As put in 1973 by psychiatrist Lee Birk in his introduction to one of the first academic books on biofeedback:

> "[I]t is perhaps not an exaggeration to point out that a new 'behavioral medicine,' biofeedback, now still in its infancy, may in fact represent a major new developing frontier of clinical medicine and psychiatry. Medicine, of course, for centuries has relied on only four major curative mechanisms: aiding and potentiating the body's (or the mind's) natural recuperative powers; pharmacologic mechanisms; surgical interventions; and the effect of person, from 'bedside manner' to transference. Now, with the

development of behaviorally derived techniques of demonstrated effectiveness, capable of bringing previously involuntary bodily functions under voluntary control, it appears we have in hand the makings of a fifth major mechanism for psychiatry and medicine, a behavioral control mechanism, in which the patient can, for the first time, take a fully active and direct role in literally learning not to be sick (p. 2)".

4. The Art of Correction Revisited: From Passive to Active Orthosis

From 1969 onwards, Miller also transitioned from several decades of "rat psychology" to clinical biofeedback. After having tried to train therapeutically patients with cardiovascular and neuromuscular disorders, his team moved into the field of orthopedia in the mid-1970s. As early as 1743, the French physician Nicolas Andry de Boisregard defined orthopedia as "the art of preventing and correcting body deformities in children", insisting on the use of non-surgical means. In the book he dedicated to the subject, this purpose and approach were illustrated by the famous engraving of a young twisted tree tied to a pole to straighten it, which later became the emblem of the modern medical specialty of orthopedics. Likewise, Miller and the psychologist Barry Dworkin, who had been collaborating in attempts to replicate visceral learning experiments, focused their work on the early, non-surgical treatment of idiopathic scoliosis.

For mid-twentieth century orthopedic specialists, the term scoliosis referred to a lateral deviation of the spine with vertebral rotation. The deformity was known to have many possible causes, including congenital vertebral anomalies, paralysis in poliomyelitis and spinal tuberculosis. In many cases, however, the cause was unknown (Shands & Raney, 1940, p. 333). This type of scoliosis, which occurred in otherwise healthy subjects, was called idiopathic. It was considered to be a condition of the growing child, especially girls, and further subdivided according to three peak periods on onset into infantile (before the age of 3), juvenile (5 to 8 years of age), and adolescent (age 10 until the end of growth) (James, 1954). By the 1960s, as the development and widespread distribution of antibiotics and vaccines promised to rid the United States of infectious causes of spinal deformities, the adolescent form had emerged as the commonest, fostering the conversion of existing school posture examinations into statewide spinal screening programs (Linker, 2012, p. 611). The objective of scoliosis screening was to catch idiopathic scoliosis early enough, before symptoms emerged, so that early treatment may be initiated, and eventual surgery prevented. Although the exact nature of the health threat posed by idiopathic scoliosis was unsettled among specialists, this strategy, as shown by historian Beth Linker, was predicated on the assumption that "curves would increase and become ever more severe if left untreated" (ibid., p. 613). By the early 1970s, early treatment involved protracted intervention, usually through exercises and bracing, and aimed at retarding and halting progression of curvature until the patient reached skeletal maturity. Toward that same end, the Rockefeller psychologists developed a special orthosis (fig. 1). Called the Posture-Training Device (hereafter PTD), this electro-mechanical artifact incorporated behavioral principles, and took the form of a dual body harness connected to a small box.

FIGURE 1

The rope tying the twisted tree in the allegory of orthopedia represented a purely mechanical model of intervention, by external restraint of a passive subject. While vaguely evocative of the rope, the two harnesses that ran around the patient's body vertically and horizontally in the PTD were obviously not intended to physically force the spine into position. These flexible components rather provided measurements for feedback, with the purpose of harnessing "the active cooperation of the patient" in the treatment process, through changes in his or her informational environment.[3]

The working principle of the PTD had been derived from conjectures about the mechanisms of actions of the Milwaukee brace. This bracing system was originally developed in the 1940s by Walter P. Blount and Albert C. Schmitt, two orthopedic surgeons practicing at the Milwaukee Children's Hospital (Blount, Schmidt, Keever, Dudley, & Leonard, 1958). Its components had been continuously redesigned, but it basically consisted of three metal bars that rose from a pelvic module to a neck ring, and to which pads were attached. This bulky full torso brace was first used in the operative treatment of polio patients to obtain correction before and after surgical fusion of the spine. When the "war on infectious diseases" seemed winnable in the late 1960s, Blount and his fellow orthopedic surgeon John H. Moe redeployed this brace in the non-operative treatment of idiopathic scoliosis, and actively disseminated its principles to other specialists (Linker, 2012, p. 212; Blount, 1964; Moe, 1971). As far as its mechanism was concerned, correction was theorized to occur through the combination of a passive and an active mechanism: the application, via pad pressure, of mechanical forces on the apex of curvature, and the inducement of self-elongation in the patient, who used her muscles to stretch vertically, so as to pull her body away from the uncomfortable neck ring and pads (Blount, 1964, pp. 364–365).

The Rockefeller psychologists readily embraced this interpretation of the Milwaukee brace's action, as it provided them with an entry point into a behavioral redefinition of scoliosis treatment. The "patient's willingness to actively adopt the posture […] prescribed" by the brace could thereby be understood as an example of behavior, in the sense of an

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adaptive response of the organism to stimuli or sensory inputs (B. R. Dworkin, 1982, p. 48). In that way, the Milwaukee brace could be brought into the realm of biofeedback, in which acquired control over bodily responses was thought to be dependent on their association with external sensory consequences. In 1975, Miller, submitting a grant request to the National Institute of Mental Health, spelled out this understanding:

> "[I]t seems plausible to the investigators that the function of the Milwaukee brace may be to provide cues of increased pressure on the pressure points to inform the cooperative child of a poor posture and to motivate her to straighten up. If this is the case, we thought that a similar function might be performed equally well, or conceivably even better, by a much less cumbersome and less cosmetically disfiguring device for training the postural behavior of the child."[4]

In other words, the sensory consequence of straightening up, that is relief of discomfort and pain resulting from pressure points, was understood as a diffuse feedback signal for good posture. The Rockefeller psychologists reasoned that using more salient cues to provide patients feedback could serve as a "reinforcement" in instrumentally learning to "stand tall" (N. E. Miller, 1975, p. 7), which they related to learning to straighten the underlying curvature.

Thus, "the general idea [was] to give the subject a signal whenever he is in poor posture and to have the signal turned off whenever he achieves good posture".[5] It was technologically implemented trough means of both mechanical and electrical engineering. In its earliest embodiments, the PTD consisted of two body harnesses: a vertical one running around the longitudinal axis of the body, to measure distance between the pubis and the shoulders, and a horizontal one measuring torso circumference. At the intersection of both harnesses, a small unit, mounted on the chest of the patient, housed a mechanical switch system. Its function was to subtract a fraction of chest expansion, due to respiration, from the lengthening of the vertical harness to "yield a pure measure of [height], free from artifact, which was related by Miller and Dworkin to the degree of curvature.[6] This unit also housed electronic integrated circuits that activated a tone signal when the special switch was closed by incorrect posture. Straightening the spine until a predetermined criterion of success was reached terminated the tone, providing the patient with an indicator of good posture. An electrolytic timer, later replaced with a digital system, completed the device, and recorded the total time spent by the patient in correct posture relative to the criterion.[7]

5. From the Lab to Daily Life

The PTD did not emerge in a single block from the Miller, Dworkin, and their physician collaborators' thinking about a behavioral treatment of scoliosis.[8] The "postural training approach"[9] it came to embody in a compact, portable form was initially tried by Dworkin and his wife, Susan, at the Rockefeller University Hospital on scoliosis patients, using cumbersome apparatuses, such as a pneumograph, a Grass polygraph and associated feedback equipment.[10] This set-up was reminiscent of the allegory of orthopedia, in which the tree, "denied self-motion", "stands still, fixed and rooted," here carrying the idea of a patient contained in a place, rather than an ambulant one (MacDonald Cornford, 1997, p. 303).

Following exploratory work, the objective quickly became to develop an automated and portable unit, capable of accomplishing the exact same functions as the laboratory-based set-up, but light and "durable enough to make its way through the world of the body of a teenage girl” (B. R. Dworkin, 1982, p. 51). This move into daily-life settings, here accomplished through miniaturization and automation, primarily reflected the temporal, rather than the spatial preoccupations of the investigators. Some orthopedists thought that, to be successful in halting progression of curve in idiopathic scoliosis, the Milwaukee brace required full-time wear (Moe, 1971, p. 30). Taking this brace as a model to be surpassed, the Rockefeller psychologists found it necessary to develop a portable device, which would extend posture measurement and feedback in space so as to achieve continuous training. Furthermore, they gradually extrapolated their work on the treatment of scoliosis to the difficulties encountered in fulfilling the clinical promises of biofeedback, maturing the idea that use of continuous recording and training devices held considerable potential to improve the efficacy of learning in this and other forms of behavioral treatments.

The development of the PTD in the mid-1970s coincided with a critical appraisal of clinical applications of biofeedback training. Motivated, in large part, by the concern that over-optimistic conclusions and exhilarated claims made along a cycle of hype and hope by both orthodox scientists and “para-scientists” would eventually lead to a wholesale rejection of this therapeutic modality, the biofeedback community undertook evaluation efforts. In 1974, for instance, psychologists Edward B. Blanchard and Larry D. Young published a review of reports on clinical biofeedback in the *Archives of General Psychiatry.* The authors argued that only in a few areas, including muscle retraining in paralyzed patients and treatment of tension headache, did “the evidence support strong conclusions on the efficacy of biofeedback training” (Blanchard & Young, 1974, p. 573). By contrast, they were relatively unimpressed with the results obtained in studies conducted in the cardiovascular area. Many of these studies were conducted with normal subjects, for a short period of time, and yielded

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"relatively small-scale changes in the response under study" that had no evident clinical value (ibid., p.579). They concluded that "wholesale therapeutic application of biofeedback techniques" was unwarranted, for these techniques were still unquestionably experimental (Blanchard & Young, 1974, p. 588).

Miller was well aware of these difficulties. For his team, the transition from research in the laboratory with curarized rats to therapeutic training of patients in medical settings had been challenging as well. The changes observed during training in the only two patients with cardiac arrhythmia they were able to secure were conservatively interpreted as "spontaneous fluctuations."[11] Likewise, by 1973, Miller could not but find that training patients "in the early stages of essential hypertension to lower their blood pressure [...] was difficult and certainly did not work in all cases[12]". Not disheartened, Miller and Dworkin began thinking about the factors that might improve the effectiveness of biofeedback training, starting with the "traditional parameters" of learning, "such as spacing of trials, length of training sessions, strength of drive, delay or rewards, and effects of instructions", and also considering other variables, such as "the rate, type and modality of feedback" (N. E. Miller & Dworkin, 1977, p. 149). They eventually concluded that one of the major problems preventing biofeedback from fulfilling its therapeutic potential was temporal in nature:

> "Compared with the amount of time required instrumentally to learn high levels of motor skill, such as juggling, tennis, or playing the violin, the number of hours spent on most forms of biofeedback is minuscule. [...] But the evidence from such skills is that control over skeletal muscles can continue to be improved by long periods of practice. Sometimes, plateaus can make one think that a limit has been reached but, if practice

continues, further improvement might be achieved."(N. E. Miller & Dworkin, 1982, p. 145?)

So reformulated, the efficacy problem could be approached through technological means already being experimented by behavioral researchers: carrying therapeutic training into daily life settings through portable devices would extend its duration. It could thereby also be branched to the problem of transfer of learning from the clinic to the life situation (N. E. Miller & Dworkin, 1977, p. 145). Made possible by portability, continuous feedback did not in itself ensure that the learned response would persist after the reinforcement for it was withdrawn. It merely obviated the problem. But the Rockefeller psychologists thought that by embedding conditioning procedures in training devices, such as those used in avoidance learning, responses could "become extremely resistant to [such] experimental extinction", up to the point that the patient may be "weaned" from the device.[13]

To them, the PTD, aside from its specific purpose as treatment for scoliosis, came to embody a technological fix to problems in the biofeedback field. It further acted as a template to envision a future of electronic-based behavioral interventions in medicine and health. In 1982, at a conference on the "Applicability of New Technology to Biobehavioral Research", Miller shared his optimistic and, to some extent, clear-sighted thoughts about the possibilities offered by exploitation of advances in engineering, electronics and computing:

"One obvious use is simply to collect better data to help in monitoring operations, reactions in intensive care units, or therapy by drugs or behavioral interventions. A related use, especially of ambulatory equipment, could be to help the physician to discover and his patients to become convinced of the relationship between a physical symptom, such as high blood pressure, and the emotional response elicited in certain

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situations. [...] Another use of ambulatory equipment will be as portable biofeedback training devices [...] Such a device will have two advantages: it will allow longer periods of training, and these can be in the life situation instead of only in the clinic" (p.323-333).

In Miller's enthusiasm for behavioral electronics, one may read much more than a fancy for beeping and blinking gadgets. Behavioral engineers seem to have understood something of the lesson once taught by Bruno Latour to STS scholars about how experimental acquisitions circulate in the social body and become effective in it. In his historical account of Pastorism, Latour called attention to the spatial dimension of the dynamic of knowledge. He argued that the transfer of scientific knowledge from the laboratory to social spaces that previously had nothing to do with the science rested on the spread of artifacts and the "extension of lab practices" (Latour, 1983, p. 155), across a "supportive infrastructure or network" (Golinski, 2005, p. xii). Likewise, portable training machines, which ensured the semi-automated delivery of embedded conditioning procedures, can be understood as a means of extending laboratory conditions in the "real world", i.e. by consistently imposing on the patient a particular informational environment in order to modify and maintain his or her behavior. However, for them to work, such devices had yet to be worn by patients while away from the laboratory or clinic. The difficulties encountered in feasibility trials of the PTD suggest that protracted use of behavioral artifacts along expected lines would be far from obvious.

6. Recalcitrant Patients

Access to scoliosis patients was initially obtained through orthopedic surgeon Gordon Engler from the New York University School of Medicine. In 1974, he referred a teenage girl who had already been wearing a Milwaukee brace for several years to the Rockefeller University Hospital. After exploratory work, she was given a pilot model of the PTD to be worn two hours a day during ordinary activities. As she explained in a letter to the psychologist of January 21 1975, she "usually planned to wear the device when [she] went out to places, places where [she] saw people", at church, basketball games and other events. "And it was a pretty good feeling to be seen by someone, and for them to not know that you're wearing anything like a brace." In addition to the relative discretion of the device, she singled out two other advantages over the Milwaukee brace: "[t]here is more freedom of movement, it's not as hot […] all of which are very important to me."[14] The prescribed time of wear gradually increased to "5 to 8 hours a day for over 7 months" in July 1975, and was likely higher when the field test stopped around the spring of 1976.[15] In a letter of March 17 1976, Miller tried to offer her words of consolation:

> "We are glad that your use of this early version of the device was able to buy some time away from the Milwaukee brace. We regret that it did not seem to be completely successful in dealing with the particular curve type that you have. If, as we hope, the device with the improvement we have been able to make as a result of your cooperation turns out to be successful with other types of curves started earlier in their course of development, you will have every right to feel that you have made an important contribution in helping these girls to control their condition in an easier way."[16]

As suggested by this letter, the psychologists had encountered several problems while working with this and another patient, who was "not yet needing a Milwaukee brace" by the time of her referral by Engler to the Rockefeller University Hospital around 1975.[17] The patients' perception and handling of the device had brought to light both procedural and mechanical flaws in its design. An early difficulty appeared when the first patient turned out to be irritated by the tone onset. Her feelings drew the psychologists' attention to the shortcomings of an ambivalent feedback system. While tone offset was intended as a reward for correct posture, immediate tone onset technically was an "aversive stimulus contingent upon incorrect behavior – a punishment" (B. R. Dworkin, 1982, p. 51). The latter was rightly perceived as obnoxious by the patient, with the unintended consequence of focusing her attention of this aspect of the task, turning it into an aversive one. Trying to deal with this problem, Miller and Dworkin introduced a ten-second delay before the tone sounded. The function assigned to "this timing feature" was to shift both the emphasis and emotional denotation of the task, "from being punished for poor posture […] to the much more satisfying one of being rewarded for good posture".[18] "This change, they later argued, made the device much more acceptable to the patients." (N. E. Miller & Dworkin, 1982, p. 253)

In her writings on telecare technologies, STS scholar Nelly Oudshoorn has pondered the "disruptive" action of digital monitoring devices equipped with audio feedback systems, when used outside home: "[s]ound signals designed to establish trust turn into a violation of patient's privacy: they threaten to disclose health problems to audiences outside the medical domain and the circle of family and friends."(Oudshoorn, 2011, pp. 158 & p155). Oudshoorn's argument about patients' work to "guard the boundaries between the public and the private" is relevant to understand a second difficulty raised by the "soundscript" of the PTD (ibid., p. 158 & p. 154). It was understood by the psychologists that the tone had to be loud enough for the child to hear it easily. If the child could hear it very clearly, and not miss a single of its occurrences, then others would hear it too. An anecdote shared with enthusiasm by the mother of the first patient conveys the awkwardness of such situations, as well as the difficulty of the task the device was set up to help her do: "[she] wore it to church recently after promising to do her utmost to not let the buzzer sound. She sat beautifully straight the whole hour with only two buzzes – so it can be done."[19]

To Miller, some level of "social embarrassment" was not irrelevant for training purposes, as it could provide patients with an incentive to stay alert to the task.[20] Yet, as Dworkin later admitted, having the patient ashamed in front of her friends and acquaintances was evidently not the best route to move the device from a domestic space to public ones, and towards continuous use; "[u]nder an optimal reinforcement schedule, it was inevitable that the tone would be activated many times a day and it seemed senseless to embarrass a conscientious patient unnecessarily." (B. R. Dworkin, 1982, p. 54). The Rockefeller psychologists thus found it necessary to make another adjustment to the feedback system, by using two instead of one signal, a weak, "private" one, followed by a louder, "public" one "if correct posture had not been achieved within 20 additional seconds".[21] A "panic button" was also added to the device.[22] The child could press it to turn off the embarrassing tone for 20 seconds, with the twist that "interruption [was] delayed for an interval varying randomly from 1 to 5 seconds", to "prevent the development of dependence on the switch"(B. Dworkin et al., 1985, p. 2494).

They were not at the end of their journey though. Other problems arose, some as a result of the adjustments made. These had less to do with the way patients felt about the device, than with the way they handled it. As Dworkin and Miller discovered in early trials, patients learned to work with, and around, the PTD. For example, the first patient discovered a convenient way to achieve the criterion and stop the tone. She lengthened the axis by moving her shoulders instead of using her back muscles to "stand tall".[23] Likewise, one of the patients found a way to trick the device, and gain some rest. In Miller's words:

> "[She] developed the bad habit of making frequent momentary responses that turned off the tone and earned a 20-second grace period, or, if it occurred within the grace period, delayed its onset by 20 seconds. By using these momentary correct responses, the child was able to remain relaxed into a bad posture for the vast majority of the time. […] With this particular child, explanations of how this type of response was defeating the therapeutic purpose of the device failed to break up the bad habit."[24]

The unscripted and unexpected ways in which the patients handled the device led to additional and proliferating changes made to its components. To counter the first trick mentioned, for example, they tightened the part of the harness going over the shoulders, which in turn required some modifications "in the switch system to reduce spring tension", leading to yet other modifications to reduce the resulting friction. One option tried out, with little success, was to ask the patient "to wear the harness over slippery undergarments". The solution eventually adopted was "to [use], wherever there might be rubbing on the skin, a small Teflon tube through which ran a smooth nylon stand".[25] The versions of the PTD multiplied until the beginning of the year 1978, when the Rockefeller University shops started manufacturing the redesigned device in larger numbers for the purpose of conducting a pilot trial with children in the early stages of idiopathic scoliosis, i.e. not yet needing a brace. The general objectives set for this trial were to "secure data on the mechanical reliability, practicability, and therapeutic promises of [the device].[26]"

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7. Tutoring Training

During feasibility trials of the PTD, the Rockefeller psychologists became aware that a portable treatment device, regardless of how effective, would not be worn if it caused the patient to be apprehensive or frustrated. As these trials unfolded, it also became apparent to them that the challenge of keeping patients motivated and compliant throughout an extended course of therapy could not be addressed only by fine-tuning the task parameter setting, nor be entrusted exclusively to the device. It also required going beyond the individualistic model of learning incorporated in the PTD. While the subject of operant conditioning had historically been an isolated organism reacting or interacting with changes in its physical environment, the testimonies of patients and their parents drew the psychologists' attention to the importance of the interpersonal context in which therapeutic training took place, even when partially outsourced to a machine.

In follow-up talks with parents, the referring orthopedists found that variations in the device and task, as well as the requirements of the experiment, could have psychological effects opposite to those expected, and cause more anxiety in the patients than those they usually encountered in a child with a brace. When planning an extended pilot trial in 1976, Miller paid lip service to the warnings of Engler. He admitted that being scrutinized in undergarments and photographed for height measurement in a laboratory every week, way more frequently than the periodic X-Ray monitoring undergone by braced patients, "could call the child's attention to her deformity".[27] While he considered it difficult to do otherwise, Miller conceded that it was necessary to give the child substantial psychological support during active treatment of scoliosis. To go back to the allegory of orthopedia, the use of a portable and partly automated device did not obviate the need for a stake to uphold therapeutic training.

To Miller, part of this supportive work was the responsibility of the parents. Exchanging about patient selection for the pilot trial with orthopedic surgeon David Levine, Miller stressed that, beyond strictly medical criteria about the type and progression of curvature, "[…] the most important thing is to try to determine as well as possible that the family is a good one with a genuine interest in the welfare of the child, that the child is willing to cooperate and not rebellious, that the family circumstances are such that it will not be a hardship for them to come in as often as once a week […]".[28] The therapist also had a part to play in orchestrating success. At the beginning of treatment, each of the twelve adolescent girls in the early stage of scoliosis they were eventually able to enlist was brought into the laboratory at the Rockefeller University. On site, Barry Dworkin and his assistants instructed the child in the use of the PTD, and guided initial training to "eliminate grossly inappropriate responses" (B. R. Dworkin, 1982, p. 56). The psychologist's task was also to adjust the response criterion over the weeks. As the prescribed time of wear increased, from two hours per day the first week, four hours the second, and up to twenty-four hours a day for most patients, the psychologists increased the difficulty of the task during visits at the Rockefeller University, trying to adjust it to levels that that would "give each patient a sense of accomplishment while maintaining sufficient motivation for continuous improvement" (ibid.). Eventually, the psychologist's role came to be understood as that of a mediating agent between the device and the patient, a coach who had to clarify and sustain the connection between the occurrence, in the present, of an annoying tone signal and the distant and uncertain prospect of medical or cosmetic gains (ibid.).

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After completion of the pilot trial in 1981-1982, the idea that the success of the device largely depended on the skills of the therapist was weaved into discussions about the manufacturing and marketing of the device. Out of the twelve patients enrolled in the trial and treated between elven and thirty-five months, ten had been followed until their growth period was completed. These children had been discharged by their orthopedists because curve progression had slowed down. The other two had been removed from the program and braced (B. Dworkin et al., 1985). A parallel study conducted in Germany by Niels Birbaumer with both scoliosis and kyphosis patients likewise yielded results deemed encouraging enough to warrant search for a manufacturer[29]. Additional incentive came from the inquiries from orthopedists, clinical psychologists, and parents, which were brought in by a mention of the device in the February 1985 issue of *Psychology Today*[30].

While making contacts with small electronics and biofeedback instrument makers, the Rockefeller University team began to inquire about the FDA's premarket requirements. This introduced the question of how the device ought to be marketed. Two options were considered by the Patent Office at the Rockefeller University: one was "a medically prescribed and supervised treatment for conditions such as scoliosis and kyphosis"; the other one was "a general-use posture improvement device, which might be available without a medical prescription".[31] At first, the possibility of targeting the market of health and cosmetic-related issues instead of an admittedly smaller medical market, did not hold against the Rockefeller psychologists' insistence that the device ought to be used in a therapeutic context. However, in the early 1990s, when the posture-training device was permitted to be marketed by the Food and Drug Administration, revamped with digital technologies that fully automated the conditioning system, and eventually manufactured,

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this oscillation resurfaced. As the device became ready for sales under the name "Micro-Straight", and just before I lose its tracks, Miller flirted with the idea of enlarging its potential market, and of "delivering therapy to the normal" (Castel, 1981, p. 10). In the margins of the 18 September 1991 issue of the *New York Times*, above an article that presented back injuries as one of the "nation's most expensive and debilitating occupational health problem", Miller wondered: "Would Microstraight help prevent them perhaps by encouraging (training) workers to hold back straight?"[32] Here, one might discern the flexible boundaries between the normal and the pathological underlying behavioral interventions based on the idea of skill building. In the 1970s and 1980s, this combined with advances in electronic technologies, and broader strategic and theoretical renewals in behavioral psychology, to opening up the spaces of daily life to technically-instrumented modes of modification of individual habits, at least in the visions of some psychologists.

8. Conclusion

In 1987, Neal E. Miller was asked by George A. Miller whether he would accept to join him in the Advisory Committee of a new American Psychological Association entity called the Fund for Public Education in Psychology, whose mandate was to spot and secure funding for projects that made psychological knowledge available to the public in concrete ways. Miller accepted the proposal, but confided that based on his "experience in […] the development of health psychology", he did "not think it is easy to 'give psychology away'". To him, the psychologist first had to become cognizant of the "details of a situation in order to know which applications of psychology will be practicable. Then one has to a) find something that

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the recipient knows that he needs; b) that one can supply in a way that will work, and c) then prove that it has worked."[33]

Focusing on the psychological reception of advances in electronics between the 1960s and 1980s, I have explored the role of technology in attempts to meet some of these conditions, and expand the scope and reach of behavioral psychology. Through the case of Miller's research on visceral learning and clinical biofeedback, I have tried to relate shifts in the subject matter, spaces of practices and aims of behavioral psychologists during this period to changes in their material culture and instrumental practices.

I have shown that, in Miller's laboratory, the addition of electronic technology to the psychological apparatus enabled new enactments of operant conditioning, based on the monitoring and reinforcement of changes in physiological processes rather than skeletal behaviors. From the early 1960s onwards, the use of electrophysiological techniques in combination with behavioral techniques made it possible to conceive of visceral functions as examples of behavior, in the operational sense that they could be brought under control using the specialized techniques of behavioral psychologists. In so expanding the domain of instrumental learning, Miller also brought its principle and techniques to bear on organic dysfunctions and otherwise involuntary bodily habits related to physical health problems.

Following Miller and Dworkin's ensuing efforts to develop a behavioral treatment of idiopathic scoliosis, I have further argued that the use of electronics literally sustained attempts to carry behavior therapy into daily life settings. Rather than solely invoking the ability of psychologists to seize upon technological opportunities, namely the increased commercial availability of miniaturized electronic components, I have related the invention and understanding of portable treatment devices to practical difficulties. I have shown that

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the Posture-Training Device, beyond its function as a treatment for scoliosis, came to materialize the solution to the efficacy and effectiveness problems encountered in the biofeedback field. To Miller and his collaborators, it ultimately represented "a way to supply" this and other forms of behavioral treatment "in a way that would work", i.e. by extending therapeutic training in space and time so as to improve learning.

One of the advantages of a material history perspective on behavior therapy is, thus, that it reveals tensions between the ideal and the actual, allowing us to question the role that these tensions have played in its expansion and diversification. Another such tension was that between the individualistic model of operant learning incorporated in the Posture-Training Device and the interpersonal context in which therapeutic training actually took place. The difficulties met by the Rockefeller psychologists in early field trials of the device led them to acknowledge that the challenge of keeping patients motivated and compliant throughout an extended course of therapy could not be entrusted solely to the device. It also required considering the role of emotional and interpersonal factors in learning. Sustained use of a behavioral device to "learn to do something for oneself" would depend on external support, whether through guidance, encouragement, or surveillance of the patient by the practitioner or parents.

This brings me to the last, and overarching tension or ambiguity I would like to briefly comment on, that between "external control" and "self-control" in behavior change discourses and practices. According to Baistow, one of the most significant shifts in the "conceptual and strategic emphases of behavioral psychology" between the 1960s and 1980s was "a move away from using behavioral approaches to modify the behavior of others, towards developing ways of enabling people to manage their own behavior" (Baistow, 2001:

311). This case study suggests a more equivocal transition. The terms "self-control" and "self-regulation" have been readily used by biofeedback promoters to convey the idea that it required the patient to become an active participant in his or her own treatment. This vocabulary further suggested that the subjects were the agents of their own behavior change. In practice, however, the responsibility for effecting change was often distributed between the patient, biofeedback apparatus and the experimenter. In the behavioral treatment of scoliosis, it was the psychologist who devised an arrangement of environmental conditions to facilitate postural change, and this arrangement was performed by a pre-programmed measurement and feedback apparatus, restricting the patient's exercise in self-control to the possibility to terminate an annoying tone signal by "standing tall".

The Posture-Training Device materialized an ambiguous shift in behavioral psychology, in which the injunction to get involved and become an active agent of one's own health coexisted with a heteronomous regulation of behavior. This tension finds resonances in today's proliferation of digital mobile self-tracking devices for health, in which, as analyzed by Natasha Dow Schüll, the "labor of self-regulation" is outsourced to external technology (Schüll, 2016). Further explorations of the behavioral electronics of the past, in its twofold dimensions of instrumental and imaginary developments, may offer historical counterpoints to the current development of technologically-assisted forms of treatment and self-care, as well as highlight remanences, such as the difficulty in ensuring sustained use of devices by patients or consumers.

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Figure legends

Figure 1: Picture of a late version of the Posture-Training Device, [mid.1980s?], photographer unknown, folder "Scoliosis", b.18, Neal E. Miller Papers, Manuscripts and Archives, Yale University Library.

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