

Symposium report

## Transferring behavioral technology across applications

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### Abstract

Application flows naturally from good science, and behavioral toxicology is no exception. Phenomena discovered and procedures developed in behavioral laboratories are being applied on a wide scale in commercial, industrial, and governmental settings. In behavioral toxicology, this transfer of technology has occurred in an ad hoc manner, albeit with a degree of sophistication. The development of technology transfer in other disciplines is instructive. A symposium at the May 2001 meeting of the Behavioral Toxicology Society examined this issue, and some participants provide their contributions here. Henry Pennypacker examines the issue of whether behavioral procedures can meet the demanding standards required to transfer technology to commercial endeavors and concludes that, under some conditions, they can. He notes that the shortage of well-developed and transferred behavioral technologies results from a lack of understanding of the process of technology transfer on the part of behavior analysts. In the field of engineering, the results of basic research are transformed to candidate technologies that meet standardized criteria with respect to three properties: quantification, repetition, and verification. Kent Anger describes the challenging steps in the trail from the laboratory to wide-scale application—steps that are essential for the scaling up of any behavioral technique. Finally, Paul Mele describes the legal background to patenting and copyrighting ideas, a process that behaviorists have rarely used. Together, these topics identify the requirements and warn of the challenges and intricacies that await those who seek to transfer behavioral technology beyond the laboratory.

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### 1. Introduction (M.C. Newland)

Behavioral toxicology is an area in which the fruits of laboratory research aimed at addressing behavioral questions have been applied to make important decisions regarding the control and regulation of neurotoxic substances. The transfer of technology from scientific laboratories to application has occurred on a large scale and, in a sense, without realizing it. It is time to realize what we are doing. The symposium held at the 2001 meeting of the Behavioral Toxicology Society entitled “Transferring Behavioral Technology Across Applications” represents an attempt to articulate the dimensions of technology transfer that apply in behavioral settings.

Two dimensions of technology transfer emerged from this symposium. One dimension, described by Pennypacker, is that in which behavior is, in a sense, industrialized and examined with an engineer’s eye for precision, tolerance (the amount of deviation in nominal values that can be tolerated), reproducibility, and verification. A second dimension, described by Paul Mele, draws from the protection of ideas through patent and copyright laws. Both dimensions make contact with the process of “scaling up” technology from a relatively limited laboratory procedure to a widely applied protocol that must be used by a highly varied group of individuals. Kent Anger summarizes his extensive experience in a series of useful guidelines for anybody thinking about application.

A rule of thumb in science is that it is impossible to predict what applications a laboratory phenomenon will ultimately find, and behavior is no exception. An excellent chapter by Laties [27] traces the surprising twists and turns

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of trails taken by several techniques. Many preparations that have been applied in behavioral toxicology could be mentioned as examples of the unpredictable trek from discovery to application. The fixed-interval schedule is an excellent case in point. The rationale offered by Ferster and Skinner [18] for examining this schedule was that the data were orderly and, in retrospect, they were right to obey the experimental mantra: follow the data. We now know that the behavior generated by this schedule is orderly and reproducible across an impressive array of species [25], and that the patterns seen after exposure carry much information about drugs and toxic substances [13,47,61]. Performance under this schedule of reinforcement has even been used to support the regulation of lead in the United States [14,15], and this schedule has been incorporated into federal legislation specifying behavioral testing of potentially toxic chemicals [58,59].

Behavior under the fixed-interval schedule satisfies the guidelines offered by Pennypacker in Section 2 and in other writings [42]. It is quantifiable, in this case along two independent, orderly dimensions of rate and temporal pattern of responding. It is reproducible across laboratories and across species. This reproducibility serves an important quality control function because it means that we know (1) how to set up this schedule arrangement; (2) what behavior can be expected under it, and therefore how to gauge when it is implemented improperly; (3) the variability to expect within a subject and across subjects, an important component of quality control and tolerance; and (4) how different drugs or chemicals affect behavior under this schedule.

The fixed-interval schedule, first described in 1938 [53], was initially used in basic behavioral research. After a detailed examination by Ferster and Skinner [18] in 1957, the characterization of behavior under this schedule expanded greatly [64,65]. Studies of drug–behavior interactions revealed the sensitivity of this schedule and its ability to distinguish the behavioral actions of different classes of drugs [9,25,51], so its incorporation into behavioral characterizations of neurotoxicant agents [13,47] was a natural development. This time course even meets a rule of thumb that I learned as an engineering student, which is that the lag from discovery to application is on the order of decades. The interval may be shorter today, but it certainly should be long enough to permit a basic understanding of a phenomenon before applying it on a large scale or in situations that affect human health.

Many other examples could be described. On first encountering the paper on technology transfer by Pennypacker and Hench [42], I was reminded of the detailed and quantitative characterization of locomotor activity conducted by Macphail [29], Macphail et al. [30], and Reiter and Macphail [46]. In these studies, locomotor activity is treated as a product and questions about reproducibility, sensitivity to the conditions of study, and variability as a function of the mean are among the many that went into

developing this preparation as an endpoint for toxicity evaluations.

Other investigators have treated batteries of behavioral endpoints with similar care. A relatively early study [45] examined endpoints as diverse as core temperature, body weight, startle, and conditioned avoidance responses along exactly the dimensions described by Pennypacker. Endpoints were characterized first for their reproducibility using a coefficient of variation. Then, the measures were characterized for their sensitivity and specificity by describing how they were affected by a collection of behaviorally active agents.

Others have extended this approach and have even conducted comparisons across laboratories. The long and extraordinarily detailed reports that came from the Collaborative Behavioral Teratology Study provided valuable information about what can be expected when similar behavioral endpoints are examined in different scientific laboratories [12,36]. One outcome of the Collaborative Behavioral Teratology Study was that there was similarity across laboratories on certain well-defined procedures whose implementation is unambiguous. The results from another group of procedures varied considerably across laboratories, and these were procedures whose implementation leaves much room for discretion by the investigator.

Even the studies mentioned above—and others could be mentioned—did not go far enough because the people conducting or supervising the procedures were seasoned scientists with considerable experience in carrying out the investigations. Scientists learn “lab lore” and technical details surrounding their applications in graduate school and at scientific meetings. As behavioral protocols become transferred to applied settings, they will be conducted by individuals with less training and without the somewhat intuitive and difficult-to-articulate understanding of how to get things done.

This transfer of applications to a broader group of individuals is exactly the point of the section by Anger, in which he summarizes his many experiences in taking testing from the laboratory to the field. Examples of the refrain “the devil lies in the details” can be found here, including some that one might not think of until actually conducting pilot tests. Training and testing are repeated in many cycles to ensure that the application is implemented correctly. The “scaling up” of a testing protocol from a laboratory to a large-scale application is a difficult task and an example of the common experience that the details are crucial. The guidelines that Anger lays out should be helpful to anybody who attempts such an ambitious endeavor.

Another example that addresses this issue is the Functional Observational Battery [32,33], which has been developed along lines broadly similar to those that guided the investigations described above. Descriptions of this battery include descriptions of the expected variability of different components of the battery, reliability, and sensitivity to different classes of compounds. Similar to others, the

Functional Observational Battery includes components selected to tap different functional domains. Perhaps drawing from work on locomotor activity, its developers have also recognized that a critical component of exporting the technology in a standardized way is the recognition that the person conducting the test is an important source of variability, and that person is unlikely to be someone who conducted a doctoral dissertation involving behavioral studies. Thus, videotapes and training sessions are available, at cost, to help train the technicians who will conduct the tests.

All this has something of an academic flavor to it. Techniques are developed in the laboratory and exported to a broad array of applications. The motivation comes partly from the simple joy of being in the laboratory and partly from the standards that influence career paths in academics or government. That is not enough, however, to support the arduous work that lies behind what amounts to a commercialization of behavioral technology. The topic of patents is a novel one for behaviorists, but one that we should face squarely. The transfer of behavioral technology to the field on a large scale may involve earning a living from it, or at least a partial living. This means that ideas need to be protected—a concept that, at first, appears to conflict with the academic standards of openness. As Mele points out Section 4, the various laws, including patent and copyright laws, exist not just to protect ideas, but also to protect the integrity of an application. The patent process can force one to state explicitly how to produce the product and what kinds of tolerances are to be expected while protecting the developer through this process.

Mele, a technology transfer officer and a behavioral toxicologist, describes these processes that exist to protect one's ideas. It is interesting that it is so difficult to come up with behavioral examples of patents, but that is just an indication of how novel this process is to our science. Perhaps more behavioral examples will arise as our laboratory activities find their way into industrial settings or even into commercialization. Application flows naturally from good science, and our science is good. It is being applied successfully. We can learn how to apply it better from those sciences that have long histories of application.

## **2. Transferring technology from the natural science of behavior (H.S. Pennypacker; (adapted from Pennypacker and Hench [42])**

In 1986, I called attention to the possibility of transferring behavioral technologies to the larger culture for the benefit of that culture [40]. An extensive example was given of a technology of manual breast examination for early detection of cancer. That technology was being successfully transferred. The intended implication was that other behavioral technologies could be developed and similarly transferred. In retrospect, however, the analysis provided in 1986 was incomplete.

Since the 1986 publication, very few additional behavioral technologies have been transferred to the marketplace. This is not, in my view, the result of any shortage of potentially transferable technologies. There has been extensive technological development in the areas of industrial safety, highway safety, organizational performance management, animal training, and educational service delivery, among others. This development has taken the form of application of the fruits of applied research [22] but only a few efforts have been made to transfer these technologies to the larger market.

The consensus among academic behavior analysts seems to be that there exists an insufficient research base to engender vigorous technologies. The focus has been on developing strategies for creating technologies, particularly by enhancing the interplay between basic and applied research. Thus, Mace [28] specifies in considerable detail the areas of basic research that should receive attention in order to enhance the effectiveness of applied behavioral research. He provides an excellent overview of the contemporary field of behavior analytic research, both basic and applied, and it is easy to recommend this article to students for exactly this reason.

Mace suggests two explicit strategies for strengthening the connection between the basic and applied research communities: (1) using deliberate animal models to analyze human behavior problems and (2) increasing replication of basic findings through human operant research. He believes that these strategies will lead to effective technologies and concludes with an example from his own collaboration with J.A. Nevin in which the concept of behavioral momentum has been extended to work with normal adults and hospitalized children.

One can scarcely quarrel with Mace's excellent overview and analysis. His is a prescription for orderly progress in the science. Indeed, if most researchers adopted as their programs one or more of Mace's suggested areas of inquiry, we would move rapidly toward a mature and complete science. Would we be any closer to launching effective technologies? Not necessarily.

My purpose here is to suggest some alternative strategies for stimulating the development and transfer of behavioral technologies. Specifically, I will outline the strategies successfully followed by a more mature discipline, engineering, and will attempt to show how many results of the science of behavior analysis may be adapted to these strategies.

The products of science, whether basic or applied, do not constitute technology. To take the first step toward launching a technology, the research finding must be reduced to practice. Once this occurs, it becomes prudent to seek intellectual property protection in the form of patents, trademarks, service marks, and/or copyrights. These often form the basis of capital formation, essential to the mass transfer of any technology. They also provide a legal mechanism for insuring quality control as the product or process is conveyed to the consumer. This element is

essential in the transfer process; without it, we are left with application in practice that is subject to dilution and deterioration.

Reduction to practice is a complex process that results in exact specification of a set of procedures that will produce a product or outcome to predetermined specifications. Procedures that constitute reduction to practice must meet three explicit criteria: *quantification*, *repetition*, and *verification*.

Storing and disposing of nuclear waste is a complex technology that provides a convenient illustration. The problem has two major components. First, how does one transform nuclear waste into a minimally radioactive material? Second, where and how does one store that material?

Since the 1950s, it has been known that nuclear waste, whether in liquid or sludge form, can be vitrified (i.e., transformed into a glassy, solid material). The process may be likened to transforming sugar syrup into candy. A new material that could be used to fashion adequate solid blocks containing nuclear waste was clearly needed. The first question therefore became: How does one define “adequate”? The answer to this question involves the first of our three criteria.

### 2.1. Quantification

In engineering, organizations that establish testing standards for various products exist. We are all familiar with the Society of Automotive Engineers that sets, among other things, the standards for viscosity of lubricants (SEA 50, etc.). In the materials field, the American Standards for Testing and Materials (ASTM) and the International Standards Organizations (ISO) usually serve this function. However, when the possibility of nuclear waste vitrification first emerged, no such standards existed. In fact, no agreement existed even as to the unit of measurement that should be applied. There was, however, agreement that superior materials would be those that minimized the leach rate of radioactive material under conditions of underground storage. Various laboratories had their own preferred materials, ranging from silicate glasses to various ceramics to complex cements and grouts. They each used their own standards and units of measurement, so there was almost no basis for comparison. Such a situation can be tolerated, even encouraged, in the conduct of basic research, but for obvious reasons, an important technological application such as storage of nuclear waste must be guided by independently established standards and units of measurement.

The federal government appointed a commission to identify and approve one standard method of testing candidate materials for nuclear waste vitrification. This body completed its assignment in 1 year. After 3 years, all but two candidate materials had been eliminated and a billion dollar plant was subsequently commissioned in Savannah, GA, to carry out vitrification. We note that the standards were developed by the scientific community and were not imposed by the government.

### 2.2. Repetition

Once measurement procedures and standards have been established, a candidate technology can be evaluated with respect to repetition. Reducing a process to practice means, in part, that the outcome or product is repeatable. The materials selected for nuclear waste storage, for example, were the result of advances in physical chemistry that, in turn, spawned a production process that could be duplicated with predictable results. In evaluating the repetition factor, one collects a large sample of the items or outcomes, measures each according to the established procedures and standards, and describes the results in terms of a mean and coefficient of variation. If the mean meets the quality standard and the coefficient of variation is sufficiently small, the process is said to be repeatable.

### 2.3. Verification

The third criterion to be met by a candidate technology before it can be transferred is verification or reproducibility. This refers to the degree to which the process or procedure, not the outcome or product, can be replicated. The process of applying for a patent forces clarification of this aspect of the technology. One is obliged to state precisely, in terms of specific claims, how one does whatever it is that produces the product or outcome. To the extent that the statement is clear and the process is reproducible, it can and should be protected for the benefit of the discoverer or inventor. An issued patent serves this function and permits negotiation of the resources necessary to proceed to market analysis and prototype manufacturing.

Verification in the case of nuclear waste storage has been an arduous and complex process involving international collaboration. Samples are buried under carefully controlled conditions of depth and temperature and then the leach rate is periodically measured. These studies have helped create an international consensus on the relative performance of high-level waste forms including borosilicate glasses, waste packages, and repository variables [20].

### 2.4. Application to behavior analysis

Is it possible for behavior analysis to foster technologies that will meet standards similar to those observed in engineering? We will consider each of the foregoing criteria as they might be applied to a discovery made in either basic or applied behavior analysis. Let us first consider how behavioral technologies differ from the extant fruits of behavior analysis.

The essence of technology is *control*. Skinner often remarked that the objective of a science of behavior was prediction and control of the subject matter. In practice, however, the science has generated a series of functional relations in which measured behavior is the dependent variable. As such, behavior has been shown to vary in

orderly ways as a result of the exertion of experimental control of designated independent variables.

As we attempt to incubate behavioral technologies, we must refocus our efforts on the control of behavior. In other words, a successful technology will produce behavior to predetermined specifications, just as material science produces, say, ceramics to predetermined specifications, or just as the pharmaceutical industry produces chemical compounds to predetermined standards of consistency and purity.

We will have established adequate control over a given class of behavior when we are able to generate instances of the behavior that are sufficiently specific and within levels of tolerance to achieve some socially desirable outcome such as reduced mortality from breast cancer or reduced recidivism by parolees from prison. An example of such a technology was the demonstration of the cost benefit of pigeons guiding bomb-laden missiles by Skinner [54], or the demonstration that pigeons can serve as quality control inspectors in a pharmaceutical assembly line by Verhave [60]. In both cases, the behavior in question was generated to specifications of very high tolerance (precision).

A current example illustrates this subtle but important point. In a study that generated considerable concern in the popular media (e.g., Ref. [7]), Thomas et al. [56] report the results of a major trial purporting to show the effects of breast self-examination (BSE) on breast cancer mortality. Two large groups of female workers in the Shanghai textile industry were randomly assigned to two conditions—one to receive training in BSE, and the other to serve as a control. After 5 years, there was no statistically significant difference in mortality between the two groups. Does this support the conclusion (drawn by some members of the media as well as some in the medical profession) that BSE is ineffective? In fact, the independent variable subjected to clinical trial by the Thomas group, BSE *training*, was not tied to BSE *performance*.

In order to evaluate properly the role of BSE on breast cancer mortality, it would be necessary to produce BSE performance to a specified level of proficiency and frequency (e.g., monthly) on the part of each and every participant in the experimental arm of the trial. In other words, BSE performance (behavior) would become the independent variable of the experiment with mortality as the dependent variable. This would be extremely expensive and has not, to our knowledge, been attempted. In order to be undertaken, however, there must exist a behavioral technology capable of generating the required performance in every case to be included in the experimental cohort.

By systematically applying the three criteria that define successful engineering technologies, we believe it possible to develop large-scale technologies that, unlike the Skinner and Verhave examples, would transfer broadly because of the extraordinary cost benefit that could be realized. How would these criteria apply?

## 2.5. Quantification

Behavior analysis enjoys a distinct advantage with respect to this criterion because it has long employed the measurement strategies of the natural sciences [23,24]. As Osborne [39] puts it, “. . . physical standards of measurement bind behavior analysis to the physical and natural sciences. Interpretation of dependent variables need not change from experiment to experiment. It is a feature of our idemnotic measures that response frequencies on a particular parameter of a fixed-ratio schedule of reinforcement can be compared validly within sessions and across sessions, within laboratories and across laboratories, within species and across species” (p. 249). The “idemnotic” measurement strategy employed in many quantitatively rigorous areas of experimental psychology is one that incorporates units having an absolute standard whose existence does not change from setting to setting. Mass in kilograms and responses per minute are examples. This stands in opposition to the “vaganotic” strategy (from the same root as vagabond, or wanderer), in which measurements are based on scales derived from units of variability in a population. Body weights based on norms, or scores on IQ tests are examples of these [23]. Thus, our measurement practices allow us to specify in precise and unambiguous quantitative terms the characteristics of the behavior to be produced by a candidate technology.

Perhaps it is time to follow the lead of our colleagues in various branches of engineering and form groups to establish standards for measurement of behavior. For example, we should now agree that academic performance is best measured in terms of both speed and accuracy of responding, not accuracy alone. We can therefore begin to establish quantitative standards of fluency for basic skills. Thereafter, instructional technologies would be validated in terms of these standards and the extent to which they reached these standards could be publicly disseminated. By virtue of its extensive reliance on the measurement system of Precision Teaching, the Morningside Model of Johnson [21] is now on the verge of successful transfer.

## 2.6. Repetition

With the standards established and measurement procedures agreed to, it becomes possible for investigators to show the extent to which their techniques generate repeatable outcomes. For example, we should be examining large collections of fluency outcomes across schools, disciplines, etc., and note the means and coefficients of variation. Such data could routinely accompany budgetary proposals and be subject to external audit and review.

Many other applications of behavior analysis are sufficiently advanced to permit evaluation with respect to repetition. Animal training procedures yield outcomes that are quantifiable and highly repeatable [44,63]. Schedule-

controlled operant behavior (SCOB) plays an important role in the field of behavioral toxicology [37] by providing standard behavioral baselines against which to assess the effects of toxic agents in the environment. The quantitative features of such behavioral baselines (terminal rates, index of curvature, interresponse time dispersion, etc.) are well known, but have never, to our knowledge, been subjected to the kind of quantitative summary description for which we are calling [38]. If data like these were to become available, comparisons across fields would be immediate and efforts to achieve increased precision would become better focused. For example, is the coefficient of variation describing a collection of frequencies of second graders' correct arithmetic facts larger or smaller (and by how much) than the coefficient of variation of a group of monkeys' lever-pressing frequencies under fixed-interval schedules of food presentation?

### 2.7. Verification

Two issues surround the criterion of verification: specification and generality. With respect to specification, the basic literature of behavior analysis is more than adequate. Descriptions of experimental spaces, manipulanda, reinforcers, schedules, experimental phases, etc., are presented in sufficient detail to insure replication. Replication is therefore routinely accomplished. Further, such descriptions are adequate to permit assessment of generality as, for example, when different species or different environmental settings are investigated [10].

The situation is less comforting in applied behavior analysis. Peterson et al. [43] first documented the lack of concern with what they term *the integrity of the independent variable* (emphasis added) in the applied research literature. Detailed specification of the procedures was often lacking as was any documentation of efforts to insure that whatever the procedures, they were consistently applied. Nowadays, a demonstration of *treatment integrity* is routinely presented. We have also begun to see the emergence of subspecialties such as the treatment of autism, industrial safety training, direct instruction, and precision teaching that rely on standardized materials and procedures. These subspecialties are well on the way to creating transferable technologies.

Building an applied science without clear specification of procedures is admittedly difficult. Building a technology under those circumstances is impossible. Recall the lengths to which the international material science community went to establish the durability of various nuclear waste disposal media under widely varying conditions of burial and temperature. Imagine trying to establish similar parameters for a behavioral technology that requires precise intervention at specific times and under specific conditions if no attention is paid the details of the intervention, control over the timing of the interventions, or detailed description of the environment in which the intervention is to occur.

The solution to this problem is attainable, as Peterson et al. [43] point out. Much greater emphasis must be directed at the problem of identifying, observing, quantifying, and thus controlling the independent variable in applied research. Similarly, any resulting technology must focus primarily on those factors. They must be isolated and refined to the point where they can be reproduced by others under a variety of circumstances and their expected effects routinely obtained.

### 2.8. Some suggestions

If it is the collective wish of the members of our discipline to foster the development of behavioral technologies, some changes in our own behavior may be indicated. Here are a few of the most obvious, based on the success of established fields like engineering and the few behavioral technologies that have emerged:

1. A group should be convened within the existing disciplinary structure to establish units and standards of measurement. This group could be associated with the Cambridge Center for Behavioral Studies, with Society for the Advancement of Behavior Analysis, or with Society for the Experimental Analysis of Behavior, but it should have provision for wide distribution of its work product.
2. We should broaden our conception of what constitutes publishable research to include demonstrations of repetition and verification. This is not a new idea. Hawkins and Hursh [19] advocate using treatment-only designs to demonstrate that satisfactory change is occurring without necessarily isolating the cause of the change (cited in Ref. [34]). Coupled with use of standardized measurement units and practices, collections of behavior changes could be published in short reports with emphasis on the exact descriptions of the procedures employed, together with evidence that these procedures remained as described [43].
3. We must eventually begin to publish information of the type just described in journals of wider circulation than our own archival scientific journals. This means becoming comfortable with editorial review rather than peer review. It also means reaching a far wider audience, possibly including representatives of organizations who can provide other forms of assistance, including financial. A new online journal has been established for this purpose [52] and readers are encouraged to submit their work for consideration. It would be helpful if this type of publication could be encouraged, or at least not punished, by enlightened university administrators.
4. We should continue to forge alliances with other disciplines, such as medicine and engineering, that have established mechanisms for technology transfer. In the health care field, for example, there are frequent calls for "lifestyle changes" that will lead to reductions in health

care costs. We regard these as calls for effective behavioral technologies that can be marketed to large subsets of the population with *confidence in the predictability and stability of the outcomes*. Without question, if benefits can be assured, such technologies will be purchased by managed health care organizations [40,41].

The first challenge of technology transfer, then, is to create transferable technologies. To do this, we must move beyond research into the arena of explicit technology development. I encourage my colleagues to broaden their efforts and thereby hasten the arrival of the day when the discipline of behavior analysis finally fulfills its promise of benefit to the species.

### 3. Neurotoxicity assessments and training in occupational populations (W. Kent Anger)

One reason scientists develop software is to create new methods or extend existing methods in order to push research boundaries, as contrasted with commercial companies that are driven by market forces. Drs. Kent Anger, Diane Rohlman, and colleagues conduct research on occupational exposures in working populations and develop training programs to teach working people to avoid those exposures and follow related safety requirements. In their 12 years at Oregon Health and Science University, this group has developed three software systems and two hardware units to support those systems. Each system was developed because existing software systems did not meet specific needs with sufficient effectiveness, especially in nonmainstream populations.

#### 3.1. 9BUTTON

Integral to the effectiveness of each of the software systems is the 9BUTTON response unit designed with nine large, backlightable buttons. The 9BUTTON replaces the keyboard for participant responses. This unit was initially developed to expand the capability of a neurobehavioral assessment system to test people who do not use computers. However, its utility appears to extend to every user, even those with extensive computer experience. The 9BUTTON allows participants to maintain focus on the task when responding, rather than having to find a keyboard key that is small and close to adjacent keys. And for those who do not use computers, any given keyboard key is found amidst a bewildering array of more than 75 other keys. The 9BUTTON is placed over the keyboard on a laptop or in front of the monitor in desktop systems. The 9BUTTON and its interface card (Fascinating Electronics, Portland, OR) was also required to achieve near-millisecond timing of responses synchronized with stimulus delivery on a computer monitor or flat panel screen.

#### 3.2. Behavioral assessment and research system (BARS)

The BARS was developed to administer neurobehavioral tests to detect and characterize neurotoxicity in the widest possible range of working and community populations. The software existing at the time BARS was developed was effective in well-educated populations, but not with those in the lower end of the education distribution. The specific gap that stimulated this development was the need to test migrant workers entering the US [1–3,5,16], often with little or no education, no experience with computers, and a general fear of touching a computer keyboard (e.g., “I might break it”).

Each BARS test begins with a series of simple instructions, broken down into individual steps, with practice at each step. The goal is to consistently teach participants how to complete the tests and thus produce consistent data across studies [48]. The 9BUTTON was designed as the exclusive response input unit for BARS, and the reach of the BARS program was further extended by the addition of a token dispenser for testing children as young as 4 years of age. Tokens, which can be traded in for nickels or toys, are delivered contingent on correct performance and intended to maintain performance in young children [49,50].

##### 3.2.1. Health screening system (HSS)

The HSS was developed to present questionnaire-format psychological tests on a computer. These psychological tests are normally administered individually to participants by a psychometrist or psychologist in paper-and-pencil format, or, in a few cases, by computer. The specific need that led to the development of this system was to present a series of 12 psychological tests to Gulf War veterans quickly and efficiently [4,55]. Although all 12 were multiple-choice tests, each one had a format that was sufficiently different that every test had to be explained individually to each participant. HSS, on the other hand, employs a common format that followed the basic design of each original test but included visual elements in common with the other 11 tests such that people were able to transition from test to test without added training or support. The 9BUTTON was used with HSS, as well, although a keyboard response option was also made available [26].

##### 3.3. cTRAIN

The cTRAIN system was developed in response to a request from the Painter’s District Council of Portland, Portland, OR, to create a Respiratory Protection training program using the 9BUTTON response unit. The specific gap that led to the development of the cTRAIN program was the lack of software that incorporated the important behavioral education principles of frequent quizzing during training to assess learning, and interactive feedback. The cTRAIN program consists of a content entry module and a module that delivers the training once it is entered. The content must be entered and thus learned in “information sets” that begin

with the presentation of the information to be learned (“information screens”) and conclude with one or more quiz question screen(s). Failure to answer a question correctly automatically returns the participant to repeat all the information screens and the missed quiz question. Correct responses produce positive feedback and allow the learner to progress to the next information set and so on until they complete the training [1,5,16].

### 3.4. Overarching goals

In addition to the primary reasons noted above for developing these methods, three goals guided the structure and function of each software system:

- Increase the efficiency of research data collection in order to reduce personnel time and thus costs.
- Limit variability in the data.
- Broaden the target population, including those with limited education and those who do not speak English.

The key to meeting these goals was to design software that was self-administered. While human examiners bring excellent skills to testing or training, they also inherently introduce variability into the process, especially as they gain expertise and improve their technique. Consistent and clear training instructions and clarity throughout BARS, HSS, and cTRAIN were the keys to reducing the influence of human examiners in the process. The participants’ instructions on “how to use the system” were carefully designed, repeatedly tested in the target populations, and revised until they were highly effective. That is, the participants would learn to complete the tests or training accurately and correctly with, in most cases, no help from the examiner. In each case, the interaction between the examiner and participant (aside from the examiner’s introduction to the purposes of the study and consent form) was to seat the participant in front of the computer and say “press button 5 to begin.”

### 3.5. Steps in developing software for human testing or training

There are several essential steps in software development. The following steps must be completed before using any new testing or training software in research. Failure to complete a step will create problems for the research and require repetition of some or probably all of the research in order to develop a valid, reliable result that will withstand peer review:

- Identify the need for the planned research.
- Determine that needed capabilities are not available in existing software.
- Identify a programmer who will work with the scientists’ design, as most programmings are too complex for amateur programmers.

- Develop prototype software to perform the testing or training function.
- Personally evaluate the prototype software to determine if it does accomplish the intended function. This will lead to revision.
- “Pilot test” the software by administering it to three to five members of the target population. Observe each individual carefully for areas of confusion or hesitation. Talk with each individual about “how can we improve it,” using both structured questions and free-form discussion. This will lead to revision.
- Modify the software and repeat the entire piloting step until the software does not produce any confusion, nor the piloting any useful feedback. Never assume that a program change, no matter how small, will work; revised software must always be pilot-tested again.
- Administer the software to 25–30 members of the target population to determine the range of completion times (to schedule testing in the research study) and repeat the administration from 1 day to 1 week later to produce test–retest reliability data for the software.
- Conduct validity assessments.

### 3.6. Challenges

Software development, as described above, is a daunting process. Several challenging problems or barriers can be identified:

- Funding to develop new, improved, and competing software when “there is widely used software already available” (to paraphrase a grant application review).
- Funding to evolve “proven” software.
- Software development takes a great deal of time, but funded grants demand rapid productivity to justify continued funding.
- Operating system changes (e.g., Macintosh operating system 9 vs. 10, or DOS vs. Windows) can cause software to become nonfunctional.
- Computer hardware changes can cause software to become nonfunctional (e.g., replacement of the serial port by USB).
- Funding to pay people to test the software.
- Colleagues want to use software at no cost (“it is already developed”).
- Colleagues use the software but do not publish their result, after obtaining the software at no cost (adding insult to injury).
- New software that challenges established software can generate understandable fears in colleagues that the new software will be discontinued due to lack of sales or grant support and thus not be available after they invested resources in it.
- Copyright ownership is claimed by both the programmer(s) who programs the software and the university where the scientist worked while designing and testing

the software. This may leave the scientist who identified the gap and the required functional capabilities to fill the gap, with little ownership to justify the effort required to generate continued funding.

- Validation, which can be achieved by testing the software under known conditions (e.g., adverse effects of lead), is often not fundable, but validation cannot be achieved by testing “unknowns,” which are the best candidate topics for fundable research.
- Maintaining academic principles while “selling” software—the scientist has the same issue when confronted by the realities of “publish or perish,” but the taint of commercialism is viewed as more smarmy.

Often, the software developed by the scientist for research might best be described as orphan software for small “niche” uses. That is, in most cases, there is no commercially viable market unless that market is created by the scientist’s research and supported by the parent organization or by external venture capital. Finding a productive long-term role and thus funding for the software may be the greatest challenge, but the one with the greatest potential rewards.

#### **4. How technology transfer actually works (Paul Mele)**

##### *4.1. Introduction*

Technology transfer is the exchange of scientific and technical information, materials, procedures, and practices for the purpose of promoting research, development, and commercialization of discoveries. Technology transfer has become a means for institutions to: (1) disseminate the results of their research activities, (2) to obtain new technology to enhance their discovery process, and (3) to put new products into the marketplace. Recently, technology transfer has undergone accelerating, worldwide growth. Today, universities, hospitals, not-for-profit foundations, state and federal laboratories, and businesses engage actively in technology transfer.

Consisting of science, business, and legal components, technology transfer is being actively applied to the physical and natural sciences, and is prominent in the biomedical and biotechnology fields today. In contrast, behavioral technology has undergone more limited transfer. Typically, behavioral technology transfer has been restricted to dissemination of information via publication in journals, rather than by more commercial activities such as obtaining and licensing patents and the subsequent marketing and sale of products.

This symposium raised questions as to the feasibility, appropriateness, and extent of transferring behavioral technology from the laboratory to a commercial or regulatory setting. To this end, an overview of basic procedures and practices of technology transfer developed from other areas

of science and engineering will be presented. These procedures and practices are directly applicable to furthering the transfer of behavioral technology.

##### *4.2. Why conduct technology transfer?*

Institutions engage in technology transfer for reasons commensurate with their missions. Universities conduct research to generate technical knowledge for the broad advancement of science. Thus, scientific and technical publications are the traditional and primary means for transferring information they develop. Universities are also prominent in licensing out their technology, frequently under protection of patents or patent applications, to private industry for further development in exchange for financial considerations. US Government laboratories have become active in technology transfer since the passage of a series of laws beginning in 1980 [57]. Government laboratories are becoming known for their extensive holdings of technology in many areas of interest to private industry. By law, the government’s broad technology transfer mission is to promote the US economy and benefit the public at large. Companies engage in technology transfer by both acquiring and providing technology. Companies obtain much of their new technology from universities and increasingly from the government, with the ultimate intent of placing new products into the marketplace. Companies also exchange technology with each other for various reasons. For one, a company may specialize in creating new technology but may lack the resources to develop technology further. This is especially true in biotechnology where “technology discovery” companies may not conduct advanced development activities such as human clinical trials, which are expensive and require specific expertise. Another reason why companies exchange technology is the realization that their unused technology may have value to others, and therefore should be actively leveraged to obtain additional resources rather than be allowed to sit on the shelf forgotten and unused.

##### *4.3. Unrestricted technology transfer*

As a guide to clarifying the basic practices of technology transfer today, and to better understand how and why behavioral technology fits into technology transfer, it may be useful to categorize the transfer of technology according to the procedures and practices used. One category involves the free and open communication and use of technology (e.g., via journal publications), while the other involves the protection and a more restricted distribution of intellectual property using one of several legal mechanisms (patents, trademarks, copyrights, and trade secrets).

Perhaps the mechanism used most frequently by the behavioral scientist has been the peer-reviewed journal article. Most research institutions encourage and require such publications. However, many of these institutions are

savvy with regard to the time when publication of results should occur, and understand that information to be published may first need to be protected by one of the restrictive and protective intellectual property mechanisms mentioned above. That such protection is appropriate for behavioral technology is indicated by a search of the US Patent and Trademark's web site ([www.uspto.gov](http://www.uspto.gov)), which shows that a variety of technologies related to behavior are under patent.

Recently, the National Institutes of Health (NIH) published guidelines for the unfettered use of research tools developed under federal funding arrangements (grants and contracts) [35]. Research tools encompass materials (e.g., cell lines, laboratory reagents, transgenic species, and monoclonal antibodies), procedures, and information. The intent of the guidelines is to provide access for the research community to technology in the face of increasingly aggressive actions by many organizations to restrict access in order to preserve commercial advantage. Although there was no specific mention of behavioral procedures, behavioral technology could certainly fall within the NIH guidelines.

One goal of neurobehavioral toxicology is the development of validated and standardized methods for identifying and characterizing potential neurotoxic agents. Just as for the research tools encompassed by the NIH guidelines, these behavioral test procedures should be widely available without restrictions; there should be no requirement for a fee or royalty paid by the user to the developer when the procedures are used for noncommercial purposes. The recent US Environmental Protection Agency [59] neurotoxicity testing guidelines, which were developed using well-established behavioral procedures, can serve as a guide as to how new tests and procedures could undergo technology transfer.

Another avenue for the transfer of test guidelines is provided by the American Society for Testing and Materials (ASTM). The ASTM is an independent, nonprofit organization that establishes and publishes consensus standards for technical methods, practices, terminology, guidelines, classifications, and specifications. Although primarily orientated towards the physical sciences and engineering disciplines, life sciences in general and toxicology in particular have received attention. Notably, the ASTM has developed and published several standards involving the use of behavioral measures in fish for monitoring environmental toxicants [6].

#### 4.4. Protected intellectual property

The dissemination of scientific procedures and results through free and open publications, and the development of guidelines on the use of such procedures and results provided by regulatory agencies and others, exemplify one aspect of technology transfer. Another aspect of technology transfer, and one that is consuming a larger portion of the activities and resources of technology transfer offices every

year, involves intellectual property protected by patents, copyrights, or trademarks, or kept as trade secrets. Briefly, patents, copyrights, and trademarks are grants by the government to protect the products of inventive and creative activities. In general, patents protect inventions; copyrights protect original works of authorship of art, literature, and music; and trademarks protect words, names, symbols, and devices that identify specific businesses or products (e.g., logos) (Ref. [8]; see also [www.uspto.gov](http://www.uspto.gov)). A trade secret is intellectual property, such as a product, method, or process, known only to a restricted set of persons and having commercial value. The formula for *Coca Cola* is perhaps the best-kept trade secret. Because a patent is the type of intellectual property protection most frequently sought for the results of scientific research, further discussion will be limited to patents.

In the US, a patent is a grant from the government for a limited time during which the owner of the patent can exclude others from making, using, selling, or importing the invention claimed in the patent. Other countries grant patents but foreign patent laws and practices frequently differ from those in the US. Most research organizations, whether government, academic, or commercial, require that employees assign to their employer ownership rights of inventions made in the course of their employment. (Assignment is essentially the transfer of ownership of the technology.) Thus, it should be noted that an inventor may or may not be the owner of a patent covering an invention. Patent rights can be assigned or, more frequently, licensed to other parties for some negotiated financial return. A license is a contract that grants the right to use an invention claimed in a patent but is less than grant of ownership of the patent. The importance of patents to promote creativity, protect inventor's rights, and enable and promote commerce in the US was recognized by our founding fathers as shown in Article I, Section 8 of the US Constitution. It is notable that Thomas Jefferson, serving as the Secretary of State, issued the first US patent in 1790.

From a strategic business perspective, the right of a patent owner to exclude others from using the claimed invention establishes the owner's ability to control the commercial development of the invention. A patent also enables the owner to use the invention for further research and development without concern that others may independently develop and patent the invention, thereby preventing the would-be owner from practicing the invention. Patents are especially important for activities, such as drug and vaccine development, that have extensive development times and costs. As one potential licensee in the pharmaceutical industry once remarked, "patents are like gold to us."

Because patents describe and claim inventions, it is important to have an understanding of the criteria used by the US Patent and Trademark Office (USPTO) for determining whether a submitted invention warrants the issuance of a US patent. In brief, inventions must meet the criteria of

novelty, utility, and nonobviousness (see [www.uspto.gov](http://www.uspto.gov) for a more detailed and comprehensive discussion of these concepts). Novelty means the invention was not previously known or used by others, or previously patented or disclosed. Utility means the invention must serve some useful purpose. Nonobvious means the invention must be sufficiently different from prior inventions so that it is non-obvious to one having ordinary skill in the area of technology related to the invention. Moreover, for an invention to exist, the inventor must demonstrate both conception of (i.e., the idea of) the invention and reduction to practice (i.e., actually show the invention works). Inventions cannot be merely descriptions of naturally occurring phenomena. The adequacy with which a given invention meets these criteria is frequently open to argument between an inventor and the USPTO.

There are several basic aspects of the patent process that the laboratory researcher should be aware of. For those researchers new to patent prosecution, one aspect often causing difficulty is public disclosure [17]. In the US, an enabling disclosure of an invention, typically in the form of a published journal article, a meeting presentation, or even a seemingly casual meeting or discussion with others that are not part of the inventor's organization and without appropriate confidentiality protection in place, starts a 1-year time period within which a patent application must be submitted to the USPTO. Beyond this 1-year period, a patent can no longer be issued. In countries other than the US, disclosure immediately prevents one from obtaining a patent. Most technology transfer officers have struggled with complications caused when a scientist reports an invention after giving a presentation at a professional meeting or when a journal article is about to be published. In these situations, the loss of foreign patent rights can have severe negative impacts on protection and commercialization of the technology. Other actions that may result in a bar to obtaining a US patent arise from the use or sale of a technology for 1 year or longer prior to filing a patent application [17].

Another complication of the patent process for researchers concerns laboratory notebooks. Because court challenges to patents require clear and verifiable evidence of when an invention was made (conception and reduction to practice), laboratory notebooks can be critical for obtaining a patent or defending a patent once it is issued. For most inventions, conception and reduction to practice may involve a complex sequence of steps over time as research progresses. Scientists in industry typically follow strict procedures for entering data into secured, numbered, and bound notebooks, and for signing, dating, and having the notebook entries witnessed. Stories are legion of researchers, especially those not working for commercial entities, using recordkeeping procedures that fall far short of the optimal criteria for determining what was invented, when it was invented it, and who invented it. It is fair to say that laboratory notebooks and other recordkeeping practices have improved dramatically as individuals and organiza-

tions become more familiar with patents, patent licensing, and product commercialization.

#### 4.5. *Technology assessment*

Although some time has been spent presenting an overview of the patent process, patents are only one step in technology transfer. The initial activity stemming directly from laboratory research involves the reporting of potential new inventions to one's institutional technology transfer office. Although the form of the reporting may vary among organizations, the critical information describing the invention, what it does, whom the inventors are, and the dates and steps of conception and reduction to practice should be common to all such reports. Once reported, the technology transfer office will perform an initial assessment of the invention to determine if indeed a new invention exists; if further development is needed; if the invention is likely to be patentable; if the invention should be patented for reasons consistent with the organization's mission; if there is commercial potential that warrants the effort and expense of seeking a patent; if there are likely to be companies or other organizations to serve as development partners, buyers, or licensees; or if publication is a preferred means of transferring the technology [31]. The technology transfer office may commission a market assessment by an independent firm for estimating the invention's commercial potential and for identifying possible licensees. Assessment by a patent attorney and a thorough search of various databases for prior art (e.g., patent applications, issued patents, and published technical articles) may be necessary early on in the technology assessment process.

#### 4.6. *Patent licensing and technology commercialization*

Patent applications and patents can be licensed or assigned to others. Depending upon what is negotiated between the parties, a patent license agreement typically grants rights to make, use, or sell inventions under patent [11]. License agreements typically grant less than full ownership of a patent, whereas assignments typically transfer ownership. Once a patent application has been filed, an academic or government technology transfer office may begin to seek a commercial partner to further develop the technology to the point where a marketable product is possible. Similarly, the technology transfer counterpart of a commercial entity, often called the business development office, is responsible for both licensing "in" technology from other organizations, as well as licensing "out" technology from its technology portfolio to others. There are many factors that determine the interest in and value of a technology for licensing. The development stage of a technology, the necessity for licensing additional patents in order to effectively develop the technology, the availability and expense of additional patents for licensing, requirements of regulatory agencies for putting a product in the

marketplace, and characteristics of the end-user market (e.g., need for the technology, the size of the market, and the estimated financial return) are but a few of the many factors to be considered when licensing patented technology. An issued patent by itself tells very little about the potential for converting technology into a viable commercial product.

Patent license agreements specify the terms, conditions, and extent of transfer of rights to develop and commercialize inventions under patent. The terms of these agreements often follow conventions established within a given industry. License agreements may involve one or more payment schemes from the licensee to the licensor. Perhaps the most frequently used financial component is a royalty on sales from use or sale of a product developed from the licensed technology. Other typical payments are license execution fees due once the license is in effect, annual minimum royalty payments, milestones payments (based on such things as the successful completion of clinical trials, the approval for marketing by a regulatory agency, the first commercial sale of a product, etc.), sublicensing fees when the primary licensee further licenses the technology to others, and patent prosecution costs. Additional payments may be made for the issuance of a patent from a patent application, sales volume of a product, and specific commercial uses of a product.

Other aspects of license agreements beyond financial considerations are important and should not be overlooked. Perhaps the most important, and the one that is a major determination of the financial terms, concerns the extent of the rights granted to the licensee. Will the license grant all commercial rights to one party (exclusive license), or will rights be restricted in some way (partially exclusive or field-of-use license), or will multiple licensees have equal access to at least some uses of the technology (nonexclusive license)? If the owner of the patent is going to continue to develop the technology, the license agreement should address how improvements to the original technology will be handled. How will improvements be defined? Will improvements be passed on to the licensee, at additional cost, for what uses? Conversely, will improvements made by the licensee be made available to the licensor for research or other purposes? What requirements will there be for the licensee to invest specific resources and make measurable progress over time? What will be the consequences if these requirements are not met? A careful consideration of these and other factors is critical for increasing the likelihood that a given technology will be successfully developed and eventually transitioned to the marketplace.

#### 4.7. Summary

Technology transfer is an active part of many areas of science and engineering today. In behavioral toxicology and other disciplines involving behavior, technology transfer has been focused more on the open dissemination of research results rather than on developing technology for entry into

the marketplace. Nevertheless, there are notable instances where behavioral technology has been developed from laboratory science into an important and viable commercial product [42]. The present report provides an overview of some of the basic issues that need to be addressed in order for behavioral technology to move forward through this developmental pipeline.

## 5. Overall summary

Viewed through the lens provided by this symposium, behavioral toxicology can be seen as a sophisticated discipline that already has a history of conducting technology transfer informally. The ideas discussed provide a framework against which those efforts can be viewed. More important, the contributors have offered valuable and innovative suggestions for improving this process in future applications.

As Pennypacker points out, with technology transfer comes standards. Contained in his section is a novel proposal for a set of behavioral standards akin to the ASTM. He even describes proposals for maintaining these standards and using them to evaluate applications. The controversy that such proposals are likely to occasion was evidenced by the considerable discussion, mostly positive, that Pennypacker's proposal produced at the BTS meeting where this symposium was held (see also Ref. [62]). Anger's section describes an excellent example of the product development cycles required to achieve high standards of implementation. Discussions of *whether* we are ready for such formalization may be moot, however, because precedents exist [58,59] and, as Mele points out, behavioral standards have already been formed by the ASTM for aquatic testing. The question instead seems to be *how* standards should be applied and what behavior is suitable for formalization. If these issues are not resolved by the scientific community, then they will be resolved by someone else.

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