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Behavior Analysis and the R&D Paradigm

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This paper considers research and development (R&D) as a style of investigation that holds promise for the field of behavior analysis. Contrasted with academic-style research, R&D tends to be highly targeted toward achievement of specific outcomes, which are determined by a user community. R&D is typically multidisciplinary in character and is coordinated by a funding source. R&D usually includes extensive field testing and systematically addresses technology transfer. A program of R&D focused on detector dogs serves as an exemplar of this approach for behavior analysis.

Key words: dogs, olfaction, research and development, detection, explosives, illicit drugs

As behavior analysts, we share the fate of having been born and reared in psychology, education, and the social sciences. Given our contrasts with sibling disciplines and specialties, it is no surprise that we may sometimes think of ourselves as changelings, placed by mischievous fairies in the wrong family.

This disorienting experience has assured us periodic bouts of depression, as we wonder why we are not loved and appreciated by family members. After all, they distort our way of looking at behavior, to the extent they notice it at all, and fail to appreciate our way of studying behavior. They routinely ignore or misunderstand our research findings. Even as our siblings appropriate our technologies in an effort to reap their benefits, they casually mutilate features for intellectual or economic convenience. It is little wonder that we sometimes feel like giving up our identity and settling for an easier life.

We are fortunate there is a world outside of our social science family. In this larger society, others do not care about where we came from, our tribal pathologies, or how we feel about ourselves. All they really seem to want to know is what we can do for them. How exciting! We have the opportunity to be judged solely on the basis of how well we can help solve societal problems. Behavior analysis will grow and prosper to the extent that it is successful in making people's lives better.

INCREASING OUR TECHNOLOGICAL PRODUCTIVITY

These familiar reflections about the basis for the survival of a science border on a truism. The argument is reassuring because it promises a cultural discrimination between those disciplines that merely talk a good game and those that actually deliver. We count ourselves in the latter category and, therefore, look forward to eternal

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salvation. Perhaps we should not skip over the fine print too quickly. We can purchase redemption from our social science origins only by passing the Test for Real Sciences. We must show that our science can discover things about behavior that can be fashioned into dependable ways of ameliorating societal problems. Our answers will be graded by a society uninterested in the niceties of scientific philosophy and method, and its standards are practical and uncompromising.

Behavior analysis has been preparing for this test for some decades now. We have worked out a coherent, internally consistent, and effective way of talking about our subject matter. We have figured out effective ways of asking and answering research questions. We have discovered the fundamental orderliness of behavioral nature and continue to refine a growing understanding of its laws. We have tried our hand at managing behavior for practical purposes and found more than a little success, particularly compared to the achievements of others. We have organized ourselves and reproduced with sufficient success to increase our numbers a bit each year. We might appear ready to take society's Test for Real Sciences and secure our future at the economic trough.

I have previously reviewed our readiness for this test and urged caution (Johnston, 1991, 1993, 1996). The worries articulated by a number of such evaluations seem to revolve around the interface between our basic and applied scientific endeavors—in other words, how we turn scientific progress into technological achievements (Birnbrauer, 1979; Deitz, 1982; Hayes, Rincover, & Solnick, 1980; Mace, 1991, 1994; Michael, 1980; Pennypacker, 1986; Pierce & Epling, 1985). In general, it has been suggested that our basic science should be more responsive to applied issues and that our technological offerings should be more completely developed and effectively delivered in practice. It is understandable if this assessment seems to conflict with the fact that we have accumulated large and varied literatures, the application of which is often strikingly effective in field settings. As Pennypacker (1986) pointed out, however, there is some distance between a principle or technique that has practical potential and the routine delivery of a consistently effective technology in the marketplace.

This distance is customarily traveled in what might be called an academic research style. This academic research style is so familiar that we may not recognize its features. Perhaps its most salient characteristic is that research directions tend to evolve from the interests and opportunities of individual researchers. Although scientists may generally be influenced by cultural needs and interests (e.g., Herman, 1995), such general priorities do not necessarily yield focused and coordinated multidisciplinary research programs. In spite of its advantages as a general approach to scientific discovery, this academic style is not always the most efficient way to pursue a research problem. Investigators may digress from an original interest. Issues may go unattended for long periods. Gaps among studies may leave questions unresolved.

This research style can be especially problematic when the research opportunities are technological in nature. In contrast with more basic research interests, the development of technologies requires attention to a specific set of preordained outcomes. This means there is usually a fairly clear sequence in which research questions need to be addressed so that the resolution of component problems occurs in a coordinated manner. In technology-driven research, each study must fit others like the pieces of a jigsaw puzzle. This need is not easily met in a research style in which organization emerges only out of mutual interests.

THE R&D PARADIGM

One solution to the scientific requirements of technological develop-

ment lies in a research style known as research and development or R&D. This variant of scientific research evolved alongside its more academic peer but attained maturity in the post-World War II era of increasing government and corporate sponsorship of applied research.

R&D has a number of characteristics that may suit the interests of behavior analysis in improving our technological productivity. R&D tends to be highly targeted toward development of specific outcomes or deliverables. These deliverables are determined by a careful and often research-based analysis of the needs of a user community. Because research agendas are driven by a set of problems rather than the interests of individual investigators, R&D is often multidisciplinary in character. Diverse areas of scientific expertise are brought to bear as needed by a research program. Coordination of R&D activities is typically arranged by a funding source, usually a government agency or a corporate product development effort. Unlike more basic research support, many funding mechanisms take the form of contracts rather than grants and specify not just outcomes but research timelines as well. One of the objectives of corporate or government sponsors is that the research agenda be not just effectively but also efficiently pursued. R&D programs typically include extensive field testing, often in competition with alternative technologies. Finally, because effective outcomes are the highest priority, this concentrated focus on technological development does not accommodate relaxation of the methodological standards of scientific research.

IBDS CANINE R&D

Background

In recent years, I have become involved in a program exemplifying this R&D style. It has been a fascinating scientific experience not only because of the nature of the research problem but also because of exposure to this approach to technological development. My involvement began in 1988 when a couple of graduate students and I set about learning how to train dogs to discriminate odors under laboratory conditions. In 1989, Auburn University formed the Institute for Biological Detection Systems (IBDS) to facilitate the efforts of myself and the founding director, a member of the College of Veterinary Medicine, to obtain support from federal agencies.

The government is interested in improving canine detection technology because the dog-handler team is generally, if sometimes reluctantly, acknowledged to be the most widely used, broadly sensitive, accurate, fast, mobile, flexible, and durable detection system available ("Technology Against Terrorism," 1991). In spite of the acknowledged sensitivity of the dog's nose, events such as the bombing of the Murrah Building in Oklahoma City make it clear that the government must continually improve its detection capabilities. To this end, various governmental agencies and offices fund millions of dollars of R&D each year to improve existing detection technologies and to develop new technologies using every conceivable detector capability science can imagine. It is clear that the dog has some serious competition.

The R&D agenda for dogs is straightforward. The government needs to know just how good dogs are, and it needs to optimize their performance in the field. The first objective is required both because no one knows exactly how good dogs are and because the detection capabilities of dogs must be characterized with the same completeness and precision as for other sensor technologies. This interest is partly operational and partly political. Learning how sensitive dogs' noses are to various substances will aid trainers and handlers, but this information is critical in helping dogs compete with other detection technologies. As behavior analysts have long known (Bai-

ley & Bailey, 1977; Breland & Breland, 1951; Skinner, 1961; Verhave, 1966), it is not easy to sell trained animal behavior as the basis for a "real" technology. Given the origins of other detection technologies in chemistry and physics, the scientific standards for this work are those of physical sciences.

In order to appreciate the second objective, it is necessary to know that canine detection technology is based on a prescientific understanding of canine behavior. What behavior analysts know about behavior, particularly about how to produce a consistent, specific performance, is usually not evident in how dog-handler teams are trained and deployed. If humans had not been training dogs to find things for thousands of years, and if we were not asking dogs to do something they are predisposed to do partly as a result of how we breed them, most trainers and handlers would not be as successful as they are.

Collaborations

Funding sources. Characteristic of the R&D style, the staff at IBDS has grown to be part of a network of interagency and interdisciplinary collaborations. IBDS funding comes via a confusing jumble of government acronyms. Also typical of R&D projects, funding is usually in the form of contracts rather than grants. IBDS is very well supported through as many as five or six funding vehicles at any one time, averaging about one year in duration. Although we do not usually have to submit NIH-style proposals for peer review to get our money, oversight by program managers and agency personnel is quite thorough. Collectively, a subset of these agencies constitutes a Canine Interagency Working Group, which requires monthly reports and onsite reviews, not to mention near-daily communication by phone, fax, and E-mail. The group's members all have degrees in the physical sciences, typically in chemistry.

Without exception, the funds are operational in their focus. That is, the deliverables they specify generally have immediate, practical value or at least directly contribute to an operationally useful capability. It would be difficult to overstate this characteristic R&D emphasis. It is not just that Statements of Work are phrased in terms of government interests in substance detection or in specific agency needs. Every facet of each research project uses particular operational considerations as touchstones, and we have had to become quite familiar with operational practices and issues. In spite of this single-minded applied focus, it has not been difficult to sell the value of laboratory research, which has thus far been our primary activity.

Research partners. One cannot study a chemical sense without chemists around. IBDS has its own chemistry laboratory using multiple analytical instruments. However, we also work with outside laboratories on particular issues. For instance, we developed our vapor generation and delivery instruments in conjunction with Battelle Memorial Institute, one of the country's large R&D corporations. We have also collaborated with Battelle in acquiring explosive substances and solving some odor analysis and delivery problems, such as how to test canine sensitivity to nitroglycerin without blowing up the dogs and the building. We also work with the Idaho National Engineering Laboratory and the Federal Aviation Administration Technical Center.

Detection agency partners. Given the operational character of this research, we also keep in touch with most of the federal canine detection programs. An early contract to visit and review a number of programs not only educated us but also established a basis for collaborations. We have a research relationship with the Military Working Dog Center at Lackland Air Force Base but maintain good contacts with the programs of the U.S. Treasury Department and U.S. Customs as well.

We also have numerous contacts with the state and local law enforcement community as well as with detection programs in foreign countries.

Professional communications. These relationships are partly maintained through scientific meetings with members of a diverse international substance detection community. My students and I are typically the only scientific registrants who are not chemists, physicists, or engineers. Many attendees represent government funding and operational agencies as well as companies developing detection technologies. It is characteristic of R&D that paper sessions intermingle presentations that range from research that is almost basic in focus to research that is quite applied, including reports of field testing or operational use. Some studies are formally experimental in nature, but they are as likely to be what we would call descriptive. The unifying focus of paper sessions is the technological objective, and those who use the technology in the field are viewed as having as much to contribute as bench scientists. All such meetings publish proceedings volumes so findings are quickly available for immediate use.

Canine Olfactory Detection Research

Technical challenges. It took at least 4 years to identify the technical barriers facing us and figure out how to overcome them. Most of these challenges revolved around generating and delivering odor stimuli vapor from liquid or solid source material at concentrations down to the parts per trillion level, a level of precision and consistency demanded by the field of trace chemistry.

Although other researchers have designed vapor generation equipment for other applications, these systems are not available off the shelf. Aided by consultation from agency chemists, IBDS developed a vapor generation instrument that works by serial air dilution. One version allows multiple dilutions within a session of a single odor source, and the other allows use of a single dilution of each of multiple odor sources within a session. The output of the instruments must be assessed by thermal desorption gas chromatography and mass spectrometry or other analytical devices in order to determine what is being delivered and at what concentrations, as well as to assure that daily cleaning procedures are effective. These vapor generators are complex, demanding, and expensive, but this is the price of olfaction research.

It is not only vapor generation equipment that has given us headaches. The odor source material we work with provides its own set of challenges. Sometimes it is a matter of acquiring material. It turns out that the Drug Enforcement Administration (DEA) does not very often get requests for 600 g of white heroin, so they had to check us out. We already had a kilo of illicit cocaine, courtesy of the Alabama Bureau of Investigation, and have since acquired another from DEA. We have become familiar with Department of Transportation requirements for shipping more than 2 pounds of high explosives like TNT or C4 and had to install special fire doors in the laboratory and put storage magazines out in the woods. Figuring out how to generate and deliver nitroglycerin vapor safely took more than a year.

Our subjects are random-source adult dogs—about 60 at any one time. Learning how to work with dogs as laboratory subjects has not provided technical challenges as much as interesting opportunities to apply what we know about behavior to a new species and set of experimental objectives. It took a while to figure out the details of our primary preparations and a while longer to get good at training the required repertoires. It has been more trouble to deal with the considerable health, regulatory, and management requirements associated with using dogs as experimental animals.

Research agenda. Our laboratory and field facilities can be used to ad-

dress a variety of questions about canine olfaction and detection performance. An important part of our job is to understand operational interests from the perspective of agency administrators, training program managers, trainers, handlers, the user public, and the detection research community and translate them into a research program. A significant portion of our budgets and time is devoted to becoming aware of the interests and problems of these groups by traveling to meetings; visiting agencies; bringing in field consultants; and following scientific, technological, and operational literatures. We in turn guide the funding interests of our agency supporters by writing research plans, recommending research themes, identifying important issues, and proposing particular studies. This informal process has generated a reasonably systematic research program.

Our continually evolving research agenda can be divided into three categories. The first includes studies of the olfactory capabilities of the dog. These questions concern the limits of detection for various substances and the odor detection signatures dogs learn to use to discriminate target from nontarget substances. These studies require a high degree of control over the generation and delivery of vapor compounds, and must be conducted under laboratory conditions. Studies of vapor collection capabilities (sniffing) also fall into this category.

The second category addresses factors that modulate the dog's detection capabilities. These factors include environmental variables such as weather conditions, task characteristics, and extraneous odors. Biological variables such as age, gender, nutrition, disease, and treatment protocols also fall into this category.

The third category addresses factors that optimize training and deployment. These studies cover issues such as training techniques, generalization across variants of odor source materials, odor source contamination, detection performance, and new detection protocols.

The studies conducted under these categories have collectively had considerable impact on the canine detection community. These studies have for the first time documented the dog's limits of detection for various compounds. Perhaps more important, they have revealed that dogs learn to discriminate a substance by responding to one or two of its most abundant vapor compounds. Field studies have revealed performance capabilities that have direct implications for training and deployment protocols. Most broadly, this entire program of research has shown administrators, trainers, and handlers that operational questions can be answered by research instead of reasoned speculation, thereby allowing the detector dog to be evaluated in the same manner as other detection technologies.

BEHAVIOR-ANALYTIC R&D

Our experiences in this R&D arena have provided us with the kind of challenges behavior analysis is good at. Behavior analysis is good at approaching behavioral problems defined by others in traditional ways and reinterpreting them in ways that allow us to offer effective solutions. We are good at dealing with diverse and difficult measurement problems and coming up with workable solutions. We are good at creating experimental plans that serve both scientific and user interests. We are good at paying close attention to issues of experimental control, whether in laboratory or field settings. We are certainly good at being thorough and persistent in considering the interests of a user community and evaluating outcomes on their terms. And we are very good indeed at using our knowledge of how behavior affects and is affected by the environment.

These competencies suggest that behavior analysis should be selling not just its technologies, but its skills at developing technologies. Although be-

havior analysts naturally focus on developing techniques for ameliorating behavioral problems with traditional populations (e.g., individuals with developmental disabilities), we may also profit from participating on multidisciplinary teams that address behaviorally based interventions that are not necessarily seen by other team members as behavior analytic in character.

For example, a sponsored R&D program charged with developing a drug rehabilitation regimen would likely benefit from participation of a behavior analyst who is able to contribute in the ways listed above. Other team members might represent other areas of expertise, so part of the challenge is finding ways of contributing behavior-analytic expertise that others find useful. Suggestions regarding ways of measuring behavior, designing experiments, identifying important contingencies, or analyzing data can influence the direction of a program if offered as a way of solving problems the research team faces. The objective should be to contribute to the team's activities, not to make it a behavior-analytic exercise.

The challenge for many behavior analysts may not be how to contribute but how to find opportunities to team with other specialties and disciplines. Although researchers in other fields may not be aware of our capabilities and may therefore fail to search us out, we may not be as flexible as we might in looking for new research roles. Every university has no shortage of multidisciplinary research opportunities, however, and they may not be in the academic units in which one would expect to find them. Research problems pursued in colleges of engineering may have a significant behavioral component if they involve a human–machine interface. The behavioral element may be even easier to find in architectural projects. Other traditional organizational units (e.g., animal sciences, biology, chemistry, forestry, pharmacy, etc.) almost inevitably support R&D style research in which behavior plays a major role.

We need to find opportunities to contribute to multidisciplinary teams not just for the contribution we can make to the research problem but for the contribution we can make to our field. Every such relationship can have a broader impact than might be obvious. There was no evidence 10 years ago that the canine detection program would create the opportunity to sell behavior analysis to chemists, physicists, engineers, and government program managers, not to mention to show the detector dog community how an understanding of operant conditioning can optimize its effectiveness.

The focused character of R&D is harder to come by. It requires someone or some entity to bring related, but still varied, interests and skills of different researchers to bear on a set of problems. This focus is usually coordinated by a funding source. Funding initiatives often define a problem, select R&D teams, and organize the research program. The Defense Advanced Research Projects Agency landmine initiative is a typical example of this approach. However, the coordinating muscle of a funding source can follow rather than precede local initiatives. Our efforts began with nothing more than an interest in learning how good dogs were at smelling things, the conviction that federal agencies would be willing to pay for our expertise, and a bit of entrepreneurial spirit. Universities are usually willing to seed promising ventures like this, as Auburn University did for us.

One of the prerequisites for success in turning locally shared research interests into a funded and focused R&D effort is a good understanding of the interests of funding sources. This is when we need to exercise our skill at looking at the world from someone else's perspective. In our case, we had to think less in terms of what we wanted to learn about canine detection performance and more about what detection agencies thought they needed to know to strengthen and defend their programs. It helps to take the long

view here. Personal priorities may have to be temporarily subjugated to the interests of a user community or funding agencies, but that is a familiar sacrifice in any style of applied research.

Finally, we should consider how to prepare our graduate students to contribute their expertise to multidisciplinary R&D teams. The required skills seem to be less a matter of formal curriculum than research experience. Students whose research experience lies only with a major professor may not be adequately prepared to appreciate the priority of the R&D objective and the compromises of the multidisciplinary team process. Furthermore, the focused and time-sensitive character of R&D can contrast sharply with the experience of working on a thesis or dissertation, where thoroughness must be pursued without balance by other priorities. The characteristics of the R&D process are probably most easily learned from first-hand participation. Lacking such opportunities, there is no reason why an otherwise academic research project cannot be bent toward the R&D style. Requiring students to establish and attempt to meet specific objectives (deliverables) and timelines may teach them that striving for a particular achievement through disciplined decision making can be both an efficient and effective means of answering a question.

In summary, it is our ability to develop and deliver technologies that are truly effective from the user's perspective that will insure growing support for behavior analysis in the academy, in the service arena, and in the culture at large. Pursuing technological development in an R&D style offers a means of not only focusing our own applied research but also broadening our relationships with colleagues from diverse fields as we team with them in addressing behavioral facets of developing technologies.

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