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Giving Psychological Science Away

The Role of Applications Courses

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ABSTRACT—*The applicability of basic research in psychological science is obvious to those in the field, but too often underappreciated outside of it. In this article, I suggest some reasons for that gap, including confusion between the relevance of psychological science and its actual application, which can lead to hype; the interdisciplinary nature of applied science, which can obscure the credit due to the field; and the considerable difficulty of moving basic research into application, including the potential for resistance to the products we deliver. I suggest that our own students constitute a relatively underutilized audience for demonstrating that psychological science has been critical to applications, and I describe an applied cognitive science course that is intended to make the case to them.*

A decade ago, a group of psychological scientists convened in Santa Barbara, CA, for a "summit" meeting, with the lofty goal of determining the future of psychological science in the U.S. Much of the discussion focused on how to promote public understanding of what we do; that is, "the public image of scientific psychology, and the transfer of knowledge from theory to application and practice" (Ruksznis, 1998b, p. 14). At the end of deliberation, the group passed a resolution calling on "government and society to take greater advantage of existing psychological science" and on "psychological scientists to equip themselves and their students and to educate the public to address the issues of importance to society" (Ruksznis, 1998b, p. 14).

Psychological science has always been pointed toward application (for historical review, see Benjamin & Baker, 2004), and in the years since World War II, it has spun off whole applied fields, most notably human factors and industrial/organizational psychology. No one at the 1998 summit meeting doubted that basic psychological science could be translated for public good. Earlier that year, the *APS Observer* featured a special report on basic research in psychological science, as a component of the ongoing Human Capital Initiative (Ruksznis, 1998a). The report suggested 11 basic research areas that were ripe for translation. The suggested areas within cognitive science, my own field, included the usual suspects—perception, learning, memory, and attention—as well as some relatively new kids on the block—expertise, decision making, and neuroimaging of the brain.

Following George Miller's (1969) elegant turn of phrase, academic psychologists often talk about giving psychology away, and it seems that we have ever more to give (for a recent compendium, see Zimbardo, 2004). Yet despite the collective commitment of psychological scientists to pursuing research that has societal relevance and despite our firm belief that we are succeeding, there are clear signs that society—including the general public and policy makers—often misses the point. The 1998 summit was called, in part, because scientists perceived a failure to connect public awareness to the utility of basic psychological research.

Why has the public generally failed to recognize the importance of basic psychological science for everyday life? For some insights, consider my own experience as I began to teach a course in applied cognitive science, which I take to be a rough conglomeration of cognitive psychology, cognitive modeling, and cognitive neuroscience. I reread the HCI-6 report with care, expecting to assign it to my students. Although I found some gems of promise and prescience, like cochlear implants, statistical decision aids, and neural correlates of memory states, to my surprise (and chagrin—I helped draft it!), I found the report unusable as a teaching vehicle. Too often, the document veered between broad pronouncements (experts know more than the untutored) and naive prognostications (mandatory attention-skills

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tasks for airline pilots; beta-blockers routinely administered to emergency medical personnel). Students, I believed, would not find it persuasive. In large part, I did not.

Academic psychologists have an ideal avenue for enhancing public recognition of the applicability of psychological science, and it is one that seems to be underexploited: our own psychology students. As a group, they are bright, interested, well educated, and their interests lean heavily toward applying what they know. Although we are well-prepared to teach them basic psychological science, we sadly lapse in teaching how it is applied. Outside of professional training programs, few courses focus on application. I searched online for applied courses in experimental psychology and found them for the most part in human factors and I/O curricula, with human–computer interaction being a relatively sparse newcomer. Here are some excerpted course descriptions from various Web sites that represent the flavor of these offerings:

- Industrial/Organizational Psychology. A comprehensive survey of psychology applied to the workplace. We hit all the major topics: job analysis, employee selection, performance appraisal, industrial training, job satisfaction, leadership, and work conditions.
- Advanced Human Factors Psychology. Foundation from which to study interactions between human beings and systems in order to maximize safety, performance and user satisfaction; integration and application of basic research and theory in sensation, perception, cognition, and motor control.
- Introduction to Human-Computer Interaction. Concentrates on the effectiveness and efficiency of computer technology from the user's point of view. We look at the complete life cycle of interface development.

These courses sound fine to me, but they aim to cover a core set of topics in a specialized field, and they are oriented toward the training of practitioners. Over the past few years, I have attempted to develop a different sort of course dealing with applications of basic psychological science. There is no professional-training agenda; it is meant simply to be a part of the core curriculum. The goals are to heighten students' appreciation of the pathway from basic research in psychological science to application, and in addition, to expose them to the ruts and potholes along the way. I focus on cognitive science, my own area of expertise, with some daring forays into topics about which I know relatively little. The evolution of this course has made me aware of a number of issues that I believe go beyond questions of course design to expose more general obstacles to giving psychological science away. In the remainder of this article, I will discuss the issues in a general sense and offer some ideas about how an applications-oriented course in cognitive science (or a parallel course in another discipline) could promote public understanding of our science.

ISSUE 1: WHAT IS AN APPLICATION OF PSYCHOLOGICAL SCIENCE?

One of the obstacles to showing how psychological science is translational, and one that is amply demonstrated in the HCI-6 Basic Research document from 1998, is the lack of what is called in forensics the *chain of evidence*. Consider the contrast between psychology and other fields. Engineers and computer scientists perform and publish research, file for patents on the ensuing widgets and software, and perhaps spin off companies. Academic psychologists tend to stop at the perform-and-publish stage. For the most part, we produce scientific discoveries that are relevant to application, and we place them in the public domain. Our work is often combined with contributions from other fields. So how do we and the rest of the world know when we've been translational?

Let's take a quote from the HCI-6 document that illustrates the problem: "For example, psychophysically based knowledge about . . . auditory factors . . . allows us to predict which aspects of the sound wave do not need to be sent with great precision and which aspects do" (Ruksznis, 1998a, p. 8).

The application of interest here is speech compression, a reduction in information content that is necessary for phone or other speech-transmitting networks in order to handle the transmission of the many messages sent at any one time. Was basic perceptual research necessary to enable this application? You bet—there is no way to know what reduced speech content is decodable by humans without experimentation. Toward this end, classical techniques of psychophysics are invaluable. In short, speech compression is an application that would seem to have a clear trail to its roots in psychological science. Yet, even with this trail, I would suggest that most people don't spontaneously link the application to basic science in our field.

Even more unfortunate are two mirror-image problems. One is failure to apply: Much psychological science that could inform application is disregarded, often with significant cost to the public. The other is a perverse aspect of our field's relevance to everyday problems, which I compare to Gresham's Law: It is all too easy to develop an product that claims to be scientifically founded, but isn't. These pseudoapplications, as I call them, obscure those that have a solid scientific basis and undermine scientific psychology's reputation as a transferable discipline.

To illustrate the failure to apply, here is another quote from HCI-6: "Research on attention in dynamic displays has direct implications for the design of work environments, car dashboards, intersection signaling, and computer displays, to name just a few examples" (Ruksznis, 1998a, p. 11). This statement has face validity, and I agree with what it says, but where's the app? Ten years after HCI-6, where are the workplace designs or intersection signals that can be directly traced to research on the number of dynamically changing events to which we can attend at any one time? In that decade, GPS systems for cars have become commonplace, and cell phones have added visual capabilities, but basic research on attention has had minimal impact on display design. There is now a body of psychological research demonstrating that attentional demands of ancillary devices impair driving (e.g., Strayer & Johnston, 2002), but only a few states have laws restricting cell phone use to hands-free displays in driving (Governors Highway Safety Association, 2008). Moreover, these laws do not address the more general attentional issues that are still present when people converse by phone without using their hands.

As these examples attest, there is an unfortunate potential for slippage between the psychological science that has relevance to application and the applied world. Few applications are so clearly founded in fundamental psychological science that their disciplinary roots are clear. Others may owe a debt to our science that is undocumented or unacknowledged. Moreover, relevance and potential are not enough to guarantee that an application will come into being.

In the context of a course in applied psychological science, these gaps between science and app raise an important problem: What constitutes a successful application? What constitutes an unsuccessful attempt to apply psychological research, and what constitutes a pseudoapplication? For purposes of the applied cognitive course, I have adopted a restrictive definition of successful application, based on the chain-of-evidence principle. Ideally, the topics I cover should show a link between basic research and a tangible outcome. For the latter, I require an identifiable application, such as a commercial product or public policy. Of necessity, the course also covers counterexamples, in which a well-intentioned attempt to apply psychological science fails or basic research is taken advantage of by pseudoappliers.

ISSUE 2: FIND ME THE APPS!

I've laid down a basic criterion for an application to be considered in my course; namely, it should link basic research to a concrete outcome in policy or product. That said, how do you find an app? It might seem that there are many resources available to someone interested in tracing the connection from basic research in psychological science to its use. There are books on applied psychology and consensus reports like HCI-6. There are applied-psychology journals. There are professional organizations. These resources provide many examples of what Nickerson (1998) described as the content of applied experimental psychology, namely, "psychological experimentation explicitly addressed to practical concerns" (p. 155), or what the editorial description of the *Journal of Experimental Psychology: Applied* characterizes as "experimental psychology linking practically oriented problems and psychological theory." The research described in these sources is of high quality—it is generally relevant to real-world concerns. However, it rarely describes an application that students (and presumably, the world at large) can immediately grasp as such. In essence, for purposes of the class I make a distinction between applied research in psychology, which meets the criterion of being directed at practical issues, and an application of psychological research, which offers specific tools to address issues of practical importance.

Faced with a plethora of documentation that we do applied research, yet finding little that I could point to as a real, successful app by my own strictures, I began my efforts at course development in a different way. I consulted a human data base, namely, the collective knowledge of the *Society for Experimental Psychology*. Its members are illustrious researchers, and many play roles in the scientific infrastructure. I suspected that those folks would have firm ideas about what constituted applied cognitive science. Accordingly, I sent the listserv a query, asking for issues and applications of cognitive and perceptual research to be discussed in a course. My colleagues did not disappoint me. The list encompassed education and training, semantic analysis systems, speech technologies, visual displays, eyewitness memory, decision aids, consumer testing, and rehabilitation. Suggestions hewed to my request for specificity and became the roots of the ultimate course content. Members also pointed to the expertise of government administrators, whose charge is to bridge basic research to application. In particular, Susan Chipman of the Office of Naval Research provided invaluable insights into course material.

In teaching the course, I have culled topics from the initial list, honed them, and added more. Although cognition remains the focus of the course, I've also found that students need to be reminded of the limitations of cognitive regulation. Hence, I've added examples of basic psychological research showing how seemingly rational behavior can stem from processes well outside of cognitive control, as well as research showing behavior that defies rationality. I've also permitted some topics that have to date generated only pseudoapplications, by my definition.

Table 1 lists the generic topics currently covered in the course, related application areas, and fields outside psychology with which these topics are interdependent, either because they were fundamental to the application, or because they make use of it, or both. The Appendix lists a couple of representative readings for each topic.

I am certain that anyone looking at Table 1 will immediately take issue with it. The table only points to the story of applied cognitive science. Many papers would be needed to describe relevant applications in detail, and that is not the purpose of this article. Then there's the problem of how well it meets consensus, which exists only to the extent that cognitive scientists could even agree on relevant topics and their ranking. There are errors of omission that reflect my personal interests and biases, and no doubt readers will want to add to the list of topics. The errors of commission are also my own. Readers may debate whether certain application areas listed in Table 1 have actually reached a level of maturity sufficient to merit the label *applied*. Some may question whether there has been significant psychological contribution. I welcome communication on these issues.

TABLE 1
Topics Covered in the Application Course, Related Application Areas, and Other Interdependent Fields Outside Psychology

Foundational topics and application fields	Maturity of application	Enabling fields outside psychology	Consuming fields
Perception and spatial cognition			
Virtual reality	Medium	Engineering, computer science	Military, entertainment
Environmental representation and wayfinding	Low	Engineering, computer science	Guidance systems
Signal-detection-based decision aids	High	Computer science, decision theory	Medicine, quality control
Memory			
Eyewitnessing	High	Law	Jurisprudence
Memory and sleep	Low	Neuroscience	Emerging
Learning			
Reading education	High	Linguistics, education	Education practice and materials
Cognitive tutors	High	Education, computer science	Education
Teaching by analogy	Low	Education, business	Education
Neural plasticity			
Training for expertise	Low	Neuroscience	Sports, defense
Training and rehabilitation	Medium	Neuroscience	Medicine
Speech and language			
Speech recognition and synthesis	High	Engineering, computer science	Communication, security
Semantic representation	High	Linguistics, computer science, math	Information systems
Beyond cognition: unconscious and emotional processes			
Consumer choice	Low	Neuroscience, marketing	Marketing
Regulation and compliance	Low	Neuroscience	Public policy, judicial

With regard to maturity, I have indicated in Table 1 my own evaluation of how much the application side of the research has been developed. For example, research on eyewitness memory has reached the point where formal policy statements based on it have been issued; hence, I consider it high in maturity. The technologies of speech recognition and synthesis are undoubtedly highly advanced. On the other hand, although research on brain-based concomitants of emotional responses has the potential to be widely used for marketing, and advertising firms have quickly capitalized on its novelty, there is considerable controversy over whether neuroscience-based marketing is valid, let alone whether it has advantages over other forms of market research (Chang, 2006). To consider another case, *virtual reality* (VR) refers to a body of research on basic sensory/perceptual processing that forms the underpinning for viewing devices like head-mounted displays, force-feedback devices for virtual haptic environments, and spatialized sound that simulates a point of origin. Whereas early simulators like mock-up aircraft cockpits reproduced the visual displays used in real environments, contemporary VR has the potential to create the perceived world itself by mimicking the basic sensory cues. This potential is now being realized, for example, with medical trainers that use haptic VR to simulate the forces encountered in procedures like gall bladder surgery and spinal puncture. Finally, as an example of a highly immature area, consider sleep and memory. Whereas emerging research provides evidence that sleep after learning aids memory consolidation, the direct application of this research to product or policy is not transparent. To the contrary, there are pseudoapplications proclaiming that "science says" it is possible to learn foreign languages while sleeping.

ISSUE 3: HOW DOES APPLIED COGNITIVE SCIENCE ACKNOWLEDGE ENABLING FIELDS AND VICE VERSA?

There is no application of cognitive science research that I have found that does not benefit from and contribute to research in other fields. The applications that I cover in the applied cognitive science course are, accordingly, interdisciplinary. Enabling fields, which provide foundational research, and consuming fields, which employ the applications. are shown in Table 1.

Substantive areas that have collaborated with cognitive science to enable applications are heavily concentrated in engineering, other sciences, and education. Seminal work in psycholinguistics, for example, characterized the speech signal and highlighted the importance of top–down processing. The developers of automatic speech recognition algorithms have brought to bear ever more sophisticated statistical models and improvements in computer hardware and software, but the path from psychology is still evident. Law and business have also played an enabling role; psychologists studying eyewitness identification have worked closely with legal professionals to develop guidelines for eliciting eyewitness reports.

Education acts not only as a foundational field for applied cognitive science, but as a consumer. Fundamental research on analogical reasoning has been used to develop negotiation training for students in Masters of Management programs (Loewenstein, Thompson, & Gentner, 1999). Psychological research on reading has been the cornerstone of educational policy that points to the importance of phonological training. Marketing firms have increasingly been applying research on unconscious and emotional processing, and despite controversy, some are specializing in measuring brain activity during consumer choice. Information technology is another consumer of cognitive research. Search engines are based on latent semantic analysis (Landauer, Foltz, & Laham, 1998), which in turn is enabled by basic mathematics of matrix decomposition. Whenever we interact with voice-response menus on the phone, we are profiting from psychological research on speech recognition, in collaboration with engineering and computer science.

I have been making the point that other disciplines are critical to moving basic psychological science into application, and that they are also essential consumers of the resulting products and policies. There is a down side, however, to all this coziness that I alluded to earlier: Interdisciplinary interaction can muddy the waters when credit is due. Other fields can overshadow contributions of basic psychology. When neural activity is correlated with some perceptual or cognitive function, it is all too easy to give the credit to neuroscience and to forget that the tasks that are used to earmark a particular function came from cognitive scientists. When we buy an off-the-shelf speech-driven word processor, we can be agog at the technology and fail to appreciate that there are psychological foundations to speech technology. Psychological contributions are often not even recognized, let alone acknowledged.

The answer to the problem of underrecognition of psychology's role is not to pretend that other fields are irrelevant. Yet, this seems to have been a common mistake of some of the broadly conceived efforts to prove the utility of our field. In trying to keep the contributions of psychology pure, position papers have often told the story at too abstract a level. Research on the psychology of X is highlighted as being relevant to application Y—you can substitute whatever you like for X and Y (X = attention and Y = driving by the elderly, for example). I've already pointed to problems of this sort in the capital initiative documents, and they don't seem to have gone away.

In fact, to show how psychological research has been translated, researchers must embrace the contributions of other fields. By doing so, we will not undermine the case for psychology. To be persuasive, we must celebrate interdisciplinary work, not avoid it.

ISSUE 4: HOW DOES BASIC PSYCHOLOGICAL SCIENCE BECOME AN APP?

Another problem with papers that wave the flag for the applicability of psychology is that they seldom confront the real difficulties of translating basic science into policy or practice. I don't think that's an accident: As I've noted, most psychological scientists doing basic research regard publication as the end point. If a connection to application is made, it is assumed that the published research will be picked up by others as needed. Sometimes, indeed, this happens. Virtual reality technology, for example, capitalizes on basic knowledge of sensation and perception, available from seminal publications. A new field called *sensory marketing* is following a similar path, albeit for very different purposes.

Spontaneous combustion is, however, not a good general model as the pathway to application. Consider again the use of in-car devices while driving. It could have been foreseen in 1998 that developers of in-car technologies would largely ignore attention research. When devices like GPS and cell phones first arrived in automobiles, there were simply no economic or social forces for translating the basic research into practice and designing them to minimize attention load. Those pressures are arising circuitously, as accidents occur and lives are lost, but the process is slow and the costs are tragic.

A clear lesson from studying applications is that translation does not happen by itself. Most successful applications have relied on scientists to go beyond publishing their basic research. They become involved, they perturb their research careers, and they end up banging on doors. The potential for research to be applied is simply not enough to get the job done. Most good ideas don't become patents, and most patents stay in the patent office. Good ideas go unsung, while lesser ideas capture market share or newspaper publicity. This story is true of applications in science and engineering, and psychology is not spared. This is why part of a course in applied anything should deal with the pressures that promote or discourage transferability. Unfortunately, discouragement is more common, making the path to application an arduous one.

Historical accounts of how basic psychological science is applied are invaluable but all too rare. These stories provide lessons that are an important part of teaching an applications course and that should be instructive to anyone promoting our science. I will describe a couple of cases for which the road to application has been tracked in published documents, as well as the lessons learned.

The first case is cognitive tutoring, an application that has a homegrown flavor for my students. Carnegie Mellon University is the birthplace of a tutoring company, Carnegie Learning Inc., which grew out of the research program of John R. Anderson. Today, more than half a million students use cognitive tutors based on his model, called ACT, to develop skills in the basic mathematics curriculum. A series of chapters on the history of ACT tutor development and its scientific roots have been published (Anderson, Corbett, Koedinger, & Pelletier, 1995; Anderson & Gluck, 2001; Koedinger, Anderson, Hadley, & Mark, 1997; Ritter, Anderson, Koedinger, & Corbett, 2007). Anderson's personal account of the roots of ACT and its development can be found in his acceptance speech for the APA Distinguished Scientific Contribution Award (Anderson, 1996).

The history begins when Anderson was in graduate school, at the start of an iterative attempt to develop a model of cognitive processing. What evolved was ACT, in a computer-based instantiation that allowed for precise accounts of performance in a variety of cognitive tasks. Initially, there was no direct plan to transition from predicting the accuracy and response times of predominantly college-age subjects to teaching middle-school mathematics. After developing an early version of ACT, however, Anderson decided to see whether students could learn a skill by being induced to resemble a successful version of the underlying model. The nucleus of the approach was ACT's description of cognitive competency in terms of a series of if–then rules called "productions," the discrete nature of which suggested that they could be trained individually.

The road thenceforth was not a smooth one. First came the realization that the general principles exemplified in the model vastly underconstrained the tutor. The gaps went beyond the selection of knobs and dials for the interface: Additional science had to be directed at tutoring per se, rather than at the basic psychology of learning. A mechanism called *model tracing* was developed to interpret students' errors in terms of erroneous productions and to guide them to correct versions. Another mechanism, *knowledge tracing*, estimated the probability with which each of the essential productions had been learned and introduced remedial exercises accordingly. With eventual results pointing to tutoring successes, the transition to an application was still merely beginning. There remained technical problems in developing robust software and making it usable by teachers without computer savvy. Beyond those, transitioning the tutors to test classrooms, and ultimately to venues beyond the local schools, was a daunting exercise in culture and politics.

The story of cognitive tutors ends with a business spin-off, a real application by any definition, but not without considerable divergence of the core research effort. Eventually, the business of tutoring and the scientific enterprise of developing ACT had to separate for both to remain healthy.

Another account of the pathway to application can be found in reports by Wells and colleagues (Wells et al., 2000; Wells, Memon, & Penrod, 2006), describing how basic research on human memory tenuously and tenaciously made its way into judicial policy and practice. The history begins with basic research on eyewitness performance in the first decade of the 20th century. The field expanded quickly with the emergence of cognitive science in the 1970s and 1980s, motivated particularly by Elizabeth Loftus's seminal and penetrating studies of eyewitness error (e.g., Loftus, 1975). The work of Loftus and others clearly demonstrated how readily witness reports could be influenced on the basis of procedural details, called into question the practices used to construct lineups, and pointed to problems with self-reports of confidence.

Yet, despite more than 3 decades of this meticulous, convincing experimental study, there was slow progress in influencing the legal system. The effort would likely have failed, with the exception of occasional expert testimony by psychologists. Then something happened that created a new impetus for application of the basic research. A means was found to prove that specific convictions obtained on the basis of eyewitness testimony were invalid according to an independent hallmark of innocence. The hallmark, of course, was DNA testing (a beautiful example of enabling psychological application by findings in another discipline). As the number of cases called into question could not be ignored, publicity grew, and a panel was convened by the U.S. Attorney General. The process culminated with the 1999 guidelines of the U.S. Department of Justice for eyewitness evidence, written by a working group that included several members of the eyewitness research community.

The history of applied eyewitness research is clearly still being written. Although Table 1 characterizes the application as mature, the 1999 guidelines have been slow to have an impact, and formal implementation has been fragmented. Reasons for resistance, both before and after the guidelines were written, are not difficult to identify. One is the widespread belief that experiments on subjects, primarily of college age, do not apply to the public at large. There is the related concern that the experimental method, with its statistical inference, has no utility for single cases: The finding that 25% of eyewitnesses can be shifted by a biased question cannot be used to determine whether a particular eyewitness has become biased by a particular question.

Barriers also arise from more pragmatic concerns. Training law enforcement agents to implement the guidelines is costly, and success is uncertain. Some feel that if psychological research is used to generate guidelines for interrogating witnesses or constructing lineups, then inadvertent lapses may invalidate the case and undermine prosecution. This concern tends to make police and prosecutors less than enthusiastic about the endeavor. Wells et al. (2006) conclude that "research has only scratched the surface of ways to help the legal system improve the accuracy of eyewitness accounts" (p. 68). Yet, it seems reasonable, given the history, to have a degree of pessimism as to how rapidly new discoveries will penetrate.

ISSUE 5: WHAT CAN STUDENTS LEARN FROM APPLIED COURSES?

A course in applied psychology may seem best suited to be an elective for the advanced undergraduate level. In my opinion, however, this would not constitute the ideal niche for a course in applied cognitive science, because of the interdisciplinary nature of the field. Therefore, I teach the course as a university-wide elective, and my course is populated not only by psychology students oriented toward cognitive science, but also engineers, computer scientists, science majors, and students in art and design. It is my experience with Carnegie Mellon students that interest in the course material and willingness to take part are more essential to success than prior courses in psychology.

As I have previously noted, applied courses offer a singular chance for the field to do self-promotion. Whether they are psychology majors or only passing through, students who study applications come away with a sense that the basic science we do really matters. One of my students who came from Turkey, where cognitive science is so little known that the language has no label for it, reported that the applied course made a real difference when he talked to people "back home," because it enabled him to explain the utility of his field of study in a society where it is not admired.

Applications courses also provide a wonderful opportunity to refresh and invigorate material presented in other classes. By the time they enter the applied cognitive course, psychology majors have likely been exposed to relevant basic topics, such as memory and perception. Nevertheless, reviews of material are essential, and redundancy does no harm. Further learning about applications related to basic science adds an important new dimension to what students have learned in earlier classes.

Another reason to take an applied course is to learn about the applications themselves. Understanding the interdisciplinary nature of applied cognitive science is invaluable for students entering related careers, where they are likely to work in teams with people from diverse backgrounds. Learning about the pathways to application gives them a heads-up about the effort involved and the barriers they may encounter, and they get an appreciation for what translational science really means.

ISSUE 6: HOW DOES ONE TEACH AN APPLICATIONS COURSE?

Variety in students' interests and backgrounds requires the instructor to provide foundational material as a grounding for application. My own course is structured much like Table 1: For each general topic, there are one or more tutorial lectures covering the basic psychological science with reference to enabling fields as needed, followed by the introduction of related applications. These core lectures provide an overview of perception, conditioning and learning, memory, speech and language processing, spatial cognition, decision making, and emotion. For students coming into the course from outside fields, all of this material is likely to be novel, and the tutorial is essential for making the step into application.

An additional fillip, made possible by seminar-class size and a computer lab, is a set of class sessions using the web as a laboratory. In these, students divide into teams to search for products or policies associated with the applied field of current interest, then report to the class as a whole.

By way of example, let me describe the curriculum for two of the application topics currently covered: cognitive tutors and programs for brain training. Teaching students about cognitive tutoring requires initial lectures on fundamentals of learning and on the tutors in particular, together with directed readings. In the Web-based lab, students are directed to a number of tutoring sites and asked to compare them with the ACT-based tutor and determine whether there is an underlying model and whether the tutor directs the curriculum based on students' errors. Discussion of brain training applications begins with general material on neural plasticity in perception and cognition. Examples are given of applications arising from this work, such as remedial training for slow language processing and rehabilitation after stroke or traumatic brain injury. In the lab session, I set students loose to find claims of brain retraining and evaluate them critically. My students have shown me that pseudoapplications in this area are easy to find; perhaps they help some people some of the time, but they are not driven by science in any direct way.

I do not claim that applied cognitive science is an easy course to teach. It stretches the teacher, but that's the fun of it, too. I get to read in areas far from my own research. Keeping the course fresh and reasonably up-to-date is a stimulating challenge, but the results make for great cocktail-party conversation. I have also found that teaching the course has strengthened and informed my own connections to application. As someone who has been involved firsthand in efforts to move basic findings and prototypes out into the world, I am well aware of the challenges that come with the commitment.

I also do not claim that applied cognitive science, as I teach it, is an easy course to take. It stretches the learner as it does the teacher. The course appeals to students who have eclectic interests and, given the material I cover, good analytic skills and basic math competency. It is my experience that students who "stay the course" feel their effort has been well worth it.

ISSUE 7: HOW CAN THE MODEL BE EXPANDED?

If psychology is to be given away through applied courses, these courses need to become part of the standard curriculum. Courses like the one I've described need not be restricted to cognitive science, of course; research in every area of psychology finds its way to application and deserves a student audience. Once courses are developed, their content could be made more widely available through Web-based offerings, such as distance learning programs or wikis dedicated to application. In any of these contexts, the rules for the underlying model that I offer are simple ones: Teach the fundamental science as a foundation; show how basic research, generally in conjunction with partner disciplines, leads to useful outcomes; and finally, teach applications, not promissory notes.

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APPENDIX

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