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Transdisciplinary Collaboration as a Basis for Enhancing the Science and Prevention of Substance Use and "Abuse"

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ABSTRACT

Transdisciplinary scientific collaborations (TDSCs) have the potential to strengthen substance use and misuse research and prevention. Despite its growing prominence as a mode for scientific research, research on TDSC remains in a nascent form and its value to the field of substance use and misuse merits further exploration. The overarching purpose of this article is to examine the potential

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contributions of transdisciplinary science to research and prevention using conceptualizations, methods, and evidence from a case study of two university-based research centers. The article provides (a) a discussion of the societal context and historical developments that have prompted increasing interest in TDSC; (b) a definition and conceptualization of TDSC; (c) a methodological approach for studying TDSC; (d) initial findings from the case study that reflect instances of transdisciplinary intellectual integration and it examines implications of these methods and findings for future research and policy development relevant to substance use and misuse.

Key Words: Transdisciplinary research; Scientific collaboration; Nicotine dependence; Collaboration constraints and facilitators.

INTRODUCTION

Substance use and misuse remain prevalent in the United States and throughout the world despite basic research and intervention efforts to ameliorate the problem. Smoking prevalence, for example, remains high in the United States (where one quarter of the population smokes) and in the world where rates are estimated to have reached one billion, despite decades of tobacco-related research and myriad interventions aimed at preventing and reducing smoking. (Breslow and Johnson, 1993; Pechmann, 1997; Pechmann et al., 1998; Rohrbach et al., 2002; Siegel, 2002). To address the lack of complete success from prior efforts and to address the persistent health and social problems associated with substance use and misuse, a new mode for scientific research is receiving increasing attention among scholars and policy makers: transdisciplinary scientific collaboration (TDSC), a concept first mentioned in the introduction of this series (Sussman et al., 2004). Despite its growing prominence, the body of literature on TDSC is almost nonexistent, yet its value to research and prevention in the field of substance use and misuse merits further exploration. The major purpose of this article, therefore, is to examine the potential contributions of transdisciplinary science to research and prevention efforts using conceptualizations, methods, and evidence from a case study of two substance use(r) research centers (i.e., Transdisciplinary Tobacco Use Research Centers, TTURCs).

Tobacco use and nicotine dependence[1] are discussed in the present article to illustrate that substance use is problematic and to demonstrate

[1]Tobacco use and nicotine dependence.

the need for a transdisciplinary approach. However, the concepts discussed herein are relevant for collaborative studies in general, including collaborative studies of other substance misuse prevention. The intractability of the development of addictions to substances such as tobacco is partly attributable to the fact that they are multiply determined, complex problems that require a broad, cross-disciplinary research and prevention approach, rather than a single disciplinary perspective. For example, the Surgeon General's Report in 2000 concluded that the most promising approaches for reducing tobacco use are those that are based on a comprehensive approach, implying the necessity of combining multiple disciplinary perspectives rather than relying on single disciplinary perspectives. The report emphasized that public heath success in reducing tobacco use requires an approach that relies on a synergy of educational, clinical, regulatory, economic, and social perspectives. The report further emphasized that a combination of pharmacological and behavioral methods of managing nicotine addiction was demonstrated to be more effective than *either* approach alone, and school-based education programs are more effective when coupled with initiatives based in communities that involve mass media and anti-smoking policies. The same statements have been made elsewhere regarding other substances (Petratis et al., 1995; Sussman and Ames, 2001).

Potential benefits of collaborations that cross disciplines have received increasing attention in recent years in health science and community health promotion (Higginbotham et al., 2001; Klein, 1996; Pellmar and Eisenberg, 2000). Yet the definition of transdisciplinarity remains nebulous. Rosenfield (1992) offers a typology of cross-disciplinary collaborations ranging from multidisciplinary, interdisciplinary, and transdisciplinary research (see Table 1).

Each of these collaborative approaches combines two or more disciplinary perspectives to address a particular problem. The intensity and regularity of intellectual exchanges among participants in the collaboration increases as one moves from multidisciplinarity toward transdisciplinarity. According to Rosenfield (1992), transdisciplinary research is the strongest form of cross-disciplinarity since it involves integrating two or more disciplines to produce novel, integrated hybrids of ideas, theories, and methods. Moreover, a distinguishing feature of transdisciplinary collaboration is the creation of a *shared* conceptual model or framework for analyzing the problem at hand, which transcends the individual disciplinary perspectives of each team member. Transdisciplinarity, thus, may provide a more comprehensive perspective for improving substance misuse research and prevention efforts. However, despite increasing academic and societal interest in

Table 1. Transdisciplinarity as distinguished from other forms of cross-disciplinary collaboration.

Multidisciplinary	process whereby researchers from different disciplines work independently or sequentially, each from his or her own disciplinary-specific perspective, to address a common problem.
Interdisciplinary	process whereby researchers work jointly, but from each of their respective disciplinary perspectives, to address a common problem.
Transdisciplinary	process whereby researchers work jointly using a shared conceptual framework that draws together discipline-specific theories, concepts, and approaches to address a common problem.

Source: Rosenfield, 1992.

transdisciplinary scientific collaboration, little is known about how to conceptualize it, what situational circumstances hinder and/or facilitate it, and how to study its antecedent factors, intervening processes, and outcomes, particularly in the realm of tobacco use and substance misuse, more generally. The overall purpose of this article, therefore, is to examine the potential contributions of transdisciplinary science to tobacco use research and the prevention of substance use and misuse.

Toward that goal, the remainder of the article is divided into five sections:

- First, we discuss the societal context and historical developments that have prompted increasing interest in transdisciplinary scientific collaboration and the potential benefits of TDSC for research and prevention science.
- Second, we provide a conceptualization of TDSC as compared with nontransdisciplinary scientific approaches and discuss certain interpersonal, organizational (e.g., processes of formal groups within institutional structures), environmental, and institutional circumstances that may facilitate or hinder effective TDSC.
- Third, we summarize new methodologies developed to record key processes and outcomes of TDSC as part of a five-year case study of the Transdisciplinary Tobacco Use Research Centers (TTURC) Initiative (Turkkan et al., 2000).

- Based on these methods, we then present initial findings from the case study that reflect instances of transdisciplinary intellectual integration in research on nicotine addiction and tobacco use (Stokols et al., 2003).
- Finally, we discuss the implications of these methods and findings for future research and policy development related to substance misuse.

SOCIETAL CONTEXT AND POTENTIAL BENEFITS OF TRANSDISCIPLINARY SCIENTIFIC COLLABORATION

Historical Examples

Transdisciplinary thinking by individuals and team collaborations can lead to many new innovations. Historical examples illustrate how being open to the methods, theories, and findings of other fields—a hallmark of transdisciplinary thinking—can inspire creativity in individuals and teams. Gordon, who posits that famous innovations and connections stem from associative thinking, cites many examples of individuals who have made an observation outside their realm of expertise and have applied it analogously to their own work (Gordon, 1974). He reports, for example, George B. Bissell's observation that a derrick used in a salt plant might effectively pump oil in a similar manner. Gordon further cites a letter in which Eli Whitney described watching a cat trying to catch a chicken through a fence. The cat's claws missed the chicken, but snagged feathers. Whitney used analogous thinking to design a cotton gin that could be used for the mass production of cotton. Furthermore, analogous thinking was used by social psychologist, William McGuire, who realized that the biologically based theory of innoculation against germs might provide a basis for better understanding human cognition (McGuire, 1964, McGuire et al., 1961). He discovered that humans could be inoculated against persuasive arguments in much the same way that they can be inoculated against germs and disease. His work influenced many fields including substance use prevention, in which researchers such as Pechmann have found that teens can be inoculated against pro-tobacco messages (Pechmann, 1997). For example, in an experimental study, she found that after youth viewed a feature film depicting popular young film stars smoking, their perceptions of smokers and intentions to smoke were enhanced when

surveyed after the film. However, after viewing a 30's anti-smoking ad immediately before the film, the youth were not influenced by the pro-smoking imagery, when surveyed after the film (Pechmann and Shih, 1999).

Teams of scientists also achieved great successes as they integrated ideas across disciplinary lines, including the discovery of DNA, the development of nuclear applications, and space exploration. Collaborations such as the discovery of the DNA helix can be cited as successful examples of what we term transdisciplinary scientific collaboration, because researchers worked jointly and integratively from different scientific disciplines toward understanding the structure of the DNA. Starting with a background in physics, chemistry, and biology, Francis Crick worked jointly with James Watson, who had migrated from studying ornithology to the study of viruses. With the help of others such as Rosalind Franklin, they integrated several disciplines and made a major impact on science and society. The ultimate destruction of life, in the form of the atom bomb, also was the result of transdisciplinary thinking among a team of scientists, in particular physicists and chemists. Successfully landing astronauts on the moon is another example of what transdisciplinary approaches can achieve. In a race against the Russians to send humankind to the moon, American scientists from different fields and disciplines, including rocket propulsion, ergonomics, life sciences, and chemistry, worked collaboratively under tight deadlines to integrate their work and, ultimately, send a team of astronauts to the moon by 1969.

In addition to specific innovations or discoveries made by individuals and by teams, entire fields of science have been developed when enough interdisciplinary work has accumulated. For example, the field of health psychology and its forerunners, social epidemiology and behavioral medicine, developed based on the interdisciplinary work of scholars who could bridge the gap between biological medicine and social medicine. Such work is exemplified by Cohen and colleagues who demonstrated the association between psychological stress and physical health in his experimental work that involved exposing medical students to cold viruses (Cohen and Williamson, 1991; Cohen et al., 1991).

The study of environmental racism is another example. Scientists and scholars have linked physical exposure to a carcinogen in neighborhood water with cancer (Bullard, 1990). Understanding the link in a larger social context led to the realization that certain ethnicities, such as blacks, were suffering greater exposure to carcinogens and, thus, developing more illness. Scholars linked the disproportionate physical exposure and illness among blacks to prejudice and inadequate environmental

protection laws, which make disenfranchised groups more vulnerable to pollution and disease. Environmental racism takes what had been viewed as simply environmental facts and biological facts (such as the link between carcinogens and illness) and interprets those facts within a broader social context where biases and prejudice exist (Bullard and Johnson, 2000).

Societal Context for the Emergence of Transdisciplinary Scientific Collaboration

Over the past two decades, universities and research organizations have shown a growing interest in and commitment to achieving the benefits of transdisciplinary research, and have taken steps to promote greater intellectual exchange among faculty members from diverse academic units (Kahn, 1993; Klein, 1990; Trostle, 1986a; Trostle, 1986b; White, 1991). For instance, at the University of California, Irvine (UC Irvine), University of California, Los Angeles (UCLA), and the University of Southern California (USC), university committees have been established to promote cross-disciplinary collaboration. As a case in point, the *UC Irvine Task Force*, *To Identify Barriers to Multidisciplinary Research*, was established to address various barriers to TDSC at UC Irvine. Based on the committee's recommendations, several strategies to overcome barriers to TDSC were identified and grant funding was provided to support the development of cross-departmental research proposals, (see ''Overcoming Barriers to Multidisciplinary Research'': www.rgs.uci.edu/rig/spa/multidisciplinary_research.htm). Moreover, several interdisciplinary academic programs have grown in size and stature over the past few decades. For example, the Program in Social Ecology at UC Irvine, an interdisciplinary degree-granting unit established in 1970, was formally designated as the School of Social Ecology by the Board of Regents of the University of California in 1992 and, as of 2003, includes over 60 faculty members, 170 graduate students, and 2170 undergraduate students.

During the same time period, governmental funding agencies and private foundations have allocated substantial resources toward the establishment of transdisciplinary research teams and centers (Kahn, 1993; Morgan et al., 2003). For example, in 1999 the National Institute on Drug Abuse, in collaboration with the National Cancer Institute and the Robert Wood Johnson Foundation, allocated $84 million toward establishing seven Transdisciplinary Tobacco Use Research Centers (TTURCs) at major universities across the nation, with the goal of

promoting transdisciplinary collaboration in the fields of tobacco science and prevention (Turkkan et al., 2000). In addition, the National Institute for Drug Abuse expanded its support of TDSC by initiating the Transdisciplinary Drug Abuse Prevention Research Center at USC. The center was established in 2003 in recognition of the potential benefits of transdisciplinary scientific collaboration for improving the science and prevention of substance misuse.

Potential Benefits of TDSC to Substance Misuse Research and Intervention

According to some scholars, cross-disciplinary approaches to scientific research and community health promotion are seen as representing "*the best efforts of researchers not only to focus on societal issues but to explore the social and practical applications of their expertise. . . . Many research problems cannot easily be addressed from within the confines of particular disciplines*" (p. 3) (Salter and Hearn, 1996). Among the benefits of transdisciplinary scientific collaboration (TDSC) cited in earlier reviews (Gray, 1999; Klein 1996; Lewin, 1936; Stokols, 1998) are the following:

1. Use of TDSC affords *higher levels of explanatory power* relative to reductionist analyses rooted in singular disciplinary perspectives (see Stokols, 1987, and Jessor, 1958 for a discussion of the pitfalls of reductionism in scientific research) (Jessor, 1958; Stokols, 1987)
2. Use of TDSC enables researchers to achieve *higher levels of convergent and discriminant validity* in their studies through the triangulation of multiple methodologies derived from several different fields (Campbell and Fiske, 1959) (also see Chou et al., this issue)
3. Use of TDSC *encourages the development of broad-gauged public policies* that are less likely to provoke unanticipated adverse side effects due to the conceptual blind spots associated with narrower, unidisciplinary perspectives (Stokols, 1996; Winett et al., 1989). For example, in the 1970s, new airtight buildings were being constructed with more complex materials and insufficient ventilation, leading to a buildup of indoor pollutants, and resulting in specific and nonspecific complaints of sickness, or "sick building syndrome" (Berglund et al., 1984; Godish, 1995; Hedge, 1989). For the next 10–12 years, building designers

were unaware that the sealed windows and other energy-saving building characteristics were having unintended negative consequences and making people sick with headaches and allergic-like reactions. If the builders had broadened their perspective and incorporated another perspective, such as a public health perspective, the problem might have been caught and remedied much earlier.

4. Transdisciplinary training programs produce researchers and practitioners who are *equipped to analyze scientific and community problems from* a broad, contextual (or holistic) perspective, rather than from the highly specialized vantage point of a particular discipline. This generalist research orientation appears to be well suited to the analysis and resolution of multidimensional community health problems (Nash et al., 2003; Stokols, 1987).

CONCEPTUALIZING TRANSDISCIPLINARY SCIENTIFIC COLLABORATION

A general conceptualization of TDSC was outlined previously. However, despite the growing interest in promoting transdisciplinary research and reaping its potential benefits within scientific and public policy arenas, there has been substantial debate about the exact meaning and distinguishing attributes of transdisciplinarity, as compared with nontransdisciplinary approaches. Moreover, very few studies have been undertaken to assess the scientific, policy, and public health benefits of TDSC (Fuqua, 2002; Kahn, 1993; Stokols et al., 2003). In this section, we briefly review earlier conceptualizations of transdisciplinary scientific research and examine certain interpersonal, organizational (i.e., based on the center as a whole), environmental, and institutional factors that may facilitate or hinder effective TDSC in research and community settings.

Defining Transdisciplinary Research

In defining transdisciplinary scientific collaboration, it is useful to begin by characterizing *unidisciplinary research*. Single scientific disciplines are organized around the study of particular topics of interest (e.g., biological, psychological, and social facts). For example, psychology is a discipline in which psychological facts or the psychological

lifespace is emphasized (Lewin, 1936), whereas the study of social facts is the defining feature of sociology as a distinct discipline (Durkheim, 1938). Although disciplines are defined as distinct fields of inquiry, the boundaries around disciplines are in fact somewhat arbitrary (having fuzzy boundaries). In turn, the boundaries between closely related fields—such as neuroanatomy, neurology, and pharmacology, which share a focus on the brain as the object of analysis—are often overlapping rather than mutually exclusive.

While some disciplines overlap with others on their fringes, some fields, such as public health and urban planning, are inherently multidisciplinary and loosely bound. These disciplines encompass substantive areas that are derived from and relevant to multiple disciplines. The scientific subfield of substance misuse research and prevention also crosses multiple disciplines, spanning very different levels of analysis—from the molecular/genetic/biological level at one end of the research spectrum to the more molar perspectives of community health and public policy, at the other. The field can be conceptualized as having systemic dimensions ranging from micro to macro. These dimensions are similar to those discussed in classical systems theory, according to Jim Miller (1978), which describes the universe as ranging from molecular to solar systems, and different levels are nested within one another. (Also see Punch 2003 for another discussion of the micro and macro systemic dimensions of relevance to perception of police corruption.) The theory acknowledges the context in which systems are embedded. Similarly, a research problem can range from a micro level to a macro level. Whatever level is chosen as a vantage point (whether it be nicotine addiction or analysis of TDSC), the system's embeddedness within a larger system should be recognized. For example, TDSC occurring at two tobacco centers is still part of an NIH initiative. It is the subjective decision of the researchers whether they want to collaborate with others, encompass another system, or stay situated at one level.

For purposes of this discussion relevant to analyses of nicotine dependence and tobacco use, four levels of analysis can be distinguished, from micro to macro, within and between TTURC centers:

- Biological/genetic/molecular: genes, cells, and microorganisms that are parts of individuals.
- Individual/psychological/developmental: the person or animal as a whole individual.
- Social: individuals interacting within groups.
- Community/Societal: society and the population as a whole.

Each analytic level encompasses certain fields that can contribute in their own distinctive ways to substance misuse research and prevention. Integrating these unique perspectives should, ideally, provide a broader understanding of substance use and misuse than would be attainable from the narrower vantage point of a single, isolated discipline.

Whereas unidisciplinary research tends to bring a single level of analysis to bear on a particular problem, and emphasizes the concepts and methods associated with a narrowly delimited field, cross-disciplinary research bridges multiple analytic levels and combines the theories, methodologies, and measures drawn from at least two or more fields.

As noted earlier, Rosenfield (1992) distinguishes among multi-disciplinary, interdisciplinary, and transdisciplinary forms of cross-disciplinary collaboration (see Table 1), with transdisciplinary research involving the most conceptually integrative form of collaboration among team members. Specifically, transdisciplinarity is defined by Rosenfield as a process through which researchers work jointly to articulate and refine a *shared conceptual framework* that draws together discipline-specific theories and methods to address a common problem. According to Stokols et al. (2003), ''it is the integrative scope of transdisciplinary research products (e.g., shared hypotheses, theories) that sets them apart from the more traditional intellectual products of unidisciplinary scientific collaboration.''

An important question raised by Rosenfield's (1992) typology of cross-disciplinary forms of research is whether or not transdisciplinary research centers such as the National Institutes of Health-sponsored Transdisciplinary Tobacco Use Research Centers (TTURC) and the Transdisciplinary Drug Abuse Research Prevention Center (TPRC) are, in actuality, distinguishable from any other large-scale scientific collaboration. After all, most large-scale scientific ventures encompass multiple disciplines and they often lead to novel integrative conceptual-izations of research and community problems. Nonetheless, what distinguishes transdisciplinary centers (such as the TTURCs and TPRC) from these other ventures is the fact that the former are established with the *explicit mission of promoting transdisciplinary intellectual integration*. In the TTURCs and TPRC, the development of shared conceptual models and frameworks are an explicitly defined goal of the center, rather than an outcome of collaborative research that may or may not occur spontaneously (i.e., as an unanticipated or non-intentional product of the center). Because transdisciplinary centers embrace the explicit goal of promoting novel intellectual integrations spanning two or more fields—consistent with Rosenfield's (1992) defining attributes of transdisciplinary research—the evaluative criteria

applied to those centers necessarily include measures of whether conceptual and methodological integrations actually are achieved by center members. We provide examples of these evaluative measures in a later section of the article.

Stokols et al. (2003) note that Rosenfield's definition of transdisciplinarity is quite stringent in that it requires a fully shared conceptual model to be developed and accepted by team members. Teams with many members may still achieve transdisciplinary success even if some members do not work closely with the majority. A team of 15 researchers, for example, could achieve transdisciplinary intellectual integration of their concepts and methods, even if five or more of the members do not share the subgroup's conceptualization of the phenomenon being investigated. If a subgroup of members achieves transdisciplinary linkages, the research center as a whole is still considered to have been successful in achieving transdisciplinary integration.

Stokols et al. (2003) further distinguishes among different forms of TDSC as encompassing either a *narrow* or *broad* scope of disciplines, achieving either *vertical* or *horizontal* conceptual integrations, and resulting in *middle-range* or *grand* outcomes. These are important distinctions because the disciplinary scope and analytic levels bridged by a collaboration are important factors that influence the pace (or rapidity) and scientific outcomes of transdisciplinary research (Fuqua, 2002; Van Dusseldorp and Wigboldus, 1994). Collaborations that are narrow in scope incorporate fundamentally similar levels of analysis (e.g., personality psychology and lifespan human development), whereas teams characterized by a broad disciplinary scope incorporate widely different levels of analysis (e.g., pharmacology, health psychology, and economics).

Linkages drawn between multiple fields sharing the same analytic level are referred to as *horizontal* integrations whereas those drawn between disciplines representing different analytic levels (e.g., cellular, interpersonal, and societal perspectives) are termed *vertical* integrations (Stokols et al., 2003). A narrow disciplinary scope (with minimal difference between researchers' perspectives and levels of analysis) may be more likely to facilitate smooth-running and rapidly progressing collaboration resulting in horizontal integrations, while a broad scope (with major differences between researchers' perspectives and levels of analysis) may be more likely to hinder or slow the collaborative research process (Fuqua, 2002). This may occur in part because a narrow-gauged collaboration is likely to encounter fewer barriers to interdisciplinarity. A collaboration attempting to bridge several major levels of disciplines may be in a better position to achieve vertical integrations that, despite

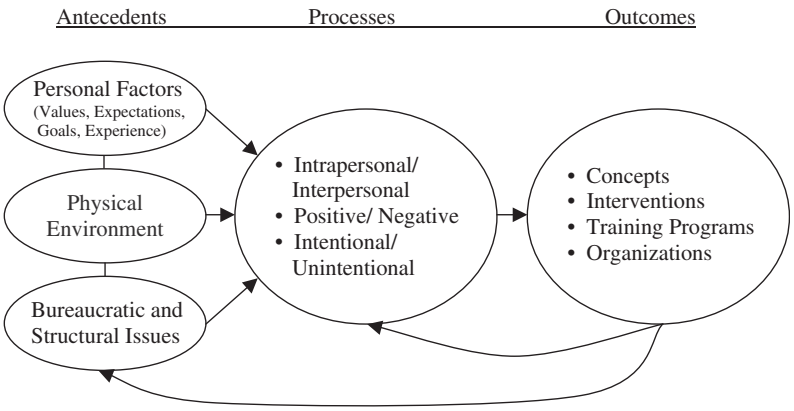

Figure 1. Case study model of transdisciplinary scientific collaboration.

their laborious and time-consuming nature, may ultimately lead to more novel, longer-term innovations that exert a profound impact on research and society.

As conceptualized here, we have chosen to use three terms (i.e., broad/narrow research scope, vertical/horizontal integrations, and middle/grand linkages) to characterize the number of disciplines and fields actively represented in a collaboration. We can distinguish the terms in that they correspond to a conceptualization of TDSC that incorporates antecedents (e.g., scope), processes (e.g., social or intellectual integration), and outcomes (e.g., middle and grand) as part of an iterative model (Stokols et al., 2003) (see Figure 1).[2]

A narrow or broad scope of disciplines is an antecedent factor that is in place when a group begins to collaborate. Once a team has begun to make progress, horizontal and vertical refers to the type of integrations the team can achieve. Horizontal integrations are those developed with disciplines sharing similar levels of analysis, whereas vertical integrations are those developed with disciplines representing different levels of analysis. Middle or grand outcomes of collaboration refer to the scope of impact the outcome has on both science and society. Collaborations can encompass any combination of the following circumstances: (a) starting with a narrow or broad scope, (b) achieving vertical or horizontal integrations, and (c) having a middle or grand impact on their fields.

[2]Adapted from Stokols, Fuqua, Gress, et al. (2003).

For example, collaborations can achieve horizontal integrations that have either a middle-range or grand impact on science (or on society beyond academia). Exemplifying teams achieving horizontal integrations, a middle-range outcome is cognitive dissonance theory, which was developed by psychologists from different fields, and has had an enormous impact on several areas of behavioral research. An example of a horizontal integration resulting in a grand outcome is the DNA double helix discovery, which involved scientists looking at a micro level of analysis whose insights advanced many different fields (e.g., ranging from developmental and cell biology to cancer genetics and epidemiology), resulting in major impacts on science and society.

Constraining and Facilitating Factors in Transdisciplinary Scientific Collaboration (TDSC)

In earlier sections of the article, we noted the potential benefits of transdisciplinary research but also alluded to barriers that may hinder effective TDSC. While the benefits of conducting TDSC may offset the potential costs of participating in collaborative research projects, there are a number of difficult challenges that a research team is likely to face (Hildebrand-Zanki et al., 1998; Kahn, 1993; Younglove-Webb et al., 1999). This section provides a few examples of constraining and facilitating factors rather than an exhaustive list.

Barriers

Intrapersonal, interpersonal, organizational, environmental, and institutional circumstances may hinder or facilitate effective TDSC. Intrapersonal factors include the values, expectations, goals, and experiences of individual team members, including a lack of respect or openness to interdisciplinary approaches (Stokols, 1999). An interpersonal factor that may hinder TDSC concerns team members having weak working relationships and conflicted (or minimal) shared history of working together on previous shared projects. Organizational factors, such as inadequate administrative support, also can be a constraint to TDSC. Without staff in place ready to run a project, time can be wasted and confusion can result. Physical environmental factors, such as a lack of spatial proximity between offices, also may hinder TDSC. As well, bureaucratic and structural issues can impede TDSC, such as a lack of reward by university policies for conducting transdisciplinary work,

which typically requires more meeting time, education time, and resources than unidisciplinary research. Finally, departmental "ethnocentrism" and conceptual biases can operate as barriers to effective TDSC (Campbell, 1969).

Facilitating Factors

In contrast to these barriers are facilitating factors that enhance effective TDSC. Many facilitating factors are simply the opposite side of the coin of barriers. For example, the opposite of this barrier—lack of respect and openness to transdisciplinarity—would be to have respect for transdisciplinarity; and as another example, the opposite of having distally located offices is to have office proximity (or virtual proximity). In addition, there are some unique facilitating factors that deserve particular attention. Two of these are the transdisciplinary ethic and planned serendipity. According to Stokols (1998), the transdisciplinary ethic is characterized by a strong commitment to certain shared values, including:

1. Inclusive rather than exclusionary thinking.
2. Broad-gauged, contextually oriented theorizing and research, in contrast with more narrowly circumscribed, reductionist thinking (Jessor, 1958).
3. Methodological pluralism encompassing qualitative and quantitative approaches (Chou et al., this issue; Nichter et al., this issue); laboratory-based experimentation as well as nonexperimental methods; survey research, environmental assessment, behavioral mapping, participant observation, epidemiological as well as individual-level analyses.
4. Optimism and stamina in the pursuit of transdisciplinary research goals.
5. An open-minded stance toward new research perspectives.
6. The cultivation of good will and cross-disciplinary tolerance (values that foster mutual respect among the proponents of divergent viewpoints).

Team members who have this ethic are likely to find that their collaboration runs more smoothly and productively.

Planned serendipity is another important facilitator of transdisciplinary collaboration. The TDSCs have the explicit mission of promoting transdisciplinary integrations. Because of the serendipitous nature of

such integrations, it is difficult or impossible to force new ideas and transdisciplinary integrations to occur between members. Therefore, it is often helpful to encourage discussions between team members under both formal and informal circumstances. The team members benefit when times, locations, and tasks are planned to help promote these kinds of discussions or by having offices near one another to allow members to learn from each other as they interact informally in the hallways outside their offices. As illustrated in Fig. 1, the barriers noted here represent factors that are in place before a TDSC begins and thus, are antecedent conditions. These are factors that constrain or facilitate TDSC early on—that is, they influence how ready a team is to collaborate, and affect the processes through which TDSC develops. The processes of TDSC reflect a dynamic interplay within the intrapersonal, interpersonal, organizational, physical–environmental, or structural factors discussed earlier. The antecedents and processes can influence the rapidity and ease with which teams develop new outcomes (concepts, interventions, training programs, and organization).

TDSC Stakeholders

The number of stakeholders, or individuals and groups that might benefit from TDSC, is potentially limitless, just as the number of stakeholders in any successful scientific collaboration is potentially limitless. Scientists who participate in TDSC have an obvious stake in developing novel intellectual theories, methods, and products that result from their TDSC; and their success benefits non-TDSC scientists (and science in general) as it advances scientific knowledge within and between disciplines. Institutions that house the scientists, such as universities, benefit because they gain funding and fame that are generated from successful results. Funding agencies share in the success of the successful TDSCs they support because they are able to show their money was well spent on a team effort that resulted in successful scientific outcomes. When successful TDSC products are translated into concepts and techniques that may benefit society, then numerous stakeholders improve their ability to do their job well, including clinicians, practitioners, educators, curriculum developers, policy makers, and policy enforcers. Each group of individuals may be able to better achieve their own goals. Finally, through these improvements, public health and society can benefit.

As an example, if a TDSC such as a TTURC were to hypothetically find that (a) certain people have brain chemistries that correspond to a hostile personality, (b) adolescents with high hostility are more likely to

smoke than adolescents with low hostility, and (c) a school curriculum designed to reduce hostility also reduced smoking in students, then several stakeholders have benefited. Scientists have advanced knowledge within and between disciplines. This will reflect well on the universities and funding agencies (NIDA and NCI) supporting the scientists in their collaboration. It also provides information for numerous others on at least one way they might improve their ability to do their job. Health educators and program educators might target highly hostile adolescents for smoking prevention efforts, which might improve their success. Policy makers might support policies aimed at reducing hostility in youth, and this could lead to not only reduced hostility/aggression/violence and smoking (as well as possibly reducing adolescent risk-taking). Thus, public health in general is improved.

NEW METHODOLOGIES FOR EVALUATING THE PROCESSES AND OUTCOMES OF TRANSDISCIPLINARY SCIENTIFIC COLLABORATION (TDSC)

The conceptual and programmatic issues outlined in previous sections provide the basis for developing methodological tools that can be used to evaluate transdisciplinary science collaborations. Evaluating the processes and outcomes of transdisciplinary collaboration can be helpful to substance use, misuse, and abuse prevention teams, regardless of whether they are comprised of researchers working to better understand why a substance is addictive, practitioners working in classrooms to prevent youth from using and/or misusing drugs, or researchers and community educators working together to translate scientific findings into practical program applications. In this section, examples of evaluative methodological tools are provided from the University of California Irvine Transdisciplinary Core Study (Stokols et al., 2003). One purpose of the study is to identify the bases of successful transdisciplinarity and in so doing, to develop a grounded theory of transdisciplinary scientific collaboration (Glaser and Strauss, 1967; Lincoln and Guba, 1986). Using a participant-observation, multiple case-study design (Eisenhardt, 1989; Klahr and Simon, 1999; Yin, 1994), the study provides an examination of the antecedents, intermediate processes, and outcomes of transdisciplinary scientific collaboration (TDSC). Proximal interpersonal and organizational processes are focused within each participating Transdisciplinary Tobacco Use

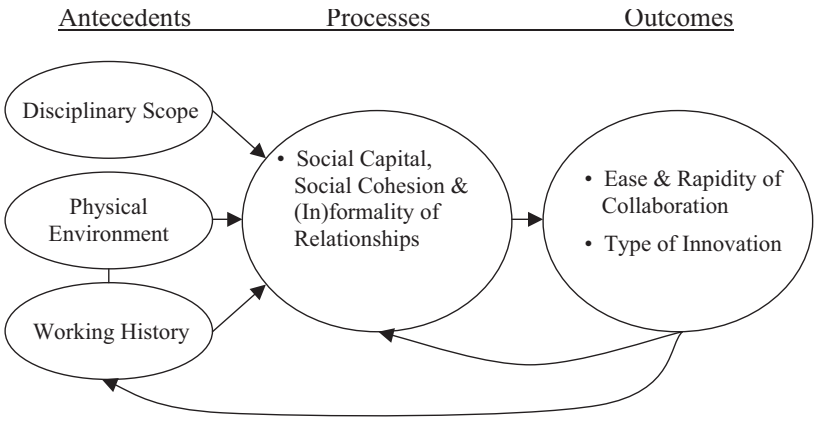

Figure 2. Comparative Model of Transdisciplinary Scientific Collaboration.

Research Center (TTURC) and the *intellectual outcomes* that emerge from those processes.

This work is guided by a working model of TDSC, illustrated in Fig. 1, that includes personal, physical environmental, and institutional antecedent conditions (e.g., participants' initial levels of commitment to transdisciplinary collaboration; the spatial separation of their offices); interpersonal, emotional, and intellectual processes that intervene to influence the prospects for successful TDSC; and a variety of collaborative outcomes including new concepts, methods, theoretical integrations, research training programs, institutional efforts to support TDSC, trainees' career development outcomes, and public health interventions that span multiple fields and levels of analysis.

Extending Fig. 1, Fig. 2 (the UCI-USC comparative study model)[3] illustrates how transdisciplinary scientific collaborations starting with a narrow disciplinary scope, a strong shared history, and spatial proximity are likely to develop informal relationships, social cohesion, and social capital[4] (Coleman, 1988; Kawach et al., 1997), all of which contribute to smooth-running and rapidly progressing collaboration and the produc-

[3]Adapted from Fuqua (2002).

[4]*Social capital* has been defined as a form of capital that develops through changes in the relations among persons to enhance mutual trust and facilitate coordinated action and has been associated with reduced high school drop out and decreased mortality. See Coleman, 1988 and Kawachi et al., 1997.

tion of transdisciplinary outcomes including a shared model of tobacco use (Fuqua, 2002). Conversely, transdisciplinary scientific collaborations starting with a broad disciplinary scope, a lack of shared history, and spatial distance between members will develop a shared model of tobacco use as well as other transdisciplinary outcomes more slowly and with less ease. Furthermore, a mediating social capital-building phase is likely to be necessary before a shared model and other transdisciplinary innovations can be created. Although a shared model is less likely to be achieved, the social capital that exists among a few members may lead to middle-range links between two or more disciplines (see Fuqua, 2002 for more information about barriers and facilitators to TDSC).

A case study of the Irvine TTURC was begun at UC Irvine from the inception of the center and is being investigated intensively over the five-year NIH TTURC Initiative. The study was expanded to include a comparison with a second TTURC located nearby at USC. The study of TTURCs was undertaken to identify the unique circumstances within each center that either facilitate or constrain TDSC. Because of USC's physical proximity to UC Irvine (the two centers are located about 50 miles apart), the research team has been able to conduct detailed interviews and administer surveys at both the USC and UC Irvine TTURCs. Resource limitations and spatial distance prevented recruitment and intensive study of other TTURCs. At the UC Irvine and USC TTURCs, all 10–12 key investigators agreed to participate. Many research associates, and graduate and postdoctoral trainees also agreed to participate. Finally, departmental and center staff members, as well as university administrators, whose jobs are relevant to the promotion of TDSC, are also interviewed regularly.

A variety of different data-gathering protocols are administered at the centers to gain as broad a perspective on the dynamics of TDSC as possible. These instruments are summarized below and can be used by researchers or practitioners interested in evaluating the process of their substance misuse research or prevention efforts. A more detailed description of the measurement protocols developed by the Transdisciplinary Core Study Team is available from the authors.

Interview and Survey Protocols

Measures from the following protocols are included in the Appendix and can be downloaded at the following website: http://www.tturc.

uci.edu/about/CoreTransdisciplinary.html (TD Core Study Protocols/Update) (Fuqua, 2002; Stokols, 2003).

Principal Investigators

The Principal Investigator Interview Protocol includes several open-ended qualitative questions designed to assess antecedent factors, collaborative processes, and outcomes related to TDSC. During the interviews, participants complete a series of brief surveys including: (1) The Principal Investigators Perspectives Scale, which measures researchers' transdisciplinary ethic or level of their commitment to shared values that support TDSC; (2) a Research Outcomes Checklist that inquires about the products that investigators have developed or are in the process of developing through their TTURC collaborations; (3) a Behavior Change Index assessing shifts in members' activities that reflect a transdisciplinary orientation; (4) an Emergent Themes Survey that asks participants to list important intellectual and methodological ideas that have emerged from their collaboration with other TTURC members; and (5) a series of Semantic Differential Scales to assess changes in members' affective experiences and impressions of their center as they participate in the TTURC over several years.

Staff and Campus Administrators

Staff and campus administrator interviews are conducted yearly to assess transdisciplinary processes from the vantage point of staff members who observe patterns of faculty collaboration; and university administrators whose roles as campus decision makers influence TDSC within academic settings. Questions are designed to elicit information that supplements the Principal Investigator interviews (e.g., staff perceptions about the benefits and costs of TDSC; administrators' efforts to facilitate scientific collaboration across departments and schools).

Behavioral Observations of Centerwide Meetings and Events

A Meeting Observation Form was developed to complement structured interview and self-report measures of TDSC. Building on Bales' model of Interaction Process Analysis (Bales, 1950), this instrument enables observers to study and record researchers' interactions at centerwide meetings for the purpose of discovering circumstances that facilitate or hinder scientific collaboration. Both quantitative and

qualitative data are gathered including objective meeting elements (e.g., number of attendees, disciplines represented), subjective qualities of the meeting (e.g., affective tone, energy, interpersonal support or conflict); and indicators of intellectual integration and product development among participants.

ASSESSING PROGRESS TOWARD CONCEPTUAL INTEGRATION AMONG MEMBERS OF TRANSDISCIPLINARY RESEARCH CENTERS: INITIAL FINDINGS FROM A FIVE-YEAR TRANSDISCIPLINARY CENTER EVALUATION STUDY

The methodological tools discussed in the previous section provide a basis for recording the intellectual progress that researchers make as they strive to achieve transdisciplinary innovations. Researchers in the University of California Irvine Transdisciplinary Core Study developed both a qualitative analysis strategy (Hierarchical Thematic Analysis, See Stokols et al., 2003) from which intellectual themes of the transdisciplinary centers emerged, as well as quantitative analyses of scaled survey items administered to center members on a semi-annual basis.

In this section, we describe four qualitative cases documenting conceptual and methodological developments that have occurred through intra- and interscientific collaborations within the context of the Transdisciplinary Tobacco Use Research Centers (TTURCs) at USC and UC Irvine. These research examples, emerging from analysis of investigator interviews, are based on investigators' retrospective accounts of their progress in collaborating with fellow TTURC members toward the development of shared conceptual and methodological integrations.[5] Moreover, the research accounts offer evidence of progress toward shared conceptual frameworks and methodological strategies—the sine qua non of transdisciplinary research, according to Rosenfield (1992). The four collaborative scenarios outlined enable us to trace the formative phases of transdisciplinary integration in terms of the shared conceptual themes that emerged over time.

[5]References supporting investigators' accounts of scientific discoveries will become available as publications are completed by investigators. For further information about the results and content of the scientific progress made at each center, investigator contact information is available at each centers: www.tturc.uci.edu and www.tturc.hsc.usc.edu.

The first example outlines intellectual vertical integrations that led to a broader understanding of the cultural correlates of smoking. The second example demonstrates horizontal integrations leading to the development of a new methodological tool. The third example details the progression of ideas leading to vertical integrations between animal and human databases as a basis for exploring the personality trait of hostility, particularly as it relates to nicotine dependence. The final example illustrates the emergence of a common theme of adolescence as a critical period for nicotine dependence between disparate studies that led to vertical integrations. Taken together, the examples of successful collaborative research on nicotine dependence, discussed below, illustrate the value of transdisciplinary studies in promoting a more comprehensive and accurate understanding of substance use than may have been achieved by unidisciplinary researchers working in isolation from each other.

Research Example #1: Cultural Correlates of Smoking

Working from a biobehavioral perspective, researchers at the UC Irvine TTURC conducted a study in Orange County, California (1999–2004) to determine whether adolescents smoked to regulate, or perhaps self-medicate, negative emotions. They assessed adolescents' emotional states and personality traits (such as hostility and depression) and discovered an association with smoking patterns indicating that teens were likely to smoke following reported feelings of hostility and depression (Whalen et al., 2001).

Simultaneously, working from a different conceptual perspective emphasizing the role of cultural factors in smoking trajectories, researchers at the USC TTURC launched cross-cultural and cross-national studies comparing adolescents in California and China, and found that Asians tend to smoke more while in a social situations (rather than alone as a response to nicotine cravings). They found further evidence that Asians smoke differently and for different reasons than do Caucasians. In particular, Asians show a later onset of smoking and longer periods of smoking before they become daily smokers. Also, there was some evidence to suggest that Asians smoked differently, inhaling less nicotine per cigarette (e.g., by taking merely a puff of a cigarette and, thereafter, holding the cigarette or throwing it away). Asians also reported more nausea when using nicotine patches.

Through a series of discussions between researchers at the two centers, ideas soon emerged concerning the interactive effects of culture,

ethnicity and genes, emotional states, personality traits, and smoking behavior. In response to these discussions, the UC Irvine TTURC team of biobehavioral researchers decided to analyze their results based on ethnicity and found that Asian smokers were different from Caucasian and Hispanic smokers in their sample; the association between smoking behavior and hostility and depression did not exist in the same way for Asians as it did for Caucasians.

Investigations of the links between culture, hostility, depression, and smoking were formalized when researchers from USC and UC Irvine developed an intercenter grant proposal in 2000 to investigate these associations. The USC and UC Irvine collaborators intend to examine the interactions among genetics, emotion, and culture to examine whether Asians have a genetic predisposition that makes them more sensitive to nicotine and perhaps less likely to be rewarded physiologically from nicotine. These joint studies and the initial findings that have resulted so far would not have occurred according to the researchers without the TTURC Initiative, which encouraged investigators from the two centers to extend beyond the limits of their own disciplines. Without the TTURC's explicit focus on and support for transdisciplinarity, the researchers would have been unlikely to integrate their disciplines, and thus, may not have achieved as comprehensive an understanding of substance use in their populations as they were able to attain working collaboratively across the two centers. (See relevant publication by Unger et al., 2003).

Research Example #2: "The Smoke in Smoking Matters": Nicotine + Acetaldehyde = Dependence (Development of a Radioligand)

Pharmacology researchers at the UC Irvine TTURC compared addicting qualities of nicotine and drugs of abuse and found that laboratory animals have less preference for nicotine than they do for other addicting substances (Manzardo et al., 2002). The researchers were aware that nicotine is addictive in humans, so they were surprised to learn that, in animals, nicotine was not as reinforcing as other substances. Seeking answers that crossed disciplinary lines, several investigators at the UC Irvine TTURC joined together to learn why nicotine was not as reinforcing in animals as in humans. They received an idea, in part from an external advisory board member to the center, who reported to the center that tobacco companies had conducted studies concerning the effects of acetaldehyde in humans and had added that substance to

cigarettes in an effort to make their products more addictive (Glantz et al., 1996). Research suggested that acetaldehyde, formed when the sugar added to tobacco is burned, combines with nicotine to increase the reinforcing effects of nicotine, making nicotine/acetaldehyde an addictive substance.

The researchers conducted a series of "conditioned place preference" experiments using varying combinations of nicotine and acetaldehyde. Animals were found to prefer places with nicotine/acetaldehyde to places with nicotine alone. As a result of the transdisciplinary discussions held between the pharmacologists, neuroanatomists, and radiochemists working at the UC Irvine TTURC, a new radioligand (a small, slightly radioactive molecule that binds to a specific large molecule) was developed to identify the presence of nicotine/acetaldehyde in the brain. The transdisciplinary process of developing and then using it is important to the study of tobacco products and nicotine dependence. These researchers were able to make transdisciplinary integrations within a horizontal (molecular–biological) level of analysis, and they credit the TTURC Initiative with encouraging them to seek answers in new fields, with successful results that might not have occurred had they relied on a traditional unidisciplinary approach. Further, their findings are important for identifying the mixture of ingredients in cigarette smoke (i.e., nicotine + acetaldehyde) that may more directly lead to conditioned place preference in laboratory rats as well as dependent, tobacco-seeking behavior in humans. (This work has not been published yet but has been included in a grant proposal.)

Research Example #3: Identifying a Personality Correlate (Hostility) Associated with Nicotine Response in Animals

Another example of transdisciplinary scientific collaboration (TDSC) occurred when a health psychology researcher at the UC Irvine TTURC, who was interested in studying personality and its association with physiology and behavior, became intrigued by the notion that hostility as a personality trait might relate to tobacco use among adolescents. Earlier the researcher and colleagues found that nicotine levels influence hostility levels on a competitive reaction time task in adults. For the task, two participants compete after selecting a mild to severe level of loud noise administered by the winner to the loser. It was found that those with higher levels of trait hostility and who were exposed to higher levels of nicotine selected higher levels of loud noise

(interpreted as being more hostile) than did those with lower levels of trait hostility and lower levels of nicotine.

Stimulated by the competitive reaction time findings of the first study, the health psychologist collaborated with a psychiatrist and neuroanatomist in a second study. Working together, they designed a study using positive emission tomography (PET) scans of human brains to investigate the relationship between trait hostility as measured by a paper and pencil instrument [the Cook–Medley (1954) hostility scale] and areas of brain activation at varying doses of nicotine. Building bridges with animal researchers, the TTURC collaborators formed a working group to explore basic mechanisms of nicotine addiction. Members of the working group wondered how the notion of human hostility, a personality trait, might be tested in animals, whose personalities are not as amenable to testing. The closest animal analog of hostility in humans is induced aggression in laboratory rats. Discussions are now occurring about the most appropriate way of integrating conceptual models about the brain and behavior in animal and human research. The neuropharmacologist is debating whether a rat model of aggression can translate well into the human equivalent of hostility, or whether other animals such as primates, or possibly even rabbits, may provide a suitable model for testing the relationship between the personality trait of hostility and nicotine. If a rabbit model of hostility is chosen for research, the researchers may need to seek outside expertise from researchers in an animal science subfield, thereby expanding even further the scope of TDSC. Whereas the human and animal nicotine-hostility research is still ongoing, it serves as an example of how TDSC stimulates the development of solutions to complex research problems related to substance use, that would not have been evident from the vantage point of a singular disciplinary perspective. (See relevant publication by Whalen et al., 2001.)

Research Example #4: Adolescence as a Critical Period in Nicotine Addiction

In the UC Irvine TTURC, researchers working on three different projects found a common theme concerning the importance of developmental stage, in particular adolescence, in predisposing individuals to tobacco use and addiction. As data began to emerge from these projects, several investigators met to discuss their findings and to work towards developing a shared conceptual model. The model that evolved highlights the potential neural mechanisms through which adolescents

may be more vulnerable to (a) deciding to use tobacco products, and (b) becoming addicted to nicotine.

In one project, a health psychologist hypothesized that adolescents who exhibit hostility and impulsivity might be more likely to smoke because they seek to palliate their negative moods. This relationship was supported by a psychiatrist who conducted PET scans of brains that had been exposed to nicotine while engaged in a high hostility task. It was found that in subjects assessed to be high in hostility, the amygdala, a brain area associated with impulsivity, and the dorsal lateral prefrontal cortex and orbital frontal cortex, brain areas associated with decision-making, were activated during the hostility task. Over the course of many discussions between the health psychologist, neuropharmacologists, a neuroanatomist, and the psychiatrist, one set of brain structures gained prominence. The researchers began to discuss the amygdala, which develops earlier than other structures and is associated with decision making and executive control, as well as the dorsal lateral prefrontal cortex (DL-PFC) and orbital frontal cortex (OFC), which function to inhibit the impulsive effects of the amygdala. They gained an idea that was new to many of the researchers—that adolescents may be likely to try smoking not only to soothe negative emotions but also because the brain systems associated with response inhibition are not developed enough to counteract feelings of hostility and impulsivity that may drive an adolescent to want to smoke.

In addition to illuminating the mechanisms through which adolescents may have brain structures that are not developed enough to control an urge to smoke, their discussions and data indicated that other brain systems, in particular the ventral tegmental area (VTA) and the nucleus accumbens (NA), seemed also to be implicated in a heightened potential for adolescents to become addicted to nicotine. Ongoing research on neuronal communication during early adolescence is being conducted on the link between the amygdala and other brain areas of interest (i.e., DL-PFC, the OFC, the VTA, and NA). For example, in rat studies conducted by neuropharmacologists, nicotine (in combination with acetaldehyde, a by-product of burning sugar found in cigarettes) was more reinforcing in adolescent rats than adult rats, and the neural pathways associated with reward appeared to be changed when adolescent rats were exposed to nicotine. This finding suggests that exposure to nicotine/acetaldehyde during early adolescence is more likely to lead to addiction than exposure during adulthood. (See relevant publication from Aramakis et al, 2000). For literature regarding the influence of the neurocircuitry of the orbital frontal cortex and the striatum and cocaine and methamphetamine use,

see a discussion of the work of Volkow and colleagues (Stacy and Ames et al., this issue).

This example is useful for highlighting three key issues in the study of transdisciplinary scientific collaboration (TDSC). First, it illustrates the concept of vertical integration among different levels of analysis. In this case, we see the linking together of findings from the molecular level concerned with the neurophysiology of hostility, decision making, and reward, to the level of behavior concerned with emotion regulation and the decision to smoke. Second, the findings presented here offer a direction for practice, suggesting that because adolescents appear to be more likely to decide to smoke and are or become more vulnerable to using and becoming addicted, prevention efforts might target adolescents and teach them ways to manage hostility and other negative moods. This potential translation of research findings into practice may be important because prevention efforts focusing primarily on social influences, for instance, might have greater efficacy if they address other physiologically based reasons that teens smoke, such as to alter their mood (Clayton et al., 2000). Finally, this example demonstrates how a common theme—adolescence as a critical period—has served to knit together formerly separate and independent research projects. Through on-going dialogue in which investigators strive to share and integrate their findings, they are creating an intellectual and social infrastructure that will support continued collaboration that is expected to contribute to a more complete understanding of adolescent smoking and addiction, as well as strengthen efforts to translate this understanding into enhanced intervention strategies.

IMPLICATIONS OF METHODS AND FINDINGS FOR FUTURE RESEARCH AND POLICY DEVELOPMENT RELATED TO SUBSTANCE MISUSE

The first research example described above, which focuses on the cultural correlates of smoking, offers a compelling illustration of the intellectual benefits that accrue from organized and sustained efforts to promote conceptual integration across multiple fields. In that example, the directors of two different TTURC centers (UC Irvine, USC) organized a series of intercenter retreats as a basis for promoting intellectual exchanges among researchers and trainees of the two centers. These meetings provided the opportunity for UC Irvine investigators studying the genetic and dispositional bases of adolescent tobacco use to

discuss their findings with USC researchers examining cultural differences in patterns of adolescent smoking found in the United States and China. These intellectual exchanges at the UC Irvine-USC intercenter meetings set the stage for the development of collaborative research proposals and ongoing studies of the interplay among genetic, dispositional, social, and cultural factors implicated in the etiology of adolescent smoking.

Thus, the collaboration that has occurred between the UC Irvine and USC TTURCs indicates that transdisciplinary centers can be instrumental in promoting serendipitous intellectual integrations across multiple fields by bringing scientists from different institutions and disciplinary backgrounds together on a recurring basis to discuss issues of mutual interest. Will the novel conceptual and methodological approaches spawned by this planned serendipity result in major advances in the science and prevention of substance misuse? That is a question that cannot be answered given the relatively brief, five-year timeframe of the UC Irvine Transdisciplinary Core Study. The evaluation of longer-term scientific and societal outcomes of transdisciplinary collaboration may well require a historical assessment conducted 10–20 years after the initial establishment of the TTURC centers in 1999 (Stokols et al., 2003). Establishing empirical links between the near-term conceptual integrations and longer-term scientific and policy outcomes (or returns on investment) of transdisciplinary centers remains as a crucial task for future research.

All of the research examples described earlier serve to illustrate the kinds of scientific advances that can be made when horizontal and vertical integrations across multiple fields, located either at the same or different levels of analysis, are achieved (see Table 2 for a summary of horizontal and vertical integrations in transdisciplinary research). For instance, in the second example discussed earlier focusing on the development of new methods for identifying the presence of nicotine and acetaldehyde in the brain, pharmacologists, neuroanatomists, and radiochemists worked together to develop a radioligand methodology for measuring nicotine/acetaldehyde traces in rat brains. Thus, a horizontal integration of disciplinary perspectives at the same (i.e., molecular-cellular) level of analysis was achieved through sustained collaboration to develop and refine new brain scanning procedures. These procedures have important implications for understanding the synergistic effects of nicotine, acetaldehyde, and related components of tobacco smoke in the complex etiology of nicotine dependence.

At the same time, the first, third, and fourth research examples described earlier demonstrate the power of combining multiple levels of

Table 2. Dimensions of transdisciplinary science.

Solitary/team	An individual or a team can conduct transdisciplinary research
Geographically based/ geographically dispersed	Teams are located in one geographical location (e.g., centers) or dispersed across several locations (e.g., networks relying on the Internet)
Broad/narrow	A transdisciplinary endeavor begins with a broad or narrow scope (i.e., number of disciplines) that is represented in the center
Vertical/horizontal	As the process unfolds, successful integrations of concepts, methods, and findings is achieved representing disciplines sharing the same level of analysis (e.g., micro levels of analysis) or different levels of analysis (micro and macro levels of analysis)
Grand/middle-range	Outcomes of the centers (such as new theories) may have a grand impact on science and society, or they may have more middle-range impact that influences a small number of disciplines or fields

Source: Stokols, 1999.

analysis (e.g., molecular or cellular-genetic, behavioral-dispositional, environmental, sociocultural) in transdisciplinary research projects to achieve vertical integrations of theories and methods bridging multiple fields. Vertical integrations are exemplified by the conceptual linkages drawn between animal and human models of hostility and aggression (Example #3); the study of adolescence as a critical period for nicotine addiction in both rats and humans (Example #4); and the UC Irvine-USC study of cultural, dispositional, and genetic correlates of adolescent smoking in China and the United States (Example #1). These examples of vertical and horizontal integration are valuable because they provide a broader account of tobacco dependence than would be achievable by any single discipline alone.

The fourth research example discussed, focusing on adolescence as a critical period in nicotine addiction, highlights the potential implications of transdisciplinary research findings for health policy and practice. Specifically, TTURC scientists including pharmacologists, neuroanatomists, and health psychologists found that both decision-making and emotional regulation processes related to nicotine addiction may differ in important ways between adolescents and adults. Adolescents may be

especially prone to using nicotine as a strategy for managing hostility and negative mood states. Thus, although prior school-based programs for preventing or reducing adolescent smoking and substance misuse have focused primarily on social influence processes (Clayton et al., 2000), future health promotion programs may be more effective to the extent that they address not only the social bases, but also the physiological and dispositional reasons that teens smoke and are more vulnerable to addictive substances of various kinds than adults.

Finally, all of the collaborative research examples presented earlier demonstrate the value of establishing a supportive social infrastructure within collaborative research centers as a basis for encouraging and sustaining transdisciplinary intellectual integrations spanning multiple fields. The close interplay between social and intellectual integration within scientific collaborations has been suggested in earlier conceptual and empirical analyses of transdisciplinary research centers (Fuqua, 2002; Stokols et al., 2003), but remains to be more fully examined and understood in future studies of scientific collaboration.

CONCLUSION

The collaborative research examples presented in the preceding section highlight several important aspects of transdisciplinary research that are relevant for research in substance misuse. First, a distinguishing feature of transdisciplinary research centers, as compared with other multidisciplinary scientific collaborations, is that the former are established with an explicit mission to promote intellectual integration across two or more fields. Conceptual integration across multiple fields may occur as a matter of course in many large-scale scientific collaborations, but the intentional and recurring efforts to promote intellectual integration bridging multiple disciplines are an essential feature—a sine qua non—of transdisciplinary research centers (Rosenfield, 1992; Stokols et al., 2003). Thus, when comparing the scientific outcomes at transdisciplinary centers as compared with other multidisciplinary collaborations (see Table 1 for a comparison of these approaches), an important question is whether or not the intentional efforts of transdisciplinary centers to promote integration actually bear intellectual fruit—i.e., conceptual and methodological advances spanning two or more fields—which provide the foundation for subsequent scientific breakthroughs and the translation of key findings into effective strategies for substance misuse prevention.

One of the commonalities across substance misuse research is the need to understand how and why different types of individuals, the same person at different times, and, the same individual in different roles is at-risk for different types of drug use and misuse, so that a more complete etiology can be understood and treatment combinations can be developed. Transdisciplinary approaches are necessary to approach these complex topics from more than one vantage point. Many of the papers in this volume acknowledge that drug use is a complex behavior influenced by multiple biological, family, and sociocultural factors; and they illustrate how concepts drawn from various disciplines offer distinct yet complementary insights into the etiology and prevention of substance misuse.

Sussman and Unger (this volume), for example, integrate previous literature on drug use and drug use prevention and propose a typology of drug misuse (Sussman and Unger, this issue). They suggest that drug misusers fall into one of two categories: *experimenters* who make mistakes and *misusers* who utilize drugs as a means to counteract a baseline state of *dis-balance*. They construe this typology as reflecting two extremes on the end of a continuum of dis-balance. They also suggest that prevention efforts must necessarily include an understanding of the dis-balance of potential drug misusers. Transdisciplinary approaches are crucial to sorting out the typology of potential drug misusers based on their respective and unique etiologies. People's genetic predisposition, for example, may lead them to try and enjoy initial experimentation with certain drugs. Certainly, though, a state of dis-balance should be addressed from more than just one perspective. Drug misuse prevention may need to focus on combinations of concepts (e.g., peer networks, life skills, self-esteem, self-control). Individual research investigators and practitioners benefit from an understanding of those factors that span different fields and disciplines. The transdisciplinary approach can enable investigators to transcend the limitations of any single disciplines and gain the benefits of using a transdisciplinary scientific approach (such as gaining higher levels of explanatory power and other benefits, see the "Potential Benefits of TDSC to Substance Misuse Research and Intervention" section of this article).

In summary, this article provides a definition of transdisciplinary scientific collaboration and outlines its societal context, potential benefits, barriers, and facilitators. These concepts and the model provided are useful to researchers and practitioners, regardless of the specific substance they are focused on. The benefits, barriers, and facilitators are still similar for a transdisciplinary team of researchers (or practitioners) joining together to attempt to collaborate. Compared to a

tobacco use prevention team or an alcohol use prevention team, a collaboration focused on cocaine use prevention might have different substance-specific issues to discuss and might be comprised of different types of members (i.e., an undercover police officer might be desirable for cocaine prevention collaboration, or models of illicit drug distribution systems may need to be explored), but the teams are still likely to encounter similar types of interpersonal, organizational, environmental, and institutional circumstances. The conceptual models shown in Figs. 1 and 2, outlining the antecedents, processes, and outcomes of TDSC, and identifying the importance of social capital in establishing effective collaborations, is considered applicable to any transdisciplinary scientific collaboration and is arguably applicable, with slight variation, to any collaboration in general. The methods developed and reported here can be utilized by members of any transdisciplinary team to study and evaluate the process of conducting transdisciplinary collaboration.

GLOSSARY

Analogous Thinking: A comparative form of thinking, described in the creativity literature, in which a resemblance is noticed that permits one to draw an analogy, which may result in a creative solution to a problem.

Environmental Racism: A form of racism, a field of study that takes what had been viewed as simply environmental facts and biological facts (such as the link between carcinogens and illness) and interprets those facts within a broader social context where biases and prejudice exist.

Radioligand Methodology: A methodology used by pharmacologists, neuroanatomists, and radiochemists for measuring substances such as nicotine/acetaldehyde traces in rat brains.

Social Capital: A form of capital that develops through changes in the relations among persons used for and/or resulting in enhanced mutual trust and which facilitates coordinated action.

Substance of Abuse: A substance that results in problematic use, interrupts social functioning and life role functions, violates legal norms, and occurs in dangerous settings.

Unidisciplinary Research: Research that does not cross disciplinary boundaries, but relies upon the concepts, methods, or findings from a single discipline or field of research.

Transdisciplinary Research: See Table 1.

APPENDIX A: INITIAL PRINCIPAL INVESTIGATOR INTERVIEW AND PRINCIPAL INVESTIGATORS PERSPECTIVES SCALE

I. Phase 1 Questions

1. What considerations led you to become involved as a participant in the TTURC project?
2. During the course of working on the NIH proposal last spring, which, if any, of the following experiences occurred for you? (refer to handout)

   (a) Gained new insights into your own area of research through discussion with other TTURC colleagues (e.g., developed a new concept or hypothesis that bridges or integrates different disciplinary or theoretical approaches to tobacco research).
   (b) Modified your original research plans for your own portion of the TTURC project as a result of your discussions with TTURC colleagues.
   (c) Established links with your fellow TTURC colleagues that may lead to future collaborative studies.
   (d) Actually began to design a new collaborative study as a result of working on the NIH proposal with your TTURC colleagues.
   (e) Any other experiences that you recall or that stand out while working on the NIH proposal (e.g., other ways your thinking changed as a result of working on the TTURC project at that time)?.

3. Several discussions were held among TTURC investigators while the NIH proposal was being developed. Over the course of those discussions, please recall any events or considerations that helped to make the collaborative process more enjoyable and run smoothly or, alternatively, created challenges, difficulties, or even tensions during that process. (*Ask participants to identify factors*)

   (a) Facilitating Factor(s).
   (b) Impeding Factor(s).

II. Phase 2 Questions—proposal submission in April and advance notification in late August of UCI's TTURC funding. (Repeat Questions 2 a–e for Questions 3, 4, 5).

III. Phase 3 Questions—the time period following notification about the TTURC funding (that is, from late summer to the present). (Repeat Questions 2 a–e for Questions 6, 7, 8).

IV. Costs and Benefits

8. Have you participated in other transdisciplinary research projects outside of the TTURC?
9. If yes—In your experience, what worked well and what didn't work well in terms of promoting effective transdisciplinary collaboration?
10. From your perspective, what are the *costs* as well as the *benefits* that result from engaging in transdisciplinary collaboration *in general*?
11. Have you experienced any of these costs and/or benefits of engaging in transdisciplinary work on this project *specifically*?
12. In what way(s) has the extent to which you value transdisciplinary collaboration changed since last year when the proposal discussions began?

V. Expectations for the Future

13. What kinds of positive scientific and training outcomes, if any, do you expect from the TTURC transdisciplinary collaboration?
14. Do you expect that your additional interaction with TTURC members will further change your thinking or research?
15. If yes—Which, if any, of the following experiences do you think will occur for you as you continue to work on the TTURC project?

VI. Transdisciplinary Model Development

16. Do you recall or can you identify a shared model that could guide the future research activities of the TTURC?

17. Can you think of any specific ideas or unifying/integrative themes that might provide the basis for developing a transdisciplinary model of tobacco susceptibility, use, and intervention over the course of the TTURC project?

VII. Administrative Leadership

18. What leadership skills and qualities are needed to foster the realization of the TTURC's transdisciplinary goals? For example, are there special/unique leadership qualities and skills that are required for ensuring the overall success of the TTURC, as well as the effective functioning of each of the TTURC's cores (administrative, transdisciplinary, informatics, and career development)?
19. What kinds of incentives should be provided to the leaders of the various cores to encourage and support the effective performance of their leadership roles within the TTURC?
20. Are there areas of administrative leadership within the TTURC that you believe:
    (a) Are functioning very well already (if so, please specify)?
    (b) Should be better supported through a more effective incentive structure at departmental, school, and campus-wide levels (if so, please elaborate)?
    (c) Warrant some modification and improvement (if so, please elaborate)?

PI Perspectives on the USC TTURC

The following items pertain to some of your thoughts and expectations about the TTURC Project. Please indicate how strongly you agree with each of the following statements. Additional comments can be added to the right or under the questions.

Comments:

1. In my own research, I typically use multiple research methods drawn from more than one discipline rather than rely exclusively on a single disciplinary approach.

( )	( )	( )	( )	( )
strongly agree	agree	not sure	disagree	strongly disagree

2. I prefer to conduct research independently rather than as part of a group.

( )	( )	( )	( )	( )
strongly agree	agree	not sure	disagree	strongly disagree

3. I would describe myself as someone who strongly values transdisciplinary collaboration.

( )	( )	( )	( )	( )
strongly agree	agree	not sure	disagree	strongly disagree

4. Generally speaking, I believe that the benefits of cross-disciplinary research outweigh the inconveniences of such work.

( )	( )	( )	( )	( )
strongly agree	agree	not sure	disagree	strongly disagree

5. I am optimistic that cross-disciplinary collaboration among USC's TTURC participants will lead to valuable scientific outcomes that would not have occurred without that collaboration.

( )	( )	( )	( )	( )
strongly agree	agree	not sure	disagree	strongly disagree

6. Overall, I believe that a high level of good will exists among the faculty associates of the USC TTURC.

( )	( )	( )	( )	( )
strongly agree	agree	not sure	disagree	strongly disagree

7. Overall, TTURC members as a group are open-minded about considering research perspectives from fields other than their own.

( )	( )	( )	( )	( )
strongly agree	agree	not sure	disagree	strongly disagree

APPENDIX B: TTURC RESEARCH OUTCOMES CHECKLIST

We are tracking various publications, innovations, and other outcomes that have occurred during the past year that are directly or indirectly TTURC related. Please check any outcomes that were or are soon to be completed. Please describe and provide examples of these outcomes, including dates and citations when appropriate.

A. Publications and Presentations

_ Journal articles.
_ Conference presentations (e.g., panel, poster, symposia, or keynote address).
_ University presentations (e.g., colloquium, seminars, or guest lectures).
_ Books or Book chapters.
_ Formal grant proposals directly or indirectly related to TTURC.

B. Practical Innovations

_ Methods (e.g., use of Palm Pilot for diary and assessment research).
_ Analysis Techniques (e.g., use of new software packages).

C. Intellectual Innovations

_ Working hypotheses; Comprehensive or narrow-range models.
_ Theories derived from research.

D. Community Relations, Interventions, and Outreach

_ Public relations (e.g., newspaper articles, magazine articles, press releases).
_ Recognition in others' presentations (e.g., mention in a university or congressional speech).
_ Information distribution (e.g., ad campaigns, website, pamphlets, interactive software).

_ Student training interventions (i.e., curriculum-based).
_ Teacher training interventions (i.e., train the trainer).
_ Community group training.
_ New or ongoing meetings with community groups.
_ New or revised policy recommendations initiated by community groups.

E. University Training Activities

_ Courses, seminar series of symposia developed or taught.
_ Academic trainees development (e.g., undergraduate, graduate, postdoctoral, and other research trainees).
_ Other transdisciplinary research projects (directly or indirectly related to TTURC).

APPENDIX C: BEHAVIOR CHANGE INDEX

Considering your involvement with the TTURC over the past three years, please assess the degree to which each of the following behaviors has increased, decreased, or remained the same using a 7-point scale where "1" indicates "decreased," "4" indicates "remained the same," and "7" indicates "increased."

1. Read journals outside your field? _____
2. Attended conferences outside your field? _____
3. Participated in working groups with the intent to integrate ideas. _____
4. Your appreciation for transdisciplinary collaboration. _____
5. Your readiness to collaborate with other TTURC investigators? _____
6. Obtained new insights into your own area of research through discussion with other TTURC colleagues (e.g., developed a new concept or hypothesis that bridges or integrates different disciplinary or theoretical approaches to tobacco research). _____
7. Your willingness to modify your original research plans for your own portion of the TTURC project as a result of your discussions with TTURC colleagues. _____
8. Established links with your fellow TTURC colleagues that have led or may lead to future collaborative studies. _____

9. Actually began to design a new collaborative study as a result of working on the NIH proposal with your TTURC colleagues.

APPENDIX D: EMERGENT THEMES SURVEY

For this portion of the interview, we are going to ask you about some of the most important intellectual or methodological ideas or approaches that have evolved or have been stimulated through your experience with the TTURC. We consider these new ideas or approaches to be emergent themes of the TTURC, which are important outcomes in their own right and which allow us to analyze the integration of ideas as it relates to organizational and social aspects of the collaborative process. In addition, we are also going to ask you questions about novel ideas that, for one reason or another, were not developed or that were set aside.

1. To start, please describe an important new idea or methodological approach that has emerged through your experience with the TTURC?

   How did this theme come about? What prompted you to begin thinking along these lines?
   Who was involved, or, who influenced your thinking?
   What kinds of circumstances facilitated the emergence of this theme?
   Was there anything that impeded its development?
   If yes—How did you overcome that particular barrier?
   Do you intend to translate this idea into a written product? Why or why not?
   (Repeat question 1 until investigator has no further themes to discuss.)

2. Can you think of any intellectual ideas or methodological approaches that at one time seemed important or exciting, but that have not been pursued?

   Why do you think this idea was not pursued or developed? (*Prompt*: *Do you think that you might devote time to developing this idea in the future?*)

Who influenced your thinking about this idea? Was this person helpful in developing the idea or did he or she impede its development? How so?
Were there any other ideas or methodologies that seemed important but not pursued?

3. Let's talk about the written products you have worked on—either solo or as a co-author—as a *direct* result of your involvement with this TTURC or with other TTURCs. (*Go through table with respondent*, *starting with journal articles/book chapters*. . .

   Have you worked on any journal articles or book chapters? (*If so*) How many?
   Are these in preparation, submitted, or published? (*Prompt to get at how many of each item fall into each category*.)
   Now, for each of these, were they sole-authored or co-authored? (*If co-authored*) With whom did you work on this?

APPENDIX E: TTURC SEMANTIC DIFFERENTIAL SCALE

TTURC Impressions

Each scale below reflects a continuum between the two anchor terms listed. For each scale, please place a check mark in the box that best represents your impression of your TTURC, as a whole.

For example, unrelated to TTURC, if you think a glass is slightly more than half full, you might place a check mark in the 5th box:

Next, please select up to five (5) terms from the previous list that best describe your impressions of your TTURC, as a whole. Then, in the second column, please rank those terms in order of importance, with "1" indicating "most important."

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

For each scale, please place a check mark in the box that best represents your feelings when you think about your TTURC.

Pessimistic	☐☐☐☐☐☐☐	Optimistic
Socially alienated	☐☐☐☐☐☐☐	Socially integrated
Intellectually integrated	☐☐☐☐☐☐☐	Intellectually isolated
Unappreciated	☐☐☐☐☐☐☐	Appreciated

Extent to which you value transdisciplinary research:

Not at all valued	☐☐☐☐☐☐☐	Highly valued

Change in your value of transdisciplinary research:

Decreased	☐☐☐☐☐☐☐	Increased

Cost-benefit analysis of transdisciplinary scientific research:

Costs outweigh the benefits	☐☐☐☐☐☐☐	Benefits outweigh the costs

Success of your TTURC center to date:

Unsuccessful	☐☐☐☐☐☐☐	Successful

APPENDIX F: TTURC STAFF AND UNIVERSITY ADMINISTRATION INTERVIEWS

TTURC University Interviews

1. How long have you been involved with the TTURC? What are your responsibilities?
2. Can you list the people with whom you work on TTURC related tasks?
3. Can you describe any aspects of the organization of the university that make it EASIER or MORE DIFFICULT for you to carry out your responsibilities for TTURC?
4. Because TTURC involves researchers and staff from different departments and schools, has the way in which you do your job changed? Can you give us some examples?
5. From your perspective, are there any barriers to collaboration among faculty in different departments and/or schools?
6. Can you think of any changes to your working environment, to policies, or the organization of the university or departments that would make working on projects that span schools and departments easier?
7. You are in a unique position to observe the transdisciplinary process. What have been your impressions of collaboration among the TTURC researchers? Can you describe some examples?
8. (*Prompting question. Wording will depend on response.*) Can you think of any reasons that would explain these kinds of interactions (i.e., personal relationships or aspects of the university environment)?
9. Have you seen any examples of faculty collaboration that have arisen as a result of this project?
10. Are there any important issues that we have not yet addressed, or any comments or ideas that you would like to share with us?

APPENDIX G: TTURC MEETING OBSERVATION FORM

Instructions for Completing the TTURC Meeting Observation Form

This form is designed to identify "Transdisciplinary" interaction across four levels or broad categories of analysis and discourse: 1) molecular/genetic/biological, 2) psychological/developmental, 3) social/organizational, and 4) macro/community policy levels.

The form has space for entering structural and administrative data including: date, location, topic, presenters, number of attendees, and times of various types of interactions or focuses that occur during meetings (i.e., announcements, presentations, and post-presentation group discussions, post-meeting or "side-bar" conversations, breaks). Please use as many forms as necessary. Two parts of the form, "components" and "tone/energy rating," require more explanation.

The form differentiates two types of Transdisciplinary interactions, Components A and B, from nontransdisciplinary interactions (i.e., those that do not cross between levels of analysis), Components C and D.

- Component A: Brainstorming, integrating or continuing ideas across levels of analysis such as from the biologic to the policy level of analysis, and integrating or continuing ideas from one meeting to the next.
- Component B: Identifying actual or proposed outcomes or products such as a future transdisciplinary course, grant opportunity, or commitment to meet for further interaction.
- Component C: Discipline-based presentations, clarification questions and answers, discussions involving various kinds of support such as material and social support, movement towards building consensus, and instances of humor.
- Component D: Occasions of meeting setbacks such as critical statements (not probing questions), interrupting others, or distracting noises. Movement towards dissensus and other disagreements may lead to some positive or even transdisciplinary outcome in the future, yet these disagreement interactions are still coded as Component D with negative tone and probably medium to very high energy.

Tone and energy ratings evaluate affective tone and energy. A meeting could have very high energy intensity (+5) and have either very positive (+2) or very negative tone (−2) ratings. Likewise, many parts

of a meeting will have a medium energy (+3) with a neutral tone (0). Tone may have positive or negative valance while energy is positive. Feel free to use half marks, such as 3.5 in the energy rating scale.

Information from this form will relate structural elements such as the frequency, affective intensity and, duration of transdisciplinary discussions with the disciplines represented, number of attendees, number of proposed outcomes, types of support offered as well as setbacks. Ultimately, the form will provide a framework for understanding how transdisciplinary process emerges as ideas move across levels of analysis.

Here is an example of transdisciplinary process. Biological and medical members of a research team found deleterious effects of tobacco during animal studies. Their findings strongly suggested that tobacco product use would negatively affect humans, contributing directly to lung disease and cancer, and exacerbating coronary heart disease among other illnesses. During a brainstorming discussion, observations made on biological levels of analysis had implications for policy analysts on the research team. Crossing disciplinary levels, recommendations were made to the California Department of Public Health. Bolstered by citizen lead anti-smoking initiatives like Proposition 99, legislative policies were implemented designed to enhance health by reducing exposure to tobacco products, (Breslow and Johnson, *Annual Review of Public Health*, 14:585–604, 1993). This form will help to identify the processes through which similar instances of transdisciplinary work occurs among TTURC members as various transdisciplinary interactions emerge within and between meetings.

All feedback is appreciated and helpful. Please forward via e-mail any questions about this form to the TTURC Trans-Disciplinary Core at the following addresses: jfuqua@uci.edi, rharvey@uci.edu, or dstokols @uci.edu. Thank you.

Other References

Bales, R. F. (1999). *Social Interaction Systems*: *Theory and Measurement*. New Brunswick, NJ: Transaction Publishers.

Klein, J. T. (1996). *Crossing Boundaries*: *Knowledge*, *Disciplinarities*, *and Interdisciplinarities*. Charlottesville, VA: University Press of Virginia.

Rosenfield, P. L. (1992). The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. *Soc. Sci. Med.* 35(11):1343–1357.

TTURC Meeting Observation Form
(sample)

page # ____

Date: _____*1/1/2001*___
Location: _____*Any Location*_____
Title/Topic(s): ____*Any Topic*_____
Presenter(s): _____*Any Presenter (s)*_____

Total Attendance: __10__ Overall Tone: _1_ To what extent did synergy occur at this meeting?
Observer: _RH___ Overall Energy: _4_ Not at all __1 __2 __3 _x4 __5 Very Much ___Not sure

Tone Scale
+2 = very harmonious
+1 = harmonious
0 = neutral
-1 = conflicted
-2 = very conflicted

Energy Scale
5 = very high
4 = high
3 = medium
2 = low
1 = very low

(list start, end, and sum min) Time	Focus (1-7)	Qualitative Description and Details *(Example)*	Component (A-D)	Tone (-2 to +2)	Energy (1 to 5)
12:05pm	1	**A**nn and **B**arry: Announcement (FOCUS 1) about publication acceptance. Movement towards consensus (Component C) about authorship and credit. Next meeting time agreed upon. **C**harles and **D**iane (two new principal investigators) brought in a humorous (Component C) Doonsbury comic related to teen smokers that could be used for advertising an upcoming anti-smoking event.	C	1	4
12:15pm	5	Late lunch arrival (FOCUS 5), noisy cart disrupts (Component D) flow of conversation.	D	-1	3
12:25pm (20 min.)					
12:25pm	2	**A**nn: Discipline based presentation (FOCUS 2) not crossing levels (Component C) about physiological factors influencing nicotine addiction and withdrawal in animals. Technical in nature. Some people looked uncertain of material.	C	0	3

1:25pm 1:35pm 1:55pm (1:30 min.)	3	**B**arry: clarification about methodology used during experimental research. Technical support offered (ComponentC). Brainstorming about unintended consequences **and policy** implications (Component A) of regulating tobacco. Will amphetamine or cocaine use increase after limiting access to nicotine? Will social violence increase after calming effects of nicotine are less available? How should the California Department of Public Health implement anti-tobacco policies in combination with other anti-drug policies?	C A	0 1	3 4
1:55pm 2:15pm (20 min.) TOTAL (2:10 min.)	4	Charles and Diane: **Proposed grant** (Component B) to study the effects of computer game-playing as an intervention to calm violent feelings that may occur during nicotine withdrawal. Set up a future meeting (Component B) to discuss this proposal. Ann & Barry: Disagreed about computer gaming approach. Dissensus (Component D) lead to further discussion about topics for future meetings such as community based interventions versus individually based computer interventions.	B D	1 -1	5 5

Focus	**Transdisciplinary Components**		**Interpersonal/Admin. Components**	
	A = Cross-disciplinary Synergy such as:	B = Proposed or Actual TD Outcomes such as:	C = Info/Support such as:	D = Setbacks such as:
1 Administrative 2 Indiv/Group Presentation 3 Open Discussion 4 Scientific Discussion 5 Post Meeting/Side Bar 6 Breaks 7 Other	• Brainstorming Crossing Levels (e.g. molecular/biological; psych/develop; sociological; policy/macro) • Integration of Disciplinary Ideas • Continuity of Ideas Across Mtgs. (e.g. past references to cross-level ideas)	• Progress Toward TD Model w/Examples • Discussions Regarding New Courses, Papers, Grants, Proposals, Software Products. • Intention Stated to Meet Further (e.g. about any of the above)	• Info/Data Presented, (not TD) • Material/Technical Support (actual or offered) • Socio-Emotional Support • Humor/ Mood Enhancement • Mvmt. Twd. Consensus	• Critical Statements • Interrupting Others • Distracting Events (e.g. equip trouble, unexpected noise) • Mvmt. Twd. Dissensus

UCI Co-PIs: __ JBz __ JF __ LJ __ FL __ CP __ SP __ RS __ DS __ TT __ CW __ JW
Affiliates: __ JBd __ JC __ PF __ JG __ DO __SO __ KP __ MS __ QZ Others: _____
Dept./School: __ Anat/NeuroBio __ EAD __ GSM __ Pharm __ PSB __ Psychtry __ SocSci __URP

TTURC MEETING OBSERVATION FORM

page # ___
Date:
Title/Topic(s):
Presenter(s): Location:

Total Attendance: _____ Overall Tone: ___ To what extent did synergy occur at this meeting?
Observer: _____ Overall Energy: ___ Not at all __1 __2 __3 __4 __5 Very Much ___Not sure

Tone Scale
+2 = very harmonious
+1 = harmonious
0 = neutral
-1 = conflicted
-2 = very conflicted

Energy Scale
5 = very high
4 = high
3 = medium
2 = low
1 = very low

(list start, end, and sum min) Time	Focus (1-7)	Qualitative Description and Details	Component (A-D)	Tone (-2 to +2)	Energy (1 to 5)

Focus	Transdisciplinary Components		Interpersonal/Admin. Components	
1 Administrative 2 Indiv/Group Presentation 3 Open Discussion 4 Scientific Discussion 5 Post Meeting/Side Bar 6 Breaks 7 Other	A = Cross-disciplinary Synergy such as: • Brainstorming Crossing Levels (e.g. molecular/biological; psych/develop; sociological; policy/macro) • Integration of Disciplinary Ideas • Continuity of Ideas Across Mtgs. (e.g. past references to cross-level ideas)	B = Proposed or Actual TD Outcomes such as: • Progress Toward TD Model w/Examples • Discussions Regarding New Courses, Papers, Grants, Proposals, Software Products. • Intention Stated to Meet Further (e.g. about any of the above)	C = Info/Support such as: • Info/Data Presented, (not TD) • Material/Technical Support (actual or offered) • Socio-Emotional Support • Humor/ Mood Enhancement • Mvmt. Twd. Consensus	D = Setbacks such as: • Critical Statements • Interrupting Others • Distracting Events (e.g. equip trouble, unexpected noise) • Mvmt. Twd. Dissensus

ATTENDEES
PIs and core members:
Non-TTURC members:
Dept./School represented:

ANNOTATED BIBLIOGRAPHY

TD SUM Paper

1. Rosenfield, P. L. (1992). The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. *Social Sciences and Medicine* 35(11): 1343–1357.
   Rosenfield was the first to suggest a continuum of interdisciplinary collaboration. She defined interdisciplinary scientific collaboration as a taxonomy ranging from multidisciplinary (the weakest form), interdisciplinary, and transdisciplinary (the strongest form), based on the extent to which researchers work together on a shared conceptual framework. The work is important because, as she outlines, it offers a definition and characterization of the strongest form of interdisciplinary collaboration with the greatest potential for ground-breaking work as well as noting that challenges associated with conducting such work become more difficult along the continuum.
2. Klein, J. T. 1990. *Interdisciplinarity*: *History*, *Theory and Practice*: Detroit.
   Klein offers one of the best historical reviews of transdisciplinary thinking in her work on interdisciplinarity. She offers insights into the conceptualizations, evolution, and current issues in transdisciplinary work. Her very thorough bibliography provides many references primarily from scholars in the humanities as well as other disciplines.
3. Campbell, D. T. Ethnocentrism of disciplines and the fish-scale model of omniscience. (1969). In Sherif, M., Sherif, C. W., eds. Interdisciplinary Relationships in the Social Sciences, Chicago: Aldine Press, 328–348.
   In the late 1960s, Campbell conceptualized and identified barriers to transdisciplinary work in departments and universities. He offers an important outline of the biases inherent within departments (e.g., tribalism and ethnocentrism), which can be found in transdisciplinary scientific collaborations.

TTURC University Administration Interviews

Thank you for setting aside time today to talk with us about your thoughts regarding interdisciplinary research and the Transdisciplinary

Tobacco Use Research Center (TTURC) project. We are interested in learning more about your impressions of research that extends over different departments and schools, as well as some of the barriers to interdisciplinary collaboration at UCI more generally. Please be assured that all of your responses will remain confidential. Only members of the Transdisciplinary Core team will have information that would link your name with your responses.

1. What are the responsibilities of your position related to faculty research?
2. What kind of role, if any, do you see interdisciplinary research playing in the research and teaching missions of the University?
3. From your perspective, what are some of the benefits of interdisciplinary research?
   (*Follow up may be needed to determine to whom benefits are afforded. For example, to faculty, to departments or schools, to the University, or to scholarship more generally*.)
4. What are some of the costs?
5. From your perspective, how do the benefits of interdisciplinary research compare with its costs?
6. Can you give some reason why this is so?
7. What have been some of the benefits of establishing a TTURC here at UCI?
8. What have been some of the challenges or costs associated with the TTURC here at UCI?
9. From your perspective, are there any barriers to collaboration among faculty in different departments and/or schools?
   [Probe for issues of assigning credit (professional and for resource allocation) with a follow-up question if not specifically addressed by respondents.]
10. Can you think of any changes to policies or the organization of the university or departments that would make working on projects that span schools and departments easier?
11. Can you think of any steps that have been taken, or could be taken to encourage undergraduate and graduate students, as well as junior faculty to become involved in interdisciplinary research?
12. Are there any important issues that we have not yet addressed, or any comments or ideas that you would like to share with us?

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Daniel Stokols, Ph.D., is Professor of Planning, Policy, and Design and Dean Emeritus of the School of Social Ecology at the University of California, Irvine (UCI). His research has examined the design and evaluation of community and worksite health promotion programs, factors that influence the success of transdisciplinary research and training programs, and the health and behavioral impacts of environmental stressors such as traffic congestion and overcrowding. He currently serves as Director of the Transdisciplinary Core Research Project within the UCI Transdisciplinary Tobacco Use Research Center and of the

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Jennifer Gress is a Ph.D. Candidate in the School of Social Ecology at the University of California, Irvine. In addition to studying transdisciplinary collaboration, her research interests concern social capital and interorganizational relationships in the field of housing and community development.

Kimari Phillips, M.A., C.H.E.S., is a Project Manager at the University of California, Irvine (UCI) Health Promotion Center, in the School of Social Ecology. Her research interests include tobacco prevention, physical activity, and nutrition, using a multidisciplinary approach to better understand mechanisms of health behavior change and maintenance. Following her undergraduate education at UCI, she completed her master's degree in health psychology education at Stanford University in 1996.

Richard Harvey, is a Ph.D. Candidate in the Department of Psychology and Social Behavior at the University of California, Irvine. His research interests include stress reactivity and psychophysiology, psychological hardiness and stress management, and modeling transdisciplinary scientific collaboration of substance use research teams.

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