A transdisciplinary approach to protocol development for tobacco control research: a case study

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ABSTRACT

The increasing complexity of scientific problems related to lifestyle risk factors has prompted substantial investments in transdisciplinary or team science initiatives at the biological, psychosocial, and population levels of analysis. To date, the actual process of conducting team science from the perspectives of investigators engaged in it has not been well documented. We describe the experience of developing and implementing data collection protocols using the principles of transdisciplinary science. The New England Family Study Transdisciplinary Tobacco Use Research Center was a 10-year collaboration involving more than 85 investigators and consultants from more than 20 disciplines as well as more than 50 research staff. We used a two-phase process in which all the study personnel participated in the developing and testing of 160 instruments. These instruments were used in 4,378 assessments with 3,501 participants. With substantial effort, it is possible to build a team of scientists from diverse backgrounds that can develop a set of instruments using a shared conceptual approach, despite limited or no experience working together previously.

Keywords

Team science, Transdisciplinary, Tobacco, Cooperative behavior, Interdisciplinary communication

The increasing complexity of scientific problems related to lifestyle risk factors has prompted substantial investments in transdisciplinary or team science initiatives at the biological, psychosocial, and population levels of analysis. Cross-disciplinary team science collaborations vary in their level of integration. *Multidisciplinary* research is the least integrated and refers to a process whereby researchers in different disciplines work to address a common problem, but do so independently or sequentially, each from his or her own discipline-specific perspective [1, 2]. *Transdisciplinary* research is the most integrated, wherein a new theory, discipline, or model emerges as researchers work jointly to address a common problem using a shared conceptual framework that draws together discipline-specific theories, concepts, and approaches [1, 3, 4]. Individuals participating in transdisciplinary science transcend their disciplines so that a common language and depth of knowledge

Implications

Practice: Data collection instruments developed by The New England Family Study Transdisciplinary Tobacco Use Research Center measure nicotine dependence and other psychiatric diagnoses while also providing symptom counts that capture the lower ranges of psychopathology severity.

Research: When evaluating transdisciplinary research, the challenges and opportunities of team science should be documented from investigators' perspectives along with the number, type, and authorship of the manuscripts produced.

Policy: The funding mechanisms for transdisciplinary team science must be structured such that sufficient time and resources are awarded for investigators to transcend their respective disciplines to develop and implement data collection protocols using a shared conceptual approach.

merges into a new synthesis of ideas, measures, methods, and analytic approaches that extend beyond the contributing individual disciplinary perspectives [5–7].

There have been a number of articles about the value [2, 5, 8] and structure [9] of transdisciplinary research; the process of facilitating team science [10]; the measurement of collaboration and integration [11, 12] and communication strategies [13] in team science; and the evaluation of team science [3, 14, 15]. Most recently, there has been a focus on the outcomes of team science initiatives compared to center-based and individual investigator funding mechanisms with regard to scientific productivity, collaboration, and impact [6, 16]. For example, Hall et al. [6] compared the publication rates of transdisciplinary research grants to investigator-initiated R01 (NIH Research Project Grant Programs) grants over a 10-year period. They found that the transdisciplinary grants were slower to become productive initially, but had higher overall publication rates and greater numbers of co-authors at the end of the analysis period.

Despite the findings highlighting the value of team science, the actual process of conducting team science from the perspectives of investigators engaged in it has not been well described. While necessarily subjective in nature, documenting the process of team science

from investigators' perspectives offers pragmatic, experienced-based reflections of the challenges and opportunities of team science, which can supplement quantitative results such as the number, type, and authorship of the manuscripts produced.

In 1999, Brown University, in collaboration with Harvard, Yale, and Brandeis Universities, was one of seven academic institutions awarded a 5-year Transdisciplinary Tobacco Use Research Center (TTURC) grant. Funded by the National Cancer Institute, the National Institute on Drug Abuse, and the Robert Wood Johnson Foundation (RWJ), the goal of the TTURC mechanism was to foster transdisciplinary tobacco control research in order to develop new approaches to the etiology, prevention, and treatment of tobacco use (for more details, see [8]). In addition, the Robert Wood Johnson Foundation provided additional funding for policy-specific studies related to the research conducted at each TTURC. In 2005, the project was renewed for an additional 5 years. This 10-year collaboration between Brown, Harvard, Yale, and Brandeis Universities will henceforth be referred to as the New England Family Study-TTURC (NEFS-TTURC). In this manuscript, we describe the experience of the NEFS-TTURC in the development and implementation of data collection protocols using the principles of transdisciplinary science. In this description, we provide evidence for the tension between short-term output and long-term impact on the production of scientific knowledge through transdisciplinary research.

NEW ENGLAND FAMILY STUDY—TRANSDISCIPLINARY TOBACCO USE RESEARCH CENTER

Overview

For the NEFS-TTURC, we proposed to enroll subjects who originally participated in the New England sites of the Collaborative Perinatal Project (CPP). The CPP was initiated in 1959 to investigate prospectively the prenatal and familial antecedents of neurological and psychological disorders of childhood. Twelve university-affiliated medical centers, including two in New England (Harvard Medical School and Brown University), participated in the national study. Women in the study were representative of the patients receiving prenatal care at each center. Overall, the CPP involved the prospective observation and examination of over 50,000 pregnancies and children through the first 7 years of life (for examples of the studies conducted with the CPP, see [17–20]).

The NEFS-TTURC was a study of transmission of nicotine dependence across three generations of CPP participants. The original CPP mothers and fathers were referred to as the G1 (generation 1) cohort. The offspring born in the CPP from 1959 to 1966 were referred to as G2 (generation 2), and the children of the G2 offspring were referred to as G3 (generation 3).

Goals of the NEFS-TTURC

The overall goals of the initial 5 years of NEFS-TTURC (TTURC-1) were to identify familial, early

childhood, and lifetime psychiatric factors that determine: trajectories of progression from smoking initiation to dependence; lifetime smoking patterns; the natural course of cessation; and the response to smoking cessation treatment. There were three major projects organized around a unifying research theme, which was to develop and validate a life span taxonomy of tobacco use and nicotine dependence phenotype. The goals of the first project were to assess the affect of in utero exposure to nicotine and other prenatal and childhood conditions on the risk of nicotine dependence in adulthood and the familial aggregation of nicotine dependence and related phenotypes. The goals of the second project were to assess adolescent comorbid disruptive behavioral disorders, mood disorders, and the progression of nicotine dependence. The goal of the third project was to investigate the relationship between familial, early childhood, and adult lifetime risk factors and response to smoking cessation treatment. With additional funding from RWJ for policy research, a fourth project added health economic objectives and methods to the goals of the other three NEFS-TTURC projects. In addition, there were six core units (Administrative, Measures and Methods, Tracing and Tracking, Genetic Epidemiology, Biostatistics, and Training) that served as resources for the projects. To accomplish the goals of the initial four projects, we conducted face-to-face interviews with representatives of each generation. G1 and G2 subjects were eligible for project 1. Families of G2s with at least one adolescent (G3) were eligible for project 2. Among the G2 subjects interviewed, all current smokers were invited to participate in project 3. All subjects were eligible for project 4.

The goals for the renewal of the NEFS-TTURC (TTURC-2) were to use data from individuals and families collected during the first 5 years to conduct a two-generation family study of genetic/familial influences on lifetime patterns of tobacco use phenotypes and comorbid psychiatric disorders (project 1); a study examining mediation and moderation of the influence of contextual (e.g., school, family, and neighborhood) factors on the progression of tobacco use, alcohol, and other drug use in adolescents and young adults (project 2); and an endophenotypic study of sibling pairs discordant for these tobacco use phenotypes, involving functional magnetic resonance imaging with nicotine challenge (project 3). There were three projects. Project 1 was a continuation and refinement of the original project 1 with data collected from G1 and G2 subjects. Project 2 was a follow-up study of the already enrolled G3s. Project 3 was a laboratory study that included G2s and other adults not involved in the CPP. In addition, there were five core units that served as resources for the project.

MEASURES AND METHODOLOGY CORE

The Measures and Methodology (M&M) Core was charged with developing and ensuring the fidelity

and integrity of all instrument protocols for the NEFS-TTURC. The specific aims of the M&M Core in TTURC-1 and TTURC-2 are shown in Table 1.

Key personnel for the M&M Core for the first 5 years of the award consisted of the principal investigator, co-principal investigator, five co-investigators, and a post-doctoral fellow. The disciplines represented by Core members included psychology, economics, and public health. The content expertise of these members included addiction research, treatment, diagnostic assessment, adolescent and geriatric health, health services, cost effectiveness, and survey methodology. While two members of the Core had worked together previously, the team as a whole had never worked together before participating in the M&M Core. In fact, some of the members had never met each other prior to beginning the NEFS-TTURC. During TTURC-2, all key personnel of the M&M Core remained a part of the team, and four additional investigators were added.

INSTRUMENT DEVELOPMENT

The process of instrument development

We use the term instrument to mean a set of items developed to assess a particular construct of interest. For instance, we considered the six-item Fagerstrom Test for Nicotine Dependence [21] to be one instrument for the assessment of nicotine dependence. Similarly, we considered a 34-item measure from the Composite International Diagnostic Interview [22] to

be a second instrument for the assessment of nicotine dependence. These instruments were then combined into project-specific protocols.

In TTURC-1, the four projects shared a conceptual framework (see Fig. 1, which has been simplified for clarity and parsimony of presentation). The framework included functional domains that we regarded as being of potential etiologic significance, relevant to prevention and treatment efforts, and elements of the broader heritable phenotype involving nicotine dependence. These domains included symptoms of mood disorders; nicotine dependence and related smoking behaviors; adult attentional problems; and other potential comorbid conditions such as antisocial personality, alcohol/substance abuse and dependence, and attention deficit hyperactivity disorder. The elements in the framework allowed us to investigate the extent to which (1) maternal G1 smoking/nicotine dependence results in nicotine exposure in utero; (2) maternal G1 comorbid psychopathology contributes to maternal smoking during pregnancy; (3) G1 psychopathology influences early childhood behavior problems (internalizing and externalizing tendencies); (4) G2's mood, attentional/antisocial symptoms, and nicotine dependence are influenced in part by corresponding conditions of the G1 parents, G1's smoking during pregnancy, and G2's early developmental factors; and (5) G3's trajectory of tobacco use is influenced directly by G2 mother's smoking during pregnancy, G2's symptoms of psychopathology, and G3's comorbid symptoms of mood and disruptive behavioral disorders.

Table 1 | Specific aims of the measures and methods core of the New England Family Study Transdisciplinary Tobacco Use Research Center (NEFS-TTURC)

TTURC-1	TTURC-2
1. Establish a set of high-quality measures and assessment methods that measure key constructs of the conceptual models examined within the NEFS-TTURC	1. Refine a set of existing high-quality measures and assessment methods developed in TTURC-1 that measure key constructs of the conceptual models examined within the NEFS-TTURC
2. Develop and evaluate innovative new methods to inform research in nicotine dependence, including establishing the reliability and validity of a novel methodology for the assessment of lifetime smoking patterns, including trajectories of smoking uptake and cessation; and developing improved multidimensional measures of nicotine dependence	2. Refine methods to inform research in tobacco use and related comorbidities, including developing a more detailed and refined measure of smoking trajectories; developing a more detailed and finely discriminating measure of lifetime alcohol use problems and dependence; and testing the validity and reliability of self-reported measures of neighborhood risk for tobacco initiation and progression
3. Ensure the fidelity and integrity of all assessment procedures conducted within the NEFS-TTURC	3. Ensure the fidelity and integrity of all assessment procedures
	4. Track, trace, screen, and enroll participants from NEFS-TTURC
	5. Provide a resource for consultation at both the local and national levels regarding issues of assessment, methods development, and methodology in conducting nicotine dependence research

TTURC-1: first 5 years of the award; TTURC-2: second 5 years of the award (renewal)

Fig 1 | Conceptual framework for the New England Family Study—Transdisciplinary Tobacco Use Research Center

In addition to the shared conceptual framework and overlapping sampling frame, each of the four projects also had a unique set of constructs being studied. Therefore, two sets of measures were required. First, a core set of instruments was administered to all participants regardless of the project(s) for which they were eligible. Second, project-specific instruments were also administered to subjects eligible for each project.

At the time we began instrument development, there was very little precedent for developing an instrument using a transdisciplinary perspective. Therefore, we initially developed three principles for how the NEFS-TTUTC would approach instrument development. First, we did not want to simply use a measure from a specific discipline without determining the extent to which the items were relevant to the conceptual model shared by investigators across disciplines. Second, we wanted to be able to compare constructs (e.g., nicotine dependence) across cohorts of participants (G1, G2, and G3), but we wanted the individual items to be tailored to the cognitive abilities and experiences of specific age groups. Finally, we wanted to construct items that were of the best possible quality rather than using particular measures simply because they had been used in prior studies (e.g., quality over precedent).

We developed the instruments in a two-phase process, as shown in Fig. 2. *Phase I:* In step 1, investigators from each of the four projects determined the constructs (e.g., nicotine dependence) needed to achieve each specific aim. Next, principal investigators (PIs) from the projects, in collaboration with the M&M Core, determined the types of instruments required and designated one member of the NEFS-TTUTC as the content expert for each construct. Content experts were nominated by

M&M Core leadership by recommending relevant investigators based on publication records and areas of expertise. Candidates and their credentials were reviewed and approved by the PIs. The initial role of the content expert was to review the literature and make recommendations, in collaboration with project PIs, about items to be included in the instrument.

Next, one of the M&M Core members, a survey methodologist, conducted an item appraisal (see below), and a team of research assistants produced initial drafts of each instrument (step 2). In step 3, the content expert and members of each project reviewed a draft of each instrument. The M&M Core then integrated recommended comments and implemented additions, deletions, and corrections. Upon agreement by the M&M Core and project PIs, each instrument was sent for review to the content expert, all NEFS-TTUTC investigators and project directors, and all members of the interviewing staff (step 4). Using this process, more than 85 investigators and consultants from more than 20 disciplines contributed feedback to NEFS-TTUTC instruments. The disciplines represented included: Biochemistry; Biostatistics; Economics; Epidemiology; Genetics; Geography; Health and Social Behavior; Health Services; Human Development; Law, Policy, and Society; Medicine; Molecular Biology; Neuropsychology; Neuroscience; Pharmacology; Philosophy; Psychiatry; Psychology (Experimental and Clinical); Public Health; Social Policy; Sociology; and Statistical Genetics. Each instrument was then pilot-tested with a small sample of participants. Steps 2–4 were repeated until there were no subsequent revisions requested by any member of the NEFS-TTUTC. The finalized instrument was then used with the study participants.

Phase II: After an instrument was field-tested, each content expert was asked to review the raw data

from that instrument for at least five interviews. Based on this review, the content expert determined whether the data collected allowed for the correct scoring algorithm and proposed data analytic procedures. The content expert then completed a Data Review and Sign-Off Sheet indicating what, if any, modifications were needed. Based on the report by the content expert, the M&M Core, in consultation with the project PIs, made changes to the instrument or requested specific interviewer training and feedback. When each instrument was designated as completed by the M&M Core, it was then sent to the Data Management team for development of data entry screens and, ultimately, data entry.

Item appraisal

In phase I of instrument development, the survey methodologist, in collaboration with members of the M&M Core or a content expert, conducted an appraisal of the potential individual items for each instrument. A number of issues related to the validity of measurement were considered for each item, such as: (1) Is the question related to the study aims? (2) To what extent is the question similar or dissimilar to other questions with comparable response tasks? (3) To what extent does an item measure a construct that is also measured in other instruments? As part of item appraisal, we implemented a number of strategies to reduce subject and interviewer burden and increase participant comprehension, including (1) writing the questions at no

higher than a fourth grade reading and comprehension level, where possible; (2) developing show cards and other visual cues for each question with four or more response options; (3) verifying that the response task was appropriate for the age of the participant; and (4) using consistent response options and coding for all items within and across instruments

Summary of instruments

The core instruments that were used with each of the three generations of participants are listed in Table 2. Because of the focus on tobacco use, we used multiple measures of cigarette smoking and nicotine dependence. In the four projects in TTURC-1, the final core protocol for the first generation (G1) included 13 interviewer-administered instruments and 10 self-administered instruments. For the second generation (G2), the core protocol included 15 interviewer-administered instruments and 12 self-administered instruments. For the third generation (G3), the core battery included 10 interviewer-administered instruments and seven self-administered instruments. In addition, 48 project-specific instruments were used (5 unique instruments for project 1, 17 unique instruments for project 2, 25 unique instruments for project 3, and 1 unique instrument for project 4). TTURC-2 built off the initial 5 years. As a result, only three new instruments were needed for G1s and G2s in project 1 and only selected core instru-

Fig 2 | Phases of instrument development in the New England Family Study—Transdisciplinary Tobacco Use Research Center

Table 2 | Summary of core instruments for the New England Family Study

Instrument	First generation (G1)	Second generation (G2)	Third generation (G3)
Interviewer-administered instruments			
Smoking measures			
Prenatal substance exposure	X	X	X
Cumulative smoke exposure history		X	X
Lifetime interview of smoking trajectories	X	X	X
Nicotine dependence	X	X	X
Quitting history and methods	X	X	X
Diagnostic measures			
Diagnostic screener	X	X	
Alcohol use disorder	X	X	X
Antisocial personality/conduct disorder	X	X	X
Depression	X	X	X
Substance use disorder	X	X	X
Attention deficit hyperactivity disorder		X	X
Family enumeration	X	X	
Family history	X	X	X
Socioeconomic and other demographic measures	X	X	X
Social history	X	X	
Self-administered instruments			
Smoking			
Fagerstrom Tolerance Questionnaire	X	X	X
Nicotine dependence	X	X	X
Readiness ladder	X	X	X
Other			
Center for Epidemiologic Studies Depression Scale (CES-D)	X	X	
Short Inventory of Symptoms	X	X	
Stress Inventory Scale	X	X	X
Peer modeling	X	X	X
Parental Bonding Index		X	X
Multidimensional Personality Questionnaire	X	X	
Gambling	X	X	
Participant opinions about the interview	X	X	X

ments were used for G2s in project 3. In project 2, 23 unique instruments were used with G3s.

Types of instrument development

The instruments that we used can be categorized into three types: standard, significantly adapted, and newly developed. Standard instruments consisted of instruments from previous studies that only required formatting for consistency, some minor word editing, and instructions and other practical applications for differences in cognitive abilities and experiences of each age group of the NEFS-TTUTC. For example, for the G1 and G2 participants, we used the Wisconsin Inventory of Smoking Dependence Motives (WISDM) developed by Piper et al. [23] as one of the measures of nicotine dependence. For G3s, we used the Nicotine Dependence Syndrome Scale (NDSS) developed by Shiffman et al. [24]. For both the WISDM and NDSS, the only modifications we made to the original instrument were clarifications in the instructions to participants. By doing

this, we attempted to increase the ease of administration of these instruments and therefore reduce subject burden. By using age-appropriate instruments for the self-administered measure of nicotine dependence, we were able to compare the construct across cohorts while maintaining items that were relevant to smokers at different developmental stages. Overall, there were 50 standard instruments.

Significantly adapted instruments consisted of instruments from previous studies that we extensively modified for use in the NEFS-TTUTC. In addition to the procedures followed for the standard instruments, the types of modifications made to significantly adapted instruments included the addition and/or revision of items; changes in the inclusion or exclusion criteria to the instrument; and more refined specification of particular constructs measured by the instrument. For example, we used the Tobacco Module of the World Health Organization's Composite International Diagnostic Interview (CIDI) [22] as a basis for our diagnostic instrument of adult and adolescent lifetime and past

year nicotine dependence. The interviewer-administered CIDI was modified to enhance its consistency with the DSM-IV criteria for nicotine use disorders and conceptual contribution to the study of phenotypes of smoking. Assessment of tolerance and withdrawal was enhanced. Next, we refined assessment of the dependence criterion “continued to smoke despite emotional or physical problems” by adding the requirement that continuing to smoke occurred despite *knowledge* that said problems were caused by, or made worse by, smoking. Finally, similar to the other psychiatric diagnostic assessments, we paid particular attention to having a low threshold for screening into the module. These low thresholds were used so that the assessment would provide more dimensional measures of psychopathology (i.e., symptom counts) for those participants who did not meet the full DSM disorder criteria. Overall, there were 71 significantly adapted instruments.

Newly developed instruments consisted of instruments developed specifically for NEFS-TTURC. While individual items or sections of the instrument may have been used in previous studies, newly developed instruments were the ones in which there was no prior experience with the full instrument. For example, we developed an instrument to assess lifetime smoking patterns specifically for NEFS-TTURC [25]. The Lifetime Interview of Smoking Trajectories was a structured interviewer-administered questionnaire that yielded an account of first exposure to cigarettes and smoking patterns across a lifetime. Major features included the assessment of ages at first puff of tobacco, latency to second puff, reactions to each [26], and situational factors related to each; age of onset of weekly and daily smoking; assessment of various phases of smoking, including the initial (earliest) phase, the heaviest phase, the current phase or the most recent phase if quit, and all abstinence phases 3 months or longer. Overall, there were 39 newly developed instruments.

Challenges faced in protocol development

Three examples highlight the types of challenges faced by the team in developing protocols that addressed the domains in the conceptual framework. First, the major focus of interest for the team was the extent to which there was a heritable nicotine phenotype including concurrent psychopathology. As a result, measurement of this nicotine dependence phenotype necessarily involved the perspectives of several disciplines including health and social behavior, psychology, genetics, and human development. Initially, investigators focused primarily on the anticipated needed measures within their own disciplines related to nicotine dependence and deferred to the other disciplines for all other items. For example, the geneticists focused on family history aspects and deferred to the psychologists and behavioral scientists for the smoking-related items, and vice versa. As a result, the instruments were lengthy and included conventional items from within disci-

plines that were not necessarily appropriate for adequately identifying a heritable nicotine dependence phenotype. However, over time, as investigators collaborated more closely with one another and more fully understood other disciplinary perspectives: (1) the conventional items were challenged, (2) items were synthesized across disciplinary perspectives, (3) instruments were developed that could more adequately capture a heritable nicotine dependence phenotype, and, ultimately, (4) the protocols were shortened. As a result, despite the challenges, our new measures have contributed to a better understanding of the development of nicotine dependence over time as a dimensional rather than categorical construct with a continuum of severity that has evidence of familial aggregation (for example, see [27, 28]).

A second example involves the mood disorders domain in the conceptual framework. As part of the mood disorders domain, decisions were required about the inclusion of items measuring depressive symptoms generally and suicidal ideation specifically. Investigators with clinical backgrounds were not in favor of asking these types of items without substantial clinical supervision and backup for research staff. On the other hand, investigators experienced in large-scale observational studies argued that such items were routinely asked without extensive clinical oversight and that such intervention was not appropriate in an observational study. Ultimately, the investigators mutually agreed to include all relevant items in the assessment, and an expanded safety protocol was developed for use by research staff if a participant endorsed suicidal ideation. The protocol involved research staff asking a series of standardized questions to assess risk, contracting for safety with the participant, and referring the participant to a licensed clinical supervisor.

A third example involves the challenges involved in integrating the cost-effectiveness components to each of the projects. Initially, a detailed health assessment for each of the three generations was developed that measured risks for and symptoms of smoking-related morbidities. The items included were chosen based on substantial clinician recommendation and feedback. However, the economists and health service researchers noted that to address issues related to cost effectiveness, measures of healthcare and productivity also had to be included. The new instrument with all recommended items was substantially longer than the time and resources allowed. As a result, the clinicians, economists, and health researchers had to closely collaborate to understand the analytic needs of the respective disciplines so that they could produce an assessment that included the critical items needed for all analyses while fulfilling the designated time requirements for completion.

REVISIONS TO INSTRUMENTS

Because many of the specific aims across projects focused on G2 participants, in TTURC-1, we initially drafted instruments for this generation.

Using the process for instrument development outlined above and depicted in Fig. 1, the initial length of the battery for G2s was 6 h on average. We attempted to conduct two 3-h interviews with the participants. However, due to the low response rates, negative participant feedback, and budget concerns, we revised the battery significantly so that the total administration time was reduced to 3 h on average.

In addition to this significant revision, there was an average of 4.3 more minor revisions (range, 0–10) to each G2 instrument. Although there were fewer revisions to the G1 and G3 protocols because they were developed after many problems had been detected in the G2 instruments, there was still an average of 3.1 and 3.4 revisions per instrument to the G1 and G3 protocols, respectively, in TTURC-1. In TTURC-2, there were averages of 2.5, 1.5, 2.0 revisions per instrument to the G1, G2, and G3 protocol, respectively. Finally, 10 instruments in TTURC-1 and 11 instruments in TTURC-2 were developed and piloted, but were not included in the final protocols because of concern with subject burden.

QUALITY ASSURANCE

Audiotaping protocol

In addition to instrument development, a primary aim of the M&M Core was to ensure the fidelity and integrity of all assessment procedures conducted within NEFS-TTURC. Initially, there was substantial debate amongst investigators about the utility and acceptability of audiotaping interviews as a measure of quality control. In general, the investigators in disciplines in which large-scale observational studies were normative were not in favor of audiotaping because of concerns about suppression of responses to sensitive items. Alternatively, investigators with experience in clinical and/or behavioral interventions were in favor of audiotaping to ensure interview fidelity. To address the differences across disciplines, we conducted a pilot study in which we randomly assigned interviews to be audiotaped or not [29]. The results indicated that audiotaping was not associated with lower rates of endorsement of potentially stigmatizing items. Therefore, the centerpiece of the quality assurance process for NEFS-TTURC was an audiotaping protocol that enabled us to maintain the quality of the interviews across time, interviewers, and projects.

Each interviewer's first five interviews were audiotaped and reviewed by his or her direct supervisor to ensure adherence to the protocol. After the initial five interviews, 50 % of each individual's interviews were audiotaped. A member of the M&M Core reviewed a randomly selected 5 % of each interviewer's interviews. Detailed feedback regarding these interviews was provided promptly to the interviewer through the use of a

semi-structured fidelity checklist. This checklist allowed reviewers to provide feedback on several different fidelity criteria for each module of the assessment battery (e.g., using skip patterns accurately, maintaining a neutral stance) as well as to provide global ratings of performance. When inaccuracy or drift was detected, further training and monitoring was conducted, in conjunction with the interviewer's supervisor. Project supervisors also reviewed a randomly selected tape for each interviewer quarterly. Finally, we developed an Interview Quality Checklist to standardize documentation by interviewers of potential threats to assessment validity (e.g., concerns about participant comprehension, concentration, substance use) and to provide a forum for rapid response by supervisors to concerns about the integrity of participants' responses.

Listserv and searchable archive

In addition to the audiotaping protocol, we developed a Listserv and searchable archive to facilitate ongoing communication between field staff and investigators. As protocol-related questions arose, interviewers posted these questions to an e-mail Listserv, and a member of the M&M Core or a content expert responded as quickly as possible. The questions and answers were archived on a web site. Examples from the Listserv include:

Question: If a parent/caretaker moves out of the family home but continues to smoke, do you code only for the number of years of contact in the same home with the subject (until the age of their moving out)?

Answer: Yes—code it for the years they were in the same home.

Question: Subject stated mother had drug problem due to dual diagnosis/ bipolar disorder when she was not on prescription drugs—code as drug abuse/use to get high or not?

Answer: This should be coded as a mental health problem not a drug problem. The intention is to assess drug abuse as a stand-alone issue vs. involvement with biochemical organic brain disease.

All staff on all projects benefited from the questions and answers posted, thereby improving the consistency of administration and coding. This was particularly beneficial because, in addition to study directors and coordinators, we employed 48 interviewers who worked on one or more of the projects over the course of the study. Besides using this process to answer interviewer questions, we used the Listserv to update interviewers about any changes to the protocol and any other issues related to study fidelity. Finally, the archive provided documentation of all protocol-related decisions and served as a resource for NEFS-TTURC investigators as well as researchers nationally. As a result, the Listserv became less needed over time as information in the archive increased.

Supervision of interviewers

In TTURC-1, interviewers worked for a single project and were supervised by a project-specific PI and project director. Despite the implementation of the audiotaping protocol and Listserv, it was difficult to ensure study fidelity, integrity, and consistency across projects. Therefore, in TTURC-2, all data collection was centralized under the direction of the M&M Core. While project PIs remained involved in study supervision, the project directors and interviewers were directly supervised by the M&M Core, and interviewers were trained to work on all projects. While some interviewers had specialized skills and tasks, all were capable of screening and/or interviewing participants on any of the studies.

CONCLUSIONS

The major strength of our transdisciplinary approach to instrument development was a set of measures and instrument methods that utilized the expertise of researchers from different disciplines. In the process, we developed new and/or refined instruments for measuring nicotine use and dependence, depression and mood disorders, disruptive behaviors, attention problems, and substance use problems [25, 28, 30–32]. The process allowed us to create instruments that met the need to obtain psychiatric diagnoses for each participant while also providing symptom counts that captured the lower ranges of severity of psychopathology. Furthermore, integrated constructs that were relevant to all contributing disciplines were assessed in every study and sample within NEFS-TTURC using consistent methods and instruments. In total, 4,378 assessments were conducted with 3,501 participants in NEFS-TTURC. Overall, the instrument development process allowed us to produce protocols that addressed the aims of the NEFS-TTURC, but have also been used for other projects by both NEFS-TTURC investigators and others (see [33, 34] for example of use of the Lifetime Use of Smoking Trajectories).

There were a number of challenges to our approach that must be considered. As noted by Morgan et al. [10], investigators who were working for the first time with new disciplines had to consider the possibilities for fusion of their own discipline with these new disciplines at the same time they were learning about the new disciplines. Kahn and Prager [35] labeled this process “wallowing.” There were three major consequences of this wallowing for the instrument development process. First, the process took longer than expected, dramatically increasing the length of time to complete instrument development relative to those developed by investigators from single or even multiple disciplines. Second, the evolution of the shared conceptual framework resulted in multiple revisions to the instruments as investigators refined their

thinking about particular constructs and better understood other disciplinary perspectives. Next, operationalizing the shared conceptual framework into common protocols was difficult and entailed trade-offs. For example, because of the number of constructs that needed to be included in the protocols, some constructs were not measured with the amount of detail that may occur in a single disciplinary approach. Finally, due to the number and associated costs of investigators and consultants required for this type of team science approach, each individual was supported at a very low rate of compensated effort. This required committed individuals who were willing to give uncompensated time to successfully meet project goals.

Despite the challenges, there were several keys to our success. First, a key set of individuals from several different disciplines across the NEFS-TTURC investigative team were consistent over the course of the study, which allowed for the development of mutual respect. Therefore, while substantial time was needed in the first 5 years to develop a shared conceptual framework and language for communicating across disciplinary perspectives, much less time and fewer revisions were needed for new instrument development during the remaining years of the project. Second, the majority of the Measures and Methods (M&M) Core remained active contributors throughout the 10-year collaboration. They each contributed content expertise to one or more of the projects while serving as project liaisons and methodological experts on the M&M Core. The consistent, shared memory of the M&M Core was extremely valuable, particularly as personnel on particular projects changed over the course of the project. Finally, extensive documentation was maintained throughout the study with regard to measure development, modification, and coding decisions.

In conclusion, our experiences suggest that with sufficient time for collaboration, a transdisciplinary approach to instrument development can produce high-quality, accessible measures that are endorsed by investigators from varied disciplines. With substantial effort, it is possible to build a team of scientists from diverse backgrounds that can develop a set of instruments using a shared conceptual approach, despite limited or no experience working together previously.

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1. Rosenfield PL. The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. *Soc Sci Med.* 1992; 35(11):1343-1357.
2. Turkan JS, Kaufman NJ, Rimer BK. Transdisciplinary tobacco use research centers: a model collaboration between public and private sectors. *Nic Tob Res.* 2000; 2(1):9-13.
3. Stokols D, Fuqua J, Gress J, et al. Evaluating transdisciplinary science. *Nic Tob Res.* 2003; 5(Suppl 1):S21-S39.

4. Thompson Klein JT. *Crossing Boundaries: Knowledge, Disciplinarity and Interdisciplinarity*. Charlottesville: University of Virginia Press; 1996.
5. Abrams DB. Transdisciplinary paradigms for tobacco prevention research. *Nic Tob Res*. 1999; 1(Suppl 1):S15-S23.
6. Hall KL, Stokols D, Stipelman BA, et al. Assessing the value of team science: a study comparing center- and investigator-initiated grants. *Am J Prev Med*. 2012; 42(2):157-163.
7. Mabry PL, Olster DH, Morgan GD, Abrams DB. Interdisciplinarity and systems science to improve population health: a view from the NIH Office of Behavioral and Social Sciences Research. *Am J Prev Med*. 2008; 35(2 Suppl):S211-S224.
8. Abrams DB, Leslie F, Mermelstein R, Kobus K, Clayton RR. Transdisciplinary tobacco use research. *Nic Tob Res*. 2003; 5(Suppl 1):S5-S10.
9. Baker TB, Cummings KM, Hatsukami DK, et al. Transdisciplinary tobacco use research centers: research achievements and future implications. *Nic Tob Res*. 2009; 11(10):1231-1244.
10. Morgan GD, Kobus K, Gerlach KK, et al. Facilitating transdisciplinary research: the experience of the transdisciplinary tobacco use research centers. *Nic Tob Res*. 2003; 5(Suppl 1):S11-S19.
11. Masse LC, Moser RP, Stokols D, et al. Measuring collaboration and transdisciplinary integration in team science. *Am J Prev Med*. 2008; 35(2 Suppl):S151-S160.
12. Hall KL, Stokols D, Moser RP, et al. The collaboration readiness of transdisciplinary research teams and centers findings from the National Cancer Institute's TREC Year-One Evaluation Study. *Am J Prev Med*. 2008; 35(2 Suppl):S161-S172.
13. Kobus K, Mermelstein R, Ponkshe P. Communications strategies to broaden the reach of tobacco use research: examples from the transdisciplinary tobacco use research centers. *Nic Tob Res*. 2007; 9(Suppl 4):S571-S582.
14. Stokols D, Misra S, Moser RP, Hall KL, Taylor BK. The ecology of team science: understanding contextual influences on transdisciplinary collaboration. *Am J Prev Med*. 2008; 35(2 Suppl):S96-S115.
15. Klein JT. Evaluation of interdisciplinary and transdisciplinary research: a literature review. *Am J Prev Med*. 2008; 35(2 Suppl):S116-S123.
16. Rimer BK, Abrams DB. Present and future horizons for transdisciplinary research. *Am J Prev Med*. 2012; 42(2):200-201.
17. Broman S, Bien E, Shaughnessy P. *Low Achieving Children: The First Seven Years*. Hillsdale: Lawrence Earlbaum; 1985.
18. Buka SL, Lipsitt LP, Tsuang MT. Birth complications and psychological deviancy: a 25-year prospective inquiry. *Acta Paediatr Jpn*. 1988; 30(5):537-546.
19. Nichols P, Chen T. *Minimal Brain Dysfunction: A Prospective Study*. Hillsdale: Lawrence Earlbaum; 1981.
20. Klebanoff MA, Zemel BS, Buka S, Zierler S. Long-term follow-up of participants in the Collaborative Perinatal Project: tracking the next generation. *Paediatr Perinat Epidemiol*. 1998; 12(3):334-346.
21. Heatherton TF, Kozlowski LT, Frecker RC, Fagerstrom KO. The fagerstrom test for nicotine dependence: a revision of the Fagerstrom Tolerance Questionnaire. *Br J Addict*. 1991; 86(9):1119-1127.
22. Robins L, Wing J, Wittchen H, et al. The Composite International Diagnostic Interview: an epidemiologic instrument suitable for use in conjunction with different diagnostic systems and in different cultures. *Arch Gen Psychiatry*. 1988; 45:1069-1077.
23. Piper ME, Piasecki TM, Federman EB, et al. A multiple motives approach to tobacco dependence: the Wisconsin Inventory of Smoking Dependence Motives (WISDM-68). *J Consult Clin Psychol*. 2004; 72(2):139-154.
24. Shiffman S, Waters A, Hickcox M. The Nicotine Dependence Syndrome Scale: a multidimensional measure of nicotine dependence. *Nic Tob Res*. 2004; 6(2):327-348.
25. Colby SM, Clark MA, Rogers ML, et al. Development and reliability of the lifetime interview on smoking trajectories. *Nic Tob Res*. 2012; 14(3):290-298.
26. Pomerleau OF, Pomerleau CS, Namenek RJ. Early experiences with tobacco among women smokers, ex-smokers, and never-smokers. *Addiction*. 1998; 93(4):595-599.
27. Shenassa ED, McCaffery JM, Swan GE, et al. Intergenerational transmission of tobacco use and dependence: a transdisciplinary perspective. *Nic Tob Res*. 2003; 5(Suppl 1):S55-S69.
28. Kahler CW, Strong DR, Papandonatos GD, et al. Cigarette smoking and the lifetime alcohol involvement continuum. *Drug Alcohol Depend*. 2008; 93(1-2):111-120.
29. Boergers J, Clark M, Colby S, et al. Effects of Audiotaping on Adolescents' Self-Reports of Tobacco and Substance Use. *Annual Meeting of the Society for Research on Nicotine and Tobacco*. Orlando, FL; 2006.
30. Gilman SE, Rende R, Boergers J, et al. Parental smoking and adolescent smoking initiation: an intergenerational perspective on tobacco control. *Pediatrics*. 2009; 123(2):e274-e281.
31. Kahler CW, Daughters SB, Leventhal AM, et al. Personality, psychiatric disorders, and smoking in middle-aged adults. *Nic Tob Res*. 2009; 11(7):833-841.
32. Kahler CW, Leventhal AM, Daughters SB, et al. Relationships of personality and psychiatric disorders to multiple domains of smoking motives and dependence in middle-aged adults. *Nic Tob Res*. 2010; 12(4):381-389.
33. Dierker LC, Donny E, Tiffany S, Colby SM, Perrine N, Clayton RR. The association between cigarette smoking and DSM-IV nicotine dependence among first year college students. *Drug Alcohol Depend*. 2007; 86(2-3):106-114.
34. Strong DR, Kahler CW, Colby SM, Griesler PC, Kandel D. Linking measures of adolescent nicotine dependence to a common latent continuum. *Drug Alcohol Depend*. 2009; 99(1-3):296-308.
35. Kahn R, Prager D. Interdisciplinary collaboration are a scientific and social imperative. *Scientist*. 1994; 8:12.