Integrating knowledge across domains to advance the science of health behavior: overcoming challenges and facilitating success

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Cite this as: *TBM* 2017;7:98–105
doi: 10.1007/s13142-016-0433-5

Abstract

Health behaviors often co-occur and have common determinants at multiple levels (e.g., individual, relational, environmental). Nevertheless, research programs often examine single health behaviors without a systematic attempt to integrate knowledge across behaviors. This paper highlights the significant potential of cross-cutting behavioral research to advance our understanding of the mechanisms and causal factors that shape health behaviors. It also offers suggestions for how researchers could develop more effective interventions. We highlight barriers to such an integrative science along with potential steps that can be taken to address these barriers. With a more nuanced understanding of health behavior, redundancies in research can be minimized, and a stronger evidence base for the development of health behavior interventions can be realized.

Keywords

Integration, Health behavior, Theory, Interventions

INTRODUCTION

Many chronic diseases in the U.S., including several cancers, cardiovascular disease, diabetes, and obesity, share a common set of behavioral determinants such as tobacco use, excessive use of alcohol, poor dietary habits, and sedentary behavior [1]. These health behaviors relate to one another in multiple ways. First, the behaviors themselves tend to cluster within individuals; for example, tobacco users are often more likely to consume alcohol [2] and less likely to adhere to medical regimens [3]. Second, health behaviors can be driven by shared mechanisms. For example, sensitivity to certain tastes may affect tobacco (e.g., use of menthol) and food behaviors (e.g., avoidance of spicy foods) [4]. Self-regulation efforts in one behavioral domain contribute to the likelihood of successful self-regulation in other domains [5], and failures to appropriately prioritize long-term health consequences over immediate affective or social benefits can contribute to addictive behaviors and unhealthy food choices (e.g., calorie-rich and low-nutrient foods) [6].

With the exception of the first three authors (who led the manuscript and/or NCI meeting described herein), order of authorship is alphabetical.

We thank all of the speakers and panelists in the NCI-sponsored meeting on “Leveraging Lessons Learned across Health Behaviors” in November 2014 (Cynthia Berg, David Buller, Meg Gerrard, Frederick Gibbons, Robert Hornik, Michael Sayette, Bonnie Spring, and Geoffrey Williams). We also thank Juanita Cox and Tonza Webb for their assistance with meeting planning, Tracey Goldner for assistance with manuscript preparation, and two anonymous reviewers for helpful comments on an earlier version of the manuscript.

Implications

Researchers: We suggest that researchers consider getting training and doing research on more than one health behavior to maximize integration.

Practitioners: Attempts to change single health behaviors are likely to be informed by research on different but related behaviors.

Policymakers: Policies designed to influence particular behaviors may be informed by research showing effects of policies on other health behaviors.

Additionally, health behaviors are influenced by shared social and environmental determinants such as social norms, media exposure, and public policy [7–10]. For example, movies and other entertainment media that portray unhealthy behaviors can promote these behaviors [9] whereas taxes can discourage them [11]. Finally, health behaviors can influence one another. Smoking cessation attempts can lead to weight gain, which in turn might reduce motivation to quit [12, 13]. Use of one tobacco product can serve as a gateway to use of another tobacco product or to other

substances [14]. Difficulty in changing one health behavior (e.g., a failed attempt to start a new exercise plan) can inform beliefs about one's ability to change other behaviors in the future (e.g., adhering to a diet).

Research on new and emerging health behaviors can be informed by existing and concurrent research on similar behaviors. For example, communication and implementation of recommendations regarding computed tomography lung screening [15] might be informed by earlier research on colorectal cancer screening. Emerging research on human papilloma virus (HPV) vaccination uptake can benefit from existing knowledge on MMR vaccination. Similarly, research on new tobacco products such as e-cigarettes might be informed by the substantial body of existing research on combustible tobacco. The latter example shows that even within a particular behavioral domain (such as tobacco use), there are often multiple distinguishable behaviors and that research on any one of them can inform what might be learned about the others.

Integration across behavioral domains can leverage existing knowledge to enhance the quality of our research on emerging behavioral health challenges, while also producing new insights relevant to existing health behaviors. By "integration," we are referring to a systematic approach to health behavior research that applies knowledge learned in one behavioral domain to others, investigates common mechanisms and determinants across behaviors, and explores how behaviors themselves are interrelated. Such integration has the dual advantage of generating greater knowledge about specific behaviors that have otherwise been studied less effectively in isolation, while also improving our understanding of common mechanisms and influences related to disparate behaviors.

Unfortunately, research that crosses behavioral domains is not the norm in behavioral medicine or its allied fields. Although there have been empirical attempts to intervene on multiple behaviors simultaneously [16, 17], proportionally less empirical work has examined mechanisms and influences across behaviors in order to identify commonalities and differences. Rather, it is typical for investigators to focus their research on one behavior at a time. This concern is not entirely new; health psychologists such as Jessor have highlighted mechanisms underlying "problem behaviors" for several decades [2], but progress in producing greater integration has been disappointingly modest.

One notable exception to this norm is in the development and testing of health behavior theories. Many of these theories were designed under the assumption that behaviors have common antecedents such as self-efficacy, attitudes, perceived norms, perceptions of autonomy, and emotion [18]. Nevertheless, research using health behavior theories has not necessarily integrated knowledge gained about different behaviors. As Noar et al. [19] assert,

"...health behavior theories have been tested across numerous health behaviors (typically, a single behavior at a time) and could potentially be synthesized and compared. The integration of findings from studies *across* diverse behavioral areas, however, is not what it could be. In fact, theoretical reviews and meta-analyses of the literature tend to use a single behavior paradigm and thus often review the application of theory to a single behavioral domain, precluding comparisons from being made." (p. 276).

The theories themselves are also not systematically compared; in a review of health behavior research, Noar and Zimmerman observed that only 13 of the 2901 (0.4 %) articles reviewed were empirical comparisons of theories [20]. Moreover, most health behavior theories focus on individual-level, psychological determinants of health behavior without taking into account external factors at other levels of influence, and many of the theories have remained static over an extensive period of time [21]. Many tests of health behavior theories also rely on correlational rather than experimental or even longitudinal data, thereby hindering causal inference [22, 23].

In short, though we possess a well-established science on particular behaviors, it has come at the cost of understanding core mechanisms and influences across health behaviors broadly. This lack of integration has multiple negative consequences for behavioral science. It inhibits serendipitous discoveries about how a particular behavior in one domain might inform the understanding of conceptually similar behaviors in other domains (e.g., diabetes medication adherence and oral chemotherapy adherence) and complicates the identification of dimensions on which behaviors differ in order to determine when a specific theory or intervention approach is more likely to apply. Lack of integration impedes attempts to understand the many possible interactive effects among health behaviors and their determinants. Opportunities for leveraging common intervention and communication strategies are also missed when research touching on different health behavior domains remains fragmented.

Many health promotion programs across different behaviors could use parallel communication channels and content in a similar context. For example, Zoellner et al. [30] addressed both healthy eating and physical activity in an intervention that took place in a rural, underserved community. A recent article by Seidenberg et al. posits that research on indoor tanning policies would benefit greatly from lessons learned in the area of tobacco control policy, particularly given the overlapping consumer groups [24]. Lack of integration also impedes the potential for repurposing interventions that may have failed for one behavior yet could be effective for other behaviors. For example, informational interventions that fail to affect

addictive behaviors such as smoking may be more effective for one-time behaviors such as vaccination or radon testing.

Leveraging lessons learned across health behaviors

With these concerns in mind, in November 2014, the National Cancer Institute (NCI) sponsored a public meeting titled *Leveraging Lessons Learned Across Health Behaviors*. Eight investigators with expertise in psychology, communication, and medicine and who have conducted successful empirical research programs that transcend or integrate specific behavioral domains were invited to give presentations about their work and to discuss the topic of fostering better integration of behavioral research across domains. The two-day meeting began with formal presentations from investigators about their research programs. The event culminated in a roundtable discussion of the overarching themes that emerged from the presentations, with the goal of developing specific recommendations to be disseminated to behavioral scientists. This discussion was transcribed and the primary themes were then organized into three key themes, expanded upon as follows: potential causes of a lack of integration among health behavior domains and consequences of this lack of integration, exemplary models that have been used to promote integration, and recommended strategies to overcome barriers to integration. Here, we summarize some of the important observations and present several recommendations and conclusions highlighted at the meeting and in follow-up discussions.

What contributes to a lack of integration among health behavior domains?

There are many explanations for the current lack of integration in behavioral research, including specialization in training, funding, and organizational structures (e.g., in academia, government agencies, professional organizations, and scientific journals). Perhaps most important, the last 40 to 50 years have witnessed increasing specialization of knowledge across all research fields. In behavioral science, specialization has included the development of behavior- and problem-specific disciplines and fields with their own graduate programs and independent funding structures (e.g., nutrition, addiction, kinesiology, exercise science, and sports science). There also has been a proliferation of health domain-specific journals and professional organizations in recent years. Of course, there are many advantages of specialization; investigators are likely to conduct better research by having firm knowledge in their domain of interest—a necessity given the increasing complexity of particular areas of research such as addiction. The increasing move toward specialization in behavioral medicine mirrors specialization in clinical medicine, which also has its advantages. However, just as specialization in clinical medicine

can inhibit the elucidation of common mechanisms underlying different diseases, specialization in behavioral research can diminish attention to the many ways in which behaviors are themselves related.

Specialization also is a hallmark of the organization of the National Institutes of Health (NIH), the nation's leading medical research agency. Many of the 27 NIH institutes and centers focus on specific diseases or organ sites (e.g., NCI; National Heart, Lung, and Blood Institute; National Eye Institute). There are varying degrees of interest in health behavior research within the NIH; fortunately, some health behaviors such as diet, physical activity, medication adherence, and tobacco use receive attention from multiple institutes and centers. Moreover, several NIH initiatives highlight the importance of work conducted across behavioral domains such as the Transdisciplinary Research on Energetics and Cancer (TREC) [25] and Science of Behavior Change (SOBC) initiatives [26]. The TREC centers focus on interrelationships among various aspects of obesity and cancer outcomes, taking a multilevel and multidisciplinary approach. The SOBC initiative encourages researchers to identify key target mechanisms underlying behavior change, develop “assays” (terminology borrowed from medical research) of those targets, and then design interventions to address those targets. Some health behaviors such as sleep and sexual behavior may receive proportionally less (or less coordinated) attention than they should because they are not the clear province of any given NIH institute or center. Work in other areas may not be optimally integrated.

There are also methodological reasons for the current lack of integration in research across health behavior domains. Existing methodological and statistical tools do not make it easy to assess temporal effects; for example, statistical analyses on multiple behavioral variables over time, within person, are quite complex (although, as we note later, data analytic techniques for “big data” are increasing in availability). Repeated behaviors such as food consumption produce highly dense longitudinal data sets that are not easily comparable to the kinds of data collected about less frequent behaviors such as screening. And, measurement of multiple behaviors (and their influences) can increase participant burden and consequently raise validity and reliability concerns.

Some of the factors that contribute to a lack of integration in health behavior research resemble commonly cited challenges in conducting interdisciplinary research. Primary among these is a lack of cross-training in higher education and research centers. Graduate training programs—even those in disciplines that are not behavior-specific, such as clinical psychology—are often organized around laboratories focused on specific health behaviors such as tobacco cessation or medical adherence. We contend that science advances most effectively when specialization is complemented by systematic attempts at integration. A lack

of integration in behavioral research may partially reflect what is valued most in science and academia—the production rather than the application of novel ideas. More research is needed at the interface of production and application using integrative models. An example is the Obesity-Related Behavioral Intervention Trials (ORBIT) framework [27], which serves as a promising model to foster interdisciplinary teams of basic and applied behavioral and social science researchers to identify, test, and refine promising new avenues for reducing obesity and improving obesity-related and other behaviors. Unfortunately, disciplines that value research on basic behavioral and social processes such as social psychology and decision science often place less value on the application of this work to specific behavioral domains. A lack of integration can produce a dearth of in-depth familiarity with the behavioral domains being explored, limited contributions to applied research teams, and minimal published work in more applied journals [28].

What are some successful models to promote integration?

There are already some useful examples of the kind of integration for which we are advocating. In Table 1, we highlight six research approaches to advance integration in behavioral research, used to varying degrees in extant research paradigms. These include applying basic principles from a particular discipline to multiple behaviors, optimizing study designs, applying common theories, identifying common mechanisms, repurposing evidence-based approaches, and harmonizing existing data. Researchers should adopt one or more of these approaches toward the end of greater integration.

These are all possible ways to conduct integrative research, varying of course in analytical and methodological needs. In order to embrace any of them, however, we contend that the aforementioned barriers to integrative research need to be addressed. Below, we consider possible solutions to this end.

How might barriers to integration be addressed?

Transdisciplinary research is defined as research that aims to integrate and ultimately extend beyond discipline-specific concepts, approaches, and methods to accelerate innovations and progress toward solving complex real-world problems. Here, we are identifying the need for complementary research that integrates concepts, theories, approaches, and methods from across behavioral domains, paralleling the integrative approach taken in transdisciplinary research but with a focus on working across health behaviors rather than across disciplines. Importantly, different disciplines may investigate the same or different health behaviors in unique and synergistic ways. For example, whereas psychologists might approach screening behaviors from the perspective of decision-making, risk communication, and individual cost/benefit analysis, public health researchers might approach screening from the perspective of organizational and social determinants

as well as population-level costs and benefits of screening. Policy researchers are more likely to approach behavior change at the population level than are researchers in nursing or social work. We suggest that the science of health behavior may greatly benefit from simultaneous cross-disciplinary and cross-domain knowledge exchange and integration. We note that integrative behavioral research can certainly be achieved by independent investigators who integrate findings from the study of two or more different behaviors in the same research program [43], but it is nevertheless more likely to be conducted by teams of investigators who each contribute knowledge from a different domain or area of expertise [44].

To facilitate the types of collaborative sharing and integration described in this paper, unique skills and competencies are needed at both the intrapersonal and interpersonal levels, and specific organizational support, technological resources, and policies can be particularly helpful [45]. The Science of Team Science (SciTS) field has included a strong focus on cross-field and cross-disciplinary integration and has developed evidence-based practices for knowledge integration across these levels of analysis.

Hall and colleagues elucidate team processes and scientific benchmarks occurring in each of the four phases in a model (development, conceptualization, implementation, and translation) of transdisciplinary research [44]. These may serve as a guide to investigators to help them plan, navigate, and/or evaluate transdisciplinary research collaboration. This four-phase model of research may be equally relevant to collaborative teams working across behavioral domains [44]. Additional conceptual models, empirical evidence, and practical tools for enhancing research are available on the Team Science Toolkit website [46].

Universities and other academic entities are already taking several measures to facilitate interdisciplinary science, such as building interdisciplinary research centers organized around targeted problems [25]. We contend that graduate trainees, when possible, should be exposed to research in more than one behavioral domain and should obtain training in how to apply behavioral principles to multiple behaviors. Graduate training can be supplemented by training opportunities in other venues—such as summer courses in specific methodological approaches—that afford the chance to learn about research in other behavioral and disease domains. For example, NIH offers summer courses in health behavior theory and implementation science. Opportunities also should be made available for faculty to gain multi-disciplinary expertise in new disciplines or domains. Given that integrative research requires collaborations among investigators with specialization in different health behavior domains, training should address effective practices for team-based science, including processes for developing shared scientific goals, a shared mental model of how the science will be integrated to address the research problem, and shared language for the

Table 1 | Research approaches to advance integration in behavioral research

Focus	Recommendation
1. Apply basic disciplinary principles	Employ basic principles from a particular discipline to address multiple behaviors. For example, the field of health communication has long investigated persuasion and communication factors (e.g., source credibility, perceptions of trust) that are relevant to a variety of behavioral domains.
2. Optimize study design	Examine related behaviors in a single study or use the intervention for each behavior as a control for the other [29]. For example, Zoellner et al. conducted a community-based study addressing both healthful eating and physical activity in the context of underserved rural communities [30]. Gold et al. addressed sexual behavior and sun safety in one experiment by using the intervention for each behavior as a control for the other [29]. Spring et al. examined the effectiveness of intervening on related behaviors such as smoking and physical activity concurrently or sequentially [31].
3. Apply common behavioral theory	Apply a more general model or theory that is then refined across a set of behaviors. For example, self-determination theory focuses on autonomy and competence and has been used to develop interventions for smoking cessation, physical activity, and weight loss [32–35].
4. Identify common mechanisms	Investigate a particular mechanism across different behaviors. For example, the concept of regulatory fit [36] has been applied to both fruit and vegetable intake [37] and vaccination [38], and emotion has been explored as a primary determinant of many different health decisions and behaviors [39]. Self-regulatory capacity has been linked with multiple behaviors [5].
5. Repurpose evidence-based approaches	Apply an accepted intervention approach from one behavioral domain to another. For example, Berg et al. applied lessons learned about dyadic coping mechanisms among adolescents with Type 1 diabetes and their parents to the coping of older adults making decisions about a prostate cancer treatment [40].
6. Harmonize data	Use common and merged data sources (e.g., data from the National Health Interview Survey [41] or Health Information National Trends Survey [42]) to examine the impact of a particular environmental influence, such as entertainment media, on different health behaviors [9].

collaborative scientific endeavor [44]. Training for team collaboration also should address communication, coordination, conflict management, and other key team processes [46, 47].

Another solution is to promote more publishing venues (e.g., *Translational Behavioral Medicine*, *Implementation Science*) and professional associations (e.g., Interdisciplinary Association for Population Health Science; Society of Behavioral Medicine) that cut across disciplines and behavioral specialties to enable sharing of scientific work in behavioral domains. It also would be prudent to embrace a paradigm where basic research in the behavioral sciences is use-inspired [28]—building on Stokes’ vision of work at the interface of basic and applied value as featured in *Pasteur’s Quadrant* [48]. Doing so would make the application of basic lessons learned in one behavioral domain to another behavioral domain a rewarding—and rewarded—scientific effort. Such an approach undergirds recent efforts at NIH to promote more research that leverages basic behavioral concepts such as delay discounting and impulsivity toward the end of designing successful behavioral interventions [26, 27]. Finally, researchers and their institutions might better recognize the reciprocal benefits of working across behavioral domains and disciplines, including a richer set of collaborative or career opportunities and visibility of one’s research to a wider universe of peers.

Consistency in measurement will also ease attempts to conduct research across behavioral domains. Basic behavioral scientists are often encouraged implicitly to develop their own measures and methodology in a de novo research effort rather than rely on validated measures from the same or possibly other domains. As leaders in NIH’s Behavior Change Consortium lamented years ago, “we have found an enormous amount of conceptual ambiguity and measurement variation across the mediators, e.g., the mediators with similar labels may be defined differently...while very similar constructs may have variant labels” (p. 509) [16]. Fortunately, there are more archives than ever before with measures contributed by and commented upon by users, such as the Grid-Enabled Measures (GEM) [49] project supported by NCI.

Of course, changing disciplinary norms is not easy, and the initial burden often must fall upon leaders in the field. Editors can assign greater priority to empirical investigations that transcend behavioral domains, and journals might even consider the establishment of separate sections that highlight successful cross-cutting findings. Scientific leaders in general can refrain from conjoining particular behaviors with particular diseases (e.g., sexual behavior and HIV), which can lead to a very narrow knowledge base about a particular behavior.

Funders can provide incentives for submitting applications that take an integrative approach and

host meetings on emerging health-related behaviors that include experts in the actual behavior and the basic underlying mechanisms. Moreover, funders might provide seed money to established investigators attempting to cross behavioral domains. NIH has developed several cross-cutting funding initiatives to cultivate interest in addressing multiple health behaviors (e.g., Behavior Change Consortium [16]), in common mechanisms across behaviors (e.g., Basic Behavioral and Social Sciences Opportunity Network, OppNet [50]), and in measurement and intervention (e.g., Science of Behavior Change [26, 51]). OppNet is a funded initiative that focuses on research in the basic behavioral and social sciences with downstream implications for health outcomes and has included funding opportunities in areas such as self-regulation, sleep, stress, multisensory processing, and decision-making.

The technological revolution of the past 20 years has introduced many tools that facilitate integrative health behavior research. One such advance is the use of sensor technologies that can collect basic psychological and physiological measures and health behaviors (e.g., type of physical activity, exposure to ultraviolet radiation) without the need to rely on self-report [52]. For example, the Affectiva Q-sensor is a wristband that measures sympathetic nervous system activity and thus provides an index of “emotional arousal,” which can be explored in the context of multiple behaviors [53]. Current computing power has enabled the creation of sophisticated databases that can include a wide variety of the types of data generated using varied methods from wide-ranging disciplines, fields, and domains. For example, research may integrate data generated by survey instruments, biological samples, observational instruments, and other approaches. Electronic health records with behavioral measures can be linked to medical outcomes [54], and new software can be developed to support data sharing and data harmonization as well as facilitate use of online archives of common measures (e.g., NCI’s Grid-Enabled Measures). These and other advances can enable researchers to integrate approaches from different disciplines, fields, and domains, and produce new findings that might not be produced within the confines of a single discipline, field, or domain [55]. Importantly, the acceleration of new “big data” sources such as these has been accompanied by an increase in the development and accessibility of new data analytic techniques necessary to handle these kinds of data sets. For example, new techniques in integrative data analysis allow researchers to merge several similar data sets to study a broader set of behaviors over a longer time period to better predict outcomes—often without the need to collect new data [55].

CONCLUSIONS AND CAUTIONS

Greater integration across behavioral research domains has the potential to provide a richer and more efficient science of health behavior. As a research community, we share in the

responsibility to address the barriers herein to promote more such research [28]. Of course, in any of this work, researchers must take care to adopt a multilevel approach, building on the long-standing recognition in ecological models that behaviors are driven by factors at the individual, family, community, health care setting, media, and policy levels [56]. It is difficult and resource-intensive to understand how these levels interact when examining even one behavior, so we should learn from these interactions when trying to understand other related behaviors. At the same time, we must take a life-course approach, looking at family context and age as critical moderators of health behaviors. In the end, it is essential to remember that multiple health behaviors are enacted by the same person, reminding us that the behaviors likely influence one another. To that end, our understanding of associations among health behaviors is likely to benefit from what we are learning in the equally nascent field of multiple chronic conditions [57].

Integrating knowledge across behavioral domains is a public health imperative. Many health behaviors have common etiologies, and even when they do not, the differences can still inform efforts to address those behaviors at a population scale. This is not a remarkably novel or implausible direction—we have offered several examples of research paradigms that have already adopted one or more of the models we presented, and we pay homage to the work of Jessor [2] and others who for years have conducted research on multiple behaviors. The challenge is to remove barriers that impede other investigators from employing these (and perhaps even newer) models of research. We have offered several strategies for minimizing these barriers and invite the community to develop and act on other innovative strategies. Science and public health will be the ultimate beneficiaries and in a way that may exhaust fewer resources and greatly increase the efficiency of health behavior research.

Acknowledgments: The findings reported have not been previously published and the manuscript is not being simultaneously submitted elsewhere. The opinions expressed here are those of the authors and cannot be construed to reflect the views of the National Cancer Institute or the US Federal Government.

This project has been funded with federal funds from the National Cancer Institute, National Institutes of Health, under contract no. HHSN261200800001E. The content of this publication does not necessarily reflect the views or policies of the Department of Health and Human Services, nor does mention of trade names, commercial products, or organizations imply endorsement by the US Government.

No royalty income or other compensation was accepted for this work.

Emily Grenen is now at ICF International. Jennifer Taber is now at Kent State University.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Human and animal rights: Human subjects were not used in the development of this manuscript, and the research was not conducted on identifiable

human material or data. Animal subjects were not used in the development of this manuscript.

Informed consent: Informed consent is not applicable.

Ethics statement: IRB approval was not warranted as the manuscript contains no ethics considerations, nor was there primary data collection.

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