Lessons from Complex Interventions to Improve Health

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Abstract

Complexity—resulting from interactions among many component parts—is a property of both the intervention and the context (or system) into which it is placed. Complexity increases the unpredictability of effects. Complexity invites new approaches to logic modeling, definitions of integrity and means of standardization, and evaluation. New metaphors and terminology are needed to capture the recognition that knowledge generation comes from the hands of practitioners/implementers as much as it comes from those usually playing the role of intervention researcher. Failure to acknowledge this may blind us to the very mechanisms we seek to understand. Researchers in clinical settings are documenting health improvement gains made as a consequence of complex systems thinking. Improvement science in clinical settings has much to offer researchers in population health.

INTRODUCTION

Fiction writer Nora Ephron, in her book *Heartburn*, describes how a mother attempts to persuade a young boy to overcome his prejudice to kreplach. Every time he sees it in his soup, he screams. So she takes him into the kitchen, and they make dough together. "Just like a pancake," she says. "Just like a pancake," says the little boy. Then she rolls up the meat. "Just like a meatball," she says. "Just like a meatball," says the little boy. Then she places the meat in the dough and rolls it up. "Just like a dumpling," she says. "Just like a dumpling," says the little boy. Then when she drops it into the soup and places it in front of him, the little boy screams, "Aaaaah, kreplach!"

Researchers at symposia, conferences, or workshops in the past decade may have witnessed a similar phenomenon, albeit not about cooking. For many of the topics covered in this article, preconceived views impede interchanges that could be more fruitful. Perhaps the area that is the most vexed is the role of randomized controlled trials in community interventions.

This article charts the evolution of interventions to promote health in populations: It starts from the point when such interventions were seen largely as multicomponent technologies and steps through to the present day, where the term complex intervention carries a more particular meaning, one that transforms the customary approach to intervention design and evaluation. Intervention research has grown exponentially as rapidly expanding problems in health and health inequities have demanded immediate, inventive, and effective solutions. Lessons from complex interventions come from diverse applications such as evaluations of effects, attempts to sustain and scale up, assessment of fidelity, implementation, and treatises on intervention design and theory. Traditional research and practice methods have been stretched to the limit in meeting this challenge. A vigorous and occasionally strident contest of ideas is now taking place. The new field of improvement science is emerging as a place of coming together by demonstrating the potential understanding of "the universal" that can be drawn from intense understanding of "the particular" in practice. But if further progress in complex interventions is to be made, scientists will have to reassess some of their essential beliefs and prejudices.

The History of Interventions to Promote Health

Interventions in public health conventionally started with the moment when John Snow removed the handle of the Broad Street pump to halt the spread of cholera (88). Historical references may go back to Hippocrates in 400 BC. The nineteenth-century environmental concerns are cited extensively. Social medicine began in the 1940s. Health was seen to reside in the whole economic, nutritional, occupational, educational, and psychological "experience" of individuals and communities (88, p. 10).

A growth of ideas, energy, and investment arose after World War II, especially in the United States, where the US government was keen to reshape the public image of science and boost its contribution to human well-being after the design and use of the atomic bomb (48). Psychologists, for example, were asked to develop the means to persuade the public to use prevailing new medical technologies, such as the X-ray chest-screening machine for tuberculosis control (116). Around the same time, large population–based cohort studies such as the Framingham study were designed and funded to identify risk factors for chronic disease (35). Framingham was among the first to identify high blood pressure, high blood cholesterol, and smoking as risk factors for heart disease, along with several other health habits identified in the Alameda county study (13).

These studies brought attention to what was called "lifestyle" factors for chronic disease, sparking some high-level championship to reverse the patterns observed: for example, the Lalonde Report led by Canada's health minister in 1974 (73); the US Surgeon General's report (131); and the launch of whole-community-based interventions to change the eating, exercise, and smoking

patterns of whole communities in the United States, Canada, and Europe. With the exception of North Karelia in Finland, these whole-community risk factor reduction trials had modest, negligible, or null effects (124, 126).

Yet two lines of argument had cast doubt on the potential value of large-scale community-targeted lifestyle-change interventions at the outset, before the results were known. First, Lynch's landmark text from 1977, the *Medical Consequences of Loneliness*, suggested that the risk factors targeted were possibly less important than generally thought (79). Context was unaccounted for. He argued that diet and exercise and smoking emerged as the most obvious risk factors for chronic illness and mortality in the Framingham study because other risk factors (such as social cohesion) were overcontrolled for. The Framingham investigators deliberately chose a community with low mobility whose residents would be easier to follow. The term "the Roseto effect" was later coined to refer to the lower incidence of chronic disease that can be attributed to the protective effect of community-based social solidarity; the phenomenon originated from intense investigations into why a particular small town had consistently lower death rates than did adjacent towns (41).

The second source of doubt arose from critics at the time, and those subsequently, who argued that interventions were being designed and implemented the wrong way irrespective of the factors being targeted. Leventhal and his colleagues, for example, argued that the Stanford Heart Disease Prevention Project was wrong to apply individual behavior change theory to something quite different, a community (75). Trickett later argued that "partial paradigm acquisition" was taking place in prevention science, such as the use of ecological theory in name more than in substance (127).

A forum on prevention science in the 1980s attempted to make sense of less-than-successful behavioral interventions (70). Investigators warned that anything beyond short-term behavior change would be difficult to sustain, and interventions would need to be adapted to the circumstances in which people lived (57). Others argued specifically for environmental-level interventions to modify forces in the community that continually put new people at risk? (125).

More meticulously designed and planned (11) behavioral health cluster randomized intervention trials ensued, followed by another decade of less-than-impressive results (28, 63, 105). Many of these interventions began to describe themselves as comprehensive and multilevel to signal that a level of complexity was involved in the design and evaluation of the intervention.

The Complex Intervention

Recognizing the growth of interest both in population and in health care settings, in 2000 the Medical Research Council of the United Kingdom produced guidelines for the design and evaluation of complex interventions (91). Designed for multicomponent interventions, the guidelines suggested that "the greater the difficulty in defining precisely what exactly are the active ingredients of an intervention and how they relate to each other, the greater the likelihood that you are dealing with a complex intervention" (91, p. 1). This proposition captured the challenge, but unfortunately it was indistinguishable from interventions in the hands of investigators who were simply untrained in the task of intervention design.

Later, the revised guidelines suggested that the complexity was signaled by the number of interacting components, the number of groups and organizational levels targeted, the number and variability of outcomes, the number and difficulty of behavior required by those delivering or receiving the intervention, and the degree of flexibility or tailoring permitted (29).

Recognizing that debates in theory and methods were continuing, authors raised issues regarding how important it was (or was not) to be able to label an intervention as simple or complex

(106). What material difference do the labels make to the approach to intervention design and evaluation? Should attention be focused on a rigorous, justifiable approach to the task at hand, forgetting the semantics? These are not trivial questions. Few investigators doubt the difficulty in bringing about and evaluating equitable long-lasting effects in populations. But there are differences in how much value is placed on formal definitions of complexity, that is, drawing on its original foundations in physics (110).

Shiell and colleagues argued that it may be useful to think of complexity as a property of the system into which the intervention is implemented (120). They construed interventions as events in systems, the effects of which are either dissipated or enhanced depending on how the dynamic properties of the system into which they are introduced are harnessed (68). Interventions can be conceived as evolving networks of person-time-place interaction. This observation invited research on how the intervention (*a*) couples and embeds with context and manifests itself in thinking and practice; (*b*) changes relationships—patterns of information giving and seeking, support, practical help, role taking, skill use, decision making, collaborating, competing, etc.; (*c*) displaces existing activities (which may account in part for intervention effect); and (*d*) redistributes and transforms resources (material, informational, social, cultural) (68). The capacity for an intervention to redistribute resources is its chief mechanism to address inequity, whether the resources are taxes or new educational opportunities/skills (68).

The Canadian Institutes of Health Research demonstrated their interest by funding the International Collaboration on Complex Interventions (involving investigators from Canada, the United States, the United Kingdom, and Australia), which produced some of the key papers in these debates (7, 16, 31, 34, 36, 55, 62, 65, 67, 94, 96, 98, 110, 120, 128, 129). This collaboration also enabled a partnership with the Centers for Disease Control and Prevention and the Prevention Research Centers with conferences in Chicago in 2009 (128), Montréal in 2010 (27), and Toronto in 2011 to advance theories and methods. The Population Health Intervention Research Initiative for Canada is pursuing these collaborations to grow the field further (39).

The remainder of this review illustrates the difference that complexity thinking makes in how interventions are designed and evaluated. Some of these observations draw on earlier work in community-based intervention theory and development, which predated the language of complexity but heralded some of the same insights. The sources of insight reflect all aspects of the problem-solving cycle: intervention design, implementation, adaptation, scaling-up, evaluation, methods design, theorizing, and synthesis.

In addition, the reader is directed to a landmark census-style review of complex interventions published between 2002 and 2011 by Datta & Petticrew (31). Their purpose was to identify the fields in which complex interventions are being implemented and the experiences and challenges being faced. The largest portion of papers was in the clinical field (45%), with substantially fewer in the fields of health promotion (23%) and public health (3%). The remaining 27% of papers addressed methodological issues. Areas requiring further development included providing more detailed intervention description, using theory in intervention design and replication across sites, ensuring fidelity, capturing multiple outcomes, and taking context into account. A special issue of the *American Journal of Public Health* in 2006 (86) and a special issue of the *American Journal of Community Psychology* in 2007 (45) featured articles on theory, methods, and models of complex systems thinking. These included case studies of system improvement by changing how a system is bounded (26), changing the mindset or "mental model" that people have about the environment or system that they are within (44), strengthening relationships (24), and providing new resources (123).

LESSONS AND INSIGHTS

Efficacy and What Constitutes the Ideal World Remain in Dispute

In the same chronic disease prevention forum where Green and colleagues discussed the difficulties in bringing about and sustaining behavior change (57), and Syme suggested an environmental approach from the outset (125), Flay transposed a model of knowledge development from clinical medicine to disease prevention (43). This distinguished efficacy trials (interventions designed under "ideal world" or optimum conditions by researchers and tested in randomized controlled trials) from effectiveness trials, which subsequently followed and addressed the real-world conditions associated with community-level implementation (43). This highly influential "pipeline" way of thinking was promulgated by the Institute of Medicine (90) and endorsed in the textbooks and logic models for community intervention planning at the time (38, 56). It enshrined the idea that best practice was defined by the university (or population equivalent of a laboratory) with consequent potential for dilution of effect occurring with progressive rollout and use in practice (51, 93).

An opposite view is given by Miller & Shinn (87). They argue that, like pharmacologists who search for and subject indigenous remedies to rigorous scientific evaluation, community researchers should identify instances of promising practice in local real-world settings and then seek ways to transfer and test them further for wider use. This sequence reverses traditional notions of the point in the knowledge development cycle when external validity is considered. Rather than investigators being concerned about generalizability after an intervention is shown to work, relevance and ecological fit (aspects of external validity) are considered first. They noted that this reversal followed some original ideas by Cronbach, who said we should observe and learn from the types of programs that already suit communities and organizations (30). Efficacy, in this sense, is the real world, and hence efficacy and effectiveness are one in the same. Using examples from the housing and school sector, Miller & Shinn argue that this alternative view has the advantage of overcoming some of the main reasons why "boutique programs" (that is, those meticulously designed and tested by external agencies) rarely enjoy widespread diffusion. Indigenous interventions have the advantage of being designed within local resource capacity limits. Indigenous interventions also reflect the values of local practitioners and host organizations (87). At present, there is little reciprocal citation between the two different views. Researchers, such as Miller & Shinn (87), adopt what might be called a bottom-up approach and refer extensively to researchers using the Institute of Medicine model, which represents the more traditional view that they challenge. But investigators within this more traditional domain show less awareness of their critics. Although some of the original proponents of the pipeline model recanted this view some time ago (53), many followers became entrenched. See Ottoson & Green (97) for a further discussion on bottom-up and top-down models.

Programs Can Be Used as Entry Points to Show How Systems Thinking Can Be Used

Many investigators have searched out and embraced complexity thinking and are using complex systems theory in intervention design and evaluation. Others are slower to embrace it and are possibly skeptical. They remain nested and vested in a program delivery way of thinking. A useful entry point for complex systems thinking therefore may be to ask how it would make the conventional processes of program design and evaluation different. The kinds of issues that are immediately affected and considered next are logic modeling in project design and evaluation,

measurement of effects (timing, range), economic evaluation, methods of defining intervention integrity and standardizing interventions across sites, assessment of context, and methods of process evaluation. Some would argue that the presence of complexity (numerous components interacting with the context) would preclude the use of cluster randomized controlled trials to assess the worthiness of particular interventions (81, 104). Others refute this idea (18, 19, 67, 80). The debate is long-standing, often heated, and ongoing. Space does not permit further elaboration here.

Logic modeling. A logic model is a pictorial representation of the theory of how a program works. The method has a long history in program planning in health promotion (38, 56). More recently, many scholars have incorporated complexity into the use of logic models (9, 32, 33, 103, 104, 122). Researchers are also encouraging the use of logic models to capture complexity in systematic reviews; authors are taking the opportunity to promote systems thinking by illustrating the relationship of the parts to the whole (4). Indeed, the logic models suggested for these purposes are similar to the type of causal loop modeling that is seen in systems thinking (69).

Logic modeling for simple linear interventions is different from models that attempt to incorporate complexity (115). This is important because a simple model applied to a complex situation risks overstating the causal contribution of the intervention (115). Suggestions to capture the dynamics include (*a*) simultaneous causal strands, where two or more simultaneous pathways are needed for the intervention to succeed; (*b*) alternative causal strands, allowing the logic model to illustrate how a mechanism may work differently in different contexts; (*c*) virtuous and vicious circles, which indicate how an initial positive effect may lead to its own reinforcement and magnification (virtuous) or where an initial negative effect is magnified (vicious); (*d*) feedback and feedback delays; and (*e*) unintended effects such as symptomatic solutions (temporary reductions in the problem of interest and its consequences) (114, 115). Funnell & Rogers also suggest using different shapes, such as circles, for logic models to challenge the dominant thinking shown in left-to-right graphics or in an up-versus-down approach (49). Given the unpredictability in complex systems, logic models can be designed to capture the central aspects of the learning cycle as interconnected problems are addressed (40, 115). Logic models can be regenerated and redrawn as the evaluation develops and is used formatively (102). This method particularly suits interventions that recognize capacity building as the central process, with activities to address the health problem(s) being derivative of the capacity building.

Intervention integrity/fidelity and standardization across sites. The COMMIT community-based behavioral health trial involved 58 mandated activities in each of the 11 intervention communities. Fisher noted these stringent requirements when reflecting on COMMIT's minimal success with smoking cessation in 1995 (42). He remarked on the difference between COMMIT and community-led and empowerment-based approaches espoused by contemporary US scholars. He suggested that an alternative approach could focus not on specifying the intervention and governance processes (as COMMIT did) but on the process by which an intervention is developed, while defining the range of choices communities could make. Instead of a "defined intervention," he ventured, "one would test a defined approach to community organisation" (42, p. 159). Some 10 years later, the notable success of some particular interventions tested in cluster randomized trials may indeed be due to their interventions being loosely defined and driven largely by local constituents (101, 109). But the foremost challenge, which the field still wrestles with, is contained in Fisher's concluding thought: Which components are considered key (42)?

The current Medical Research Council guidelines of the United Kingdom suggest a distinction between the components to be provided in all sites (key and standardized) and those components

that are optional or allowed to be different (29). Key components traditionally take the same form in every site, which some practitioners resist (66, 113). To overcome this, others suggest that standardization should be conducted in a different way (67). They suggest that the form that the components take may vary across sites, but the function that they perform in the local context is always the same. Standardizing by function, rather than by form, requires investigators to consider the role that a component plays in the overall change process (67). Standardizing by function is the chief means by which a complex intervention is allowed to adapt to local context without sacrificing fidelity. Fidelity resides in the theory of the change process, rather than in any particular technology, component, or delivery channel per se. Thus, the role and meaning behind a particular component, rather than its face value, are what matter. Local-level adaptation is important for maximizing effects and encouraging ongoing sustainability (15, 107, 108). Byng and his colleagues provide an in-depth account of how 12 primary health care teams participating in a randomized controlled trial articulated the functions of components within the change process, along with the relative role that the different functions played (22).

Insight on the functions played by interventions and their components can also come from unexpected sources, such as the literature on the persistence of ineffective interventions. Birkeland and colleagues showed that one widely diffused and ineffective drug abuse resistance program in schools is maintained to preserve good relationships between schools and police (14). Gal & Prigat found that organizations produce ineffective patient education leaflets to reward proactivity by staff members and to compete with rival organizations (50). These illustrate the powerful demands on programs within wider contexts. They invite the design of more effective interventions to preserve the same function.

The contemplation of worst-case scenarios can also help articulate functions within the intervention change processes. A thought experiment by some evaluators of a maternal health promotion intervention contrasted various scenarios of acceptability of the distribution target of an information kit (for example, to reach 70%, 60%, or 50% of the population). Investigators eventually asked: "But what if no mother says that she has received and read the kit? Is there any way that the kit could be effective?" This prompted the team to brainstorm the function that the kit played in providing an "excuse" for the health care worker to talk to the mother about her own needs (instead of focusing all discussion on the new baby) (121). This process exposed a relationship-building function that was disguised within an information-distribution function. Now exposed, it could be embraced more consciously.

Intervention theory. Underlying the specification of intervention component functions is the intervention theory, which is how the intervention accomplishes its effects. Intervention theory underpins the arrows and shapes in the logic model. The adaptation and replicability of an intervention are tied to how well the mechanism of operation (the theory) is articulated (12, 49). If a theory is not well specified, components can be misunderstood and their functions subsequently obscured.

Much is learned when an intervention is first designed. Even more is learned when it is replicated. Studies of transfer, adaptation, and scale-up investigators using a complexity lens have confirmed that programs are rarely duplicated intact (74, 100). Instead, what is essentially transferred are core principles and "powerful ideas" (87, p. 176). Fullan, for example, describes large-scale school reform as the transfer of capabilities rather than the transfer of products (47). Knowing this in advance can prompt investigators to distill the essence of an intervention and design more conscious processes to embed it and enhance its effects. Ottoson provides an insightful interrogation of five different theories (knowledge utilization, diffusion, implementation, transfer, and translation) to distill the core of what is conveyed, or "what moves" from place to place and which particular insights are privileged using one theory over another (96, p. 7). Knowledge utilization

theory, for example, draws attention to a program's symbolic meaning (among others). Translation draws attention to the power of language.

Numerous investigators have begun to review the theories underpinning interventions in different domains, such as schools (17) and behavior change interventions (1). This article cannot do justice to the extent of the field here. The reader should, however, be careful to note what a theory purports to be about. The change process within the individual being "targeted" may be well described; however, the changes in the context which bring about, aid, or sustain the change may not be. The latter is the focus of work by recent theorists in health care settings. In 2006, May offered a model for understanding complex interventions within the microcontexts of practice: normalization process theory (82–84). Normalization means "the routine embedding of a classification, artifact, technique or organisational practice into everyday life" (85). The theory suggests that the work of implementation is operationalized through four generative mechanisms: coherence (sense-making work to differentiate, specify, and internalize the new practice), cognitive participation (the relational work to build and sustain a community of practice), collective action (operational work to enact and represent the practice), and reflexive monitoring (appraisal work to understand how the practice affects self and others) (85). The theory echoes Callon's earlier work in the sociology of translation (23). The theory resonates with Foster-Fishman and her colleagues, who argued that successful change involves alterations of policies, routines, relationships, resources, power structures, and values (46). The reader is also directed to a large body of work by Greenhalgh and colleagues, who have studied the uptake (or otherwise) of information technology in health care systems. They offer theoretical insights that link and further develop understandings of evolving interactions among human agents, technologies, and social structures. These legitimize the authority of some actions and choices and extinguish others, across micro, meso-, and macro policy contexts (58–61).

Evaluation and economic evaluation. Many of the evaluation issues and methods for complex interventions are well trodden because they arise in real-world settings and were extensively discussed before complexity thinking came to the fore. In particular, researchers who have drawn attention to the understanding and measurement of context (6, 130) have provided critical insights that are all the more important, given that complexity theory demands that "the background," or context, of interventions becomes the "the foreground" (65, p. 89). Evaluation methods must be sensitive to dynamics of complex interventions and to the privileged role that agents (people delivering interventions and making choices) are acknowledged to have in complex adaptive systems (25).

These are important issues especially when interpreting results of complex interventions. Burton provides an interesting illustration (21). He used the results of individual studies extracted from systematic reviews to contrast the nature of effect sizes from interventions with high complexity (multiple interacting components delivered in differing ways and circumstances, such as those designed to make sustained changes to heath care practice) with that of interventions with modest complexity (treatments delivered consistently to individual patients with little impact of social context; e.g., nicotine replacement therapy, physician advice to stop smoking, motivational interviewing). He showed that compared with the low-complexity interventions, and with simulated data that represent random variation around a mean effect size (to represent a simple intervention), effect sizes in high-complexity interventions have long, heavy tails. Thus, when comparing interventions across different sites, there will be a few examples with very large effect sizes (21). Burton argued that this observation was consistent with the intervention being an intervention in a complex system because the heavy-tailed distributions are typical of complex systems observed in nature (21). The reason for this particular form of distribution still remains unclear however

(2). The practical implication is as follows: Although one may be tempted to choose these outlying interventions as examples of best performers for a wider rollout, to do so would be a mistake. Burton's point is that this is just the natural statistical property of the context or complex system within which the intervention is operating (21).

Several evaluation theorists have developed methods peculiarly adapted to understanding context-driven outcomes using participatory approaches to capture multiple views and values. This illustrates the vital role of iterative processes of intervention development and interpretation (102–104). Although readers are likely familiar with process-evaluation methods that assess participants' exposure to components and packages delivered in a standard (form) way (105), complex intervention evaluation emphasizes and explores site-specific understanding and implementation practices. Designers of complex interventions give practitioners maximal information about the goal or target to be achieved, and minimal specifications about how to get there, to foster learning processes and to benefit quickly from innovation and failure (8). Evaluators can capture change processes in social network analysis (77) and in practice-based narratives to record the cause-and-consequence thinking, thoughts, feelings, strategies, and influence of context (111, 112). Ling provides a six-stage approach for real-time synthesis of insiders' insights about causality as a complex intervention unfolds (78).

Economists have considered the implications of complexity for economic evaluation (5, 71, 120). They point to factors that affect all evaluations of complex systems, not just economic evaluations, such as time lags in showing effects (owing to nonlinear relationships) and the need to search for outcome clusters rather than to tie success to a change in a single health outcome. Two additional issues relate directly to economic evaluation. First, both costs and effects are likely to be multiple and multiplied by an intervention in a complex system (120). Second, resource transfer across networks transforms the value of those resources. According to community development theory, resources (material, informational, emotional, appraisal, cultural symbolic) are likely to improve in value as they are shared, endorsed, translated, and reframed as part of a capacity-building process. But conventional economic theory would discount or conclude the opposite, so these are issues that must be tackled (119). However, it should be noted that some researchers write of methods to evaluate complex multifaceted and multilayered whole system interventions and do not consider how any aspects of complexity reviewed here (such as interactivity, time lags, reflexivity, or feedback loops) may affect the interpretation of effect (117).

Language, Metaphor, and Terminology: Troubled Territory for Complex Interventions

"The internet is not a super highway," argues US law academic Kristen Osenger (95). Neither is it a cloud, a coffee shop, or cyberspace (95). The wrong metaphors, she argues, are stymieing meaningful public engagement in global communication and information policy. Consequently, the legal, regulatory, and human rights aspects of the Internet are not being fully scrutinized and understood by everyone who rightfully has a stake in the Internet's development (95). In the field of complex interventions to improve health, the pipeline metaphor, where proven truths in the laboratory flow along a lengthy pipe, eventually spreading across the field of practice at the other end, is also defective (or at the least incomplete) and it is hampering advancement.

Words such as "dissemination" and "diffusion" suppose that knowledge originates in one location and is moved to others. Other words such as "translation" and "adaptation" capture the fear that field-based practitioners change aspects of the intervention in ways that compromise intervention integrity. But what if local-level adaptation drives stronger effect, as opposed to diluting it? What if the science of implementation and the science of adaptation are both part of the science

of effect, and not ancillary add-ons? Complex systems thinking considers practitioners (agents) in the system to be active not passive. So the pipeline metaphor and associated terminology may blind us to the possibility of observing the very mechanisms we seek to understand (118).

A new language is needed that gives expression and legitimacy to models of coproduction of knowledge. We also need to overcome the confusion arising from the tendency for scholars to invent new names for familiar processes. For example, the term translational epidemiology was recently proposed to describe the role of epidemiology in translating scientific discoveries to population health impact (72). However, this idea is essentially the same process outlined by Flay in 1986 (43). The difficulty with this framing is that it assumes that science lives up one end of the spectrum and application and impact live on the other. It does not recognize the primary knowledge that is generated in practice contexts, which holds its own integrity and foundations and is in no way a sole derivative of bench, laboratory, or even descriptive population sciences.

Differences in orientation and use of terminology mean that readers are never sure of what they are reading. One set of investigators may describe a new intervention to encourage practitioners to adopt "the evidence" (from a systematic review of best practice) as "implementation research." Others may consider this to be primary intervention research, itself generating "evidence," with the need to measure and understand implementation considered as part of a greater whole. Capacity building suffers similar differences in use. For example, Wandersman (132) uses the term capacity building to refer to the training of communities to be able to deliver and sustain (particular) evidence-based interventions. Others use the term to refer to the development of generic organizational structures, resources, and problem-solving skills (52).

Some of the use of the language and terminology appears to be combative, as if it were designed to mark out distinctions and identities (even copyrights) and to make value judgments about alternatives. So the idea of one practice being labeled theory-based implies that another is devoid of theoretical underpinnings; or one approach being labeled realistic condemns the alternatives to being fanciful. The implied subtext in the use of labels may hamper meaningful engagement and debate about the finer distinctions and potential new insights behind the labels. It generates the little boy's kreplach reaction, which is emotional rather than rational. Ways forward will have to find mechanisms for interdisciplinary dialogue that do not stumble over preconceived assumptions, the same terms being used differently, or the same terms being used preciously. The prejudice and depth of feeling are not overstated. For example, a leading series of articles in the 1980s advised clinicians not to bother reading a study assessing the effect of a treatment if the study was not a randomized trial. Indeed they were advised not to read a paper at all if the authors did not have a good reputation (37). In many ways, the field is still dealing with the ripple effects of such advice.

Learning From Improvement Science

Leykhum and colleagues published a systematic review in 2007 which demonstrated that organizational interventions to improve care for diabetes were more effective if they employed principles from complexity science (76). Their review signaled that clinician-researchers in the field of quality improvement were not simply implementing evidence-based practices and reporting compliance rates; they were generating new types of knowledge. Other examples of intervention studies in quality improvement using complexity methods in intervention design include improvements in adherence to antiretroviral treatment for HIV in Kenya and infection control in US hospitals (74). A landmark special issue of the *British Medical Journal of Quality and Safety* in 2011 reported on an international interdisciplinary symposium on the epistemology of quality improvement (10). It was designed, among other things, to interrogate the insights from plan-act-study-do cycles in clinical settings (92, 99) and to build "small theories" of system improvement from quality-improvement replications (99, p. i88).

Perhaps the review of complex interventions by Datta & Petticrew (31) showed a dominance of results from clinical settings because of the presence of clinician-scientists (practicing physicians who lead research). The population health equivalent of this position is lacking. One reason for the gap between evidence and practice in population health may be the occupational division of researchers and practitioners. Complex interventions are being designed by researchers, but it is practitioners who have a greater appreciation for the local characteristics of the complex systems in which they work. The occupational division relegates practitioners to the distal end of the knowledge pipeline, to be seen only as end users of knowledge and not as creators. A lopsided evidence base on complex interventions in populations potentially and unjustifiably ensues (54).

CONCLUSION

There is much cause for optimism in the field of complex interventions, that is if Pierre Bourdieu is right to start a paper on scientific reasoning with a quote from Bachelard: "People, if they truly wish to understand one another, must first have contradicted one another" (20, p. 3). The contradictions are not simply the result of differences in understanding or communication. Differences arise from creativity and from the diversity of sources of insights.

Recent moves in the United Kingdom to incorporate guidance on process evaluation into complex interventions are welcome (89). A checklist may help researchers better describe their interventions, including the contexts within which they are situated (3). As the underestimation of context punctuated the history that preceded large-scale, community-based interventions, prompts such as these may help to direct researchers' attentions. However, one cannot rely on a checklist for thoughtful in-depth analyses that question taken-for-granted assumptions. Many of the studies reviewed here took an in-depth approach, and thus the trajectory of the field was lifted. We can hope that continued interactions among the field's diverse contributors will advance it further, and that all of us take the opportunity to venture beyond that which we think we already know.

SUMMARY POINTS

1. Although "complex intervention" is in common usage, complexity is a property of the intervention and the context/system into which an intervention is placed.
2. Multiple interacting parts create nonlinear relationships, so traditional dose-effect patterns are not seen. Instead, there can be long periods when nothing happens (lags) and then a lot happens (phase transition).
3. In complex adaptive system thinking, the agents of the system are considered thoughtful, self-monitoring, and self-correcting in response to feedback (reflexive). Responses to micro changes in their immediate environment can add up to emergent properties (patterns seen at higher levels) consistent with the notion of being a self-organized system. Improvement science interventions harness and generate knowledge from this concept, whereas conventional behavior change interventions do not.
4. It is possible to standardize an intervention across different sites by the function different components play in the theorized change process instead of imposing the same form of components on each site. This allows adaptation to context while maintaining fidelity.

5. Interventions in complex systems may produce extreme results (long-tailed distributions of effect size) across multiple sites. Random and context-specific effects in a complex system may be mistaken for the intrinsic merit of what appears to be the best-performing intervention.
6. Theory and evaluation of complex interventions have moved away from viewing an intervention as a program, technology, or set of products to represent interventions as routines, relationships, resources, power structures, symbols, forms of talk, "powerful ideas," and sets of values.
7. Conventional terminology (e.g., efficacy versus effectiveness, diffusion, translation) is contrary to the insights of complex systems thinking because it privileges a pipeline metaphor of knowledge generation at the expense of understanding and finding ways to convey primary knowledge emanating from practice contexts. The metaphor may be blinding us to the very mechanisms we seek to understand.

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