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Social Interface Model:

Theorizing Ecological Post-Delivery Processes for Intervention Effects

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Abstract

Successful prevention programs depend on a complex interplay among aspects of the intervention, the participant, the specific intervention setting, and the broader set of contexts with which a participant interacts. There is a need to theorize what happens as participants bring intervention ideas and behaviors into other life-contexts, and theory has not yet specified *how* social interactions about interventions may influence outcomes. To address this gap, we use an ecological perspective to develop the social interface model. This paper presents the key components of the model and its potential to aid the design and implementation of prevention interventions. The model is predicated on the idea that intervention message effectiveness depends not only on message aspects but also on the participants' adoption and adaptation of the message vis-à-vis their social ecology. The model depicts processes by which intervention messages are received and enacted by participants through social processes occurring within and between relevant microsystems. Mesosystem interfaces (negligible interface, transference, co-dependence, and interdependence) can facilitate or detract from intervention effects. The social interface model advances prevention science by theorizing that practitioners can create better quality interventions by planning for what occurs after interventions are delivered.

Keywords. intervention development, logic models, ecological perspective, implementation science

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Interventions aimed at behavior change include messages that call for individuals to enact some form of behavior or practice (e.g. delay initiation of substance use, engage in particular forms of food consumption, integrate specific exercise routines). The extent to and ways in which individuals enact these forms of practice depend on a complex interplay among aspects of the intervention, the participant, the specific intervention setting, and the broader set of contexts with which participants interact. Extant theory and research have offered useful models for intervention development, adaptation, and implementation (e.g., Berkel et al., 2011; Pettigrew & Hecht, 2015), so an emerging area for inquiry is to examine what happens to intervention messages after they are delivered. Existing theories and typologies also provide a foundation for understanding how information travels through social networks (e.g., Rogers, 2003; Southwell, 2013; Valente, 2012), but, there remains a need to conceptualize post-delivery processes that bear on intervention effects. Considering these processes will advance prevention science by offering more robust theorizing about program outcomes as intervention messages are received, enacted, and adapted by participants moving throughout their varied social environments.

A fundamental assumption for understanding the effects of intervention messages is that health intervention participants are not passive recipients of programs. Rather, they actively engage or disengage with program concepts and skills they encounter and carry this information into other realms of their lives such as their family or peer groups. This transference is necessary, but has seldom been theorized or measured. Health messages often target forms of behavior that individuals are expected to perform across multiple contexts. For example, school-based diet programs encourage healthy eating not only at school but also in other settings (e.g. home).

Additionally, interventions delivered in one context sometimes rely on individuals enacting the targeted behavior in collaboration with other individuals. Teaching parents new discipline techniques, for example, anticipates a parent-child relational context for behavior practice but this may not be explicitly stated in intervention frameworks or implementation guidance. Thus, many interventions may have *invisible logic models*—a set of unspecified or unanticipated mechanisms for behavior change—as they do not map relevant mechanisms that extend beyond the specific contexts in which they are delivered.

The purpose of this paper is to present a model that depicts salient social processes that occur once a health intervention has been delivered. We describe participant adoption and adaptation processes (Pettigrew & Hecht, 2015) based on an ecological perspective (Bronfrenbrenner, 1974; Bronfenbrenner & Morris, 2007) by theorizing intervention message effects as they traverse micro and mesosystems. The bioecological perspective proposes that biological, micro, meso, macro, exo, and chronosystems form a sociocultural ecology for human development (Bronfenbrenner, 1974; Bronfenbrenner & Morris, 2007). Within these systems a person experiences proximal processes, which are considered the "primary mechanisms producing human development" (Bronfenbrenner & Morris, 2007, p. 795). Communication (e.g., verbal messages, nonverbal behaviors, environmental structures, implied norms, and expectations) is one of these proximal processes and we propose that communication in micro and mesosystems is particularly relevant for understanding how individuals receive and enact intervention messages.

Microsystems include groups to which a person belongs and in which they consistently experience social roles and interpersonal relationships. The microsystem is where interactions occur that most directly influence one's development (Bronfenbrenner & Morris, 2007).

Examples of microsystems include family, work, school, religious institutions, and health care settings. Privileging three particular microsystems, primary socialization theory foregrounds socialization processes that occur in family, peer, and school, positing that efforts in these arenas lead to internalized attitudes and beliefs that manifest in behaviors (for review, see Petras & Slaboda, 2014). Interventions based on this way of thinking focus on individuals and socialization messages within specific microsystems. However, when interventions target behaviors that are expected to be enacted across microsystem contexts (e.g., diet, decision making), there is a need to consider interactions between microsystems. Indeed, to produce effects, we argue that some interventions may explicitly or implicitly depend on interaction between microsystems.

Mesosystems consist of links and processes occurring across two or more microsystems. For example, a child may interact in both school and family microsystems. When these two microsystems collide—or an intervention message moves from one microsystem to another—it occurs in the mesosystem (Bronfenbrenner & Morris, 2007).

Our model adopts ecological thinking to consider processes that lead to effective and ineffective interventions. It also accords with recent attention to intervention-context interactions and the recognition that contexts are not static (Marsiglia & Booth, 2015; Rutter et al., in press). We aim to advance the field of prevention science by focusing specifically on how intervention messages may interact with different contexts and systems to produce varied outcomes. We highlight potential processes for multiplicative or additive intervention effects and also suggest processes through which interventions span multiple contexts. First, we present the model and describe its components. We then draw out practical and theoretical implications that follow from considering interventions in light of our model.

Social Interface Model

Intervention messages take various forms (e.g., public service announcements, product warning labels, school-based curricula, individualized counseling, etc.) and are communicated to groups and individuals. Across these forms, individuals encounter messages within a particular microsystem or a constellation of microsystems. For example, manualized curricula in schools and families may contain intervention messages about decision making, parental monitoring, and resistance skills. Intervention messages include the content of the program, nonverbal feedback (e.g., looks, voice inflections, etc.) given by implementers and other program participants, and classroom or group discussions that are prompted during intervention implementation. These messages encountered within a microsystem, ultimately, can be transferred to new contexts through the mesosystem.

Figure 1 presents the social interface model. It depicts two microsystems (e.g., family, school) with potential mesosystem interfaces between them. Adjacent to each microsystem are macrosystem contexts that necessarily influence processes occurring within and between microsystems. Within the microsystems are individual, social, and message factors that combine to affect how interventions are received and/or enacted. This action, we propose, takes place within various microsystems and subsequently ripples through other, future microsystem processes. On the left side of the model are intervention and other messages (e.g., media material about alcohol use, public service announcements, parental values) entering the two different microsystems through various implementation processes (e.g., magazine ads, billboards, YouTube commercials, school assemblies, parent-child conversations). At the heart of the model and the focus of much of our theorizing is the mesosystem. We propose at least four mesosystem

interfaces that can occur between microsystems. On the right side are distal intervention outcomes that result post-delivery through the complex processes indicated within the model.

To illustrate the general concepts presented in the model, we focus on specific processes. Our review is not exhaustive but heuristic. For each concept we describe salient processes to exemplify the ideas and stimulate future thinking and research into what occurs after interventions have been delivered. We first consider various microsystem processes, including factors of the message, individual, and social environment that affect message reception and enactment. We then suggest ways the macrosystem intersects intervention messages. Finally, we introduce social interfaces that occur in the mesosystem.

Microsystem Processes

Interventions call for behaviors (e.g., utilizing a certain parenting discipline practice, following a decision making model). The likelihood of behaviors being enacted depends on aspects of the message content and its presentation as well as how these correspond or diverge from the individual and social practices extant in the microsystem where the message is delivered (e.g., family, school) vis-à-vis other competing or reinforcing messages (e.g., parenting advice from extended family members, presentations during school assemblies) entering the microsystem. In other words, intervention messages enter into and become part of the microsystem and interact with individual and social processes in complex ways.

Message factors. Interventions necessarily "intervene" on a microsystem through implementation processes. We propose that after implementation, messages become part of the microsystem on which they intend to intervene. Our thinking follows normalization process theory (May & Finch, 2009), which specifies how new practices invited by interventions become embedded and integrated into social contexts. Some intervention messages are quickly forgotten,

but efficacious if the behavior for which they call is routinized. Other intervention messages may be long remembered but never change behavior. In either case, intervention messages become part of the microsystem environment that interfaces through mesosystems.

There are many particular aspects of a message that help determine its efficacy. Diffusion of innovations theory (Rogers, 2003) outlines five factors that influence an innovation's rate of adoption (relative advantage, compatibility, complexity, trialability, and observability). Southwell (2013) draws attention to messages' content, emotional appeal, narrativity, and rhetorical structure. We suggest that intervention effects may also depend on similar processes as they enter a microsystem and traverse into mesosystems. For example, a smoking cessation intervention may employ emotional appeal and narrativity, but likely will never achieve prevention effects if it fails to convince participants that quitting is (1) advantageous in comparison to the status quo, (2) relatively compatible with existing values and current needs, (3) not overly complex or difficult to understand, (4) able to be trialed, and (5) yielding observable benefits. Messages delivered through interventions interact with individual and social factors to comprise the microsystem environment.

Individual factors. Bronfenbrenner and Morris (2007) identify various person characteristics that explain development. Although myriad individual factors exist, we choose to focus on two factors: biological and psychological. Biological factors may include differing levels of ability (i.e., relatively stable phenomena, such as hearing ability, language fluency, developmental state) and other physiological factors (i.e., more temporal factors such as tiredness, attentiveness, motivation, level of physiological arousal). Research has also examined how biological dispositions interact with environmental forces to influence developmental trajectories and behavioral outcomes (for review, see Fishbein, 2000). For example, in one study,

high testosterone levels in adolescent males predicted aggressive behavior as association with deviant peers increased (Ryan et al., 2013). This evidence shows that biosocial interactions can predict treatment effects. Indeed, Brody et al. (2013) reviewed "gene by intervention" research and contended that intervention effects can be moderated by genetic conditions and potential problems that rise from genetic predispositions can be averted through interventions on the environment. Following these lines of research, we propose that an array of dynamic and static biological and physiological expressions can influence if an intervention message is received or enacted.

An individual's predisposition toward or against a call for behavior may also depend on his or her familiarity with the message. The World Health Organization, building on the transtheoretical model, suggests that individuals move through psychological states relative to novel messages and health behaviors (UNICEF, 2012). They describe the process as HIC-DARM: one must Hear an intervention message (i.e., behavioral summons), become Informed about it, become Convinced the behavior is worthwhile and feasible, Decide to do something, Act on the behavior, and have the action Reinforced for it to be Maintained (UNICEF, 2012). An individual's position along this continuum of familiarity or readiness to adopt behaviors invited by an intervention is an individual factor that can influence an intervention messages' effects.

Finally, diffusion of innovation theory has proposed various individual factors that may be associated with adopting and enacting intervention messages. Rogers (2003) provides an overview of the personality characteristics associated with early and late adopters of innovations, many of which likely influence intervention message effects. For example, in comparison to late adopters, early adopters typically view change more favorably, are better able to cope with uncertainty, are less fatalistic (i.e., believe people can control their own future), less dogmatic,

and are more empathetic. Similarly, communication and social connectivity differences exist between early and late adopters: Early adopters are more likely to actively seek information and are typically more active participants in a more connected social system. Together, these variables present interesting possible influences on intervention message adoption. Those who actively seek information may proactively reinforce intervention messages through independent research and people who are less dogmatic and have a favorable attitude toward change may be more primed to receive and deliberate over intervention messages. Finally, it is worth noting that other models not discussed herein (e.g., Health Belief Model, Theory of Planned Behavior) also emphasize individuals' perceptions as precursors to action or behavior change. Well established theory and research demonstrate how individual biological and psychological factors can impact message adoption and enactment.

Social factors. Prevention messages are generally encountered within a particular social environment (e.g., clinical setting, classroom, group counseling, etc.). Even when interventions are encountered individually (e.g., from published materials or websites) there are social considerations potentially influencing message adoption and enactment. Examples of social variables include cultural norms, social roles for the individuals sharing and receiving the message, behavioral and performative scripts related to the health behavior (e.g., rules for interaction, social hierarchies), the general social environment within the microsystem, previous and ongoing messages about the health behavior, and rules or sanctions related to it. The combination of these variables in complex ways helps comprise a microsystem's social environment and this environment facilitates or impinges intervention message adoption and enactment.

To illustrate social processes, we focus on social norms as mediators of intervention outcomes. Research shows that family expectations can predict adolescent substance use (e.g., Miller-Day, 2008). When parents communicate advice and rules about substance use, they can limit adolescent risk (Miller-Day, 2008; Reimuller, Hussong, & Ennett, 2011;). These conversations tend to set non-use expectations (Pettigrew et al., in press). Similarly, in the peer context, social norms, such as the acceptability of substance use, perceived peer approval of substance use, and accurate knowledge of peer prevalence of use all mediate school based intervention outcomes (Cuijpers, 2002). Evidence of relationships about how social (e.g., family, peer) environments are related to behavioral outcomes demonstrates their importance. Depending on the social environment, or at least one's perception of it, intervention messages may fall on hostile or fertile soil. Thus, the social environment can impinge or facilitate adopting or enacting intervention messages. Microsystem processes, however, are also interdependent with broader social structures.

Macrosystem Processes

Macrosystems help determine the social and structural affordances available within microsystems (Bronfenbrenner & Morris, 2007). We define structural affordances as the material environment available to actors in a microsystem. Individual and social processes are interdependent with aspects of the environment. Microsystems interface in patterned ways with physical spaces that are characterized by available resources (e.g., built environment, prevalence of alcohol retail outlets, financial capital, etc.). In the face of different structural affordances, interventions or the actions they invite can take on new meanings. For example, messages delivered in elementary school about healthy eating presume that home and neighborhood environments afford healthy eating options or that child participants can select their diet

(Bennett, Wolin, & Duncan, 2008). In the face of limited affordance, an intervention message could be completely ignored because of the mismatch between the message and the affordances. Alternatively, the message could be reinterpreted to mean the healthiest of the possible options. In either case, the intended meaning of the intervention message changes.

Intervention messages that call for behaviors unsupported by structural affordances may have limited intervention effects. They may alter attitudinal dispositions but not have any impact on actual health behaviors. That is, interventions may attempt to use messages to change attitudes without accounting for the wider structural barriers. For example, the Ontario Printed Educational Message (OPEM) intervention aimed to improve referrals and medical prescribing practices through changing the behavioral intentions of general practitioners (Grimshaw et al., 2014). However, high levels of intentions at baseline resulted in no significant differences. This study focused on general practitioners as change agents and neglected to consider the broader social and structural constraints related to referrals and medical prescribing practices, such as formal referral guidelines and informal practices for each independent clinic, local and national policies, and interactions between staff and patients. The need to consider macrosystem affordances is further evidenced by a systematic review of the health promoting schools approach, which found that interventions combining education with social and environmental manipulation were most likely to produce positive results (Langford et al., 2014). For example, one successful intervention for tobacco harm reduction, a classroom curriculum was combined with supportive school policies and school nurse trainings (Hamilton et al., 2005). Another study successfully changed obesity-related behaviors among Latino children through combining family intervention elements with culturally appropriate media messages, community-level structural changes (i.e., provision of playgrounds, salad bars, equipment for physical activity) and social

policies, such as classroom practices (Crespo et al., 2012). These studies imply that interventions do well to consider macrosystem structural affordances to maximize efficacy.

Mesosystem Processes

In addition to microsystem and macrosystem processes, we propose that mesosystem interfaces have important consequences for intervention effects. In his review of network interventions, Valente (2012) concludes that interventionists can "use the power of human interaction to improve the human condition" (p. 53). Reviewing evidence around this topic, Southwell (2013) shows that interpersonal interactions can result in knowledge gain, enhanced memory, awareness of social norms, and exposure to counter arguments. These processes do not always act in predictable or desired ways, but evidence is clear that interventions can be extended through interpersonal interactions. Some recent empirical findings illustrate the importance of this diffusion for prevention scientists. Using network analysis methods, Rulison et al. (2015) show positive effects for friends of intervention participants who did not receive the intervention. In another study, A Stop Smoking In Schools Trial (ASSIST), identified and trained only influential students in smoking prevention strategies but subsequently found reduction in the average level of cigarette use among all students in the school (Campbell et al., 2008). Furthermore, recent findings show that trigger events, such as news stories, parental work experiences, or school-based interventions, can induce family conversations about substances (Pettigrew et al., in press). This evidence suggests that intervention programs may guide the topics of conversations in families as they diffuse to new microsystems.

Pettigrew and Hecht (2015) argue that intervention developers need to recognize that participants likely adapt intervention messages. This adaptation could be positive or negative. Advancing the concept of social talk (i.e., conversations between two intervention participants),

Choi, Hecht, and Smith (2017) demonstrate that program participants talk to one another about content, even when such interactions are not explicitly part of the intervention, and that these conversations are related to key proximal outcomes. They suggest that the extent to which participants engage in social talk potentially affects intervention efficacy (Choi et al., 2017). Other evidence confirms that attending to the group composition is an important consideration for family-based interventions (Segrott, 2013). Social talk within an intervention group has the potential to normalize pro-social behaviors, provide social support, and create positive role modeling, but this depends on the normative beliefs and behavioral experiences of the group members (Segrott, 2013). In the absence of pro-social talk, deviant social talk can work against intervention aims. For example, Piehler and Dishion (2014) found that engaging in deviant talk as adolescents predicted early adult substances use. Southwell (2013) cautions that the valence of conversation can enhance or dampen effects of an intervention.

As a group, these studies demonstrate the relevance of considering mesosystem processes. What has yet to be specified is *how* social interactions about interventions may influence message effects, particularly if it becomes clear that the original intent of the intervention diverges from the conditions of a new microsystem. The social interface model encompasses four key mesosystem interfaces that shape the adoption and adaptation of intervention messages (see Figure 1). We deal with each of these interfaces in turn.

Negligible interface. The most limited case of mesosystem interface is where there is no awareness or further mention of an intervention in separate microsystems. Message effects, in the case of negligible interface, will be dependent on message, individual, and microsystem factors in coordination with the macrosystem structural affordances. It is important to note that there are no isolated systems and that whatever occurs in one system has the potential to

influence other systems, but interfaces in these cases may be negligible. That is, intersections with other microsystems may be relatively inconsequential because the intervention practice is introduced, embedded, and integrated (May & Finch, 2009) completely within the school microsystem. Such interventions do not explicitly seek to influence behaviors beyond the microsystem in which they are implemented.

Transference. A second type of interface occurs when a message is delivered in one microsystem with the expectation that it will generate behavior change in another microsystem. For instance, a school-based intervention on sexual behavior expects that participants will transfer learning into settings outside the school. Intervention effects that depend on transference require participants to take information from one setting to another and are subject to macro and micro system variables that comprise the presumed locus for enacting intervention behaviors.

Transference to new environments may result in newfound relevance for intervention content. That is, the call to action from an intervention message may be perceived as implausible in one microsystem (e.g., due to financial resources or social capital), but when it interfaces with a different system with different structural affordances, the message can gain new relevance. Taking the substance use prevention example, the opportunity to accept or decline a substance offer will not likely occur on school property but rather in other social settings like the home or parties (e.g., Pettigrew et al., 2012). Thus, a prevention message about how to resist a drug offer may lay dormant until it interfaces with the social and structural affordances of a different microsystem. Practically, intervention developers can (and often do) anticipate this and use role plays, discussions, and other forms of skill practice that invite participants through the program into these prototypical scenarios. In this case, transference facilitates intervention effects.

Alternatively, a message can be rejected outright or more quickly discarded if it does not match the culture, social norms, and structural affordances of the new microsystem. In this case, transference may mutate the meaning of the intervention message to null or deleterious effect. For example, iatrogenic effects that were found in early instantiations of the D.A.R.E. program (Flynn, Falco, & Hocini, 2015; West & O'Neal, 2004) may have resulted from participant adaptation. Information-only approaches, such as D.A.R.E., are not as effective as active learning, skill-based programs (Tobler et al., 2000) and may have been viewed by some participants as a cafeteria offering of possible drug-induced "highs," complete with drug facts, prices, and street names. Or, D.A.R.E. may have inadvertently increased perceptions of peer prevalence for substances use making social talk about substances more favorable. The intent of the D.A.R.E. officers was not to give a smorgasbord offering of various "highs" or to misrepresent the prevalence of use, but participants in peer microsystems outside of the school/classroom may have interpreted and discussed the program in these ways. These types of program mutations are made possible because of transference to divergent microsystems. They also can be preempted by carefully crafting intervention content to align with existing guidelines for curriculum development (e.g., Pettigrew & Hecht, 2015) and research on improving positive social talk (e.g., Southwell, 2013).

Co-dependence. A third type of interface occurs when an intervention is delivered in one microsystem and depends on inputs from another microsystem for it to have effects. Consider the case of healthy eating. At school, a child's class participates in an intervention that advocates eating fresh fruits and vegetables daily. When the child goes home for dinner, these foods are not available. Atop the difference between what is ideal and available, the family diet typically does not incorporate many vegetables and protein but primarily consists of carbohydrates. Such a

nutrition intervention is co-dependent on family microsystems to produce effects. The key in this example is that the intervention priorities are defined by and located within the school but depend on family inputs to produce effects in and beyond the school. This is possible, and some evidence from an Irish trial of the Food Dudes shows positive intervention effects through co-dependent processes. Researchers measured the amount of fruits and vegetables that young children brought to school and the Food Dude intervention groups, relative to controls, packed more healthy food in their lunches (Horne et al., 2009), implying that parents changed their behavior as a result of their child's participation in the intervention. An important question, however, is whether promoting certain practices in the family microsystem in order to fulfill behavioral goals in the school are acknowledged and form part of the intervention's mechanisms of action.

Interdependence. A final type of interface that we propose is when intervention outcomes take place through bi-directional interface between two or more microsystems. Some evidence suggests that interventions delivered in two different microsystems are more effective than one intervention (e.g., DeGarmo et al., 2009; Koning et al., 2011). Positive findings from multisystem interventions beg the question whether they are effective because the individual components act independently within separate microsystems and achieve their effects through a cumulative (or dose) effect or because the components reinforce messages across microsystems or connect the relevant microsystems in other meaningful ways. In the latter instance, unless developers have clearly theorized how interventions operate through mesosystem interfaces the intervention will be operating through an invisible logic model. To examine whether interdependence matters, prevention researchers might develop a factorial research design. Holding dose constant, such a design could test two complementary interventions delivered in

separate microsystems (e.g., school and family) and two complementary interventions delivered in the same settings (e.g., school) against controls. Analysis could examine a wide range of proximal outcomes (e.g., family interaction variables, school level variables, individual level program mediators) in families and youth from all conditions. Such a test would move toward uncovering if and how interventions across microsystems mutually reinforce each other or lead to outcomes through similar underlying psychological and social mechanisms.

Model Summary

Intervention effects based on the social interface model come about as intervention messages are received and enacted by participants through social processes occurring within and between relevant microsystems. The interfaces between microsystems can facilitate or detract from intervention effects. To the extent that intervention developers consider the potential social interfaces through which intervention messages traverse, the quality of interventions being developed should also increase. This model stimulates thinking about how intervention messages might make explicit the previously invisible logic models that connect across existing microsystems. Few, if any systems, are closed entities. The adoption and enactment of intervention messages may frequently take place as a result of weaving among different microsystems, even when developers plan programs for only a single microsystem.

<div align="center">**Discussion**</div>

The social interface model recognizes that participants are not passive recipients of prevention messages but that they actively receive, interpret, adopt, and adapt prevention content within and between a multifaceted and varied set of microsystems. Unfortunately, if prevention researchers do not anticipate these processes, there will be no way to measure the mechanisms for change. This leaves developers, evaluators, and practitioners to rely on invisible rather than

explicit logic models. The social interface model helps explain and predict processes through which health interventions produce effects when introduced into a particular microsystem and then diffused through social interactions (Southwell & Yzer, 2009). In this paper, we illustrate at least four mesosystem interfaces (negligible interface, transference, co-dependence, and interdependence) which hold implications for intervention effects.

Implications for Prevention Science

At a broad level, the social interface model underscores that interventions do not exist within an isolated environment or microsystem. An ecological perspective recognizes interventions occur in open systems—what happens in school interfaces with what happens among peers, for instance. A corollary is that individual risk behaviors are not always individual decisions. They are batted around through interface with social systems and structural affordances of various micro and macrosystem environments. Recognizing the embedded and interdependent nature of prevention programs is an important contribution of the social interface model.

Theorizing about social interfaces moves developers from relying on an invisible logic model toward querying the interactive processes that occur between complex systems. When interventions show null effects, it could be that the intervention message was poorly developed (e.g., did not achieve salience its original microsystem; did not have high enough dose; was poorly implemented) resulting in negligible interface, or the message may be thwarted when transferring from the microsystem where the intervention is delivered into the microsystem where behavioral enactment is expected. Alternatively, structural affordances in co-dependent microsystems may prevent enacting health behaviors (e.g., no fresh fruits and vegetables are available), or, microsystems lack meaningful interdependence (or worse, contradict one another)

and thereby preclude enacting intervention behaviors. It could also be possible that multiple interfaces occur for particular participants.

Program developers can use this model to map sets of probable mesosystem interfaces for their intervention messages. Some interventions may seek to deliver components across multiple microsystems and use the model to harness effective interface between these systems (e.g., building positive relationships between schools and families). The model foregrounds questions such as: What program components are co-dependent on other microsystems for enactment? What likely will happen when program messages transfer to divergent or hostile microsystems? How are multiple interventions interdependent or in what ways do programs reinforce or undermine each other? Using the social interface model as a heuristic tool to improve intervention programs is a practical benefit of this model.

Taking a complex view of intervention systems implies that although intervention programs and messages are an important part of promoting health, it is probable that their efficacy could be improved through combination with higher level intervention components that seek to remove structural barriers or change social environments (Biglan, 2016). For example, local and national policy contexts can have profound implications for micro and mesosystem functioning (Gaias et al., invited submission). Based on this perspective, we describe three strategies for increasing intervention effects: priming, framing, and coordinating interventions.

Priming. A pre-intervention focused on changing the dynamics of a microsystem might be required to maximize effects. In a summary of network interventions, Valente (2012) recommends that when a network exhibits some form of dysfunction, various techniques can be used to "create a network amenable to change" (p. 52). Based on the social interface model, priming techniques would seek to change properties of the system (e.g., individuals, social norms

and conditions, structural affordances) that bear on targeted health behaviors. This might be considered as priming an intervention site for an intervention message or assessing the capacity or community-readiness for an intervention (cf. McWilliam, Brown, Sanders, & Jones, 2016). Interventions aimed at changing entire school climates or neighborhood environments may also be considered as priming the site by preparing those within the environment to hear and respond to other types of intervention messages (i.e., interdependent social interface). For example, school bonding is a proposed mediator for the school-based All Stars intervention (Harrington et al., 2001) and potentially decreases substance use. Developing intervention capacity or promoting intervention readiness can increase the efficacy of interventions. Whereas interventions are designed to work across multiple microsystems, intervention priming might focus on forging connections between microsystems and maximizing the likelihood that intervention messages can transfer readily from one microsystem to another.

     Framing. Another possible strategy for intervention developers is to attempt to frame messages in ways that increase message receipt and enactment. Developers should consider microsystem, mesosystem, and macrosystem factors that can impact what happens to their intervention messages after delivery. For example, at the microsystem, emphasizing for adolescents the superficial implications of engaging in negative health behaviors, such as bad skin due to smoking, may be more efficacious than focusing on long-term health risks. At the mesosystem, a school-based drug prevention program would do well to consider message framing that considers family contexts youth will enter. It is probable that several youths' parents drink alcohol, so an intervention message for youth that presents drinking as a moral failure would encourage participant adaptation because those youth would enter a divergent family microsystem. Conversely, a choice-consequence framing of prevention may transfer more easily

to other microsystems. Careful consideration of the implications of how message framing may interface across varied microsystems with different structural affordances is needed. Particular messages or message goals may persist, but framing that is sensitive to the overarching social ecology is advisable.

Coordinating. Another strategy for improving intervention effects is to coordinate interdependent interventions across microsystems. A harmony of interventions may be more effective than a single, independent intervention or a series of intervention components that are not explicitly connected within a logic model. This implication draws from advertising and health campaign recommendations to blanket a market with a single message that advances a specific behavioral objective (UNICEF, 2012). Messages should be coordinated across microsystems, repeated, timed appropriately, synchronized toward the same end, and their interactions across microsystems theorized within a logic model. Previous work shows that family and school-based programs produce positive effects (e.g., DeGarmo et al., 2009; Koning et al., 2011) and a school-based program coupled with a media campaign produced positive results (Slater et al., 2006). Similarly, interventionists can follow advertising campaigns and "launch" new programs systematically, moving participants from ignorance to behavioral adoption through coordinated, precisely timed message strategies (see UNICEF, 2012). Coordination among microsystem interventions has been recommended (e.g., Pettigrew & Hecht, 2015), and the social interface model provides a rationale for how coordination accrues benefits.

A corollary to coordinating interventions across microsystems is that it may be beneficial to develop mesosystem interventions that explicitly target the ways two microsystems interface with each other. Mesosystem interventions may mitigate the potential to alter intervention meanings or may improve microsystem harmony. Such an intervention could be a joint training

for parents and teachers or could involve policies that coordinate social services across civil sectors. Although we are unaware of any interventions targeted directly toward the mesosystem, some intervention systems (e.g., Communities that Care, PROSPER) aim to coordinate across sectors to address specific community needs. These may be early prototypes of mesosystem interventions that help bolster intervention effects through transference, co-dependence, or interdependence.

Conclusion

This paper presents novel concepts that can help describe mechanisms of participant adaptation and holds implications for prevention science research and practice. Our model is premised on a bioecological perspective, focus on intervention messages, and identifies four mesosystem interfaces. The social interface model draws attention to the important, but poorly understood, processes that affect behavior after interventions have been delivered.

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Compliance with Ethical Standards

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Disclosure of Potential Conflicts of Interest. The authors declare that they have no conflicts of interest.

Research Involving Human Participants and/or Animals. This article does not contain any studies with human participants or animals performed by any of the authors.

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References

Bennett, G. G., Wolin, K. Y., & Duncan, D. T. (2008). Social determinants of obesity. In F. B. Hu (Ed.) *Obesity epidemiology*. (pp. 342-376). New York, NY: Oxford University Press.

Berkel, C., Mauricio, A. M., Schoenfelder, E., & Sandler, I. N. (2011). Putting the pieces together: An integrated model of program implementation. *Prevention Science*, *12*, 23–33. doi:10.1007/s11121-010-0186-1

Biglan, A. (2016). The ultimate goal of prevention and the larger context for translation. *Prevention Science*. doi:10.1007/s11121-016-0635-6

Brody, G. H., Beach, S. R. H., Hill, K. G., Howe, G. W., Prado, G., & Fullerton, S. M. (2013). Using genetically informed, randomized prevention trials to test etiological hypotheses about child and adolescent drug use and psychopathology. *American Journal of Public Health*, *103*(S1), S19–S24. doi:10.2105/AJPH.2012.301080

Bronfenbrenner, U. (1974). Developmental research, public policy, and the ecology of childhood. *Child Development, 45,* 1-5. doi:10.2307/1127743

Bronfenbrenner, U., & Morris, P. A. (2006). The bioecological model of human development. In W. Damon & R. M. Lerner (Eds.), *Handbook of child psychology* (6th ed., pp. 793-828). Hoboken, NJ: Wiley.

Campbell, R., Starkey, F., Holliday, J., Audrey, S., Bloor, M., Parry-Langdon, N., … Moore, L. (2008). An informal school-based peer-led intervention for smoking prevention in adolescence (ASSIST): A cluster randomised trial. *The Lancet*, *371*, 1595–1602. doi:10.1016/S0140-6736(08)60692-3

Choi, H. J., Hecht, M., & Smith, R. A. (2017). Investigating the potential impact of social talk on prevention through social networks: the relationships between social talk and refusal self-efficacy and norms. *Prevention Science*, *4*, 459–468. doi:10.1007/s11121-017-0764-6

Crespo, N. C., Elder, J. P., Ayala, G. X., Campbell, N. R., Arredondo, E. M., Slymen, D. J., … McKenzie, T.L. (2012). Results of a multi-level intervention to prevent and control childhood obesity among Latino children: The *Adventuras para Ninas* study. *Annals of Behavioral Medicine, 43*, 84-100.

Cuijpers, P. (2002). Effective ingredients of school-based drug prevention programs: A systematic review. *Addictive Behaviors*, *27*, 1009–1023. https://doi.org/doi: 10.1016/S0306-4603(02)00295-2

DeGarmo, D. S., Eddy, J. M., Reid, J. B., & Fetrow, R. A. (2009). Evaluating mediators of the impact of the Linking the Interests of Families and Teachers (LIFT) multimodal preventive intervention on substance use initiation and growth across adolescence. *Prevention Science*, *10*, 208–220. doi:10.1007/s11121-009-0126-0

Fishbein, D. (2000). The importance of neurobiological research to the prevention of psychopathology. *Prevention Science*, *1*, 89–106. doi:10.1023/A:1010090114858

Flynn, A. B., Falco, M., & Hocini, S. (2015). Independent evaluation of middle school–based drug prevention curricula: a systematic review. *JAMA Pediatrics*, *169*, 1046–1052. doi:10.1001/jamapediatrics.2015.1736

Gaias, L., Lindstrom Johnson, S., White, R. M. B., Pettigrew, J., Dumka, L., (invited submission) Understanding the mesosystem between school and neighborhood contexts. *Journal of Adolescent Research Review*.

Grimshaw, J. M., Presseau, J., Tetroe, J., Eccles, M. P., Francis, J. J., Godin, G., … Zwarenstein,

M. (2014). Looking inside the black box: Results of a theory-based process evaluation

    exploring the results of a randomized controlled trial of printed educational messages to

    increase primary care physicians' diabetic retinopathy referrals. *Implementation Science,*

    9, 1-7.

Hamilton, G., Cross, D., Reniscow, K., & Hall, M. (2005). A school-based harm minimization

    smoking intervention trial: Outcome results. *Addiction, 100*, 689-700.

Harrington, N. G., Giles, S. M., Hoyle, R. H., Feeney, G. J., & Yungbluth, S. C. (2001).

    Evaluation of the All Stars character education and problem behavior prevention

    program: Effects on mediator and outcome variables for middle school students. *Health*

    Education & Behavior, 28, 533–546.

Horne, P. J., Hardman, C. A., Lowe, C. F., Tapper, K., Le Noury, J., Madden, P., … Doody, M.

    (2009). Increasing parental provision and children's consumption of lunchbox fruit and

    vegetables in Ireland: the Food Dudes intervention. *European Journal of Clinical*

    Nutrition, *63*, 613-618.

Koning, I. M., van den Eijnden, R. J., Verdurmen, J. E., Engels, R. C., & Vollebergh, W. A.

    (2011). Long-term effects of a parent and student intervention on alcohol use in

    adolescents: A cluster randomized controlled trial. *American Journal of Preventive*

    Medicine, 40, 541-547. doi:10.1016/jamepre.2010.12.030

Langford, R., Bonell, C. P., Jones, H. E., Pouliou, T., Murphy, S. M., Waters, E., … Campbell,

    R. (2014). The WHO Health Promoting School framework for improving the health and

    well-being of students and their academic achievement. In The Cochrane Collaboration

    (Ed.), *Cochrane Database of Systematic Reviews*. Chichester, UK: John Wiley & Sons.

May, C., & Finch, T. (2009). Implementing, embedding, and integrating practices: An outline of

normalization process theory. *Sociology*, *43*, 535–554. doi:10.1177/0038038509103208

Marsiglia, F. F., & Booth, J. M. (2015). Cultural adaptation of interventions in real practice settings. *Research on Social Work Practice*, *25*, 423–432. doi:10.1177/1049731514535989

McWilliam, J., Brown, J., Sanders, M. R., & Jones, L. (2016). The Triple P implementation framework: The role of purveyors in the implementation and sustainability of evidence-based programs. *Prevention Science*, *17*, 636–645. doi:10.1007/s11121-016-0661-4

Miller-Day, M. (2008). Talking to youth about drugs: What do late adolescents say about parental strategies? *Family Relations, 57*, 1–12. doi:10.1111/j.1741-3729.2007.00478.x

Petras, H., & Sloboda, Z. (2014). An integrated prevention science model: A conceptual foundation for prevention research. In Z. Sloboda & H. Petras (Eds.) *Defining Prevention Science* (pp. 251–273). New York, NY: Springer.

Pettigrew, J., Miller-Day, M., Krieger, J., & Hecht, M. L. (2012). The rural context of illicit substance offers: A study of Appalachian rural adolescents. *Journal of Adolescent Research, 27*, 523-550. doi:10.1177/0743558411432639

Pettigrew, J. & Hecht, M. L. (2015). Developing school-based prevention curricula. In K. Bosworth (Ed.) *Prevention Science in School Settings* (pp. 151-174). New York, NY: Springer.

Pettigrew, J., Miller-Day, M., Shin, Y., Krieger, J. L. Hecht, M. L., & Graham, J. W. (in press). Parental messages about substances in early adolescence: Extending a model of drug talk styles. *Health Communication.* doi:10.1080/10410236.2017.1283565

Piehler, T. F., & Dishion, T. J. (2014). Dyadic coregulation and deviant talk in adolescent friendships: Interaction patterns associated with problematic substance use in early adulthood. *Developmental Psychology, 50*, 1160-1169. doi:10.1037/a0034698

Reimuller, A., Hussong, A., & Ennett, S. T. (2011). The influence of alcohol-specific communication on adolescent alcohol use and alcohol-related consequences. *Prevention Science, 12*, 389–400. doi:10.1007/s11121-011-0227-4

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed). New York: Free Press.

Rulison, K. L., Feinberg, M., Gest, S. D., & Osgood, D. W. (2015). Diffusion of intervention effects: The impact of a family-based substance use prevention program on friends of participants. *Journal of Adolescent Health*, *57*, 433–440. doi:10.1016/j.jadohealth.2015.06.007

Rutter, H., Savona, N., Glonti, K., Bibby, J., Cummins, S., Finegood, D. T., … White, M. (in press). The need for a complex systems model of evidence for public health. *The Lancet*. doi:10.1016/S0140-6736(17)31267-9

Ryan, S. R., Brennan, P. A., Cunningham, P. B., Foster, S. L., Brock, R. L., & Whitmore, E. 2013). Biosocial processes predicting multisystemic therapy treatment response. *Biological Psychology*, *92*, 373–379. doi:10.1016/j.biopsycho.2012.12.002

Segrott, J. (2013). Recruitment and group composition strategies for family- based substance misuse prevention interventions: an exploratory evaluation. *Journal of Children's Services*, *8*, 89-109. doi:10.1108/JCS-03-2013-0007

Slater, M.D., Kelly, K.J., Edwards, R.W., Thurman, P.J., Plested, B.A., Keefe, T.J., et al. (2006). Combining in-school and community-based media efforts: Reducing marijuana

and alcohol uptake among younger adolescents. *Health Education Research*, *21*, 157–167.

Southwell, B. G. (2013). *Social networks and popular understanding of science and health: Sharing disparities*. Baltimore, MD: Johns Hopkins University Press.

Southwell, B. G., & Yzer, M. C. (2009). When (and why) interpersonal talk matters for campaigns. *Communication Theory*, *19*, 1–8. doi:10.1111/j.1468-2885.2008.01329.x

Tobler, N. S., Roona, M. R., Ochshorn, P., Marshall, D. G., Streke, A. V., & Stackpole, K. M. (2000). School-based adolescent drug prevention programs: 1998 meta-analysis. *Journal of Primary Prevention, 20*, 275-336.

UNICEF (2012). Communication for behavioural impact (COMBI): A toolkit for behavioural and social communication in outbreak response. Retrieved from http://apps.who.int/iris/handle/10665/75170

Valente, T. W. (2012). Network interventions. *Science*, *337*(6090), 49-53.

West, S. L., & O'Neal, K. K. (2004). Project D.A.R.E. outcome effectiveness revisited. *American Journal of Public Health*, *94*, 1027–1029. doi:10.2105/AJPH.94.6.1027

Figure 1. Social Interface Model