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Mental Model Based Repeated Multifaceted (MRM) Intervention Design: A Conceptual Framework for Improving Preventive Health Behaviors and Outcomes

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Abstract:
Improving the effectiveness of health interventions is a major challenge in public health research and program development. A large body of literature has found low or no impact of health education and promotional interventions. We aim to develop a conceptual framework in support of intervention designs for preventive health behavior improvement programs and outcomes. The proposed approach is based on a narrative review of empirical literature assessing the limitations of less effective or ineffective field experiments regarding preventive health education and promotion interventions. We found three major limitations regarding the mental model's balance of treatment and comparison groups, treatment groups' willingness to adopt suggested behaviors, and the type, length, frequency, intensity, and sequence of treatments. To minimize the influence of these concerns, we propose a mental model-based repeated multifaceted (MRM) intervention design framework to provide an intervention design for improving health education and promotional programs.

Keywords: Public Health Intervention, Health Education and Promotion, Behavior Change Intervention, Intervention Design, Multifaceted Intervention, Repeated Intervention, Mental Model Mapping, Low- and Medium-Income Country (LMIC).

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Introduction

Increasing the effectiveness of interventions focused on improving preventive health behavior is a major challenge in public health research and program development[1] due to the complex nature and context dependency of these behaviors.[2–4] Intervention programs typically require a change in behavior among the members of a treatment group (e.g., individual, household) to improve preventive health behaviors and health outcomes.[5] Behavior change interventions may be minimally effective or ineffective due to inappropriate experimental and treatment designs, the influence of contextual factors,[3] or unobserved events, especially in low- and middle-income countries.[6–9]

In interventions focused on preventive health behavior, we noticed three distinct concerns regarding low or no treatment and intervention effects. First, intervention approaches implicitly assume that all treated individuals or households are identical and have similar mental models or cognitive capacities; making this assumption increases the likelihood of sample imbalance and bias in outcome estimates.[10] Sample balance tests frequently disregard behavioral or cognitive factors[11] but do consider observable socioeconomic and demographic characteristics (e.g., income, wealth) and, sometimes, knowledge levels regarding health behaviors. Second, behavior change interventions require a long time period,[12] and treatment effects wane over time after single-treatment-based interventions.[13] Third, the treatment groups' exposure to the intervention does not vary or repeat throughout the study period.[14] These three elements can, in combination, be a significant intervention-related source of poor health behaviors and outcomes. A framework is needed to shape preventive health behavior intervention designs that consider concerns related to balance tests, the waning of the treatment effect, and the persistence of the impact. We, therefore, develop a conceptual framework for a mental model-based repeated multifaceted (MRM) intervention design to improve the effectiveness of preventive health behavior interventions, which will require further validation through field experiments.

Major Challenges in Program Interventions

Based on our review of the literature and synthesis of the evidence, we found three major areas of concern in intervention design and implementation; these concerns underpin the theoretical foundation of our proposed framework. First, standard intervention design assumes that treatment subjects are similarly willing to adopt suggested preventive behaviors and have similar cognitive capacities; in fact, individuals have different cognitive capacities and mental models. These differences might lead to low-level outcomes. Human behavior is influenced by human attitudes, knowledge, perceptions, social norms, and beliefs;[15,16] these elements together help constitute individuals' mental models. Therefore, it is crucial to identify whether one of these elements could potentially affect intervention outcomes. Second, the impacts of single and short-term interventions wane over time[5,13] because lasting behavioral change requires long-term intervention. Third, treatment groups' responses to a specific intervention can vary under different or changing circumstances; most of the time, this concern has not been fully recognized. For example, a few individuals may prefer monetary incentives to behavioral nudging while unemployed. In addition, some treatment groups may respond better to behavioral nudging and hands-on experience than other groups.

Conceptual Framework

The MRM intervention design framework assumes mental model mapping to be essential and further includes two core ideas: multifaceted intervention and repeated interventions (Fig. 1). First, mapping mental models in the design stage allows the researcher or program analyst to understand a treatment group's mental or cognitive abilities with regards to adopt suggested preventive behaviors as well as their willingness to do so (Stage 1 of Fig. 1). Sample balance tests need to consider mental model-related variables (e.g., flexibility), together with socioeconomic and demographic variables, such as age, sex, education, income, and wealth. Mapping mental models before and after each intervention is particularly important, as any changes can then be identified across time and treatments. Second, multifaceted interventions allow multiple-component treatments and can generate more lasting effects than single-component interventions.[17] For example, different types of educational, financial, and behavioral interventions at different intensity levels (e.g., low, standard, and high) can be combined to design a treatment package (Stage 2 of Fig. 1). In some cases, both monetary and behavioral interventions are essential to encourage the treatment groups to adopt behavior. Third, repeated interventions may produce more pronounced intervention outcomes (Stage 2 of Fig. 1) and are more effective than single interventions. While the impacts of single interventions wane over time, mixed interventions with multiple rounds are more likely to produce the anticipated outcomes. However, the lengths and intensities of the treatments may differ and should be tailored to relevant behavior-related outcomes (Table 1). A field experiment using close variants of interventions of Table 1 can be administered to reveal the goal-specific lengths and intensities of the treatment.

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Intervention Design and Implementation

The proposed MRM framework proposes a basic intervention design with three main features: mental model mapping, repeated interventions, and multifaceted interventions. In Stage 1, mapping the mental models of a treatment group before a baseline survey is essential to designing the initial intervention (Fig. 1). A mental model is an overall representation of an individual's characteristics (e.g., attitudes, values, beliefs, social and cultural norms) that explains that individual's reasoning, inferencing, and decision-making processes. These processes influence an individual's ability to grasp, and willingness to accept, suggested health behaviors.[18–22] Mapping mental models using modified versions of available methods[19,22,23] would provide insights into an individual's or household responder's behavioral and cognitive capacity as they relate to the adoption of suggested health behaviors.

Stage 2 includes two different types of interventions: initial and intermediate (Fig. 1). The number of intermediate interventions, as well as their type (e.g., informational, educational, financial, behavioral) and sequence (e.g., informational-practical-behavioral, informational-behavioral-practical), should be adjusted in line with a program's short- and long-term goals. Researchers will need to identify the appropriate length (e.g., short-, medium-, long-term) and intensity (e.g., low, standard, high) of each treatment, depending on their research goals. In the final evaluation (Stage 3), researchers will compare the final outcomes with the baseline and intermediate outcomes to arrive at conclusions regarding specific stage-level outcomes. Redesign will be necessary if the initial treatment produces lower-than-expected outcomes.

A hypothetical MRM intervention design is presented in Table 1. Each component has three distinct features in terms of intervention type, length, and intensity. A standard information component can be employed in the short-term in the initial stage. In the final stage, five different components can be employed sequentially as a treatment package. This sequence could be a cluster of mixed interventions in which the order of interventions (and their close variants) is based on the mental models of the treatment group members and expected outcomes from the programs. Thus, individuals with limited learning or adoption capacity, for instance, could be treated with higher intensity. To find the appropriate treatment package and sequence, an experimental design can include

Outcome Analysis

As each intervention combines multiple treatments, researchers should consider all the treatments at a given stage as a treatment package (e.g., treatments 1, 2, and 3 are a treatment package for intermediate intervention #2). Comparing the outcomes of each intervention with previous interventions (e.g., comparing intermediate intervention #2 with the baseline and with intermediate intervention #1) will be necessary to reveal whether the effects of treatment package have persisted. If a promotional component is included as a treatment, the possibility of courtesy bias[6] on the part of the responders during after-intervention data collection should be accounted for to minimize the bias in outcome estimates.

Most importantly, researchers will need to check to the mental model after each intervention to compare it with the initial mental model, the subject's willingness to accept the behavioral change (as stated in a baseline survey), and the subject's actual or demonstrated willingness to accept the suggested behaviors. Sub-group analysis is essential to assess adherence to suggested behaviors by different groups within or between treatment groups. A crossover design will allow for various evaluation techniques, such as a quasi-experimental design (e.g., pre-post) for the initial intervention and an experimental design (e.g., difference-in-difference) for the intermediate and final interventions.

Implementation Challenges and Public Health Implications

First, individual or household responder-level mental models vary contextually; therefore, a suitable mental model mapping and classification procedure needs to be adopted that takes experimental contexts into consideration. A professional behavioral profiler is needed to ensure accuracy, as typical enumerators are not trained to perform mental model mapping. Second, identification of the appropriate lengths and intensities of different treatments will be challenging during the initial and first intermediate stages due to various contextual factors. Researchers can use these two stages to test initial treatments and identify appropriate treatment conditions to employ in the later stages. Third, the effect size of intermediate interventions may be misleading due to a variety of outside factors (e.g., unexpectedly bad or good weather).

This conceptual framework for MRM intervention design offers an alternative intervention approach to improve individual and household-level preventive health behaviors and outcomes by enabling more comprehensive treatment designs for interventions. This approach can be applied to any behavioral change intervention. Basic field experiments using this framework should be employed to assess whether the proposed MRM intervention design improves health behaviors and outcomes.

Declarations

Draft Version: July 17, 2020.
Authors' Contributions: MGA conceived the original idea and developed the logical sequence of the intervention design flowchart, interpreted data from the overview of published articles, and wrote the first draft using literature jointly sourced by MGA and FT.
Ethical approval: Ethical approval was not sought, as we used secondary meta-data on the limitations of program interventions cited in peer-reviewed articles and working papers.
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Figure and Tables

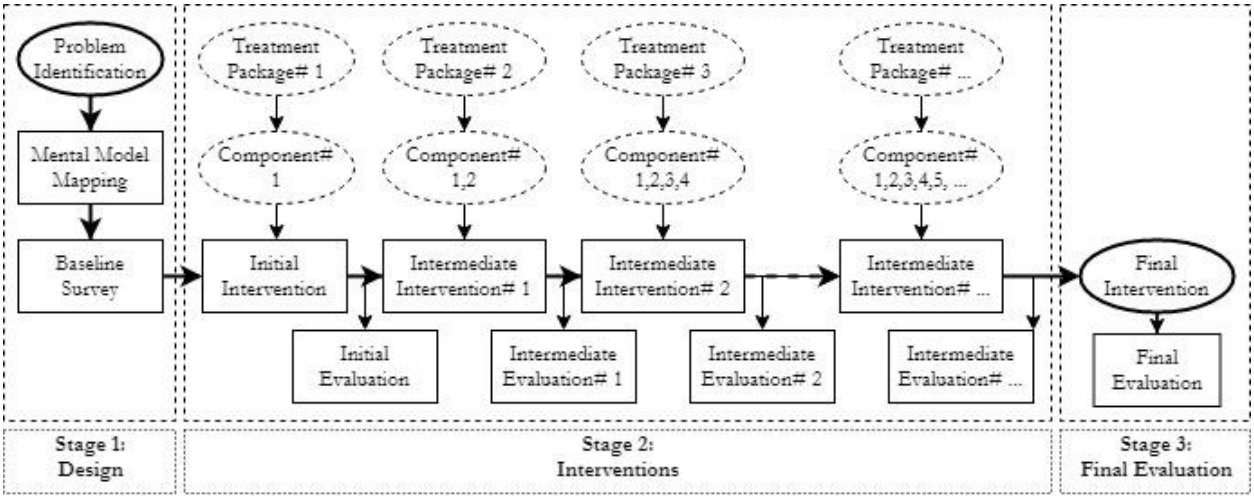

Figure 1: Conceptual framework for mental model-based repeated multifaceted (MRM) intervention design.
Notes: The MRM framework is based on major concerns cited in existing systematic and scoping reviews, trials, and recent empirical studies regarding the approaches, frequency, treatment components, sample balance variables, and time dimensions of treatment interventions in published WASH-related field experiments (Table S2). It considers mental model mapping to be essential and further includes two core ideas, namely, multifaceted intervention and repeated interventions, to develop a modified intervention design that minimizes limitations.

Table 1: An example of treatment package design for initial, intermediate, and final interventions.

Round	Component					
	Feature	**Comp. #1**	**Comp. #2**	**Comp. #3**	**Comp. #4**	**Comp. #5**
Initial	Type	Informational				
	Length	Short-term				
	Intensity	Standard				
	Evaluate	with baseline				
Int. #1	Type	Practical	Behavioral			
	Length	Short-term	Medium-term			
	Intensity	Standard	Low-level			
	Evaluate	with baseline and initial interventions				
Int. #2	Type	Informational	Practical	Financial	Promotional	
	Length	Short-term	Medium-term	Short-term	Short-term	
	Intensity	Minimum	Low-level	Standard	High-level	
	Evaluate	with baseline, initial, and intermediate #1 interventions				
Final	Type	Informational	Practical	Behavioral	Financial	Promotional
	Length	Short-term	Medium-term	Short-term	Short-term	Short-term
	Intensity	Low-level	High-level	Low-level	Standard	Low-level
	Evaluate	with baseline, initial, intermediate #1, and intermediate #2 interventions				

Notes: Int. = Intermediate; Comp. = Component.

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Supplementary Materials

Table S1: Literature search strategy for MRM intervention design, 2010—2020.

Database	Query	Results
PubMed	Search: (((water) AND (sanitation)) AND (hygiene)) AND (WASH) Filters: Meta-Analysis, Review, Systematic Review, in the last 10 years	80
	Search: ((((water) AND (sanitation)) AND (hygiene)) AND (WASH)) AND (behavioral change) Filters: Systematic Review, in the last 10 years	6
	Search: ((((water) AND (sanitation)) AND (hygiene)) AND (WASH)) Filters: Randomized Controlled Trial, in the last 10 years	49
Cochrane Library	(water):ti,ab,kw AND (sanitation):ti,ab,kw AND (hygiene):ti,ab,kw AND (WASH):ti,ab,kw (Word variations have been searched)" with Publication Year from 2010 to 2020, in Trials (Word variations have been searched)	129

Notes: We conducted a narrative review of the literature, including systematic and scoping reviews and empirical articles, on the limitations of water, sanitation, and hygiene (WASH)-related health education and promotion interventions and outcomes, especially in low- and middle-income countries. We applied our search strategy to PubMed and the Cochrane Library to source peer-reviewed articles published from January 2010 to June 2020 that used experimental field data (Table S1). A total of 86 systematic reviews and 49 empirical articles from PubMed and 129 trials from Cochrane Library were identified.

Table S2: Major features of, and concerns regarding, preventive health behavior-related interventions.

Issues	Category	Key Feature	Concern/Strength
Approach	Single	Only one treatment	Treatment effect wanes over time
	Multifaceted	Multiple treatment	Persistent treatment effect
Frequency	Single intervention	One round	Treatment effect wanes over time
	Multiple intervention	Several round	Creates more persistent effect
Balance test	Socioeconomic and demographic factors	Income, wealth, age, sex, education	Mental model or cognitive capacity-related factors are mostly absent
Treatment component	Informational	Information-based letter	Less effective
	Educational	Education	Effective but depends on the curriculum
	Training	Hands-on experience	Effective but depends on the type and length of training
	Financial	In cash only	Attractive but ineffective if stopped
	Promotional	In kind or service	High effective with other treatments
	Behavioral	Weak or strong norm-based nudging	High effective with other financial treatments
	Mixed	Both financial and behavioral	Effective than either financial or behavioral alone
Time dimension	Short-term	Less than one year	Treatment effects wanes over time
	Medium-term	One to five years long	Better than short-termed intervention
	Long-term	More than five years	Creates more persistent effect

Notes: We used systematic reviews and empirical articles from PubMed and trials from the Cochrane Library to explore the limitations of existing design approaches and their respective intervention outcomes.