Original Article

The Development of Effective and Tailored Digital Behavior Change Interventions: An introduction to the Multiphase Optimization Strategy (MOST)

Marta M. Marques
Comprehensive Health Research Centre (CHRC) NOVA Medical School, Portugal

Kate Guastaferro
The Pennsylvania State University, USA

Digital behavior change interventions (DBCI) are uniquely equipped to deliver personalized solutions to influence complex and challenging health behaviors. Rich information about individual(s) and their context may be used to deliver the best suited approach to behavior change. However, there is a lack of precision regarding what needs to be personalized or tailored or adapted (e.g., is it the choice of the content of the intervention, its dose or is it the mode of delivery?) and how (e.g. fixed based on baseline values, or adaptive from contextual information). Traditional approaches to DBCI development and testing wherein the intervention is assembled and tested as a package do not provide answers to these questions. Thus, to advance intervention science, dynamic approaches to the development of DBCI are needed. The aim of this paper is to introduce the Multiphase Optimization Strategy (MOST) as a potential solution to this need. In the context of a DBCI, it is possible to develop a fixed intervention wherein all participants receive the same intensity of intervention, but more commonly there is usually a degree of tailoring or personalisation of the content or delivery which necessitates the development of an adaptive intervention, such as a Just-in-Time Adaptive Intervention (JITAI; Nahum-Shani et al., 2018). We will provide a brief overview of the application of MOST to the development of an adaptive DBCI. We offer a suggestion for the way in which MOST may be integrated with other DBCI development frameworks, such as the Behavior Change Wheel (BCW; Michie et al, 2011; Michie et al, 2013), to improve the effectiveness and tailoring of DBCI. As an approach rather than an off-the-shelf method, our intention is to inspire intervention scientists working in the digital behavior change space to creatively integrate innovative and dynamic approaches to intervention development to maximize public health impact.

Overview of MOST

MOST is an engineering-inspired framework to support the development, optimization and evaluation of multicomponent behavioral, biobehavioral, biomedical, or social-structural interventions (see Collins, 2018 for a more comprehensive overview). In contrast to traditional intervention development approaches, MOST introduces a phase of optimization prior to evaluation. Optimization is the process identifying an intervention that produces the best expected outcome obtainable (i.e., effective) given key implementation constraints. A constraint is anything that could impact implementation such as participant time, cost, or provider capacity. Thus, an optimized intervention is one that is not only effective but is also moving toward desired attributes of affordability (i.e., can be delivered without exceeding budgetary constraints), scalability (e.g., can be immediately implemented with fidelity), and efficiency (e.g., comprised only of active components). The goal is to empirically identify which intervention components work and which do not work, which ones work well together, and under which contextual characteristics. Using MOST, an intervention scientist over time is able to balance intervention effectiveness with affordability, scalability, and efficiency.

MOST consists of three phases: Preparation, Optimization and Evaluation (Figure 1). In the preparation phase, scientists will: develop and refine their theoretically and empirically derived conceptual model; identify candidate components; conduct any pilot work (e.g., hypothesis generating, unpowered experiments designed to assess acceptability and feasibility); and, identify the optimization objective. The optimization objective is the goal of the optimization, or stated differently, it describes how you will balance intervention effectiveness against affordability, scalability and efficiency. Reflecting the goal that you want to achieve, the optimization objective considers any constraints on implementation; for example, "the most effective intervention delivered in less than 30 minutes." Accounting for this constraint in the design of the DBCI, the optimized intervention is not only effective, but also efficient and has increased potential for scalability.

In the optimization phase of MOST, the scientist conducts an optimization trial to identify and build the optimized intervention. When matched appropriately with research questions and intervention type (i.e., fixed versus adaptive), the optimization trial provides the empirical data needed to identify which components meet the optimization objective and will be included in the optimized intervention. It is beyond the scope of the current paper to provide details about all possible experimental designs used in the optimization trial (readers are referred to Collins, 2018 for an overview), however the optimization of an adaptive intervention necessitates the use of an adaptive experimental design for the optimization trial. Common adaptive experimental designs used in MOST are the Sequential, Multiple Assignment Randomized Trial (SMART; Almirall et al., 2018), Micro-Randomised Trials (MRT; Klasnja et al., 2016), or System Identification experiments (Heckler et al. 2018). Regardless of the experimental design selected, the goal is to understand the effect of each component on the outcome of interest individually and in combination with other components.

In the evaluation phase, the effectiveness of the optimized intervention is compared to a suitable comparator (e.g., control, placebo, standard of care). Generally, this comparison is done via a randomized controlled trial, but this is not a requirement of the evaluation phase - any experimental design matched to the research question is suitable. Inherent in the MOST framework is the engineering-inspired continual optimization principle, which holds that even an optimized intervention may be further optimized. Optimized DBCI have the potential to hasten the progress of translational research, thereby maximizing the potential public health impact. Box 1 offers a high-level overview of a hypothetical example of how MOST may be applied to the development of a DCBI.

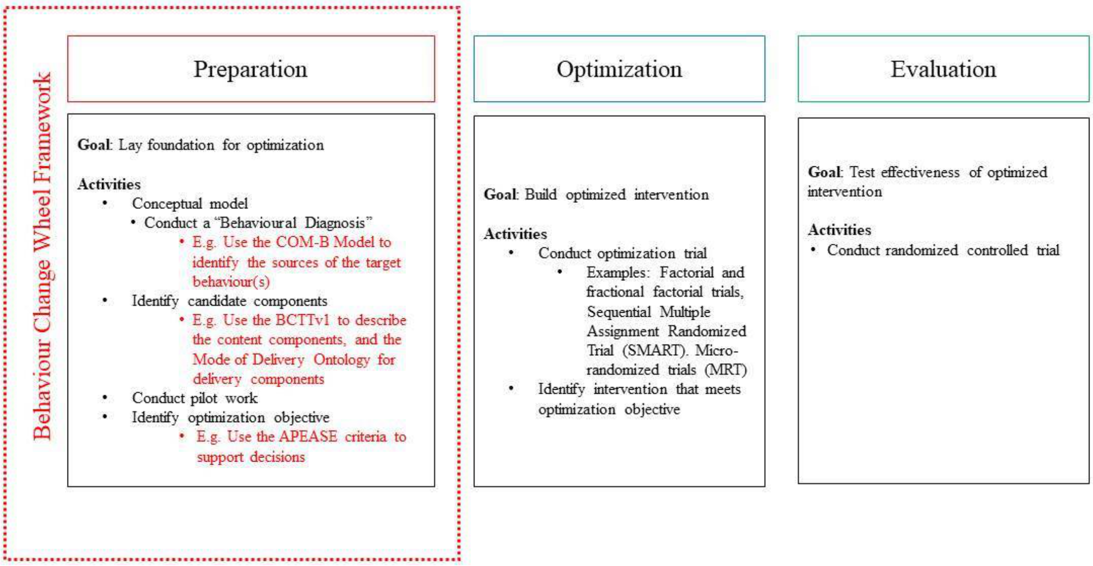
Ensuring that the DBCI meets the needs: bringing frameworks together

Overall, the MOST framework and other intervention development frameworks from behavioral sciences are complementary, especially in the preparation phase. At a minimum, we believe there are two ways in which MOST may be integrated with other frameworks that could contribute to selecting and building DBCI that are effective and tailored to the needs of the target population.

Supporting the conceptual model and selection of components. As described above, hallmark activities of the preparation phase are the development of the conceptual model and the identification of the candidate components. These preparatory tasks ensure that the DCBI identified in the optimization phase and tested in the evaluation phase of MOST will indeed target the individual and/or social factor/determinants that can bring about the desired behavioural changes. Moreover, these preparatory tasks ensure the intervention includes the techniques/strategies or components that can actually impact on these factors. However, the MOST framework makes no assumptions about the process of achieving these activities. Other behavioral science frameworks may support this preparatory work. In this paper we describe how the Behaviour Change Wheel (BCW; Michie et al, 2011; Michie et al, 2014), one of the main frameworks currently used for developing DBCI, may augment this preparatory work. Figure 1 describes how the BCW may be integrated with MOST to achieve the goals of the preparation phase.

The BCW framework provides detailed standardized guidance on how to develop an effective behavioural intervention. The process begins with a "behavioural diagnosis" which consists of three steps: (1) identification of the target behaviours(s) and population; (2) specification of the behaviours - who needs to adopt the behaviour, when and what needs to be done; and (3) identification of the sources/factors influencing the target behaviours. The third step is particularly relevant for the development of a conceptual model in the preparation phase of MOST. The BCW framework proposes the use of the COM-B model (Michie et al, 2011; Michie et al, 2014) to categorize/conceptualize the factors - barriers and facilitators - influencing BEHAVIOURS in relation to the physical and psychology CAPABILITY (e.g. stamina, planning skills), social and physical OPPORTUNITY (e.g. social support) and reflective and automatic MOTIVATION (e.g. habits, beliefs, goals) (For further reading, consult Michie et al, 2011; Michie et al, 2013). Once the behavioural diagnosis is finalized, the next steps in the BCW framework are to identify what the intervention will consist of (intervention functions) and map them to the COM-B model (or formal theory selected). By intervention functions we mean strategies such as modelling, enablement,

Figure 1. Overview of the phases of the multiphase optimization strategy (MOST) with an example integrating the Behaviour Change Wheel Framework (Michie et al, 2011, 2014) in the preparation phase



persuasion, environmental restructuring, or coercion. These interventions functions are then further specified into specific behaviour change techniques that will be implemented (e.g., goal setting, demonstration of behaviour, social comparison, self-monitoring, problem solving (see Michie et al, 2013, 2015 for a full list of behaviour change techniques that are described in the Behaviour Change Techniques Taxonomy v1)) and the way in which the techniques will be delivered (i.e., their mode of delivery (Marques et al, 2021)) and technical specifications. The intervention functions and behavior change techniques may correspond to (or inform) the "candidate components" in the MOST framework.

Ensuring a shared language. MOST can also benefit from linking with other approaches to the standardization of components. Classification systems such as the Behaviour Change Techniques Taxonomy (Michie et al. 2013, 2015), the compendium of self-enactable techniques (Knittle et al., 2020), the Intervention Mapping taxonomy of behavior change methods (Kok et al, 2916) or the Behaviour Change Intervention Ontology (Michie et al., 2020), can bring a standardized approach to MOST by classifying the components of the MOST- based intervention in an unambiguous way using a shared language. Not only this will improve reporting of what goes on in interventions and, consequently, accumulation of scientific knowledge, but mainly using these standardized classification systems can support researchers and interventionists in identifying, selecting and optimizing the candidate components for the intervention. In the context of MOST, by components we mean aspects that can be selected, modified and tested in the context of a behavioural intervention, such as the content of the intervention (e.g., techniques such as goal setting, self-monitoring or stress management), the source of delivery (Norris et al., 2021), its mode of delivery (e.g., using a video, audio, wearable; Marques et al., 2021), the schedule and dose of delivery, and tailoring options (Michie et al., 2021).

Advancing the potential of MOST through international collaborations

Using the MOST framework for developing, optimizing, and evaluating DBCI, it is possible to identify which intervention components work and which do not work, which ones work well together, for whom, and their synergistic effects. This identification is crucial to avoid research waste and build efficient and scalable DBCI, at the same time taking into consideration the level of personalisation and adaptation that is needed to maximise the potential of digital solutions in changing health behaviours and improving health outcomes. MOST has been applied to a number of public health priorities including smoking cessation (Piper et al., 2016), obesity (Spring et al., 2020), heart disease (Celano et al., 2018), HIV (Caldwell et al.,2012; Gwadz et al., 2017), palliative care (Wells et al., 2020), and the prevention of sexually transmitted infections (Wyrick et al., 2020; Tanner et al., 2021). In the U.S., more than 100 projects using MOST have been funded by the National Institutes of Health. In Europe, though MOST is a newer approach slowly gaining attention from the research community, other behavioural science frameworks for intervention development, such as the BCW, are widely disseminated, tested and implemented. There is an opportunity to borrow expertise across both sides of the Atlantic to advance the science of DBCI.

As described, these frameworks can be integrated with MOST to improve the preparation phase and ensure the necessary level of standardization that can effectively contribute to evidence accumulation, but the ways in which these frameworks can be integrated require further discussion and analysis. In addition, we believe the establishment of international U.S. and European research networking and collaborative opportunities would be a major contribution to improve our current knowledge on what and how to select, and implement optimisation designs in the context of DBCI. To pursue this endeavor, the Special Interest Groups, and expert networking opportunities provided by scientific societies such as The European Health Psychology Society, the Society for Behavioural Medicine, or the International Behavioural Trials Network could play a major role. Further, in collaboration with other colleagues we will be soon launching an expert consultation exercise on the applications of the various experimental designs that MOST can include.

References

Almirall D., Nahum-Shani I., Wang L., Kasari C. (2018) Experimental designs for research on adaptive interventions: Singly and sequentially randomized trials. In: L. Collins, K. Kugler (Ed.) *Optimization of Behavioral, Biobehavioral, and Biomedical Interventions*. Statistics for Social and Behavioral Sciences (1st ed., pp. 89-120). New York: Springer, Cham.

Bartholomew, L. K., Parcel, G. S., Kok, G., Gottlieb, N. H., & Fernández, M. E. (2011). *Planning health promotion programs: An intervention mapping approach* (3rd ed.). San Francisco, CA: Jossey-Bass.

Caldwell, L. L., Smith, E. A., Collins, L. M., Graham, J. W., Lai, M., Wegner, L., Vergnani, T., Matthews, C., & Jacobs, J. (2012). Translational research in South Africa: Evaluating implementation quality using a factorial design. *Child & Youth Care Forum, 41*(2), 119–136. https://doi.org/10.1007/s10566-011-9164-4

Celano, C. M., Albanese, A. M., Millstein, R. A., Mastromauro, C. A., Chung, W. J., Campbell, K. A., Legler, S. R., Park, E. R., Healy, B. C., Collins, L. M., Januzzi, J. L., & Huffman, J. C. (2018). Optimizing a positive psychology intervention to promote health behaviors after an acute coronary syndrome: The Positive Emotions After Acute Coronary Events III (PEACE-III) randomized factorial trial. *Psychosomatic Medicine, 80*(6), 526–534. https://doi.org/10.1097/psy.0000000000000584

Collins, L. M. (2018). *Optimization of behavioral, biobehavioral, and biomedical interventions: The Multiphase Optimization Strategy (MOST)* (1st ed.). New York: Springer.

Guastaferro, K., & Collins, L. M. (2019). Achieving the goals of translational science in public health intervention research: The Multiphase Optimization Strategy (MOST). *American Journal of Public Health, 109*(S2), S128–S129. https://doi.org/10.2105/ajph.2018.304874

Gwadz, M. V., Collins, L. M., Cleland, C. M., Leonard, N. R., Wilton, L., Gandhi, M., Scott Braithwaite, R., Perlman, D. C., Kutnick, A., & Ritchie, A. S. (2017). Using the multiphase optimization strategy (MOST) to optimize an HIV care continuum intervention for vulnerable populations: A study protocol. *BMC Public Health, 17*(1). https://doi.org/10.1186/s12889-017-4279-7

Hekler, E. B., Rivera, D. E., Martin, C. A., Phatak, S. S., Freigoun, M. T., Korinek, E., Klasnja, P., Adams, M. A., & Buman, M. P. (2018). Tutorial for using control systems engineering to optimize adaptive mobile health interventions. *Journal of Medical Internet Research, 20*(6), e214. https://doi.org/10.2196/jmir.8622

Klasnja, P., Hekler, E. B., Shiffman, S., Boruvka, A., Almirall, D., Tewari, A., & Murphy, S. A. (2015). Microrandomized trials: An experimental design for developing just-in-time adaptive interventions. *Health Psychology, 34*(Suppl), 1220–1228. https://doi.org/10.1037/hea0000305

Kok, G., Gottlieb, N. H., Peters, G. J. Y., Mullen, P. D., Parcel, G. S., Ruiter, R. A., Fernández, M. E., Markham, C., & Bartholomew, L. K. (2015). A taxonomy of behaviour change methods: an Intervention Mapping approach. *Health Psychology Review, 10*(3), 297–312. https://doi.org/10.1080/17437199.2015.1077155

Knittle, K., Heino, M., Marques, M. M., Stenius, M., Beattie, M., Ehbrecht, F., Hagger, M. S., Hardeman, W., & Hankonen, N. (2020). The compendium of self-enactable techniques to change and self-manage motivation and behaviour v.1.0. *Nature Human Behaviour, 4*(2), 215–223. https://doi.org/10.1038/s41562-019-0798-9

Marques, M. M., Carey, R. N., Norris, E., Evans, F., Finnerty, A. N., Hastings, J., Jenkins, E., Johnston, M., West, R., & Michie, S. (2021). Delivering Behaviour Change Interventions: Development of a Mode of Delivery Ontology [version 2; peer review: 2 approved]. *Wellcome Open Research, 5*, 125. https://doi.org/10.12688/wellcomeopenres.15906.2

Michie, S., Atkins, L., & West, R. (2014). *The behaviour change wheel: A guide to designing interventions.* London, UK: Silverback Publishing.

Michie, S., Richardson, M., Johnston, M., Abraham,C., Francis, J., Hardeman, W., Eccles, M. P., Cane, J., & Wood, C. E. (2013). The Behavior Change Technique Taxonomy (v1) of 93 hierarchically clustered techniques: Building an international consensus for the reporting of behavior change interventions. *Annals of Behavioral Medicine, 46*(1), 81–95. https://doi.org/10.1007/s12160-013-9486-6

Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science, 6*(1). https://doi.org/10.1186/1748-5908-6-42

Michie, S., Wood, C. E., Johnston, M., Abraham, C., Francis, J. J., & Hardeman, W. (2015). Behaviour change techniques: The development and evaluation of a taxonomic method for reporting and describing behaviour change interventions (a suite of five studies involving consensus methods, randomised controlled trials and analysis of qualitative data). *Health Technology Assessment, 19*(99), 1–188. https://doi.org/10.3310/hta19990

Michie, S., West, R., Finnerty, A. N., Norris, E., Wright, A. J., Marques, M. M., Johnston, M., Kelly, M. P., Thomas, J., & Hastings, J. (2021). Representation of behaviour change interventions and their evaluation: Development of the Upper Level of the Behaviour Change Intervention Ontology [version 2; peer review: 2 approved]. *Wellcome Open Research, 5*, 123. https://doi.org/10.12688/wellcomeopenres.15902.2

Nahum-Shani, I., Smith, S. N., Spring, B. J., Collins, L. M., Witkiewitz, K., Tewari, A., & Murphy, S. A. (2017). Just-in-Time Adaptive Interventions (JITAIs) in mobile health: Key components and design principles for ongoing health behavior support. *Annals of Behavioral Medicine, 52*(6), 446–462. https://doi.org/10.1007/s12160-016-9830-8

Norris, E., Wright, A. J., Hastings, J., West, R., Boyt, N., & Michie, S. (2021). Specifying who delivers behaviour change interventions: development of an Intervention Source Ontology [version 1; peer review: awaiting peer review]. *Wellcome Open Research, 6*, 77. https://doi.org/10.12688/wellcomeopenres.16682.1

Piper, M. E., Fiore, M. C., Smith, S. S., Fraser, D., Bolt, D. M., Collins, L. M., Mermelstein, R., Schlam, T. R., Cook, J. W., Jorenby, D. E., Loh, W., & Baker, T. B. (2015). Identifying effective intervention components for smoking cessation: A factorial screening experiment. *Addiction, 111*(1), 129–141. https://doi.org/10.1111/add.13162

Spring, B., Pfammatter, A. F., Marchese, S. H., Stump, T., Pellegrini, C., McFadden, H. G., Hedeker, D., Siddique, J., Jordan, N., & Collins, L. M. (2020). A factorial experiment to optimize remotely delivered behavioral treatment for

obesity: Results of the Opt-IN study. *Obesity, 28*(9), 1652–1662. https://doi.org/10.1002/oby.22915
Tanner, A. E., Guastaferro, K. M., Rulison, K. L., Wyrick, D. L., Milroy, J. J., Bhandari, S., Thorpe, S., Ware, S., Miller, A. M., & Collins, L. M. (2021). A hybrid evaluation-optimization trial to evaluate an intervention targeting the intersection of alcohol and sex in college students and simultaneously test an additional component aimed at preventing sexual violence. *Annals of Behavioral Medicine*. Published. https://doi.org/10.1093/abm/kaab003
Wells, R. D., Guastaferro, K., Azuero, A., Rini, C., Hendricks, B. A., Dosse, C., Taylor, R., Williams, G. R., Engler, S., Smith, C., Sudore, R., Rosenberg, A. R., Bakitas, M. A., & Dionne-Odom, J. N. (2021). Applying the multiphase optimization strategy for the development of optimized interventions in palliative care. *Journal of Pain and Symptom Management, 62*(1), 174–182. https://doi.org/10.1016/j.jpainsymman.2020.11.017
Wyrick, D. L., Tanner, A. E., Milroy, J. J., Guastaferro, K., Bhandari, S., Kugler, K. C., Thorpe, S., Ware, S., Miller, A. M., & Collins, L. M. (2020). itMatters: Optimization of an online intervention to prevent sexually transmitted infections in college students. *Journal of American College Health*, 1–11. https://doi.org/10.1080/07448481.2020.1790571

Marta M. Marques
Comprehensive Health Research Centre, NOVA Medical School, Portugal
mmarques@nms.unl.pt

Kate Guastaferro
The Pennsylvania State University, USA
kmg55@psu.edu

Box 1. A hypothetical example of how to apply MOST to the development of a digital behavioral change intervention

Aim: To develop a mobile-based intervention designed to promote adherence to physical distancing guidelines during the COVID-19 pandemic

Preparation Phase

- *Develop a conceptual model*: The research team conducts a scoping literature review to identify the core barriers related with capability, motivation, and opportunity related to the outcome of interest. From the literature, and based on behavioral change theory, the team identifies the following core aspects to be addressed in the mobile-based intervention:
    1. Beliefs about consequences
    2. Context facilitation (physical and social)
    3. Improving trust in government
- *Candidate components identified*: The core aspects identified in the conceptual model are translated into the behavior change techniques to be used in the intervention component. For example:
    1. Information about how keeping physical distance from others can prevent COVID-19 spread; reinforce values around COVID-19 protective behaviours;
    2. Support in finding ways to be with family, friends or colleagues, keeping the physical distance (e.g. prompts to enact at times where the person is usually in contact with others); Empowering to take action and influence others in the community;
    3. Regularly updated information about physical distance guidelines from credible health authority sources;
- *Pilot test components*: Components are tested in pre-posttest design to determine acceptability and feasibility of each component.
- *Identify optimization objective*: The team decides to prioritize efficiency; thus, the optimization objective is the most effective intervention delivered in less than a total of 15 minutes of participant time.

Optimization Phase

- *Conduct optimization trial*: The team chooses a SMART design to identify which combination of components produces the greatest improvement in adherence to physical distancing guidelines.
- *Identify optimized intervention*: Empirical information from SMART trial indicates that optimized intervention should consist of components 1 and 2.

Evaluation Phase

- *Conduct randomized controlled trial*: Compare the optimized intervention to a control condition consisting only of information about the distance that should be kept.