Crossing the Chasm between Clinical Evidence and Clinical Practice: Persuasive Technology and Translational Science

Sriram Iyengar, Jack W Smith, Jose F Florez-Arango

Center for Biomedical Informatics, Texas A&M Health Science Center
iyengar@medicine.tamhsc.edu, jack.w.smith@gmail.com

Abstract. Translational Science is receiving increasing attention in order to accelerate the process of developing useful clinical interventions starting with basic biological discoveries. The stages in translation are denoted T0, T1, T2, T3, T4. The four transitions between stages can pose formidable difficulties and are called the four 'Valleys of Death'. In this paper we suggest that the methodologies of Persuasive Technology and Behavior Change Support Systems can provide a conceptual and theoretical framework for crossing the valley between T2 (Clinical Research) and T3 (Clinical Implementation). We present several studies that provide intriguing evidence for this suggestion.

Keywords: Translational Science, Persuasive Technology, Behavior Change Support Systems

1 Background: Translational Science

Translational science, also called *Translational Medicine*, is concerned with the process of converting fundamental clinical research findings into clinical practice(s) to improve the health of individuals, and ultimately of populations. In recent years this discipline is experiencing a surge in attention. Emphasizing its importance, in 2012 the US National Institutes of Health created an institute, the National Center for Advancing Translational Science (NCATS) to support and perform research in Translational science. A major motivation for this recent interest is the observation that there is very often a substantial time lag, accompanied by considerable expense, from basic biological discoveries to widespread realization(s) into clinical practice benefiting humans and populations. According to some estimates [1] the mean time to implement a new clinical research finding into practice is 17 to 24 years with correspondingly substantial costs. Thus, there is growing interest in understanding the process of translation and decreasing the time lag from basic discovery to useful interventions that eventually improve public health.

The National Center for Advancing Translational Science defines Translation as "the process of turning observations in the laboratory, clinic and community into interven-

tions that improve the health of individuals and the public — from diagnostics and therapeutics to medical procedures and behavioral changes". NCATS identifies a sequence of five stages called the *Translational Science Spectrum* [2] consisting of the following. *Basic Research* to reveal "fundamental mechanisms of biology, disease or behavior", *Pre-Clinical Research* that "connects basic science and human medicine", *Clinical Research* that includes "studies to better understand a disease in humans and relate this knowledge to findings in cell or animal models", *Clinical implementation* that includes the "adoption of interventions into routine clinical care". This stage also includes "implementation research to evaluate clinical trial results". Finally, in the *Public Health* stage "researchers study health outcomes at the population level".

As in any evolving discipline, there is some variation in definitions and terminology. The original definitions of translational science included only two stages [3] or three stages [1]. In the rest of this paper we will use the terminology in [4] in which the above five stages are denoted T0, T1, T2, T3, T4.

1.1 Translational Valleys of Death

An interesting viewpoint of Translational Science is presented in [5]. Here, the authors point out that transits from successive stages, i.e. T0 to T1, T1, to T2, T3 to T4 entail crossing four chasms. These chasms are called "Valleys of Death" because transiting them entails very considerable difficulties. For example, in the case of stem cell research, crossing from T0 to T1 encountered almost insurmountable political and ethical hurdles as well as failures and disappointments in the science and its implementation [5].

In this paper we are concerned with crossing the valley of death between T2 and T3, called the *T3 valley* in [5]. T2 Translational medicine is concerned with "translation of results from clinical studies into everyday clinical practice and health decision making." [3]. In particular, the goal of research in T2 is to " improve quality by improving access, reorganizing and coordinating systems of care, helping clinicians and patients to change behaviors and make more informed choices, providing reminders and point-of-care decision support tools and strengthening the patient-clinician relationship."[3]. In [6], the goal of T2 research is defined more precisely as "evidence-based guidelines and recommendations by professional organizations and independent panels", a description that is echoed in [4]. Regarding T3, in [4] the authors express the goal of T3 research to include "concepts and methods to disseminate new clinical knowledge for integration into practice, including health services research". This description is similar to that in [6] for T3 research.

1.2 Biomedical Informatics and Translational Science

The activities listed above as goals of the T2 and T3 stages are topics of great interest to biomedical informaticians. An important methodology for helping clinicians and patients to change behaviors is to provide informatics tools that support and enable them to comply with evidence-based clinical guidelines that promote health, cope with chronic disease, or recover from medical conditions such as cancer, or major surgery. For example, currently there is great interest in developing informatics tools

that help mitigate and manage chronic and non-communicable diseases such as Type II diabetes, hypertension, depression and the like. Healthy persons may need to improve their health and prevent chronic disease such as Type 2 diabetes, and hypertension, by engaging in health promoting and disease-prevention activities such as exercise, losing excess weight, and proper nutrition. Those who are not ill, but have harmful habits such as alcohol, opioid or tobacco addictions need help to overcome these addictions.

Crossing the valley of death from T2 to T3 can be a daunting task without obvious solutions or directions. For example, in [7-9], it is shown that even when equipped with paper-based guideline materials the performance of Community Health Workers in applying these guidelines in clinical practice can be sub-optimal. In other words, the guidelines developed in the T2 stage failed to make a successful transition to T3, at least in the implementations investigated in these studies.

Clearly, the issue is that in order to maximize its impact and enable widespread adoption, T2 research needs to be transitioned into T3 practice in a useful, easy-to-use, actionable form, to the intended users that achieves meaningful behavior change. Currently the translational science literature seems to provide limited guidance for this task. However, this issue is receiving increasing attention. For example, in [6] the authors identify this activity as an important area of research in its own right, termed *Implementation Research* or *Implementation Science*.

2 Persuasive Technology

The Translational Science goal identified in [3], i.e., "helping clinicians and patients to change behaviors" corresponds very well with the goal of Persuasive Technology (PT) to identify technological attributes that enhance behavior change without coercion [10]. Fogg's original principles for systems that achieve this goal were as follows: i) Reduction: The system should reduce complex tasks/behaviors into simple tasks; (ii) Tunneling: The system should lead users through the process or steps needed for the desired behavior change; (iii) Tailoring: The system should frame the tasks and task steps in a manner that matches the target user group's educational, linguistic, ethnic/social characteristics; (iv) Personalization: A further refinement of Tailoring to match an individual user; (v) Self-monitoring: Enable the user to keep track of their performance or progress in meeting the desired behavior change; (vi) Simulation: Provide users with the ability to simulate tasks/behaviors; (vii) Rehearsal: The system should enable users to walk through the desired tasks/behaviors before real-world application.

These principles were extended in [11] to provide a framework, called the *Persuasive Systems Design* (PSD) model to define software requirements to guide development of persuasive systems. The PSD model defines three categories, *Dialogue Support, System Credibility Support*, and *Social Support*. Each category includes several principles. Details are in [11]. Recently, a cognate area called *Behavior Change Support Systems* [12] is also receiving increasing interest. For the sake of brevity we shall refer to this spectrum under the collective name Persuasive Technology.

2.1 Central Conjecture

With this background, in this work-in-progress, we suggest that *the techniques, principles and methodologies of Persuasive Technology can provide a useful conceptual and theoretical framework for crossing the T3 valley of death and enhance productivity in Implementation Research.*
In the remainder of this work-in-progress paper we present some evidence to support this conjecture.

3 Related Work

3.1 Smartphone implementation of IMCI guidelines

In 2006 the World Health Organization issued an influential report [13] pointing out that the bulk of healthcare providers in developing countries are Community Health Workers (CHWs). In many developing countries these CHWs are poorly educated and suffer from literacy and educational deficits, in common with the people they treat. The WHO further suggested that the care they provide would be improved if they practice guideline-based care. An example of such a guideline is the Integrated Management of Childhood Illness (IMCI) [14] originally developed by experts at WHO and UNICEF as a strategy to promote health and provide preventive and curative care for children under the age of 5 years. A version specific to newborns under the age of one week is IMNCI [15]. These guidelines have been translated into multiple languages including Spanish, where IMCI is known as AIEPI (*Atencion Integrada a las Enfermedades Prevalentes de Infancia*). Clearly, the activity of developing IMCI belongs to the T2 stage of translation science. The next step is to translate IMCI into clinical practice in developing countries, i.e., to move IMCI into the T3 stage. To this end, the WHO publishes textbooks and workbooks for IMCI in both paper and the equivalent electronic forms. Clearly, the effectiveness of IMCI with respect to eventual improvement of health outcomes is dependent on the extent to which the target audience, i.e., CHWs in developing countries, can understand and apply IMCI. However in [15] it is pointed out that practice tools implementing IMNCI the tools fall short of meeting needs in many countries.
In [16, 17] relevant metrics including Procedure compliance, practice errors, and perceived workload of AIEPI for two implementation platforms of IMCI were compared in a prospective Randomized Controlled Trial, with 50 CHWs, using a randomized cross-over design. The first platform consisted of the AIEPI guidelines on paper. The second consisted of Windows Mobile 6.5 smartphones and presented the AIEPI in a media-rich step-by-step format that was shown to incorporate major elements of PT, Tunneling, Reduction, and Tailoring [18].

The study [16,17] showed that as compared to paper, the smartphone version of IMCI resulted in 35% fewer errors, 30% increase in compliance with AIEPI, greater acceptability, usability, intention to use. In addition, perceived workload (cognitive, frustration, overall) workload were significantly lower. A study in rural south India, with a subset of IMCI in Tamil language, produced similar results [19]. We conjecture that a major proportion of the improved performance of CHWs when using the

smartphone tool, as compared to paper-based materials, can be attributed to PT-based design of the former. The paper-based guidelines did not, and could not, incorporate these principles of PT in a substantial way, and certainly not to the extent that the smartphone version of IMCI did. The Smartphone IMCI explicitly supported Reduction by breaking up the complicated IMCI into small steps to prevent cognitive overload. Tunneling was implemented by providing a small number (typically not more than two) buttons providing the CHW with a limited number of choices for the next step. Tailoring was supported by providing the information in multiple modalities matching the educational attainment of the target CHWs. These included providing instructions for a step in audio and/or video enhanced their understanding and ability to do clinical tasks such as recognizing signs and symptoms of respiratory distress.

3.2 Systematic reviews of medication adherence and obesity interventions

Some more evidence for PT as an effective means for implementing clinical research and guidelines is provided in two systematic reviews [20, 21]. In [20], a systematic review of behavioral interventions to enhance compliance with medication guidelines by older adults was described. Here, the authors conducted a search in MedLine [22], CINAHL[23], and PsycINFO[24] databases for studies in the timeframe 1977 to 2012 concerning medication adherence among adults aged 60 years and older. The designs of these interventions were based upon prior behavioral and clinical research. In other words, each study was an attempt to move T2 research into T3 clinical practice. The systematic review assessed whether interventions containing principles of PT were more effective and which, if any, principles of PT support enhancing medication adherence in this populations. Out of 979 initial results a total of 40 papers met inclusion and exclusion criteria. These studies divided themselves into two self-reported categories, 25 successful studies and 15 unsuccessful. For each study, the team examined the intervention in detail and identified presence or absence of PT and PSD attributes. The successful studies were found to have an average of 3 persuasive attributes versus 2.25 for the unsuccessful ones. However this difference was not statistically significant ($p = 0.038$). The "Tailoring" PT attribute was present significantly more often in the successful interventions ($p < 0.01$). The simulation and reduction PT elements were also present more often in the successful interventions but the difference was not statistically significant. Similar results were found in a systematic review of studies comparing behavioral interventions for obesity control [21].

Summarizing, these two reviews provide some evidence that PT principles can have a beneficial effect on outcomes of interventions in medication adherence and obesity control. The interventions belong to the T3 stage of translational science while the medical and behavioral theories on which these interventions were based belong to the T2 stage. In addition, the intervention design and effectiveness research also are of interest in Implementation science. One limitation, that prevented suggestive results from statistically significant were small sample sizes in the final number of papers that met inclusion/exclusion criteria.

4 Conclusion

We conjecture that Persuasive Technology, including Persuasive Systems Design and Behavior change Support Systems, can provide methodologies and techniques for translating T2 research into tools that support the practice and implementation of this research, i.e., for enabling the translation from T2 to T3 and thereby crossing T3 "valley of death".

4.1 Future work and Challenges

While this paper presents some intriguing evidence, considerable amount of work remains to investigate the central conjecture that Persuasive Technology principles can provide a theoretical and conceptual framework for T2 to T3 transition in Translational Science. Large scale systematic reviews comparing interventions, systems, and tools, similar to those described above, are needed to establish an evidence base for the role of Persuasive Technology in Translational Science. These have to be followed by prospective RCTs comparing interventions, systems and tools based on PT versus those not using PT principles. An interesting challenge is to develop frameworks for specific health domains, knowledge and goals (T2 research) and specific information and communications technology implementations and target users (T3). Such mapping frameworks can potentially be of great service to designers of systems and tools, by guiding these designers on the specific features that their tools should implement to maximize potential for success.

References

1. Trochim, W., Kane, C., Graham, M.J., Pincus, H.A.: Evaluating translational research: a process marker model. Clinical and translational science 4(3), 153-162 (2011).
2. National Center for Advancing Translational Sciences, https://ncats.nih.gov/translation/spectrum
3. Woolf, S.H.: The meaning of translational research and why it matters. Jama 299(2), 211-213 (2008).
4. Waldman, S.A., Terzic, A.: Clinical and Translational Science: From Bench-Bedside to Global Village. Clinical and translational science 3(5), 254-257 (2010).
5. Meslin, E.M., Blasimme, A., Cambon-Thomsen, A.: Mapping the translational science policy 'valley of death'. Clinical and translational medicine 2(1), 14 (2013).
6. Glasgow, R.E., Vinson, C., Chambers, D., Khoury, M.J., Kaplan, R.M., Hunter, C.: National Institutes of Health approaches to dissemination and implementation science: current and future directions. American journal of public health 102(7), 1274-1281 (2012).
7. Rowe, S.Y., Kelly, J.M., Olewe, M.A., Kleinbaum, D.G., McGowan, J.E., McFarland, D.A., Rochat, R., Deming, M.S.: Effect of multiple interventions on community health workers' adherence to clinical guidelines in Siaya district, Kenya. Transactions of the Royal Society of Tropical Medicine and Hygiene 101(2), 188-202 (2007).
8. Rowe, A.K., Onikpo, F., Lama, M., Osterholt, D.M., Rowe, S.Y., Deming, M.S.: A multifaceted intervention to improve health worker adherence to integrated manage-

ment of childhood illness guidelines in Benin. American journal of public health 99(5), 837-846 (2009).
9. Rowe, A., de Savigny, D., Lanata, C.F., Victora, C.G.: How can we achieve and maintain high-quality performance of health workers in low-resource settings? The Lancet 366(9490), 1026-1035 (2005).
10. Fogg, B. J.: Persuasive Technology: Using Computers to Change What We Think and Do. Morgan Kaufmann Publishers, San Francisco (2003).
11. Oinas-Kukkonen, H., Harjumaa, M.: Persuasive systems design: Key issues, process model, and system features. Communications of the Association for Information Systems 24(1), 28 (2009).
12. Oinas-Kukkonen, H.: A foundation for the study of behavior change support systems. Personal and Ubiquitous Computing17(6), 1223-1235 (2013).
13. World Health Organization. The World Health Report 2006: Working Together for Health, 2006. http://www.who.int/whr/2006/en/.
14. World Health Organization, http://www.who.int/maternal_child_adolescent/topics/child/imci/en/
15. Costello, A., Dalglish, S.L.: Towards a grand convergence for child survival and health: A strategic review of options for the future building on lessons learnt from IMNCI. WHO Press, Switzerland (2016).
16. Florez-Arango, J.F., Iyengar, M.S., Dunn, K., Zhang, J.: Performance factors of mobile rich media job aids for community health workers. Journal of the American Medical Informatics Association 18(2), 131-137 (2011).
17. Iyengar, M.S., Florez-Arango, J.F.: Decreasing workload among community health workers using interactive, structured, rich-media guidelines on smartphones. Technology and Health Care 21(2), 113-23 (2013).
18. Iyengar, M.S., Florez-Arango, J.F., Garcia, C.A.: GuideView: a system for developing structured, multimodal, multi-platform persuasive applications. In: Proceedings of the 4th international conference on persuasive technology, pp. 31 ACM, New York (2009).
19. Gautham, M., Iyengar, M.S., Johnson, C.W..: Mobile phone–based clinical guidance for rural health providers in India. Health informatics journal 21(4), 253-66 (2015).
20. Xu, A., Chomutare, T., Iyengar, S.: Persuasive attributes of medication adherence interventions for older adults: A systematic review. Technology and Health Care 22(2), 189-198 (2014).
21. Xu, A., Chomutare, T., Iyengar, S.: Systematic review of behavioral obesity interventions and their persuasive qualities. International Conference on Persuasive Technology (pp. 291-301). Springer International Publishing, Switzerland (2014).
22. U.S. National Library of Medicine: https://www.nlm.nih.gov/bsd/pmresources.html. Retrieved March 3, 2017
23. CINAHL Database - The Cumulative Index to Nursing Retrieved March 3, 2017
24. American Psychological Association: http://www.apa.org/pubs/databases/psycinfo/index.aspx. Retrieved March 3, 2017