Applied Interdisciplinary Theory in Health Informatics
P. Scott et al. (Eds.)

doi:10.3233/SHTI190105

The Need for Theory to Inform Clinical Information Systems and Professionalise the Health Informatics Discipline

Jeremy C. WYATT[a,1]
[a] *Professor of Digital Healthcare and Director, Wessex Institute of Health Research, Faculty of Medicine, University of Southampton, UK*

Abstract. This chapter introduces the idea of theories in health informatics, defines what we mean by theory and distinguishes theories from models, frameworks and predictive principles. After explaining why theories and predictive principles are needed to help us professionalize our discipline, the chapter offers five criteria for a successful predictive principle, discusses how to evaluate predictive principles and theories and links this with the emerging field of evidence-based health informatics. The chapter concludes with three actions needed to move the discipline of theory-based health informatics forward.

Keywords. Theory, Professionalism, Evaluation, Scientific methods, Health informatics

Learning objectives

After reading this chapter, the reader will be able to:

1. Define "theory", know where to locate relevant theories and understand what types of theory are relevant to health informatics.
2. Describe the importance of predictive principles and theories in advancing the health informatics discipline, health informatics research and in educating students and practitioners.
3. Explain the importance of theory in developing usable, effective health information systems, and the relevance of theory to procurement decisions.

1. Introduction: What are theories, and why do we need them in health informatics ?

Nilsen [1] has written a valuable contribution about the nature of theory in the related field of implementation science which I believe should also inform our work in health informatics (HI). She conducted a careful review of the types and uses of theory and of the related concepts, models and frameworks [1] in her discipline, with two main findings.

[1] Corresponding Author: Jeremy Wyatt, E-mail: j.c.wyatt@soton.ac.uk

First, she distinguished carefully between a ***theory*** (a set of analytical principles designed to structure our observations, understanding and explanation of a phenomenon in the world; a theory must be explanatory and predictive as well as descriptive), a ***framework*** (a structure, overview or plan consisting of various elements, concepts, or variables and their relationships, intended to describe a phenomenon) and a ***model*** (a deliberate simplification of a phenomenon or part of a phenomenon, typically descriptive). Unlike theories, frameworks and models do not specify the mechanisms of change. Second, she identified five important categories of theory, model or framework, based largely on their origin and intended use [1]:

1. Process models: these typically specify the steps to be followed to achieve some goal. A historic example relevant to health informatics could be the waterfall model for software engineering (Figure 1)
2. Determinant frameworks: a list of key determinants (e.g. barriers and enablers of change) and their relationships that may influence project outcome. An example relevant to health informatics is Schneiderman‘s checklist of eight user interface features associated with high usability (see Box 1) [2]
3. Classic theories: these are predictive theories that arise from external disciplines (e.g. psychology, sociology or management science) that can assist understanding and / or explanation. An example relevant to health informatics is Michie’s COM-B theory: Behaviour change requires Capability, Opportunity and Motivation [3]
4. Implementation theories: theories that arise from within the implementation science discipline that can assist understanding and / or explanation. Note that this category was named by Nilsen from the perspective of implementation science. In our case, an “implementation theory” might become a Classic theory, and I would like to substitute “health informatics theories” for this 4th category, i.e. theories arising from within the health informatics discipline. An example of an health informatics theory is van der Lei’s suggestion that data collected for one clinical purpose can rarely be used for another purpose without careful reassessment [4]

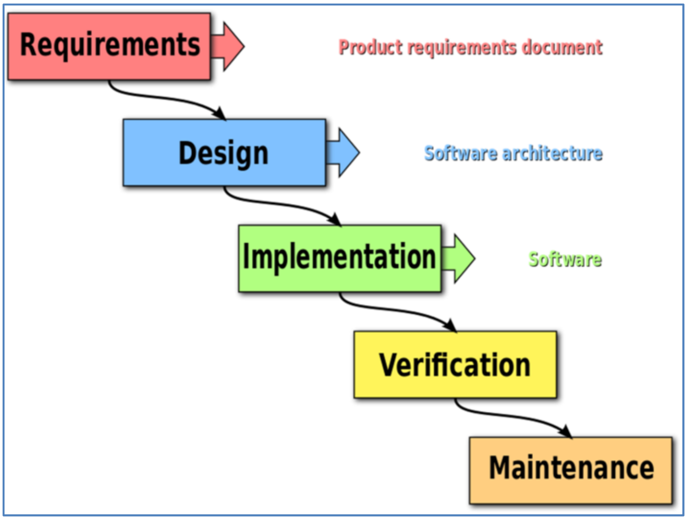

Figure 1. The Waterfall model for software engineering (By Peter Kemp / Paul Smith - Adapted from Paul Smith's work at wikipedia, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=10633070Carver & Scheier 1982).

Box 1. Schneiderman's checklist of eight user interface feature associated with high usability [2]

1 Strive for consistency
2 Enable frequent users to use shortcuts
3 Offer informative feedback
4 Design dialog to yield closure
5 Offer simple error handling
6 Permit easy reversal of actions
7 Support internal locus of control
8 Reduce short-term memory load

5. Evaluation frameworks: a framework or checklist that specifies aspects of a project that can be evaluated to determine if it is successful. An influential example in health informatics is Kidholm's Model for ASsessment of Telemedicine applications, the MAST framework [5].

In this book, process models and evaluation frameworks are considered to be of less importance than determinant frameworks, classic theories and health informatics theories, so I will confine our discussion to these three categories, referring to them henceforth as "theories".

It is no exaggeration to state that the editors and most authors of chapters in this book would agree that the identification, testing and use of theories is crucial to the future maturation of health informatics as a recognized profession, for at least five reasons. First, no one would argue that we currently know how to produce usable, effective clinical systems every time – indeed, it seems that sometimes success in clinical informatics is the exception rather than the rule [6]. So, we need predictive theories to make health information systems better: that is, more usable, better accepted, more accurate, more clinically and cost effective, and readily transferable to other settings. Second, we need theories to help us build an evidence and scientific basis for our discipline, to help it evolve from a craft - based on anecdote, apprenticeship and learning from mistakes - to a professional engineering discipline [7] similar to, for example, the development of aeronautical engineering. Box 2 describes an example from aeronautical engineering of how formulating and testing a theory became a key method both to enhance aircraft safety and to promote the emergence of a professional discipline.

Third, we need theories (and an understanding about which theory to use, and when) to teach our students and practitioners. Fourth, we need theories to guide organisations procuring systems, so that they can distinguish between theory-based systems that are likely to be effective from atheoretical systems which are less likely to help. Finally, we need a list of tested theories (both useful and useless theories) to help decide rationally whether to carry out a full evaluation of a clinical system following an update or not, according to whether the components that were theory-based are still included. There is an analogy here with medical devices regulation [9]: a previously approved cardiac catheter does not need further testing and regulatory approval if the changes are minor, but it does if the changes are "material". In our case, we could be confident if a lifestyle app, for example, is altered in a minor way, but not if theory-based behavior change features are removed.

Box 2. The importance of theory in aeronautical engineering: a sobering example

In the 1950s there was a disastrous series of 13 aircraft accidents in which the world's first passenger jet airplane, the de Havilland Comet, exploded in midair or on the runway, with a total loss of 426 lives [8]. After some delays, the cause of most of these Comet accidents was traced to cracks in the fuselage of planes, which by then were a few years old. Materials scientists hypothesised that the cracks were caused by metal fatigue starting at the corners of the square fuselage windows and spreading during multiple pressurization cycles. This clear, generic, testable and enduring theory was confirmed by metallurgists examining fragments from crashed planes and subjecting new fuselage segments to multiple compression cycles in a water bath. Fuselage metal fatigue as a cause of aircraft failure is now eliminated by rounded window corners. This is a compelling example of how a theory was identified, tested, then applied universally to make a very complex device more reliable. A long series of such events has led to aeronautical engineering becoming a theory-based discipline in a way that health informatics sadly cannot yet claim to be.

2. Another perspective on "theory", where do relevant theories originate, and which theories are useful?

Although Nilsen defines theory as a set of analytical principles designed to structure our observations, understanding and explanation of a phenomenon in the world, I would advance a slightly nuanced perspective on what definition is needed for "theory" in health informatics: "*a concise, testable predictive principle that can guide the design, development or implementation of clinical information systems*".

Such predictive principles can be derived from an existing theory or can be the basis for a new theory after sufficient testing in multiple settings. Predictive principles derived from theories originate in many disciplines, including psychology; management, implementation or computer science; or healthcare [10]. Some examples:

- Psychology: theories of information design, behavior change or self-efficacy
- Management science: innovation theory, organization theory, marketing theory
- Implementation science: active implementation of guideline recommendations, informed by a study to elicit relevant barriers and enablers, is more effective than simple dissemination
- Computer science: software engineering theories, human computer interaction theories, persuasive technology theory
- Healthcare: investigation is more efficient when test-treatment threshold is considered; prescriptions are safer when drug allergies, interactions and disordered drug metabolism or excretion are considered.

Once we know where we can locate potentially useful theories, we need to understand which predictive principles derived from these existing theories are most likely to be relevant to health informatics, and to be useful so that we can select the most promising. Or we can define and test new predictive principles to help develop new theories. My theory (!) is that, to help our discipline, a predictive principle needs to be clear, predictive, testable, generic but relevant and enduring [10]. Table 1 explains these terms, gives examples and some counter examples of hypothetical predictive principles that would violate each criterion.

Table 1. *Characteristics of a useful predictive principle, examples and counter examples*

Characteristic	Explanation	Example predictive principle	Counter example [explanation]
Clear	Worded so that the implications for system design, development or implementation are explicit	Clinical systems that are problem focused, usable, and incorporate relevant technical standards will be well accepted by users	High quality systems work best [too vague and imprecise to be useful]
Predictive	Applying a predictive theory correctly will result in a clinical information system that is superior in terms of usability, acceptability, effectiveness or cost effectiveness	Clinical information systems that apply Schneiderman's user interface principles will be better accepted by professional and public users	The pricing of clinical information systems depends on the amount of business benefit they help organisations to realize [not predictive]
Testable	Can be readily tested for its relevance in predicting the usability, value or cost effectiveness of health informatics or clinical information systems	User interface designs for clinical information systems that ignore portrait and landscape screen formats will be rejected by tablet computer users	When people believe in a system, it will help them. [Not testable – and a self-fulfilling prophecy]
Relevant	Can be applied to the design, development or implementation of clinical information or clinical research systems	Incorporating Michie's behavior change taxonomy into the design of digital tools to influence health-related behaviours will make them more effective	The development of infection control measures needs to focus on the source and vector of the infection and the nature of the pathogen [not relevant to design of clinical information systems]
Generic	Applicable across wide range of technologies, use cases, users, care settings and health systems	Attention to usability and the balance of perceived benefits and costs, including time to use and privacy risks, will improve the engagement of health professionals with digital tools	Use no more than 15 Cyrillic characters per prompt on ePrescribing app screens for use in Crete [too specific to be useful except in rare contexts]
Enduring	Not likely to be rapidly outmoded by changes in technology or clinical practice	Data that is captured once in a neutral context and is accompanied by meta data is more likely to be reusable	Avoid using batteries with less than 8 hours life in a wearable [will be obsolete once kinetic energy harvesting and thermoelectric generator technologies mature]

3. Testing the validity of a theory and link to evidence based health informatics

One challenge with this new view on theory in health informatics as a predictive principle is that any self-appointed expert can formulate an apparently credible predictive principle that seems to comply with the five criteria listed above and then market it using a catchy acronym (eg. Include Technology When One Risks Knowledge Shrinkage, ITWORKS©), resulting in a generation of clinical information systems that respect the new principle but are actually less usable and effective than those which ignore it. However, the fundamentals of evidence based informatics (EBHI) teach us that expert opinion and authority are not sufficient to provide valid theories, and that principles should be tested before dissemination. So, each predictive principle should be subjected to rigorous evaluation studies in relevant settings, to test if it really does contribute to making systems better. Only if it passes these tests should it be accepted as a predictive principle for our discipline, to be applied in systems development and taught as part of accredited educational programmes for newcomers [10].

The details of designing and carrying out such theory-based evaluations are beyond the scope of this chapter but are summarized in a chapter introducing the concept of evidence-based health informatics [10] and detailed in a textbook on evaluation methods [11]. These evaluation principles need to be understood not only by academics developing and testing new principles but also by system designers and developers applying new principles, so that they can confidently carry out a critical appraisal of the studies that have been conducted to test the principle before applying it. Thus, the central idea discussed in this book of using theories or predictive principles more widely is closely linked with the idea of developing and testing theories central to evidence based health informatics.

Figure 2 below illustrates the suggested process, from identifying a theory relevant to HI, deriving a predictive principle from it then incorporating the principle into system development and testing if this improves the system, for example by making the system more usable, accurate or effective.

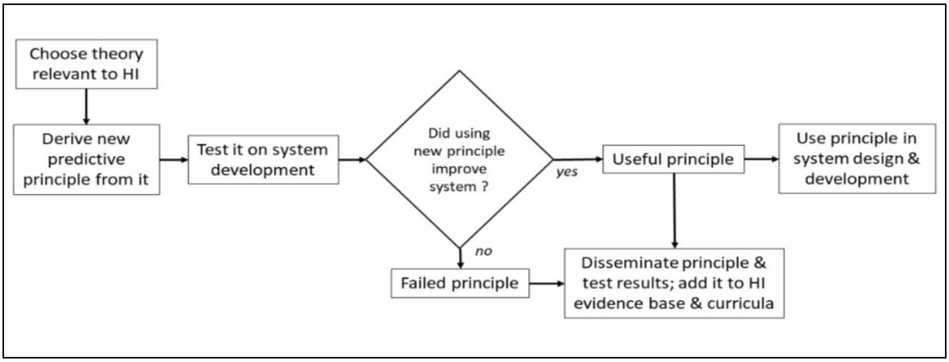

Figure 2. *How to identify and use a useful health informatics principle*

An example of this kind of evaluation is the study we carried out to test the applicability of Fogg's theory of credible website design, based on the design of eCommerce websites, to inform health-related decisions [12]. We designed two version of a website about organ donation with near identical content and usability, one of which followed all Fogg's credibility recommendations while the other site lacked all of these. We then recruited over 800 students via email and randomized them to experience either the credible website or the less credible version. After 4 weeks, we asked participants to join the NHS Organ Transplant Register. Surprisingly, an identical proportion of about 38% joined the register in each group, demonstrating that credible website design had no role in taking this decision [12].

4. Discussion and conclusions

The remaining chapters of this book describe many examples of theories or principles which have been tested in health informatics, with mixed results. However, for the reasons identified in section 1 above, we need to accelerate our progress on theory-based informatics, which requires three specific actions. First, we need to identify more theories that seem relevant to our work from the many existing sources, and derive predictive principles from them for testing. We should also not hesitate to formulate our own testable, generic principles (perhaps to explain failures in a clinical information system we developed, by analogy with the aeronautical engineers investigating the Comet disaster in the 1950s, described above in box 2). Second, we need to test the applicability of each principle in a variety of contexts, to build confidence that the principle – and the theory from which it was derived - does indeed lead to more effective systems [10]. Finally, whether the result of the testing process is positive or negative, we need to work with research and professional organizations at the national and international scale to share that principle and the test results with students and system developers, to encourage them to adopt useful, relevant principles and to drop any that testing shows to be unhelpful, or even harmful. Only this way, in my view, can we move our discipline out of the shadows of authoritarian tradition, superstition or even mysticism, where systems are as likely to harm as to help [13, 14], into the bright light of professionalism where robust, scientifically tested theories and principles guide our work, resulting in predictably usable, safe and effective information systems [15].

Teaching questions for reflection

1. How can the use of tested theories and principles move the health informatics discipline forward as a scientific discipline?
2. What are the potential risks and downsides of a greater reliance on theory?
3. Why are theories or principles advocated by experts not necessarily useful to guide the development of better clinical information systems?
4. How would you test the impact of a new principle that claims to guide the design of safer ePrescribing systems?
5. Will we ever have a Grand Theory of health informatics? If so, could it pass all five criteria for a useful predictive principle listed in the table in section 2?

References

[1] P. Nilsen. Making sense of implementation theories, models and frameworks. *Implement Science* **10** (2015), 53.

[2] User interface design principles. Section 3.3.4 in B. Shneiderman, C. Plaisant, M. Cohen, S. Jacobs, and N. Elmqvist. *Designing the User Interface: Strategies for Effective Human-Computer Interaction*: Sixth Edition, Pearson (May 16).

[3] S. Michie, M.M. van Stralen, R. West. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Science* **6** (2011), 42.

[4] J. van der Lei. Use and abuse of computer-stored medical records. *Methods Inf Med.* **2** (1991), 79-80.

[5] K. Kidholm, A.G. Ekeland, L.K. Jensen, J. Rasmussen, C.D. Pedersen, A. Bowes, S.A. Flottorp, M. Bech. A model for assessment of telemedicine applications: mast. *Int J Technol Assess Health Care.* **1** (2012), 44-51.

[6] R. Koppel, J.P. Metlay, A. Cohen, B. Abaluck, A.R. Localio, S.E. Kimmel, B.L. Strom. Role of computerized physician order entry systems in facilitating medication errors. *JAMA.* **293** (2005), 1197-203.

[7] H. Heathfield, J. Wyatt. The road to professionalism in medical informatics: a proposal for debate. *Methods Inf Med.* **34** (1995), 426-33.

[8] Anon. The de Haviland Comet. https://en.wikipedia.org/wiki/De_Havilland_Comet

[9] European Commission. Guideline on the details of the various categories of variations to the terms of marketing authorisations for medicinal products for human use and veterinary medicinal products. https://ec.europa.eu/health/sites/health/files/files/betterreg/pharmacos/classification_guideline_adopted.pdf

[10] J.C. Wyatt. Evidence-based Health Informatics and the Scientific Development of the Field. *Stud Health Technol Inform*. **222** (2016), 14-24. (Also published as Chapter 2 in: Ammenwerth E, Rigby M. Evidence based health informatics. Amsterdam: IOS Press ISBN 978-1-61499-634-7 (print) | 978-1-61499-635-4 (online)

[11] C. Friedman, J.C. Wyatt. *Evaluation Methods in Biomedical Informatics* (second edition 2006). New York: Springer https://www.springer.com/gb/book/9780387258898

[12] T.J. Nind, I.W. Ricketts, F.F. Sniehotta, J.C. Wyatt, S. Cole. Do credibility cues affect the persuasiveness of a web site? Symposium: Influencing People with Information. Aberdeen. (2012)

[13] E. Ammenwerth, N.T. Shaw. Bad health informatics can kill--is evaluation the answer? *Methods Inf Med*. **44** (2005), 1-3.

[14] Bad health informatics can kill - https://iig.umit.at/efmi/badinformatics.htm

[15] J. Wyatt. Medical informatics, artefacts or science? *Methods Inf Med*. **3** (1996), 197-200