Internet, health, and adaptivity : lessons learned and future directions

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Internet, Health, and Adaptivity: Lessons learned and Future Directions

The advent of the Internet dramatically changed the modalities of health care delivery. Considering the increasing number of people who utilize the Internet to seek health information and treatment programs, a variety of challenges are posed to communication research in the medical domain. Some of these challenges relate to the quality and the effectiveness of online health programs, while others are grounded in the exploration and exploitation of the potential offered by Web. This paper is focused on a specific challenge that encompasses all these issues: the adaptivity of eHealth interventions. The pre-conditions, the modalities, and the limitations of adaptive online interventions are conceptually reviewed. The resulting considerations are discussed along with relevant hints for future research.

Keywords: adaptivity, tailoring, health communication, eHealth.

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1. Introduction

The advent of the Internet dramatically changed the modalities of health care delivery. With more than 75 % percent of people going online to seek health information or help from health professionals (Fox 2008), it is essential to understand and enhance communication processes that can foster the effectiveness of online health care delivery. Indeed, the quality of eHealth interventions and their ultimate impact depends largely on the way they are designed. If the Web offers intuitive advantages to the delivery of health care, such as easiness of access, rapidity, reachability, and so forth, it is also true that research shows mixed results in terms of eHealth effectiveness (Kroeze et al. 2006; Ryan & Lauver 2002). This article focuses on a strategy that proved very successful in inducing behavior change and health improvement: the adaptivity of eHealth interventions. Generally speaking, if Web-based interventions work better than their offline counterparts (Wantland et al. 2004), this is due to the flexibility of the Internet with regard to the production of content and interactions tailored to the users' needs, interests, and knowledge (O'Grady et al. 2009). Despite these promising results, confusion exists about the concept of adaptivity in the health care domain because different research traditions (e.g., computer science, artificial intelligence, health communication) tackled the topic independently. While computer scientists typically study how to make a system more adaptive (e.g., Brusilovky 1996), communication scholars are concerned about the individual characteristics and the processes that enhance the effects of adaptivity (e.g., Rimer & Kreuter 2006). However, to our knowledge, only few attempts (e.g., Cawsey et al. 2000, 2007) have been made to bring these two traditions together and to summarize the theoretical and empirical findings reached on adaptivity. In an attempt to fill this gap, this paper presents a conceptual review of the concept of adaptivity. The main goal of this review is to underline the current perspectives on adaptivity, focusing on four main questions, namely a) what are the definitional issues around the concept of adaptivity, b) what are the preconditions to design and implement adaptive systems, c) what are the modalities of adaptation, and d) what are the limitations and future challenges of research on adaptivity.

2. Online Adaptivity: Definitional Issues

Adaptivity is a very broad concept. As such, it can be applied to different domains. For example, in studies on doctor-patient communication, the way parties adapt to one other during the encounter has been studied in depth and found to be a strong predictor of shared decision-making (Street 1992). In communication literature, the notion of adaptive behavior has been studied in the context of media interaction (Barry & Fulmer 2004). Eventually, computer scientists began to think and design adaptive systems able to boost human-computer interaction (Fischer 2001). Because of its wide scope, the concept of adaptivity can hardly be bound in a single definition. However, since we are to focus on online adaptivity in the health care domain, two definitions must be reported. The first one comes from the computer science tradition and states that adaptivity refers to a characteristic of those systems that build a model of the goals, preferences, and knowledge of each individual user, and use this model throughout the interaction with the user in order to adapt to the needs of that user (Brusilovsky 2001).

The second definition comes from the health communication tradition and uses the term *tailoring* rather than adaptivity. Tailoring was defined by Rimer and Kreuter as the process to create individualized communication by gathering and assessing personal data related to a given health outcome. This process must determine the most appropriate information or strategies to meet a person's unique needs (Rimer & Kreuter 2006).

The two definitions are not far from each other. Tailoring is a concept that implies adaptivity and personalization. In this respect, each tailored system is also an adaptive system. For example, in the taxonomy of adaptive hypermedia systems proposed by Brusilovsky (1996, 2001) a tailored health system is a specific kind of online information system that supports the performance of a specific behavior. In the health care domain, Cawsey et al. (2000) published a good example of the application of tailoring and adaptation. These authors evaluated a system that dynamically generates hypertext pages on cancer treatments and found a strong preference of the users towards personalized information. In general, tailoring strategies have proved to be more effective than traditional online communication of a less dynamic nature in enhancing comprehension, retention of

information, and the overall user experience with the system (Hawkins et al. 2008), although its impact can be moderated by a number of factors such as health behavior or the type of population (Noar et al. 2007). To achieve these improvements, however, specific choices must be made in planning an adaptive online intervention. In the following sections, the critical challenges of online adaptivity are presented, conceptually reviewed and discussed.

3. Adapt to what? Pre-conditions of Adaptivity

According to Brusilovsky (2001) and Cawsey and colleagues (2007), an adaptive eHealth system should meet some pre-conditions in order to serve its goals. A first issue in the design process is the definition of the *goals* of adaptation. A second issue is the *modeling* of the end users.

3.1. Goals Definition

As are the majority of eHealth interventions, adaptive systems are meant to impact a number of outcomes in the end users. These outcomes include improved decision-making skills, compliance, knowledge, communication skills, empowerment and self-efficacy, intention and attitudes, behavior, and, ultimately, health status (Hawkins et al. 2008; Cawsey et al. 2007). These goals may vary depending on the actual intervention and on the strategy used to construct the adaptive message. Some tailored interventions move from a bottom-up approach, i.e., they gather data from the users' interaction with the system and provide them with personalized information (e.g., a website can keep track of the most visited pages and link them to a user profile, adapting the navigation to that individual). In this sense, bottom-up interventions are not guided by an *a priori* theoretical model. Rather, their functioning is based on the generation of user models in real time, or *a posteriori.* Other tailored interventions are strictly top-down in their approach, i.e., they are theory-based. This latter case is typical for adaptive systems that are meant to change people's behavior (e.g., physical activity, see Doshi et al. 2003). In such cases the goals of the system are guided by the constructs of the theory of reference. For example, a website can tailor the messages to enhance attitudes, subjective

norms, perceived behavioral control, and intention because it relies on the Theory of Planned Behavior (Ajzen 1988) to produce change in the end users. Both bottom-up and top-down approaches to goals definition are generally aimed at the construction of a user model, which is the core of an eHealth adaptive system.

3.2. User Modeling

Once the goals of the adaptive eHealth system are defined the end user characteristics must be modeled. According to Brusilovsky & Millán (2007) there are six dimensions that can be modeled in an adaptive system: the domain knowledge, the users' interests, the users' goals and tasks, the users' background, the users' individual traits, and context of reference.

The *domain knowledge* dimensions refers to the modeling of the know-that and know-how of the specific domain of interest. For example, Camerini and colleagues developed a tailored system for patients affected by Fibromyalgia syndrome (Camerini et al. 2011). In this system, the expert knowledge of the syndrome is the domain knowledge that must be modeled (e.g., what are the main treatments, what are the main symptoms, how the syndrome develops). The end user typically has a sub-set of this domain knowledge, usually labeled *overlay* model. Adaptivity can therefore be implemented by matching the expert knowledge with the end user's knowledge.

The *users' interests* are usually modeled as part of the users' profile. Following the example of Fibromyalgia syndrome, some users can be more interested in the treatments, while others in the coping and support strategies. Basic ways to capture the users' interests include direct asking, interaction tracking, keywords and tag inputting. Adaptivity can be implemented based on users' interests, e.g., by providing them with tailored recommendations.

The *users' goals and tasks* are, together with the users' interests, a part of the user profile. For example, patients affected by Fibromyalgia syndrome rest in different stages of the disease, and consequently have different goals (Caiata-Zufferey & Schulz 2009). Modeling these goals and tasks is essential to adaptation because the system has to enhance proactive goals

(e.g., doing more physical exercise), while reducing disruptive ones (e.g., to abandon physical exercise in favor of painkillers). Taken together, users' interests, goals, and tasks are the core of adaptive systems that tackle the problem of self-management. Moreover, when the adaptive system relies on stage theories (e.g., the Transtheoretical model, Prochaska & DiClemente 1983) users' goals and tasks can be used to determine the stage the user is currently experiencing and consequently adapt to this stage.

The *users' background* is a very broad term employed to indicate the set of knowledge and experiences a user has outside the domain of interests. For example, if the goal of the adaptive system is to promote physical activity, it is useful to gather information on the working environment of the users, though not directly related to the primary goal of the system.

The *users' individual traits* are often modeled in persuasive systems (Fogg 2003). They include personality traits (e.g., introvert/extrovert), cognitive styles (e.g., holist/serialist), cognitive factors (e.g., working memory), and learning styles (e.g., individual/social). Individual traits are exploited in the adaptation process to induce central thinking as one of the persuasive strategies towards behavior change.

Eventually, the *context of reference* is modeled in adaptive systems to enhance the feasibility of task performance. For example, Fibromyalgia patients can be provided with exercises requiring certain tools (e.g., a theraband or a mattress). In this case, the system has to acquire contextual information to adapt to the user's situation.

The definition of the domain knowledge, users' interests, goals and tasks, background, individual traits, and contextual information constitutes the basis of the user model included in an adaptive system. Therefore, before starting the implementation process, careful data collection with regard to these variables must be performed and evaluated.

4. How to adapt? Modalities of Adaptivity

Online adaptivity can be implemented in several modalities. In eHealth applications, at least three different ways must be mentioned: textual, navigational, and multimedia.

Textual adaptivity is by far the most frequently used modality implemented in eHealth recommendation systems (see for example Cawsey

et al. 2000). This technique is based on Natural Language Processing (NLP) algorithms that produce personalized texts. The textual personalization is based on the goals and the characteristic of the user model presented above. Textual adaptation is particularly useful when the goal of the system is to produce a change in attitudes and intention towards a behavior. For example, the project OPERA (MacKay et al. 2007) exploits tailoring and adaptation to automatically generate textual arguments on breast cancer risks. These arguments are meant to educate the users about the risks of genetic breast cancer and its prevention.

Navigational adaptivity refers to systems that modify their hypertext patterns according to the user model, rearranging their structure and contents. This modality of adaptivity is useful in reaching goals of increased knowledge, compliance, and self-efficacy, while reducing potential risks linked to information overload. For example, Pagesy and colleagues (2000a, 2000b) designed a medical system that adapted its structure to the users' navigational preferences, in order to increase their general experience and knowledge.

Multimedia adaptivity is perhaps the most recent modality implemented in eHealth applications. This form of adaptation provides the user with individual material in multimedia format (i.e., images and videos). Examples of video tailoring include the work of Eakin et al. (1998), Pieterse et al. (2006), and Camerini et al. (2011). The first study used tailored videos in primary care settings to boost smoking cessation rates. The second study assessed the influence of individual video-feedback training for cancer genetic counselors on the interaction during initial visits. The last study presents the design, implementation, and preliminary evaluation of a tailored system providing users affected by Fibromyalgia syndrome with personalized videos on different physical exercises. All these systems proved to be effective but also report some limitations of multimedia adaptivity. In particular, the level of adaptation cannot be as in-depth as the one provided by textual adaptivity. The video is intrinsically a uniform unit of content and thus the adaptation is performed only at the level of the selection and the presentation of this material to the end user.

Textual, navigational, and multimedial adaptivity can be combined together to enhance the system adaptation and, possibly, its effectiveness

(for example, see Campbell & Quintiliani 2006). Yet, the differential effect of these different modalities is still to be determined given the few studies on the most recent forms of adaptivity.

5. How much Adaptation? Limits and Challenges of Adaptivity

The potential of adaptive eHealth systems is bound by limitations and challenges that must be faced in future research. On the one hand, limitations and challenges are linked to the development of Web technologies (e.g., the exploitation of semantic ontologies, see Dolog & Neidl 2007). On the other hand, they arise from the specificity of the health care domain. Particularly relevant from a health communication perspective is this second set of limits and challenges, because they pose theoretical and practical problems explained hereafter.

5.1. Setting the Benchmark of "Expert Knowledge"

Previously, we introduced the concept of domain knowledge modeling and the overlay model that constitutes its subset. In eHealth applications, however, consensus on what should be included in the domain knowledge model is not easily reached. For example, a strong debate exists in the medical community on the guidelines to define and treat Fibromyalgia syndrome (Forslind et al. 1990; Goldenberg et al. 2004; Perrot et al. 2008) that go beyond the official criteria for its diagnosis (Wolfe et al. 1990). In such cases it is difficult to model the domain because of the lack of clear guidelines. Moreover, in eHealth applications that are meant to deliver tailored information on treatments it is extremely difficult to model the user in real-time and, consequently, adaptivity should not be intended as a full substitute of the health professionals' guidance. The need for clear guidelines to be used as a benchmark for "expert knowledge" is therefore very relevant, as pointed out by Lustria and colleagues (2009) in their review of computer-based tailored interventions. As suggested by Camerini et al. (2011), having clear guidelines on the domain knowledge brings several advantages to adaptivity, including a) the matching of high-quality criteria for eHealth interventions, b) the boosting of the translation into adaptive algorithms of the intervention, c) the possibility

of refining the rules for tailoring, d) the facilitation of the testing phase of the online intervention, and e) the increased validity of the data extracted and manipulated by the adaptive systems. When these guidelines are not at disposal, some techniques have been proposed for their elicitation (e.g., Knowledge Acquisition, Reiter et al. 2003). Such methods, however, do not guarantee exhaustiveness in the elicitation process and assume that the system should fully capture the medical knowledge. In this respect, they are more medically-oriented and leave less space for the needs of the users. We therefore suggest that tailoring can be most effective in situations where these guidelines are at disposal, e.g., in breast cancer risk assessment, rather than when limited consensus on the domain knowledge is available.

5.2. Balancing Conflicting Goals

Adaptation, as described above, is about matching users' characteristics with medical guidelines. The discussion about the goals of an adaptive system, however, goes beyond this dual perspective. Indeed, an adaptive system should provide the users with contents that balance their goals and the ones of the health professionals. The majority of studies on computer-based tailored interventions (Lustria et al. 2009) are more concerned with the translation of medical guidelines into algorithms that produce a user-based or user-oriented presentation of the contents. However, problems occur when the goals of the user are different than the ones foreseen by the medical doctors. This issue generates a distinction between doctor-oriented and patient-oriented adaptive systems (Bental et al. 1999). In doctor-oriented systems health professionals set the goals of adaptation and the system provides its users with tailored justifications for the medical point of view. Patient-oriented systems are more concerned with the preferences of the users. As an example, consider a chronic patient who values an extra hour with his family more than an extra hour of physical therapy. This patient is likely to favor painkillers to non-pharmacological treatments despite the "expert" preference for physical therapy. The goal of an adaptive system should be to reconcile these competing perspectives of the self-management problem. Different techniques have been tested to provide such a system with the correct domain knowledge, including

focus groups and qualitative interviews (Mercer & Sweeney 1995). However, the extent to which an adaptive system can really balance the conflicting goals of users and medical guidelines is still rather unclear. In other words, a major challenge for the evaluation of tailored interventions is not only to focus on whether they work, but also to question how they work, i.e., what kinds of mechanisms occur between adaptation and outcomes (Hawkins et al. 2008).

5.3. Evaluating Adaptivity

The development of eHealth adaptive systems requires different expertise. From a computer science perspective, a major challenge resides in the elaboration of user models, algorithms, and decision rules that can fully capture the user experience and merge it with the domain knowledge. From a health communication perspective, the focus is rather on the ultimate impact of tailoring and adaptation on health outcomes, and on the strategies to maximize it. Because of these different foci, two perspectives on the evaluation of adaptive systems have emerged in the literature.

The first viewpoint is to test adaptation in respect to system-oriented and user-oriented parameters. System-oriented parameters include performance, completeness, and usability. User-oriented parameters are self-report measures of relevance, satisfaction, preferences, and task achievement. This kind of twofold evaluation is often adopted in artificial intelligence.

The second strategy is to test tailored systems with a theory-driven evaluation. As previously noted, one of the most frequently used theories is the Transtheoretical Model (Prochaska & DiClemente 1983). The theory-driven approach is less centered on the technical characteristics of an adaptive system and more focused on the pathways of change from tailoring to outcomes. However, Abrams and colleagues (1999) showed that such an approach to evaluation may never be exhaustive due to a variety of factors, including the diversity of theories applied, the scarcity of studies on mediators and moderators, the constellation of different behaviors and outcomes under analysis, and the different measures employed to capture the relevant constructs (see also Ryan & Lauver 2002). Cawsey and colleagues (2007) acknowledged that clinical trials

and other methods typically applied in the health care domain could provide computer scientists with a more holistic perspective on the evaluation of adaptive systems. However, discrepancies still exist in the two approaches, making the evaluation of tailored and adaptive applications so challenging. A possible solution would be to reduce in complexity the two approaches, i.e., focusing on the impact of a limited number of technical features (e.g., the kind of user model implemented or the level of interactivity enabled by the system) on theory-driven individual constructs (e.g., attitudes, knowledge, behavior). An alternative, proposed by O'Grady and colleagues (2009), is to conduct three different kinds of evaluations: formative, summative, and outcome assessment. The formative evaluation is basically a test of the system parameters. The summative evaluation is a test of system efficacy and goals achievement. The outcome assessment is the ultimate level of testing, where the impact on health outcomes or on the health care system is measured. These authors suggest that it is useful to conduct each one of these evaluations at the level of the users, the content, the technology adopted, the interaction, and the integration with the health system. Although theoretically and empirically sound, this approach is overwhelming in terms of time and resources. As we suggest, a balanced or intermediate choice, accounting for both technical and individual variables, would be more feasible and still remain informative.

6. Conclusion

In this paper we presented a conceptual review of adaptivity as the one of the most relevant strategies to deliver eHealth interventions. The Internet and new communication technologies show great promise for the design and implementation of adaptive applications for health education and treatments provision. By merging the concept of adaptivity with tailoring and explaining goals and modalities, we've underlined its impact with regard to traditional health care communication. Additionally, we've acknowledged limitations that should be addressed in future research challenges: the definition of "expert" knowledge, the balancing the goals of users and health professionals, and the evaluation of adaptive systems.

Several reviews on adaptive systems (Lustria et al. 2009; Noar et al. 2007; Kroeze et al. 2006; Ryan & Lauver, 2002; Abrams et al. 1999) conclude that future research on eHealth adaptive systems should focus on the mechanisms that maximize the effectiveness of tailored interventions from a technical and individual perspective. Following this direction, a recent meta-analysis on computer-based tailored interventions (Krebs et al. 2010) summarized research findings on their impact at the individual level, across modalities and behaviors. Yet the systematic inclusion of technical features in the evaluation of eHealth adaptive interventions is still missing. In this respect, a more holistic view of the research on adaptivity, taking into account the contributions from computer science and communication studies, seems a promising route to follow.

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