IJCSI International Journal of Computer Science Issues, Vol. 3, 2009
ISSN (Online): 1694-0784
ISSN (Print): 1694-0814

Pharmaco-Cybernetics as an Interactive Component of Pharma-Culture: Empowering Drug Knowledge through User-, Experience- and Activity-Centered Designs

Kevin Yi-Lwern YAP[1,2], Xuejin CHUANG[2], Alvin Jun Ming LEE[2], Raemarie Zejin LEE[2], Lijuan LIM[2], Jeanette Jiahui LIM[2] and Ranasinghe NIMESHA[2]

**[1] Department of Pharmacy, Faculty of Science, National University of Singapore
Block S4, 18 Science Drive 4, Singapore 117543, Singapore**

[2] NM5206 Project Team, Communications and New Media Programme, Faculty of Arts & Social Sciences, National University of Singapore

Abstract

The advent of the World Wide Web (WWW) has led to the creation of many web publishing platforms. Patients are becoming more well-informed through drug and health-related information over the internet. The integration of interactive media technologies and the WWW provides an opportunity to improve the pharmaceutical care of patients on anticoagulant therapy. In this paper, the concept of 'pharmaco-cybernetics' is introduced through the creation of an interactive tool which consists of a pill-catching game and hangman game designed to enable users to learn about warfarin tablet strengths and drug interactions, based on user-centered (UCD), experience-centered (ECD), and activity-centered design (ACD) approaches. Currently, this tool is largely based on UCD and ECD. However, the potential of incorporating the ACD approach in the tool's design is definitely attractive. Pharmaco-cybernetics can empower patients with the appropriate knowledge regarding their therapy so that they can better participate in the management of their health.

Key words: *Drug Information, Interactive Games, Pharmaco-Cybernetics, User Interaction, Warfarin.*

1. Introduction

Anticoagulation therapy involves the use of drugs to help prevent and treat blood clots in the arteries or veins. Anticoagulants, also known as 'blood thinners', work in various ways to inhibit blood-clotting factors in the body. Warfarin is an oral anticoagulant which works by blocking the action of vitamin K in the liver. It is usually prescribed for people with certain types of cardiovascular conditions or those suffering from deep vein thrombosis [1]. Patients on warfarin therapy are usually treated for a period of time ranging from a few months to long term chronic therapy. The dose of warfarin taken by the patient is adjusted according to the results of a blood test known as the International Normalized Ratio (INR), which is a measure of how long a patient's blood takes to clot. An INR above or below a set target means that the patient is at a higher risk of bleeding and clotting occurrences respectively. Thus, the dose of warfarin has to be individualized according to the patient's response to the drug.

Warfarin comes in many brands. Patients are advised not to switch among brands as different brands have slightly different efficacy. In Singapore, the brand Marevan® is used, and it comes in a tablet with three strengths which can be identified by its color: 1mg (brown), 3mg (blue) and 5mg (pink). Patients on warfarin therapy may need adjustment of their dosages until their INR stabilizes, and this may be confusing for some patients, especially during the initial stages. Hence, it is important to educate them to recognize the tablets which they are taking and remember the dosages of their therapy. It is easier for the patient to remember the dosage if they can correlate it with the strength of the tablets, which in turn, can be identified by their colors.

Warfarin also has many drug interactions. In a broad sense of this paper, these include other medicines, nutritional supplements, traditional herbs, and foods which are rich in vitamin K. It is prudent that patients on warfarin therapy also know some of its common interactions so that they can adapt to any changes in their dietary habits and lifestyles.

In traditional medical practice, healthcare professionals have always played active roles in the care of patients. For example, doctors tell their patients what is wrong and how to get better, and pharmacists counsel patients with regards to their medications. For warfarin therapy, patients currently see a pharmacist-run clinic for counseling, where they are educated about the drug itself and how to recognize and manage signs and symptoms of adverse effects and drug interactions. In addition, they are also given supplementary materials such as pamphlets as part of their education. However, the patients' understanding of warfarin therapy is limited to the time for each counseling session, and the frequency in which they revisit the clinic for follow-up. Thus, their knowledge on warfarin may be limited, particularly for those who are on this medication for the first time. The lack of knowledge or misinterpretation of information about the drug or its use can affect their compliance to their medication, which may consequently lead to the patients suffering from drug-related problems (DRPs) such as under- or overdosing, or potential drug-drug, drug-food or drug-herb interactions [2].

Human-computer interaction (HCI) has become a norm in society. The roles between patients and healthcare professionals have evolved with the information age. Internet and informatics technologies brought about by the cyber era have been critical in transforming the public's attitudes towards healthcare and medicine. The interface between HCI and health services has led to the birth of medical informatics, which aims to develop studies and instruments to solve clinical issues in the practical setting [3]. Its ultimate goal is to improve the healthcare of patients. As such, many issues from the genetics, social, economic and environmental factors, cognitive, emotional and behavioral domains can also play a role [4]. The emergence of the World Wide Web (WWW) is one of the most significant developments in the history of the internet [5]. The internet is rapidly gaining importance not just for healthcare professionals, but for patients as well. Although healthcare professionals access information on the internet to help them make decisions regarding patient care, patients are also becoming more well-informed about their health and health-related issues through the information which they can get over the internet. Patients are now just as likely to be able to highlight the risks, various therapies and available treatments to their healthcare providers [6]. As traditional therapy is being translated to the internet, the layman is now more aware of his health and is able to better understand the science behind the various illnesses through information he gets from the WWW. Albeit the uncertainty as to whether cybermedicine will ever be comparable to non-cybermedicine [7], the WWW has nevertheless impacted the way healthcare is being practiced today. The challenge is for both healthcare professionals and patients to critically evaluate the vast amounts of available information so as to provide the best care for the patients' well-being.

1.1 The Roles of the Internet and Interactive Media in Healthcare

The traditional role of media in healthcare has involved the use of audio and video programs in public health education, such as with psychiatric diseases, cancer and smoking. Film and photography were used as forms of 'Edutainment' – an Education-Entertainment strategy – to address the stigma of people experiencing depression [8] and schizophrenia [9]; while the American Cancer Society leveraged the use of movies as an educational tool for the public on cancer in the 1920s [10]. In fact, popular Hollywood films in the 1930s to 1970s also used this strategy to portray some cancers as being more 'favorable' since they were more photogenic and less offensive [11]. Furthermore, a recent trial also showed the usefulness of digital media in improving the knowledge and awareness of prostate cancer screening among African-American men [12]. However, the two most pressing health-related issues currently which involve the impact of digital media are on its effects on the views and attitudes of sexuality [13] and smoking among youths [14,15].

In recent years, the internet has become a very popular HCI tool in a person's daily life. It is not uncommon nowadays for patients to search for health-related information online. The World Wide Web Consortium (W3C) [16] and the Internet Engineering Task Force (IETF) [17] have not only provided common standards for data, information and software applications for the WWW, but also encouraged users to discuss about various internet-related operational and technical problems. Users can now navigate through a vast and complex web of linked computer documents through an inexpensive, easy-to-use, cross-platform, graphic interface which supports items like buttons, scroll lists, tables and pop-up menus for user interaction. However, the current hype in healthcare not only embarks on the use of IT and the WWW, but also the integration of interactive media technologies. Interactive media not only establishes a two-way communication among its users, but allows active participation as well. An opportunity exists for web users to gain information and knowledge in a more interesting manner. Internet interactivity can exist in both digital and multimedia forms, and is most commonly represented by means of text, audio, video, graphics, images and animation [18]. As long as one has the hardware, software, talent and skills for developing an interactive application, it can be mounted on the WWW through inexpensive browsers.

1.2 Animation as an Interactive Tool in Healthcare

Animations have always been promoted as a way to showcase the dynamics of user interface actions. People encounter animations frequently since they have been used for various purposes, particularly in web pages and online advertisements. Animations are useful for presenting highly abstract or dynamic processes, or when the user is involved in an action or process [19]. It is known that user satisfaction with animations is usually quite high, unless they distract the user from focusing on key issues [20]. The applications of animation are widespread, normally involving the entertainment and advertising industries.

However, this form of interactivity is also getting more widely accepted in the healthcare world.

There are many examples of animation applications in the medical sciences, such as in medicine and dentistry [21], orthopedics [22,23], and aesthetics surgery [24,25]. A virtual human simulation using a 3D phantom was developed by Oak Ridge National Laboratory and its collaborators [26] at the beginning of the century as a computer representation of the human anatomy. Animated films can also be used in the field of psychology for teaching purposes, such as characterizing personality types. An example can be extracted from the animated film 'Who Framed Roger Rabbit' [27], in which Roger exhibits a whole range of personality traits from being extroverted and aggressive to being insecure and anxious. However, film animation is only one of animation techniques that can be used in the health sciences.

Advancements in computer technology have revolutionized the way healthcare is practiced. As computers become more affordable and newer technologies emerge, traditional animation techniques of tweening and morphing have transformed into computerized versions created by two- (2D) and three-dimensional (3D) bitmap and vector graphics. The development of the WWW has led to the creation of many web publishing platforms, including HyperText Markup Language (HTML) and its variants, Java applets, Flash and Shockwave, among others. Web technologies have also enabled the generation of other forms of web pages like Hypertext Preprocessor (PHP) and Active Server Pages (ASP). HTML has been the well-known standard format for publishing content on the WWW, but its limitation lies in the management of interactive and animated content. However, the WWW has now managed to successfully integrate Flash technology for this purpose due to its advantages of not having cross-platform and cross-browser compatibility problems, and the 'Flash everywhere' phenomenon is getting very popular with website developers [28]. Websites can now be created using a combination of HTML and Flash, or created entirely in Flash. A recent small-scale usability study done by Piyasirivej reported that users generally enjoy Flash sites more than HTML sites [28]. Examples are the 'Virtual Knee Surgery' and 'Choose the Prosthetic' games developed by Edheads + COSI where the user takes on the role of a virtual surgeon to diagnose knee replacement patients and carry out a total knee replacement surgery [29]. However, despite the attractiveness of such technologies in the various areas of healthcare, their progress in the pharmaceutical arena is still slow.

1.3 Pharmaco-Cybernetics as Part of Pharma-Culture

The objectives, roles and value-addedness of clinical pharmacists have always been in continuous debate. Nevertheless, many organizations such as the World Health Organization (WHO) and the Nuffield Foundation have recognized pharmacists as essential health care providers [30]. The practice of pharmaceutical care forms the cornerstone of clinical pharmacy, and its concept revolves around identifying, solving and preventing drug-related problems (DRPs) with regards to a patient's drug therapy [31]. Although this area has significantly contributed to new approaches in pharmacy education, several 'driving forces' that will impact the value of pharmacists have been identified [30]. These include: (a) improved care and protection for patients, especially the chronically ill or those with particular types of diseases (e.g. acquired immune deficiency syndrome or AIDS); (b) training new pharmacy professionals to be more patient orientated; and (c) the need for advanced pharmaceutical expertise and new skills to keep up with accelerated information technology so as to be able to manage new treatments.

Pharmaco-cybernetics is an upcoming area of pharmacy which involves advanced skills and expertise to deal with HCI concepts and technologies in relation to medicines and drugs. The term 'pharmaco' is derived from the Greek term 'pharmakon' meaning drugs or poisons [32], and 'cybernetics' comes from the Greek term 'kubernetes', which can be translated to mean 'the art of steering' [33,34]. Originally defined by Norbert Wiener in his book of the same title, he defined 'cybernetics' as the science or study of 'control and communication in the animal and the machine' [33-35]. Aptly described by the American Society for Cybernetics (ASC) as the design, discovery and application of principles of regulation and communication [35], this is a multi-disciplinary area which has been applied to many fields such as system theory, psychology, anthropology, sociology, and more recently, biology, engineering and computer science [34]. The single characteristic that defines a cybernetic system is the relationship between endogenous goals and the external environment [36]. In fact, this was not a new concept in healthcare, and was already applied in the 1970s by Maltz as a means of setting goals of positive outcomes for his patients who were not satisfied by their plastic surgery procedures [37]. However, the traditional concept of cybernetics has evolved into a modern theory known as 'new cybernetics' or 'second-order cybernetics', in which information is viewed as construct and reconstructed by individuals interacting with the environment [38,39]. This means that the system is not only dependent on the observer or person interacting with it, but it also links the individual with the society as a whole.

The science of cybernetics has further led to the term 'cyberspace' being coined by Gibson in his famous book Neuromancer, which identified a virtual representation of information in varying states of accessibility, linked to various people and organizations [40-42]. A similar concept was brought up in the movie 'The Matrix' and its sequels in which Neo, a computer programmer, who lived in a future world perceived by humans as reality, was actually a simulated matrix created by sentient machines to subdue the human race [43]. This term is now ubiquitously used to describe anything which is associated with computers, information technology, and the internet. It also incorporates the elements of social experiences and interaction of individuals through the exchange of ideas and the sharing of information [44].

Thus, 'pharmaco-cybernetics' or 'pharma-cybernetics' aptly describes the science of dealing with medicines or drugs through applications of HCI concepts and technologies so as to reduce or prevent DRPs, and ultimately, improve pharmaceutical care in patients. It involves communication and feedback with the users, and connects control (i.e. actions taken in the hope of achieving goals) with communication (i.e. the flow of drug information and knowledge between the user and the cybernetic system or environment).

In this paper, we attempt to introduce the concept of 'pharmaco-cybernetics' through the creation of a simple interactive tool aimed at improving the knowledge of users on anticoagulation therapy. In particular, two prototype games which are targeted at students in the pharmaceutical sciences and patients on warfarin therapy will be discussed. Ten web animation principles [45], as well as user- (UCD), experience- (ECD) and activity-centered design (ACD) approaches which can be considered in the designing of pharmaco-cybenetic systems will also be elaborated through a critique of the tool based on a pilot usability survey that was done. Due to space constraints, only important concepts related to the design frameworks will be discussed. The reader is referred to **Appendices 1, 2** and **3** for more detailed application summaries.

2. Creation and Evaluation of WarfarINT

The WarfarINT interactive tool was created as an information resource for patients, students and the general public who are interested in learning about anticoagulation therapy. WarfarINT stands for '*Warfarin INTerative*', and consists of 2 games (**Fig. 1**) which provides the interactive component for users.

The first is a pill-catching game in which users have to catch different colored warfarin tablets dropping from the top of the screen by moving a pill bag with their mouse in a horizontal direction. Their scores are correlated with the strength of the tablets that are caught, which in turn are reflected by the different colors. The second is a hangman game in which users are supposed to guess a drug, food or herb that interacts with warfarin. The objectives of this tool are to enable users to correlate the tablet colors with their strengths, as well as know the drugs, herbs or foods that interact with warfarin in an interesting manner.

Fig. 1 Screenshots of the interaction tool which consists of 2 games: (a) Warfarin Game, and (b) Warfarin Hangman.

A pilot usability study was also carried out on a group of pharmaceutical science students at a local educational institution to evaluate how well the interactive tool helped in improving their knowledge of the anticoagulant drug. Participants were given 15 minutes to answer a questionnaire which consisted of questions categorized into 3 parts: (a) user demographics, (b) general knowledge and views on anticoagulation therapy and online interaction tools, and (c) feedback and experiences on using the interactive tool (warfarin games). A fifth of the time (3 minutes) was dedicated to playing the games. The results were then evaluated based on descriptive statistics and participants' responses.

A total of 25 participants were recruited in the study, with a response rate of 92%. Two responses were excluded from analysis due to incomplete submissions. The mean age of the respondents was 19.7+/-0.8 years, and majority were females (87%). All respondents had previously heard of warfarin before participating in the study, but did not know about its tablet strengths and interactions.

3. Human-Computer Interaction Frameworks in Pharmaco-Cybernetics

3.1 The User-Centered Design (UCD) Approach

User-centered design (UCD) is a broad term used to describe design processes in which end-users play a role in influencing how a product's design takes shape. Users are placed at the center of the design process throughout the planning, creation and development phases of the product. The concepts of visibility, mapping and feedback play crucial roles in the UCD approach [46].

The principle of visibility states that the user should be able to figure out the use of a product based on the visibility of its components. In other words, the product's parts or components should convey a correct message regarding its usage [46]. This can be correlated to the animation principles proposed by Weir and Heeps (**Appendix 1**) [45].

The product, in this case is the tool consisting of the games, should not distract users' attention from salient information, but rather, convey its intended message across. Users should be drawn to the essential features of the animation so that they can focus on the relevant aspects. The graphical user interfaces (GUIs) of the tool (**Fig. 2**) are located in the middle of the webpages so that the user's attention will be focused on the games. The white backgrounds of the webpages are meant as contrasts to the background of the games, and the titles of the games are kept simple and self-explanatory so that first-time users would know what to expect of the tool.

Fig. 2 Graphical user interfaces of the (a) warfarin pill-catching and (b) hangman games.

In addition, visibility was demonstrated in the games through short and concise instructions to users on what the games entail and how to play:

"Collect as many warfarin tablets as you can! Move your mouse to shift the pill bag left and right. Each tablet color awards you points equivalent to its strength." – Instructions of the pill-catching game.

"Choose a letter by clicking on it… The letter changes to green if your guess is correct, and red if your guess is wrong." – Instructions of the hangman game.

The use of 'backup' text to provide additional details can help users understand the rationale of the animation better provided it is used sparingly. Animations combined with text and sound can reduce the likelihood of an ambiguity in interpretation by the user. However, when used inappropriately, it may cause distractions and cognitive overloads.

Besides textual information, sounds can also support ambiguity and provide feedback to the users regarding certain results. However, it should only be used to enhance the purpose of the animation. When used inappropriately, sounds can confuse the user instead of enhancing their information-retrieval experience. In the pill-catching game, users would hear a 'boing' when they manage to catch a tablet, but if they miss, a 'splash' would be heard instead. This enables the users to discriminate between a score and a miss, which would be important since the users would strive to hear more 'boings' than 'splashes' to gain higher scores.

The use of appropriate colors and adherence to color conventions are also important for visibility of the product. Like sounds, irrelevant color differences can also distract and mislead users of the product. Colors are more than just a cosmetic effect. They do not only help convey messages to users, but also affect the users' perceptions of depth and space. The colors of the animated tablets follow the actual color convention of warfarin tablets in reality with regards to their tablet strengths. A 3D aspect is also achieved in the hangman animation through the use of different colors. A brown surface with red diagonal lines gives the ground a horizontal effect, and the pole and stool seem to be situated on the ground. The background is green to distinguish it from the other objects in the animation, and to give a sense of calm to the user playing the game, since green is often associated with safety (e.g. traffic lights) or nature (e.g. trees).

Humans have limited visual processing capability. When faced with a visually cluttered display, users tend to ignore some components in their perceptual field, and this often impedes the delivery of the intended message. To avoid clutter of our online tool, the animation screens are centralized in the middle of the webpages (**Fig. 2**). In the pill-catching game, the title, instructions, and scores, are placed on the top left and right corners respectively. The button to start and restart the game, indicated by 'Play Again', is placed below the 'Game Over' message so that users can click on it to play the game. Similarly, the title and instructions of the hangman game occupy the top half of the screen, and the animation of the hangman is located just beside the words that users are supposed to guess, so that they know how many wrong guesses they have made. Clutter is also minimized as users are allowed to expand or collapse the categories of drug interactions as appropriate.

Mapping [46], the second principle of UCD, describes the link between one's intended actions (what one wants to do) to actual operations (what appears to be possible). In animated products, it is crucial for the designer to appreciate the insight of semiotics. Users will be able to play the games if the games can be mapped to processes or objects that are known or familiar to them. The target audiences of the games are pharmacy/ pharmaceutical science students and patients on warfarin therapy, who are expected to be familiar with the drug. Furthermore, users can guess the interactions based on their previous experience of knowing how to play the hangman game.

Proper positioning and organization of objects in the games can help users understand how to play the games. The tool uses natural mapping of the left-right clicks on the mouse controls that are familiar to users. This leads to an immediate understanding of how to use these controls to play the games. Incorporating these controls in the games allows for easier manipulations of the various animated components such as moving the pill-bag to catch the dropping warfarin tablets, and selecting the alphabets of the interacting drug. Gestalt's law of proximity which states that 'related items should be placed closer together than non-related items' also applies here. Similarly, information deemed to be of greater importance should appear in positions of greater importance on the screen from the user's perspective. Related items in the games are grouped together in time, space and shape, such as with the warfarin tablets dropping in a vertical direction while the pill bag moves in the opposite horizontal direction; and the hangman animation being grouped side-by-side with the word of the interacting drug. Users who play the games will then be able to better remember the warfarin interactions, as well as the tablet strengths.

For animations, the duration of exposure to users also affects their ability to interpret and understand the information about the product. Too short an exposure time will leave the viewer confused, but too long a time can lead to boredom and fatigue. Both games provide an adequate amount of exposure time to users – the pill-catching game lasts less than a minute so that users do not get bored, yet have enough time to learn and correlate the tablets' colors with their strengths; while users are given an option to end the hangman game in the middle of gameplay or if they give up guessing the word, or else, frustration will result and lead to the user not wanting to play the game again. Generally, if the correct amount of information exposure cannot be determined, the common rule of 'too-much is better than too-little' can be applied.

A principle that deserves special mention in this paper is that of complying with the Co-operative Maxims. Based originally on Grice's Coorperative Principle, Weir and Heeps have defined them with regards to animation in terms of (a) quality (the animator tells/ portrays the truth), (b) quantity (the intended message is adequately conveyed without use of excess animation), (c) relation (the animations are organized in a meaningful order), and (d) manner (the animations are clear and natural, avoiding ambiguity and disorder). The warfarin tool follows these principles in the form of simple instructions and information that is easily understood by the layman, with the exception of drug names which cannot be simplified, so as to avoid misinterpretation and ambiguity. Similarly, these principles can and should be applied in any tool/ product that are designed for the purpose of providing drug information. The explanations of these 'Four Pharmaco-cybernetic Maxims' are provided in **Table 1**.

Table 1: The 'Four Pharmaco-cybernetic Maxims' for designing pharmacy and/or pharmaceutical science tools.

Design principle	Explanation of principle with regards to pharmacy and/or pharmaceutical sciences
Quality	Drug information content provided by the informatics or

	internet tool(s) should be accurate and follow appropriate resources for evidence-based therapies (e.g. research articles, established databases or product information).
Quantity	Adequate information about the drug or drug therapy is provided so that users of the tool know enough to minimize the likelihood of drug-related problems (e.g. underdose, overdose, drug interactions).
Relation	Drug information provided by the tool(s) is/are relevant to what the target audience needs to know, and should clarify their doubts instead of making them more confused.
Manner	Drug information provided by the tool(s) is/are conveyed clearly in an appropriate manner which avoids ambiguity and misinterpretation (e.g. layman language for the patient and medical jargon for healthcare professionals).

In UCD of products, feedback is largely a crucial component as it reflects to the user about what action has been done and what result is achieved [46]. Feedback is accomplished in the warfarin tool as the user seeing the pill bag move in response to his mouse movements, and parts of the hangman animation or the letters appearing as part of the word when he selects wrong or correct alphabets respectively.

Feedback in animated tools should also follow the traditional features developed by Walt Disney Studios, which aims to make animations as realistic and entertaining as possible. The 'Squash and Stretch' and 'Timing and Motion' aspects are most commonly accepted by the public. The former defines an object's rigidity and mass by distorting its shape during an action, and the latter follows the natural motion of an object such as acceleration and deceleration, moving in curved paths, or experiencing color and texture changes. Potentially 'unreal' aspects of an animated object's behavior could hinder users from interpreting the correct message. 'Squash and Stretch' in the games (**Fig. 3**) is demonstrated by the distorting/ shrinking of the pill bag when the user catches the tablet and the rope becoming taut when the hangman is no longer supported by the stool. On the other hand, 'Timing and Motion' is seen through the acceleration of the dropping tablets and the hangman and his feet dropping lower when the stool topples. These give users the perceptions of gravity and friction in the animations, which translates a sense of virtual reality when playing the games.

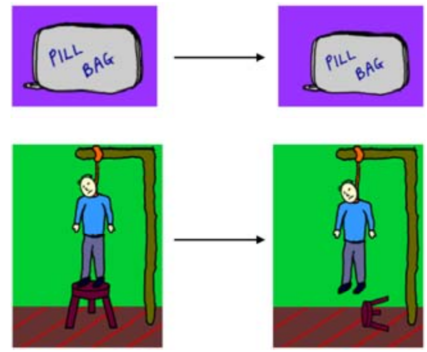

Fig. 3 'Squash and Stretch' aspect in the pill-catching game, and 'Timing and Motion' aspect in the hangman game.

Users are a central part of the UCD developmental process. Although UCD is about engineering usability, it fails to take into account other important elements such as environmental and socio-cultural factors. In the creation of the interactive tool, it was assumed that all users would be familiar with the mouse even though some users might be more familiar and comfortable playing the games with the keyboard instead. The games also did not take into account the varying educational levels, or the settings and/or situations in which potential users would be using this online interactive tool. This is a condition known as 'design myopia' which is characterized by the short-sightedness of the designer. To the designer, the product may appear suitable, even ideal. Yet, to the common layman, the same product may seem unobvious and obscure. This can result in an 'adverse outcome' of breaking the user's focus in the games and hindering his learning potential. One approach to solving this problem is to seek 'fresh eyes' on the product through means of user-testing to ensure that a suitable product is produced for the intended purpose, and is also efficient and effective during its development [47]. In this case, the pilot study was to minimize possible misinterpretations and potential problems before the product is released on a larger scale to patients and pharmacy undergraduate students.

The results showed that although 75-85% of the respondents deemed the instructions of the games to be clear, one respondent actually commented to "*Give some instructions on playing the games*" as a free-response feedback. This situation could not have been predicted or detected if a usability study had not been carried out on the games. The participants in our pilot study had different requirements and experiences with the games, and this proved to be one of the major limitations of UCD which can be accounted for by experience-centered (ECD) and activity-centered designs (ACD), discussed in later sections. Thus, there is a need to involve potential users in the environment in which the interactive tool would be used so as to increase its effectiveness, and consequently, its acceptance and success.

3.2 The Experience-Centered Design (ECD) Approach

Norman's principles on emotional design stem from our varied responses towards everyday things. The variables that deliver a positive emotional experience vary greatly with the appearance or functioning of a tool [48], and can be matched with the visceral, behavioral and reflective levels of design [49].

At the visceral level, the physical features of a product (e.g. look, feel, sound) dominate over an otherwise usable but plain looking product [49]. The current designs of the warfarin tool are meant to pique the users' interest in playing the games. However, from our results, 10-20% of the respondents rated the visual appeal as 'fair' even though majority (45-70%) rated it 'good' to 'excellent'. This suggests that both games could be improved with more aesthetically pleasing designs so as to give users a thrill during gameplay which will enhance their overall experience [49].

The behavioral level sees functionality as being paramount [49]. The pill-catching game affords function and usability through the user's mouse movements as an 'instinctive' extension of his hand to move the pill bag to catch the dropping tablets; while the hangman game does this by leveraging on the user's prior experience of playing the 'pen-and-paper' version. Feedback is present through real-time score updates in the pill-catching game, and the various stages of hanging in the hangman game. However, the underlying objectives of the games are not explicitly made known to the user. Users may find it difficult to keep track of their scores while simultaneously trying to relate it to the strengths of the tablets. Similarly, users who do not know any warfarin interactions would not find the game useful. To further improve on the behavioral aspects, immediate feedback on the scores and the tablet strengths can be expressed through a storyline, such as a better health-related outcome of a virtual patient, and increasing the sizes and color intensities of the tablets with higher strengths. Providing the interaction effects of the drug, herb or food will also allow the user to understand the need of knowing the drug interactions.

The reflective level [49] is related to the 'emotional thread of experience' by McCarthy and Wright which describes personal meaning derived from use of a product [50]. Sixty-five percent of the survey respondents thought that the interactive tool did help them learn about warfarin, even though it took a while for the learning to be assimilated. The factors that could probably keep them motivated in playing the games are the high scores in the pill-catching game, since they indicate the user's level of accomplishment, and he is motivated to better his scores and learn about the tablet strengths; and the congratulatory message indicating "*[the hangman] is alive!*" when the user guesses the word correctly. This gives meaning and satisfaction to the user when he saves the hangman. However, if he loses, words of encouragement "*Don't give up!*" appear to motivate him to play another round.

The 'sensual thread' describes the involvement of the human senses in shaping an experience [50]. Both games currently focus on sight and utilize the user's experience of moving and clicking the mouse to play. Sound effects which provide feedback when the user catches ('boing') or misses ('splash') a tablet cater to his sense of hearing. However, the user plays the hangman game in silence. Short midi, wav or mp3 files to indicate a win or loss in the game can further enhance the user's experience in this case. Mounting the games on other platforms such as personal digital assistants (PDAs) or iPhones can also provide touch-alternatives and a completely different experience to mouse-clicking.

The 'compositional thread' describes how one frames the many parts that make up one's whole experience [50]. According to this principle, the games should be considered in relation to the rest of the WarfarINT website. A common feedback from the survey was the lack of adequate information about the drug. Although this could be due to the limited time given in the pilot study to explore the rest of the website, this was seen as a 'breakdown' by the respondents as the games seemed to be relatively disjointed from the rest of the website. Questions such as "*how do these things go together*" and "*I wonder what will happen if [action occurs]*" could not have been answered by the users. Thus, an improvement would be to include the warfarin dosing information on the same page as the pill-catching game instead of a separate page, as is the current case. Another suggestion from the respondents was to "*show image[s] of the food interaction with the correct word*" in the hangman game for a more positive and added visceral feel to the experience.

The 'spatio-temporal' thread describes one entering a state of 'flow' as he becomes engrossed in his experience [50]. Both games managed to keep the respondents engrossed in gameplay, with 55% and 70% of the respondents indicating that their levels of concentration increased during continuous gameplay of the pill-catching and hangman games respectively. However, some comments from the respondents also suggested to "*make the pill catching game more interesting.*" This can be done by splitting the game into varying difficulty levels and an animated storyline, for example, a virtual patient whose blood vessels become less blocked due to the blood-thinning effect of warfarin, resulting in the patient improving from his medical condition. On the other hand, only users who have adequate drug vocabulary knowledge of the warfarin interactions (e.g. pharmacy or medical students) are immersed in a state of flow when playing the hangman game. Patients who might not be as well-versed in the interactions might suffer from a 'disruption of flow' due to frustration of not getting the correct word. Hints can be provided in this case to ease the current steep learning curve of the game.

The designing of interactive systems require an understanding of how a person experiences the product from an interaction-centered viewpoint [51]. Cognitive user-product interactions require users to focus on the product at hand, thus users of both games have to learn what their actions will lead to during gameplay. It was suggested in the survey that the warfarin tablets drop too quickly in the pill-catching game, and that users could not keep track on their scores without comprising their gameplay. Increasing tablet sizes and/or color intensities can improve the cognitive interaction as users will find it easier to relate the animated tablets to their strengths, since bigger and more intensely-colored tablets would be worth more points. Furthermore, the games currently do not account for the fact that users will gain competence over time and probably stop playing. To improve users' scalability of experience, splitting the games into varying difficulty levels will continually challenge users and provide a different experience each time they play the games. Additional features to allow for customization of the backgrounds and interfaces to suit users' preferences, or mounting the games on a variety of platforms like PDAs, mobile phones, and social networking sites (e.g. Facebook or MySpace) will not only facilitate expressive interactions and co-experience, but also reinforce the reflective and emotional threads of users' overall experiences.

3.3 The Activity-Centered Design (ACD) Approach

The ECD approach gives designers an insight to users' experiences of the interaction tool. However, it does not explain how the activity of playing these games affects the user. Activity Theory (AT) describes a framework for understanding how people operate in the world, taking 'activity' rather than 'person' or 'mind' as the central unit of analysis [52-54]. Several other interpretations of AT exist, but we will discuss the online tool based on the principles described by Kaptelinin (**Appendix 2**) [53].

The principle on unity of consciousness and activity states that the human mind (consciousness) is inseparable from his interaction with the environment (activity) [52,53]. Users of the online tool know that the tablet colors in the pill-catching game are related to their strengths, and the objective of the hangman game is to learn about the warfarin drug interactions. However, they may not see the relevance of knowing the strengths and interactions. Thus, providing a form of text or storyline would help make users aware of the consequences of DRPs such as under- and overdosing, and the severity of a drug interaction with warfarin.

Object-orientedness, in this case, is to educate users on the warfarin tablet strengths and drug interactions. In a broad sense, the object in this principle need not be related to physical objects, but includes socially/ culturally defined properties as well [52,54]. Although the tool fulfils its objectives, the significance of the activity itself can be enhanced through making explicit to the user why it is important to know about the tablet strengths and the consequences of the drug interactions.

The hierarchical structure of activity is associated with a tri-level scheme describing activities, actions and operations which are oriented towards the goals and motive of the whole activity [52-54]. This hierarchy differs in patients and students playing the games. Students would want to know the tablet strengths and drug interactions to better prepare for exams, instead of improving their health. Based on Leontiev's principles [52], the relationship between higher and lower objectives of a patient who undergoes anticoagulant therapy and uses the online tool is illustrated by **Fig. 4**. The smooth transition of conscious actions to subconscious operations when playing the games orients the user towards the objectives of learning about warfarin. A breakdown, however, will disrupt the user's game playing activity, and may lead to disorientation of the user or even frustration. An example would be the shift in alphabet locations when the browser is resized, resulting in the user trying to find out where to click the alphabets.

The concept of internalization-externalization states that our mental processes are derived from external actions through the course of internalization, and is related to the socio-cultural environment [52-54]. There is currently no means of knowing whether the user has assimilated the learning objectives of the games. Feedback mechanisms such as short quizzes on simple warfarin interactions or doses of different colored tablet combinations can be incorporated so that the user is able to 'internalize' the knowledge he has gained from the tool and 'externalize' this knowledge by correctly answering the questions.

The principle of tool mediation is the most significant concept in AT, and it describes how a tool reflects the accumulation and transmission of social knowledge, and experiences of others who have tried to solve similar problems before to make the tool more efficient [52-54]. Improvements of the 'tools' in the games would also improve the users' cognitive skills and knowledge on warfarin. For example, a pill-box, cupped hand or a mouth to simulate catching the warfarin tablets would better mediate the process of how a patient takes the medication in reality. Similarly, an animated form of the traditional 'pen-and-paper' hangman can probably provide a more familiar and fun way of learning the warfarin drug interactions.

Lastly, the principle of development is used to understand how tools are developed into their existing form [52-54]. The underlying concepts of why the games were developed have been explained throughout the various sections of this paper, but it can also be used to further develop and improve the games. Voice reporting of the user's score status can improve his gameplay so that he does not need to simultaneously focus on the rapidly changing scores and correlating the strengths of the different colored tablets. Similarly, having different difficulty levels in the hangman game can also ease the user's learning curve.

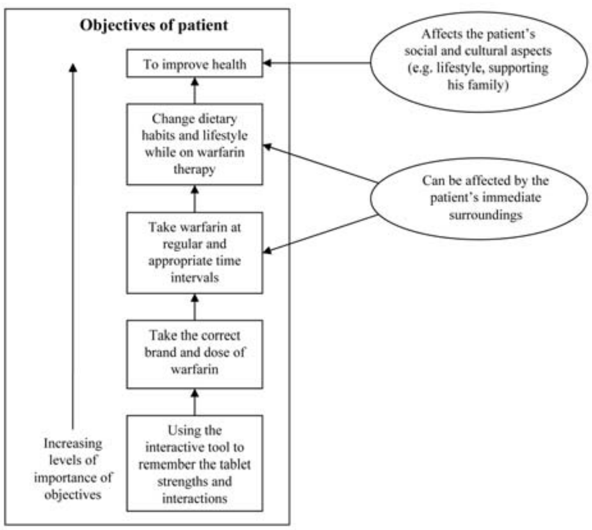

Fig. 4 Hierarchy of objectives of a patient on anticoagulant therapy, and how they are affected by socio-cultural factors.

3.4 Pharmaco-Cybernetics from an Ecological Perspective

The Ecological Systems Theory by Urie Bronfenbrenner describes how users interact with their immediate environments (micro, meso, exo, macro, chrono), and how these environments affect the user in a wider context [55]. From a pharmaco-cybernetics perspective, this theory can be applied in the context of users learning about anticoagulant therapy from the interaction tool (**Appendix 3**). The bi-directional influences of each individual system on the others can help identify possible avenues for improvement, as well as the pitfalls and disturbances in the activity of using the tool. This warfarin tool also allows the possibility of creating other larger-scale and more complex interactive tools that will not only encompass the magnitude of influences across the various environments, but also reduce DRPs by empowering patients with the appropriate drug knowledge so that they can better participate in their therapies and management strategies with their healthcare professionals, and ultimately improve their health.

4. Conclusion

Developers of healthcare interactive tools often overlook relevant user characteristics, tasks, preferences and usability issues, thus resulting in systems or tools that decrease productivity or simply remain unusable [56]. Medical tools need to be robust and easy to use in a wide variety of environments [57]. Thus, healthcare applications must be carefully crafted to ensure that they meet the standards and models outlined by their target users.

The integration of interactive media and informatics technologies with the WWW has enabled computational tools to play an important role in pharma-culture. In this paper, the concept of 'pharmaco-cybernetics' is introduced through the creation of an interactive tool on oral anticoagulation therapy. Interactivity was developed in the form of two games for users to learn about warfarin tablet strengths and drug interactions. Currently, this tool is largely based on the principles of UCD and ECD. However, the potential of incorporating the ACD approach in the designing of this tool is definitely attractive, and can lead to better quality healthcare tools for other chronic medication therapies. Prototype sketches of how the games can be improved in future versions are provided in **Fig. 5**. It is hoped that these improved versions will not only cater towards enhancing the user's experience, but also his interactions with the tool.

In conclusion, pharmaco-cybernetics can empower patients with the appropriate knowledge regarding their therapy so that they can better participate in the management of their health. This can potentially help them to adapt to any changes in their dietary habits and lifestyles, as well as improve compliance, and ultimately, improve the pharmaceutical care of patients who are on anticoagulant therapy. Healthcare providers, patients and developers of health information systems should realize the importance and know the concepts and related principles when designing for pharmaco-cybernetics applications. However, understanding how users structure their individual experiences, immediate environments, and tasks is just the beginning when designing such products. Designers should also take into account how external forces such as socio-cultural and inter-personal factors shape a user's overall experience, attitude and goals in using the applications, and through an ecological perspective so as to cater the interactive tools for a wider audience; as well as how they can be applied to the designing of other pharmaco-cybernetics products involving medication therapies.

(a) (b)

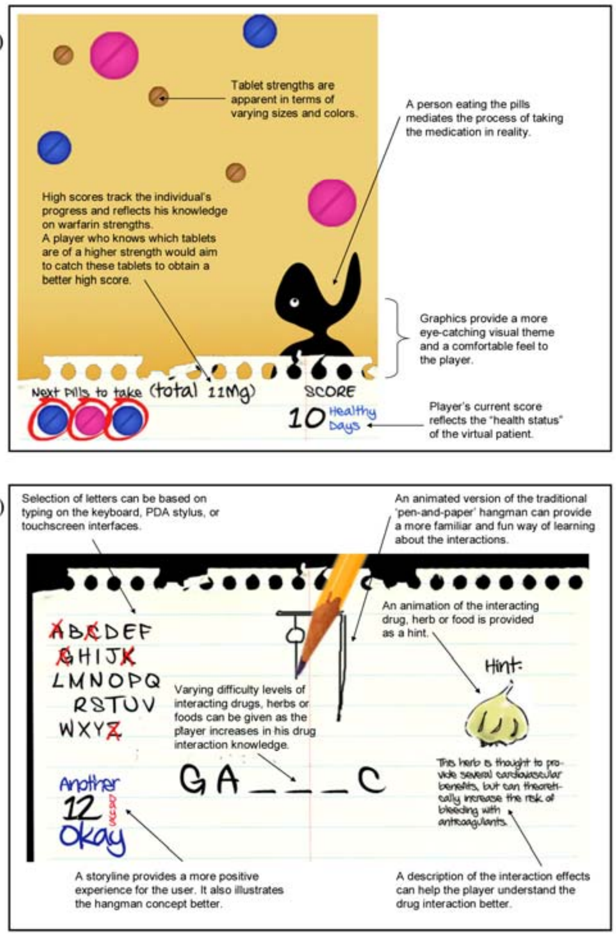

Fig. 5 Prototype sketches of improved versions of the interactive tool consisting of (a) the warfarin pill-catching game and (b) the warfarin hangman game.

Acknowledgments

The authors would like to thank Asst. Prof. Timothy Marsh, lecturer for the NM5206 module, and Ms. Cecilia Chua from the Republic Polytechnic, Singapore, for their support for the *WarfarINT* tool and contributing to the success of this article.

References

[1] L. H. Lee, M. C. Kong, Y. M. Wong, *et al.*, **Clinical Pharmacy Practice Guidelines. Anticoagulation - Warfarin,** March 2006 ed., Singapore: Ministry of Health, Singapore, 2006.

[2] American Society of Hospital Pharmacists, "ASHP statement on pharmaceutical care", **American Journal of Hospital Pharmacy,** Vol. 50, 1993, pp. 1720-1723.

[3] E. H. Shortliffe, and A. M. Garber, "Training synergies between medical informatics and health services research", **Journal of the American Medical Informatics Association,** Vol. 9, No. 2, 2002, pp. 133-139.

[4] D. R. Masys, P. F. Brennan, J. G. Ozbolt, *et al.*, "Are medical informatics and nursing informatics distinct disciplines? The 1999 ACMI debate", **Journal of the American Medical Informatics Association,** Vol. 7, No. 3, 2000, pp. 304-312.

[5] H. J. Lowe, E. C. Lomax, and S. E. Polonkey, "The World Wide Web: a review of an emerging internet-based technology for the distribution of biomedical information", **Journal of the American Medical Informatics Association,** Vol. 3, No. 1, 1996, pp. 1-14.

[6] S. Nettleton, "The emergence of e-scaped medicine?", **Sociology,** Vol. 38, No. 4, 2004, pp. 661-679.

[7] G. Collste, "The internet doctor and medical ethics: ethical implications of the introduction of the internet into medical encounters", **Medicine, Health Care, and Philosophy,** Vol. 5, No. 2, 2002, pp. 121-125.

[8] B. Chung, C. E. Corbett, B. Boulet, *et al.*, "Talking Wellness: a description of a community-academic partnered project to engage an African-American community around depression through the use of poetry, film, and photography", **Ethnicity and Disease,** Vol. 16, No. 1 Suppl 1, 2006, pp. S67-S78.

[9] U. Ritterfeld, and S. A. Jin, "Addressing media stigma for people experiencing mental illness using an entertainment-education strategy", **Journal of Health Psychology,** Vol. 11, No. 2, 2006, pp. 247-267.

[10] D. Cantor, "Uncertain enthusiasm: the American Cancer Society, public education, and the problems of the movie, 1921-1960", **Bulletin of the History of Medicine,** Vol. 81, No. 1, 2007, pp. 39-69.

[11] S. E. Lederer, "Dark victory: cancer and popular Hollywood film", **Bulletin of the History of Medicine,** Vol. 81, No. 1, 2007, pp. 94-115.

[12] K. L. Taylor, J. L. Davis 3rd, R. O. Turner, *et al.*, "Educating African American men about the prostate cancer screening dilemma: a randomized intervention", **Cancer Epidemiology, Biomarkers and Prevention,** Vol. 15, No. 11, 2006, pp. 2179-2188.

[13] G. Wallmyr, and C. Welin, "Young people, pornography, and sexuality: sources and attitudes", **Journal of School Nursing,** Vol. 22, No. 5, 2006, pp. 290-295.

[14] C. Jackson, J. D. Brown, and K. L. L'Engle, "R-rated movies, bedroom televisions, and initiation of smoking by white and black adolescents", **Archives of Pediatrics and Adolescent Medicine,** Vol. 161, No. 3, 2007, pp. 260-268.

[15] J. D. Sargent, "Smoking in movies: impact on adolescent smoking", **Adolescent Medicine Clinics,** Vol. 16, No. 2, 2005, pp. 345-370.

[16] Jean-Guilhem, "World Wide Web Consortium (W3C)"; http://www.w3.org/ [accessed 3 July 2009].

[17] Internet Society (ISOC), "The Internet Engineering Task Force (IETF)"; http://www.ietf.org/ [accessed 3 July 2009].

[18] J. Liaskos, and M. Diomidus, "Multimedia technologies in education", **Studies in Health Technology and Informatics,** Vol. 65, 2002, pp. 359-372.

[19] G. G. Moghaddam, and M. Moballeghi, "Human-computer interaction: guidelines for web animation", **East/West Interaction : An Online English Chinese Journal**, 2006; http://eprints.rclis.org/archive/00007823/ [accessed 3 July 2009].

[20] R. E. Weiss, D. S. Knowlton, and G. R. Morrison, “Principles for using animation in computer-based instruction: theoretical heuristics for effective design”, **Computers in Human Behavior,** Vol. 18, No. 4, 2002, pp. 465-477.
[21] A. Demirjian, and B. David, “Learning medical and dental sciences through interactive multi-media”, **Medinfo,** Vol. 8 Pt 2, 1995, p. 1705.
[22] R. W. Pho, S. Y. Lim, and B. P. Pereira, “Computer applications in orthopaedics”, **Annals of the Academy of Medicine Singapore,** Vol. 19, No. 5, 1990, pp. 691-698.
[23] K. Penska, L. Folio, and R. Bunger, “Medical applications of digital image morphing”, **Journal of Digital Imaging,** Vol. 20, No. 3, 2007, pp. 279-283.
[24] D. M. Smith, S. J. Aston, C. B. Cutting, *et al.*, “Applications of virtual reality in aesthetic surgery”, **Plastic and Reconstructive Surgery,** Vol. 116, No. 3, 2005, pp. 898-904.
[25] D. M. Smith, S. J. Aston, C. B. Cutting, *et al.*, “Designing a virtual reality model for aesthetic surgery”, **Plastic and Reconstructive Surgery,** Vol. 116, No. 3, 2005, pp. 893-897.
[26] R. C. Ward, M. W. Yambert, R. J. Toedte, *et al.*, “Creating a human phantom for the virtual human program”, **Studies in Health Technology and Informatics,** Vol. 70, 2000, pp. 368-374.
[27] J. E. Champoux, “Animated films as a teaching resource”, **Journal of Management Education,** Vol. 25, No. 1, 2001, pp. 79-100.
[28] P. Piyasirivej, “Towards usability evaluation of Flash web sites”, in **World Forum Proceedings of the International Research Foundation for Development,** Tunis, Tunisia, 2005.
[29] Edheads + COSI, “Virtual Knee Surgery and Choose the Prosthetic games”; http://www.edheads.org/activities/knee/ [accessed 3 July 2009].
[30] H. Leufkens, Y. Hekster, and S. Hudson, “Scenario analysis of the future of clinical pharmacy”, **Pharmacy World and Science,** Vol. 19, No. 4, 1997, pp. 182-185.
[31] T. Westerlund, A. B. Almarsdóttir, and A. Melander, “Factors influencing the detection rate of drug-related problems in community pharmacy”, **Pharmacy World and Science,** Vol. 21, No. 6, 1999, pp. 245-250.
[32] T. L. Stedman, **Stedman's Medical Dictionary,** 28th ed., Baltimore, Maryland: Lippincott Williams & Wilkins, 2005.
[33] P. Pangaro, “"Getting started" guide to cybernetics”; http://pangaro.com/published/cyber-macmillan.html [accessed 3 July 2009].
[34] Wikipedia, “Cybernetics”; http://en.wikipedia.org/wiki/Cybernetics [accessed 3 July 2009].
[35] American Society for Cybernetics, “Foundations - the subject of cybernetics: defining 'cybernetics'”; http://www.asc-cybernetics.org/foundations/definitions.htm [accessed 3 July 2009].
[36] P. A. Corning, “Synergy, cybernetics, and the evolution of politics”, **International Political Science Review,** Vol. 17, No. 1, 1996, pp. 91-119.
[37] 'Psycho-cybernetics' Author, “Plastic surgeon tries to heal 'inner scars'”, Los Angeles TimesB5, 1973, pp. B5-1.
[38] Wikipedia, “New cybernetics”; http://en.wikipedia.org/wiki/New_cybernetics [accessed 3 July 2009].
[39] F. Geyer, “The challenge of sociocybernetics”, **Kybernetes: The International Journal of Systems & Cybernetics,** Vol. 24, No. 4, 1995, pp. 6-32.
[40] P. C. Adams, “Cyberspace and virtual places”, **Geographical Review,** Vol. 87, No. 2, 1997, pp. 155-171.
[41] R. Trappl, “The cybernetics and systems revival”, in **14th European Meeting on Cybernetics and Systems Research (EMCSR'98),** University of Vienna, Austrian Society for Cybernetic Studies, February 1998, p. Preface.
[42] W. Gibson, **Neuromancer (Special 20th Anniversary Edition),** Hardcover ed.: Ace Books, 2004.
[43] Wikipedia, “The Matrix”; http://en.wikipedia.org/wiki/Matrix_movie [accessed 3 July 2009].
[44] Wikipedia, “Cyberspace”; http://en.wikipedia.org/wiki/Cyberspace [accessed 3 July 2009].
[45] G. R. S. Weir, and S. Heeps, “Getting the message across: ten principles for web animation. ”; http://eprints.cdlr.strath.ac.uk/2513/ [accessed 3 July 2009].
[46] D. A. Norman, “The psychopathology of everyday things”, **The Design of Everyday Things**, pp. 1-33, USA: Perseus Publishing, 2002.
[47] J. Preece, Y. Rogers, and H. Sharp, **Interaction design: beyond human-computer interaction,** 1st ed., New York, NY: John Wiley & Sons Inc., 2002.
[48] D. A. Norman, “Emotion and design: attractive things work better”, **Interactions,** Vol. 9, No. 4, 2002, pp. 36-42.
[49] D. A. Norman, “Three levels of design: visceral, behavioral, and reflective”, **Emotional Design: Why We Love (or Hate) Everyday Things**, pp. 63-98, New York, NY: Basic Books, 2004.
[50] J. McCarthy, and P. Wright, “The threads of experience”, **Technology as Experience**, pp. 79-104, Cambridge, MA: MIT Press, 2004.
[51] J. Forlizzi, and K. Battarbee, “Understanding experience in interactive systems”, **Symposium on Designing Interactive Systems. Proceedings of the 5th Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques. DIS '04**, 2004, pp. 261-268; http://doi.acm.org/10.1145/1013115.1013152 [accessed 3 July 2009].
[52] V. Kaptelinin, K. Kuutti, and L. Bannon, “Activity theory: basic concepts and applications. A summary of a tutorial given at the east west HCI95 conference”, **Lecture Notes in Computer Science, Human-Computer Interaction,** Vol. 1015, 1995, pp. 189-201.
[53] V. Kaptelinin, “Activity theory: implications for human-computer interaction”, **Context and Consciousness: Activity Theory and Human-Computer Interaction,** B. A. Nardi, ed., pp. 103-116, Cambridge, MA: MIT Press, 1996.
[54] V. Kaptelinin, and B. A. Nardi, “Activity theory in a nutshell”, **Acting with Technology: Activity Theory and**

Interaction Design, pp. 29-72, Cambridge, MA: MIT Press, 2006.

[55] D. Paquette, and J. Ryan, “Bronfenbrenner’s Ecological Systems Theory”; http://pt3.nl.edu/paquetteryanwebquest.pdf [accessed 3 July 2009].

[56] C. M. Johnson, T. R. Johnson, and J. Zhang, “A user-centered framework for redesigning health care interfaces”, **Journal of Biomedical Informatics,** Vol. 38, No. 1, 2005, pp. 75-87.

[57] R. Gagnier, “User centered design of medical devices: managing use related hazards”, **Macadamian White Papers**, n.d.; http://www.macadamian-usability.com/resources/whitepapers/Maskery-designing_medical_devices.pdf [accessed 10 November 2008].

Kevin Y.-L. Yap *(B.Sc. in Pharmacy (Hons), M.Eng., Sp. Dip. Digital Media Creation)* is currently a Ph.D. candidate in the Department of Pharmacy, National University of Singapore, and a registered pharmacist in Singapore. He has worked as a pharmacist in the hospital and community settings, as well as an academic facilitator in the biomedical sciences, based on the problem-based learning pedagogy. His research interests lie in the application of informatics, digital media, interactive and web technologies in clinical pharmacy practice, particularly with regards to pharmaceutical care and the solving of drug-related problems; and he has presented in various international conferences and published several papers in this area. He is a member of the Pharmaceutical Society of Singapore, American Association for the Advancement of Science, and the Healthcare Information and Management Systems Society. He has also been featured in Marquis Who’s Who in Science and Engineering (10^{th} ed.), and in Medicine and Healthcare (7^{th} ed.).

Xuejin Chuang, Alvin J.M. Lee, Raemarie Z. Lee, Lijuan Lim and **Jeanette J. Lim** were undergraduates, while **R. Nimesha** and **Kevin Yap** were postgraduates in the National University of Singapore during the time in which the pilot usability study was carried out. The *WarfarINT* tool was originally designed and created by Kevin Yap. All authors were members of the project team in the module NM5206 Emerging Media Interaction Design offered by the Communications and New Media (CNM) Programme, Faculty of Arts and Social Science, in the first semester of the Academic Year 2008-2009.