Efficacy of web-based tailored health communication for behavioural modification in sun safety: A comparative study of tailored and response independent information delivery

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Efficacy of web-based tailored health communication for behavioural modification in sun safety: A comparative study of tailored and response independent information delivery

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Author:
Bellraj Eapen

Supervisor:
Dr. Ruta Valaitis

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AUTHOR: Bellraj Eapen

SUPERVISORS:
Dr. Ruta Valaitis
Dr. Ann McKibbon
Dr. Ken Deal
Dr. Colleen VanBerkel

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Abstract

Exposure to ultraviolet (UV) radiation is the single most important risk factor for skin cancers. The incidence and severity of skin cancers are on the rise in most parts of the world including Canada. Melanoma is the most aggressive form of skin cancer with a poor prognosis.

It is possible to calculate the approximate time required to develop sunburn based on the skin type of an individual and the UV index of the region of residence. A tool was constructed for this purpose using various web technologies such as PHP and JavaScript. The tool was named SUNBUC as an acronym for Sun Burn Calculator. There were two phases of the study: 1. Usability testing and 2. A controlled trial, which was designed to test the impact of the tool on the sun protection behaviour of the respondents over a period of 3 months. The null hypothesis was that tailored information and response independent information has a similar impact on sun safety behaviour as measured by the frequency of usage of sun protection methods such as sunscreen. Ethics board approval was obtained for the study.

The usability of the online survey and SUNBUC was tested on five respondents using the think-aloud method and evaluated using the System Usability Scale. The evaluation showed average usability and system modifications were made according to the findings of the think-aloud study.

The controlled trial design consisted of the control group with 48 respondents and intervention group with 53 respondents. Post intervention survey responses were obtained from 46(96%) and 48(91%) respondents belonging to the control and intervention groups respectively. Having implemented SUNBUC, findings showed no significant difference between the respondents who used the tool and the control group in short-term sun protection behaviour. However, many respondents felt that SUNBUC gave them a sense of control over their behaviour, a proximal determinant of the behaviour itself as per the Theory of Planned Behaviour.

Dedication

This is dedicated to all my patients who thought I could diagnose melanoma.

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Audrey for teaching me how to get this done in Canada.

And to all others who ever asked me: How is it going?......

Contents

List of Figures

List of Tables

List Of Acronyms

BIT - Behavioral Intervention Technology

CDSS - Clinical Decision Support System

CRM - Customer Relationship Management

EC - Environment Canada

HTML - HyperText Markup Language

MED - Minimum Erythemal Dose

mHealth - Mobile Health

NMSC - Non Melanoma Skin Cancers

PBC - Perceived Behaviour Control

PHP - PHP: Hypertext Preprocessor

phpESP - php Easy Survey Package

PMT - Protection Motivation Theory

SCAPE - Skin Cancer Awareness, Prevention and Education

SUNBUC - Sun Burn Calculator

SUS - System Usability Scale

TPB - Theory of Planned Behaviour

URL - Uniform Resource Locator

UV - Ultra Violet

UVA - Ultra Violet A

Chapter 1

Introduction

It is generally believed that ultraviolet (UV) radiation from the sun and other sources such as tanning beds is the major cause of skin cancer although the extent to which UV radiation contributes to cutaneous carcinogenesis is still uncertain (Iles et al., 2013). This relationship becomes even more complex as the various types of skin cancers such as melanomas and non-melanoma skin cancers are considered. However, a considerable proportion of skin cancers can be attributed to UV exposure, especially during childhood (Volkmer & Greinert, 2011).

The incidence of skin cancers is on the rise worldwide, and Canada is no exception. Though this can be partly attributed to improvements in skin cancer detection, climactic and behavioural changes may also be responsible. The depleting ozone layer has resulted in an increase in harmful UV radiation levels, reaching the surface of the earth escalating skin cancer incidence in countries such as Australia (Bornman et al., 2015).

The measurement of UV intensity is similar to the measurement of light intensity. The scientific measure of UV irradiance is usually given in units of watts per square meter or millijoules per cm2 (mJ/cm2). The UV spectrum reaching the surface of the earth has a range of wavelengths. The effects of UV radiation on human skin vary with their wavelengths. Certain wavelengths have higher potential to produce redness or burn the skin. Hence, a generic UV measurement is not sufficient clinically to recommend safe exposure time (Wang et al., 2014).

Canadian scientists proposed a new unit-less scale in 1992 to measure the sunburn potential of UV by weighting spectral intensity based on the potential to produce skin redness (Fioletov, Kerr, & Fergusson, 2010). The linear scale called the UV index was adjusted in such a way that a value of 10 representing roughly to midday summer sun with a clear sky in Toronto. The World Health Organization and World Meteorological Organization adopted the standardized UV index as a popular international scale for UV intensity measurement. The UV index varies from place to place and is also influenced by factors such as cloud cover, season and level of pollution. The UV index can be predicted for regions by using complicated computational models. The Weather Canada website provides daily UV index values for Canadian cities (*Canadian Daily UV Index Forecast - Environment Canada*, 2013).

The response of skin to UV irradiation also depends on intrinsic factors such as skin color and genetic predisposition. Fitzpatrick skin type is a classification scheme for the intrinsic sensitivity of skin to sunlight (Fitzpatrick, 1988). Fitzpatrick skin type can be estimated by questions related to sun exposure response.

Minimum Erythemal Dose (MED) is the minimum dose of UV irradiation required to produce visually perceptible erythema or sunburn (Sola & Lorente, 2015). MED depends on the Fitzpatrick skin type. If the Fitzpatrick skin type and the UV index for the region are known, the time required to develop a sunburn can be approximately calculated using a mathematical formula.

Various cognitive models provide theoretical frameworks for basing ehealth initiatives for health promotion that are aimed at behaviour change. One such popular model is the Theory of Planned Behaviour (TPB) (Ajzen, 1991). According to TPB, if a person is empowered with tailored information that makes it easy to introduce health promotion behaviour, the tailored information provided would have a positive impact on the intention to change and the change itself. This work is informed by the TPB by providing tailored sun safety information to the user.

In the next section, the aims and objectives of this study are explained followed by a review of literature. The review of literature is divided into 4 sections; The Sun, The Skin, Technology, and Human Behaviour. It is followed by a detailed description of the materials and methods used for this study and the results. Finally the results and their implications are discussed along with the conclusion.

Chapter 2

Aims and Objectives

The aim of the study was to examine the following primary research question:

How effective is web-based tailored delivery of sun safety information based on UV index of the region and the skin type of the individual, compared to response independent information, in improving short term behavioural modification and perceived behaviour control (PBC) related to sun safety in adult population in Canada?

Our hypothesis was:

Tailored information delivery has a larger positive impact on behaviour modification as measured by the frequency of usage of sun protection methods such as sunscreen and perceived behaviour control related to short-term sun exposure, compared to response independent information.

The study had the following additional secondary objectives:

- To understand usability issues in web-based eHealth interventions.
- To test the impact of tailored health information on the frequency of skin examination.
- To utilize software design methodologies in implementing a web-based eHealth tool.

- To explore the use of customer relationship management systems in eHealth research.
- To provide a novel eHealth tool for providing tailored sun safety information.

Chapter 3

Review of Literature

3.1 The Sun

The sun, worshipped as a God in some mythologies, has several beneficial effects on the skin such as vitamin D synthesis. However, the ultraviolet (UV) irradiation, a major component of solar spectrum can be detrimental to the skin. The measurement of UV irradiation and the recommended sun protection behaviour is reviewed below.

3.1.1 Ultraviolet (UV) radiation measurement and interpretations

Solar UV radiation is divided into three spectral regions based on the wavelength: UVA (between 400 to 320 nanometers); UVB (320 - 280nm); and UVC (280-100nm). The earth's atmosphere, especially the ozone layer, absorbs UVC that has shorter wavelength (Mitchell, 2006). UVB is considered to be the wavelength range most responsible for skin cancer risk. UVA is needed for vitamin D synthesis by the body (Kannan & Lim, 2013), but is responsible for premature ageing and darkening of the skin (Telang, 2013).

Two measurements are important for UV quantification: intensity or the strength of UV at a point in time and the dose or the total UV energy received over a period of time. The UV Index is a pragmatic and clinically important representation of UV intensity that was first defined by Environment Canada and has since been adopted by the World Meteorological Organization (Fioletov, Kerr, & Fergusson, 2010). The UV Index, in technical terms, is the integral of the UV power spectrum weighted according to erythemal action spectrum and then divided by 25 mW/m2 to generate a convenient index value. The UV index may range from 0 during night time to over 10 in the tropics.

The dose is generally quantified in terms of MED; it is the amount of UV irradiation required to produce a visually perceptible redness in previously unexposed skin within a 24 hours period (Sola & Lorente, 2015).

3.1.2 Sun Safety Messaging by Health Agencies

The Canadian and American cancer societies stress the importance of avoiding mid-day sun while the Australian Cancer Council insists on use of protective clothing. All societies agree on the need for adopting sun protective behaviour such as sunscreen, sunglasses and hats. The sun safety messaging by various health agencies is detailed below (Diao & Lee, 2013).

Canadian Cancer Society

- Avoid sun exposure between 11 am and 3 pm or when the UV index is more than 3.
- Find shade or take an umbrella.
- Use appropriate clothing (loose-fitting, tightly woven and light weight); wide -brimmed hat and a broad-spectrum sunscreen.
- Wear sunglasses.

- Avoid indoor tanning beds.

Australian Cancer Council

- Slip on sun-protection clothing.
- Slop on broad-spectrum, water-resistant sunscreen; 20 minutes before going outdoor; never use sunscreen to extend time in the sun.
- Slap on a hat.
- Seek shade.
- Slide on some sunglasses.

American Cancer Society

- Avoid direct sun exposure between 10 am and 4 pm.
- Seek shade.
- Follow the Slip! Slop! Slap! rules.
- Wrap-on sunglasses.
- Don't use sunscreen as a way to stay out in the sun longer.
- Sun protect even on cloudy or overcast days.
- Avoid other sources of UV light.

3.2 The Skin

The skin, which is the largest organ in the human body, has three layers: the epidermis, the dermis and the subcutaneous layer. The top layer of skin is the epidermis. The outer part of epidermis is composed of thin, flat squamous cells and the lower part comprises relatively round cells called basal cells. The colour of the skin is due to a pigment called melanin produced by yet another type of cells called melanocytes. Other cell types are less common (T. Burns, Breathnach, Cox, & Griffiths, 2010). In this section the various skin cancer types are discussed along with their risk factors and epidemiology. Various skin types are briefly mentioned. The section concludes with a discussion of the controversies related to melanoma research and skin cancer control.

3.2.1 Epidemiology of skin cancers worldwide

Four percent of all skin cancers worldwide are melanomas which are responsible for 80% of skin cancer deaths and 1%-2% of all cancer deaths. Estimates for 2012 recorded 230,000 new cases worldwide with an estimated 55,000 deaths. Higher rates of melanomas were noticed in Australia, New Zealand and North America compared to lower rates in Asia (Arnold et al., 2014).

3.2.2 Skin Cancer Types

Cellular proliferation and turnover are tightly regulated by various hormonal and genetic mechanisms (Medh & Thompson, 2000). A permanent failure of these regulatory factors of physiological cell turnover often leads to a malignancy or cancer.

Malignant melanoma (melanoma) is a type of malignancy that develops within melanocytes and is the deadliest form. Different types of melanomas exist such as superficial spreading type, lentigo maligna type, acral lentiginous type and the nodular type. The lentigo maligna type of malignant melanoma shows maximum association to sun exposure, but fortunately has the lowest mortality when compared to the other types.

The malignancies that arise in cell types other than melanoma are grouped together as non melanoma skin cancers (NMSC). The two common types of NMSC are Squamous Cell Carcinoma and Basal Cell Carcinoma developing from their respective cell types. Squamous Cell Carcinoma is generally more aggressive than Basal Cell Carcinoma. Several subtypes are within each category (T. Burns, Breathnach, Cox, & Griffiths, 2010; Leiter, Eigentler, & Garbe, 2014).

3.2.3 Risk Factors for Skin Cancer

Consensus exists on the involvement of UV radiation in skin cancer though controversies remain regarding the extent of its influence. Though sun is the main source of UV radiation, other non-solar sources of radiation such as tanning equipment and welding arcs also might play a role (Holly, Aston, Char, Kristiansen, & Ahn, 1990). Several factors including location, altitude, weather and the time of day and year also determine UV intensity (Chang et al., 2009). Certain treatment modalities such as psoralen UVA used to treat psoriasis also increases the risks for skin cancer though therapeutic benefits are present (Stern, 2001).

3.2.4 Epidemiology of skin cancer in Canada

With an estimated 6,500 new melanoma cases and 76,100 NMSC cases each year, skin cancers top the list of common cancers in Canada. There has been a significant increase in melanoma incidence between 1986 and 2010 with nearly 5500 Canadians diagnosed with melanoma in 2010 alone. The deaths from melanoma are estimated at 1050 and 440 deaths from NMSC in 2014 (Canadian Cancer Society, 2014). A limited number of provincial registries routinely collect data on NMSC as treatment of NMSC is sometimes performed without histological confirmation. Hence the Canadian statistics on NMSC may not be reliable and are underreporting the actual cases.

Melanoma is more common in men in Canada and an increasing trend has been noticed among men and women during the past 25 years. The two standardized rates routinely used for comparison of skin cancer are age-standardized incidence rate and age-standardized mortality rate . Age-standardized incidence rateis the number of new cases of cancer per 100,000 people, standardized to the age structure of the 1991 Canadian population. Age-standardized mortality rate is the number of cancer deaths per 100,000 people, standardized to the age structure. Age-standardized incidence rate increased an average of 2% and 1.5% for men and women respectively between 1986 and 2010. Age-standardized mortality rate during the same period increased 1.2% for men and 0.4% for women. Saskatchewan had the lowest melanoma incidence rate for men while women had the lowest incidence in Newfoundland. The incidence rate of melanoma rises exponentially with age (Canadian Cancer Society, 2014).

Despite skin cancer being one of the most preventable types of cancer, Canadian national statistics indicate that prevention efforts have had only limited success so far.

3.2.5 Economic Burden of skin cancer in Canada

The annual direct and indirect costs of skin cancers in Canada were estimated at $532 million out of which $443 million was the estimated cost for melanoma management. Projected economic burden of skin cancer in 2031 is estimated based on these data. It is estimated that the total economic burden of skin cancer in Canada will rise to $922 million annually by 2031 with melanoma accounting for close to $700 million. This projection takes into account both direct medical costs and indirect costs related to lost productivity (Krueger, Williams, Chomiak, & Trenaman, 2010).

3.2.6 Fitzpatrick Skin Types

The commonly used method for sun sensitivity self estimation is the Fitzpatrick's classification system based on the tendency to burn and tan (Fitzpatrick, 1988). Fitzpatrick skin types range from type I (fair) to VI (dark) with various shades in between (Fitzpatrick, 1988). Several other factors such as gender, age and perceived barriers to undertake sun protection also influence sun exposure behaviour (Berndt et al., 2011). If an objective measurement of sun sensitivity is needed for clinical studies, phototesting is performed (Falk, 2014). A recent study showed a poor correlation between self-reported and actual UV sensitivity and that low perceived risk leads to inadequate sun protection. If people have the information about their sun sensitivity available, this information might motivate them to take better precautions (Falk, 2014).

3.2.7 Melanoma Controversies

Sun exposure is the primary risk factor for melanoma since Fitzpatrick skin types I and II have a twofold higher risk of melanoma compared with skin types III and IV that are darker (Gandini et al., 2005). The risk increases with holidays spent in tropics (Chang et al., 2009).

Studies show a protective effect for chronic sun exposure (Bataille et al., 2005) raising the possibility of genetic and other environmental factors being equally important (Iles et al., 2013). Chronically sun exposed areas of skin are not the common sites of involvement in melanoma except for the lentigo maligna type of melanoma. Melanoma is commonly seen on the legs in women and the trunk in men corroborating a hormonal effect and a probable connection with melanocyte migration pathways (Bulliard, De Weck, Fisch, Bordoni, & Levi, 2007). The number of certain types of naevi such as junctional and atypical naevi are also correlated with increased melanoma risk, reiterating the contribution of genetic factors

(Rivers et al., 1995). Based on these observations it is generally assumed that two disparate phenotypes confer melanoma risk: chronic sun exposure and excess of naevi (Bataille, 2013).

Childhood sun exposure is especially detrimental for melanoma risk later in life (Whiteman, Whiteman, & Green, 2001) with a sudden spike in incidence around puberty suggesting an effect of hormonal influence as well as sun on melanoma (Baade, Green, Smithers, & Aitken, 2011). Hence it is particularly important to enforce sun safety behaviour in children. Certain genetic disorders such as xeroderma pigmentosum with a defective DNA repair mechanism confers heightened melanoma risk (Budden & Bowden, 2013).

An interesting pattern noticed over the past few decades is a considerable increase in melanoma incidence without a corresponding increase in mortality. This supports the fact that the increase in screening activities in people along with public awareness may have improved diagnosis and treatment. However, many of the treated melanomas were probably inconsequential to start with (Coory et al., 2006).

The role of sunbeds in melanoma incidence has always been controversial and a recent meta-analysis of more than 10,000 melanoma cases found only a very weak association (Boniol, Autier, Boyle, & Gandini, 2012). However, premature photoaging and NSMC are definitely associated with sunbed use (Wehner et al., 2012). The ban on sunbeds adopted by some countries is justified. The role of sunscreens in melanoma prevention is yet another controversial issue. Though sunscreens are part of sun safety education in many parts of the world, a large meta-analysis failed to demonstrate any conclusive protective effect of sunscreen lotions (Huncharek & Kupelnick, 2002).

A rising incidence of vitamin D deficiency in many populations is also alarming considering the increased susceptibility to many solid tumours and overall mortality in vitamin D deficiency. Strict sun avoidance and indiscriminate use of sunscreens are not to be encouraged in Caucasians (Field & Newton-Bishop, 2011).

3.2.8 Skin Cancer Prevention and Control

Apart from protection from UV irradiation, a few other factors can influence skin cancer prevention. Folate is a dietary factor that has a skin cancer prevention role by facilitating DNA repair, replication and control of gene expression (Williams, Jacobson, Kim, Kim, & Jacobson, 2012). Grape seeds contain proanthocyanidins that may play a protective role in skin cancer through inhibition of oxidative stress and protection of immune system (Katiyar, 2008). The administration of a combination of anti-oxidants may also be more effective than isolated anti-oxidants (Bialy, Rothe, & Grant-Kels, 2002). Melanoma has a poor prognosis once it spreads deep and to other structures (metastasis). Though therapeutic options are limited, the latest advances in oncogene targeted immunotherapy provides hope within this otherwise dismal scenario (Aris & Barrio, 2015).

3.3 The Technology

The Internet has huge potential as a source of health information. The Canadian population with access to Internet rose from 79% in 2010 to 83% in 2012 (Statistics Canada & Uhrbach, 2013) though the digital divide still persists in Canada (Haight, Quan-Haase, & Corbett, 2014). An average Canadian spent more than 35 hours per month online, which is the highest online engagement rate in the world. Canadians have a similar trend in the use of social media (Comscore Inc, 2014). The role of the Internet in health information access is also on the rise. Seventy percent of Canadians search for health information online and the Internet is the first source of health information for many of them even before clinicians (Tonsaker, Bartlett, & Trpkov, 2014).

Many eHealth and mHealth (use of mobile technologies for health) behavioural intervention technologies could be designed to target behaviour and cognition of target groups to improve health outcomes (M. N. Burns, Montague, & Mohr, 2013). eHealth interventions have been successfully used for behaviour modifications in conditions ranging from obesity (Hutchesson et al., 2015) to alcoholism (Stoner & Hendershot, 2012). Mobile telemedicine devices capable of transmitting images for remote diagnostics and monitoring are available (Rasmussen, Froekjaer, Joergensen, Halekoh, & Yderstraede, 2015). Technology can also be leveraged to promote self-monitoring by patients with melanoma (Hall & Murchie, 2014).

With the increasing strain on health care delivery, eHealth information and communication tools should be used for preventive health care (van Beelen et al., 2013). Many studies demonstrate the effect of mobile interventions in preventive health (Brendryen & Kraft, 2008; Holtz & Whitten, 2009; Lim, Hocking, Hellard, & Aitken, 2008). Melanoma screening apps that analyse the melanoma risk from uploaded images of naevi have sensitivity ranging from 7% to 98% (Wolf et al., 2013). The United States Food and Drug Administration has issued guidance for mobile medical applications and such regulations may be required in Canada as well (FDA, 2015).

3.3.1 Tailored sun protection advice on mobile framework

Tailored health communications customize the message, source of the message and the channel of the message delivery according to individual characteristics (Kreuter & Wray, 2003). Web based applications can collect real time UV Index information from online sources and combine them with the time of day and location information of users. Sun safety apps may also collect personal information such as skin type and local environmental factors. Tailored advice based on a combination of these data should be able to improve the response efficacy of users (Buller et al., 2013). Smartphone applications have the added advantage of reaching high-risk individuals such as men and young adults (Buller et al., 2011). No studies have compared tailored and non-tailored messages in the context of healthcare. A non-tailored message relevant for a given individual may also be equally effective as a tailored message(Kreuter & Wray, 2003).

3.3.2 Melanoma screening Apps

Some moles or naevi can progress to melanoma. Hence it is important to identify moles that have a higher risk of developing melanoma and those that have already undergone a malignant transformation. This assessment is usually done by a professional skin examination. The number of apps available for melanoma screening such as Skin Scan, Skin of Mine, Skin Prevention and Mole Detective 2 is considerable and increasing. These screening apps either upload the image to a dermatologist for professional examination or analyse the image for the risk of evolving into a melanoma. However, many of these self-analysing apps are not validated and many of them may be grossly inaccurate. An innovative experiment was performed on one of the popular apps by using it for analysing the risk on 93 biopsy proven melanoma pictures. The app classified 88% of biopsy proven melanoma pictures as medium-risk (Ferrero, Morrell, & Burkhart, 2013) indicating that the algorithm is grossly inaccurate.

Another study evaluated four melanoma screening apps using a case-control study design with 60 melanoma cases and 128 benign lesion controls. The study demonstrated that 3 out of 4 smart phone applications incorrectly classified 30% or more of melanomas. The app that sends the image to a dermatologist for diagnosis demonstrated highest sensitivity (Wolf et al., 2013).

3.3.3 Measurement Tools in Skin Cancer Prevention

The most practical way for surveillance and intervention research is the use of self-assessment. However, the rate and quality of self-assessment data related to skin cancer prevention might not be comparable across populations. The US National Cancer Institute and the Emory Prevention Research Center convened a workshop in United States of skin cancer prevention investigators to compile a consensus-based set of core survey questions on UV radiation exposure and sun safety behaviour. The participants submitted questions they were using along with scoring algorithm and psychometric data prior to the workshop. The group evaluated the corpus of questions from all members and reached a consensus on 7 core questions and 5 secondary questions for adults. The consensus list was further refined by interviews with participants after they completed the questionnaire to understand their cognitive processes during the process. After this cognitive interviewing process to reduce systematic error of selected items, the workgroup proposed core skin cancer prevention questions for adults, children 10 years or younger, and adolescents aged 11 to 17 years (Glanz et al., 2008). The current study adopts this set of questions for adults with further enhancements as described in the materials and methods section.

3.4 Human Behaviour

3.4.1 Cognitive Models and Behavioural Theories

Human behaviour is determined by beliefs and attitudes (Sutton, 2001). Cognitive models specify these beliefs and attitudes that shape behaviour. Though various cognitive models are conceptually similar, each has some distinct characteristics. The five cognitive models that are widely in use are the health belief model, the Social-Cognitive Theory, the Theory of Reasoned Action and Theory of Planned

Behaviour (TPB) and the Protection Motivation Theory (Munro, Lewin, Swart, & Volmink, 2007). Social cognition models can be used as the basis for health behaviour interventions.

3.4.2 Health Belief Model

The Health Belief Model is based on the premise that an individual's rational consideration of the balance between the barriers to, and benefits of, the action motivates the action (Blackwell, 1992). The Health Belief Model may explain why some people do not use health services such as immunization and screening. This model proposes high susceptibility, high severity, high benefits and low barriers as proximal determinants that lead to a high probability of adopting the recommended action (Sutton, 2001). The main weakness of this theory is the failure to state the relationships between the model's factors (Stroebe W, 1996).

3.4.3 Social-Cognitive Theory

The Social-Cognitive Theory by Bandura suggests that observation and imitation play an important role in behaviour change (Bandura, 1986). The Social-Cognitive Theory is a very comprehensive theory that evolved from social learning theory which posits reciprocal determinism in which a continuous, dynamic interaction occurs between the individual, the environment and behaviour as the fundamental predictor of behaviour change (Redding, Rossi, Rossi, Velicer, & Prochaska, 2000). The wide focus of this theory and the difficulty in operationalizing the theory are its main drawbacks (Munro et al., 2007).

3.4.4 Protection Motivation Theory

The Protection Motivation Theory originally developed to help clarify fear appeals by Rogers was extended to explain how people respond to health threat communications that arouse fear related to issues such as skin cancer (R. W. Rogers, 1975). The Protection Motivation Theory proposes vulnerability and severity as the major predictors and has been supported by many empirical tests (Floyd, Prentice-Dunn, & Rogers, 2000).

3.4.5 Theory of Planned Behaviour (TPB) and the Theory of Reasoned Action

The Theory of Reasoned Action is based on the premise that the person's intention to perform behaviour is the best predictor of that behaviour (Ajzen & Fishbein, 1980). Intention in turn is influenced by the attitude towards the behaviour and the perceived expectations of important others with regard to the individual performing the behaviour. The TPB was an extension of the Theory of Reasoned Action to include behaviours that are not entirely under volitional control, by adding another variable called perceived behavioural control, that reflects the perceived ease or difficulty of performing the behaviour (Ajzen, 1991, 2011). This modification has been found to be useful for explaining intention (Godin & Kok, 1996).

3.4.6 The Transtheoretical Model

The The Transtheoretical Model by Prochaska & DiClemente conceptualizes change as a gradual process rather than an action that occurs immediately after an intervention (Prochaska & DiClemente, 1983). The The Transtheoretical Model is a comprehensive model of change and may be applicable in eHealth change management as well. The Transtheoretical Model describes change as a five step process that involves (1) Pre-contemplation, (2) Contemplation, (3) Preparation, (4) Action, and (5) Maintenance (Bensley et al., 2004).

3.4.7 eHealth behaviour management model

The eHealth Behaviour Management Model uses concepts of The Transtheoretical Model and the behavioural intent aspect of the TPB, as well as the principles of persuasive communication, to engage Internet users. Most of the current online healthcare resources are static or non-interactive. The eHealth Behaviour Management Model recommends a bidirectional persuasive communication between the computer algorithm and the user thereby stressing the importance of response-dependent, interactive communication. Preliminary results have found this model to be promising in Internet-based tools for behaviour change (Bensley et al., 2004).

The social cognitive models have several limitations. All the models assume that individuals always consider the costs and benefits of possible future courses of action. The models are criticized for offering an unrealistical account of how people form intentions and make decisions (Sutton, 2001). Besides these theories do not take into account non-voluntary factors which can affect behaviour (Gebhardt & Maes, 2001). The models fail to address the design requirements of behaviour intervention technologies. The Behaviour Intervention Technology (BIT) model addresses this limitation by defining both the conceptual and technological architecture of a BIT. The BIT model provides a direction for technical implementation of the BIT by systematically analyzing why, how, what and when of a BIT and links conceptual how to technical how (Mohr, Schueller, Montague, Burns, & Rashidi, 2014).

SUNBUC displaying tailored information based on the users skin type and the real-time UV index value for the city of residence. SUNBUC aligns with the eHealth behaviour management model and the TPB by providing tailored sun safety information. A controlled trial was conducted to test whether SUNBUC is indeed capable of improving sun safety behaviour as described in the next section.

Chapter 4

Materials and Methods

4.1 The Development of SUNBUC

No free web application was available for calculating the time to develop sunburn based on skin type and UV index. Hence a web application was developed that could display the time to develop sunburn tailored according to the respondents skin type and the real time UV index value for the respondent's city of residence. The web application calculated the skin type of the user based on the responses to a questionnaire. The daily UV index value for the nearest city of the user was fetched from the Weather Canada website. The tool was called SUNBUC (Sun Burn Calculator).

4.1.1 Calculating Fitzpatrick skin type

The calculation is based on a questionnaire consisting of eight questions. (Appendix C). The responses for each question are ranked from 0 to 4. The sum of all responses is calculated and the Fitzpatrick skin type is estimated based on the sum as per Table: 4.1 (*Fitzpatrick Skin Type Calculator*, 2015). JavaScript is used for performing this calculation in the web application. JavaScript is a client side scripting language implemented by most modern web browsers. The Fitzpatrick skin type calculated by the JavaScript code is used only for the final ‘time to burn’ calculation and is not saved in the database. The JavaScript code used for Fitzpatrick skin type calculation (*Fitzpatrick Skin Type Calculator*, 2015) is given in Appendix A.

Score	**Fitzpatrick Skin Type**
Less than 7	Type I
7-12	Type II
13-18	Type III
19-24	Type IV
25-30	Type V
31 and above	Type VI

Table 4.1: Fitzpatrick Skin Type conversion chart to estimate skin type from the response scores based on the standard questionnaire.

4.1.2 Obtaining the UV Index value

The Environment Canada (EC) website provides daily UV Index values for major Canadian cities (*Canadian Daily UV Index Forecast - Environment Canada*, 2013). EC gives permission to download and use this information subject to the terms and conditions set forth in EC’s license agreement. However, EC does not provide any application programming interface or web service that offers this information in a way suitable for other web applications to use. Hence a screen scraping script was created in PHP that receives the HTML response from the weather Canada website and converts it into UV index values for Canadian cities using PHP string functions. The PHP code that performs this function is available in Appendix B.

4.1.3 Calculating ‘Time to Burn’

MED is the minimum amount of UV energy required to produce visually perceptibly redness within 24 hours of UV exposure on previously unexposed skin. The MED progressively increases with Fitzpatrick skin type. This progressive increase in MED or the UV energy required to produce sunburn can be approximated as a scale factor on a base value of 21 mJ/cm^2. The scale factors progressively decrease from 1.4 for Skin Type I to 0.4 for Skin Type VI. When the scale factor is 1, the projected MED is 21 mJ/cm^2 and when the scale factor is 0.5 the projected MED is 42 mj/cm^2.

The dose rate of UV radiation is expressed in MEDs per hour. This is related to UV index as per the below conversion factor: The base MED rate of $21mJ/cm^2$ is approximately equal to $\frac{3}{7}$ of the UV Index value.

To estimate the minimum time of sun exposure required to produce sunburn, one can divide the 'Dose to Burn' by the 'Current Dose Rate'. For example: 0.5 MEDs / 2 MEDs/hour = 0.25 hour = 15 minutes. This method holds true for all skin types (*Interpreting UV readings.*, 2015).

A PHP script that makes the above calculation was made that displays the value to the user. The PHP code that makes this calculation is given in Appendix B.

4.2 The efficacy testing of SUNBUC

The SUNBUC efficacy testing had 2 phases.

1. The usability-testing phase
2. The controlled trial phase.

4.2.1 Usability Testing Phase

Many eHealth interventions do not accomplish the intended effects because of usability issues (Scandurra, Hägglund, Persson, & Ahlfeldt, 2014). Testing the usability of an information system provides the system developers the ability to understand user needs, improve the overall utility of the product, and increase user satisfaction (Brock, Kim, Palmer, Gallagher, & Holmboe, 2013). Usability testing is especially important for clinical information systems because of the patient safety implications (M. L. Rogers, Patterson, Chapman, & Render, 2005). Several innovative methods have been tried for usability testing of health information systems such as scenario-based usability testing (M. L. Rogers et al., 2005), in-situ analysis (Kushniruk, Borycki, Kuwata, & Kannry, 2011), cognitive task analysis (Kushniruk & Patel, 2004), think aloud technique (Lewis, 1982) and System Usability Scale (SUS) (Brooke, 1986) with various levels of success.

Think Aloud Technique

The Think Aloud technique is a popular method to help understand how users interact with the application. In the think aloud technique the respondent verbalizes his or her thought processes and system interactions while using the system. Audio and video of the interaction are usually recorded for future qualitative analysis. Four to five subjects per iteration are considered optimum for this method (Virzi, 1992). Two iterations are usually performed (Bastien, 2010). Cognitive engineering methods such as think-aloud technique during system design is essential for designing clinical information systems that support clinical workflows (Jaspers, Steen, van den Bos, & Geenen, 2004). The biggest drawback of this technique is the difficulty in cross-cultural adaptation as cultural factors could have an influence on the test (Perri, Shao, Swai, Mitchell, & Staggers, 2014).

To improve the usability of the questionnaire and SUNBUC, usability testing was performed using the think-aloud technique after the initial design on 5 random respondents. The respondents completed the survey and then used the SUNBUC as the intervention group would during the study. They verbalised their thoughts during the process, which were recorded. Since the interactions required with the tool were minimal, screen capturing was not performed. No time limit was set for the respondents to finish the interaction. The response to the questionnaire and SUNBUC was tested simultaneously. Only a single iteration of testing was performed. The verbalized audio responses were analysed for common themes. Since the sample size was small, no qualitative analysis software tools were used. Problems identified during this phase were rectified prior to the commencement of the study.

System Usability Scale (SUS)

SUS is a simple 10-item Likert scale tool to measure the subjective perception of usability of a system in a short time developed by Brooke (Brooke, 1986). SUS is usually done after the respondent had the opportunity to use the system, but before any debriefing or discussion about the system. SUS yields a single score ranging from 0 to 100 representing the composite measure of the overall usability. A study of about 2,300 surveys showed a mean SUS score of 70. The reliability analysis gave Cronbach's alpha of 0.9 and the factor analysis confirmed a one-factor model (Bangor, Kortum, & Miller, 2008).

The respondents answered the SUS questions after finishing their interaction with SUNBUC [Appendix E]. The negatively worded SUS questions were normalized and the cumulative SUS score was calculated. A SUS score of 68 means that the usability is average.

4.2.2 Controlled Trial Phase

During the controlled trial phase the baseline sun protection behaviour was assessed using a questionnaire for all participants. Approximately half of the participants were given access to SUNBUC along with a webpage with sun safety information (intervention group), while the other half had access to the webpage only (control group). The same questionnaire was used to repeat the assessment of sun safety behaviour after 3 months of initial survey. The two groups were compared using appropriate statistical methods. The null hypothesis was that the two groups would show similar sun safety behaviour as measured by the frequency of usage of sun protection methods such as sunscreen and hat. The study protocol is illustrated in Figure 4.1.

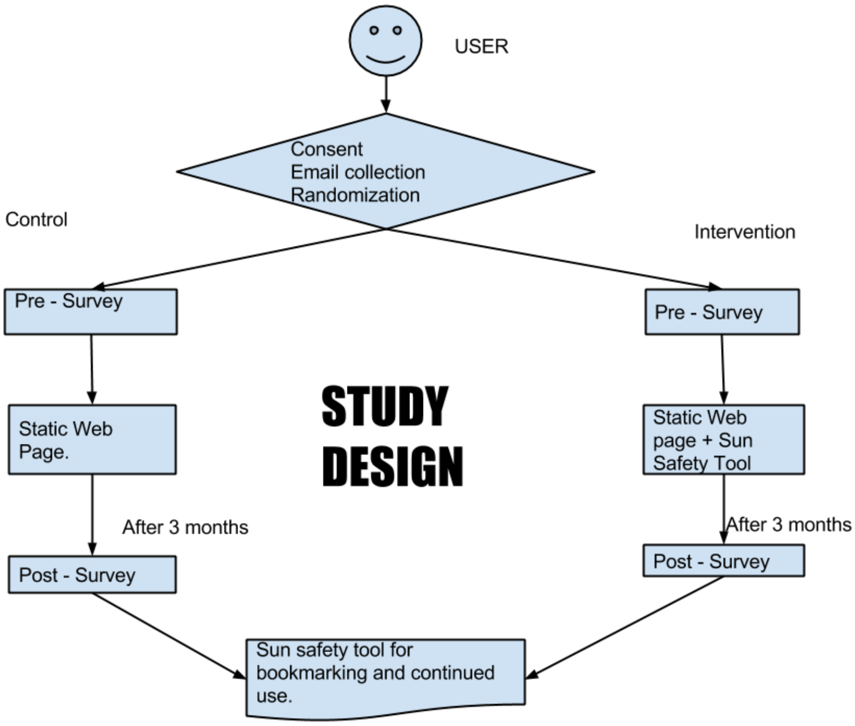

Figure 4.1: Study Design

Recruitment Strategy

A snowball sampling technique was employed for recruitment (Goodman, 1961). A relatively small number of potential recruits were requested to encourage their friends and family members living in Canada and over the age of 16 to participate in the study. The source of initial recruits was the investigator's personal contacts, mostly in the provinces of Ontario and British Columbia. The summary of protocol was presented to the Ontario Sun Safety Working Group. Due to anonymous study design, the exact demographic profile of the sample is not known.

Sun safety behaviour assessment

UV radiation can cause harmful effects not only on the skin, but also on other structures such as the eye and the immune system. Hence the measurement of harmful effects of UV radiation based on behaviour assessment from verbal reports or self-reports have limitations. However a self-assessment is the most practical way of getting information for eHealth intervention research. The questionnaire used for this study [Appendix D] is based on consensus questions from a collaborative national effort of researchers in United States as explained in materials and methods (Glanz et al., 2008). It covers several factors such as sunscreen use, eye protection, shade seeking behaviour, exposure duration, self and professional examination.

Impact on Cognitive models and behaviour theories

Cognitive models are theories that explain the impact of beliefs and attitudes on behaviour. It is important for eHealth interventions to base their work on these well-tested theoretical frameworks to have the maximum impact on health improvement. Since eHealth interventions such as SUNBUC provides additional information that empowers the user to make appropriate decision that affects health outcome, the impact of the tool as per the TPB was measured (Ajzen, 2011). White et al tested the extended theory of TPB in Brisbane, Australia on 1134 participants. The tool used in that study with good inter-item reliability was incorporated in the questionnaire to measure perceived behaviour control, one of the proximal determinants of TPB (White et al., 2008). [Appendix D, Question 8]

4.2.3 Study Protocol

A uniform resource locator (URL) represented the single point of entry to all respondents. The webpage at this URL displayed the instructions to the participants and collected their personal email address. This email was encrypted and stored in an online text file. An email address was the only personally identifiable information collected during the course of the study. It was only used for sending up to three reminder emails for post intervention survey and was not used in the final data analysis or reporting. A simple PHP script enabled the randomization of the participants into the control and intervention group, with each participant having an equal chance of being allocated to either group (See Figure 4.1).

The randomization script at the entry point URL recorded the email, allocated the user to the group and sent the respondents to the pre-intervention survey. The respondents allocated to the intervention group were directed to a web page that displayed SUNBUC along with a static webpage that displayed information on sun safety. Both the pages were displayed using HTML frames (See Figure 4.2). The control group was directed to a static webpage that displayed information on sun safety. The static webpage for both groups was randomly chosen from a collection of three webpages to prevent the content on any webpage having an effect on the outcome. Three authoritative webpages were used from Canadian Cancer Society (Canadian Cancer Society, 2015), Health Directorate (Directorate, 2008), and Government of Canada (Government of Canada, 2012).

The static webpage that was displayed to respondents was randomly chosen from a selection of 3 webpages as described before. The App displayed to the intervention group calculated the skin type of the respondent based on the skin type, retrieved the UV index data for the city of residence and calculated the time to develop sunburn as described before. However the response of the participant to these questions or the calculated time were not recorded or analysed to ensure

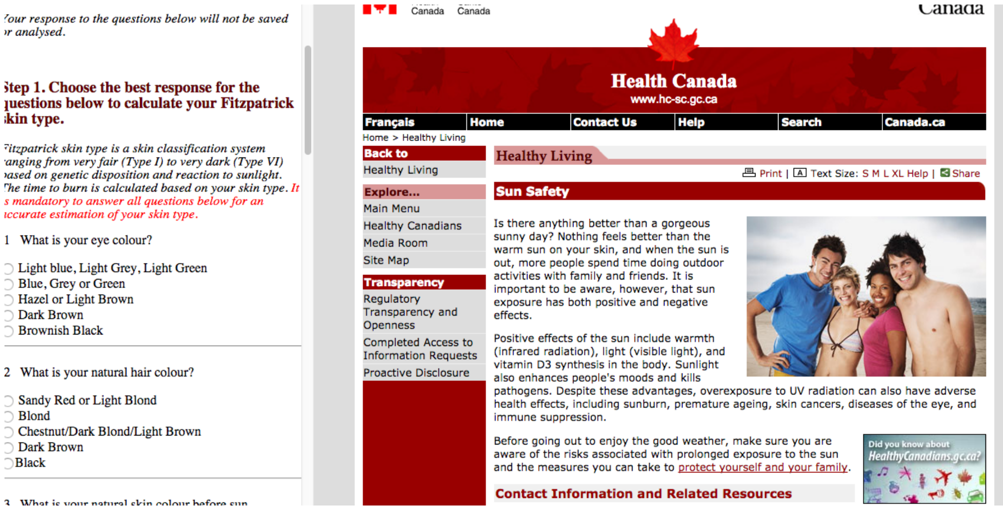

Figure 4.2: The intervention group view with the app and static page displayed side by side in HTML frames.

confidentiality. Besides, the user specific response from SUNBUC was not important for the objectives of the current study. Only the responses from the sun safety surveys before and after the study were recorded for analysis.

The respondents were sent a reminder email three weeks after their initial response and were requested to answer the post-intervention survey that was similar to the pre-intervention survey in content. A repeat reminder email was sent to all respondents after one more month to encourage those who have not completed the post-intervention survey to answer it. The responses from the post-intervention survey were separately recorded for two groups.

After the post-intervention survey the respondents were redirected to the tool to allow them to bookmark it for continued use. The study protocol is illustrated in Figure 4.1.

4.2.4 Survey Software

The pre and the post intervention survey was designed and delivered online using a PHP based survey script called phpESP version 2.1.4. (*phpESP - php Easy Survey Package — Free Communications software downloads at SourceForge.net*, 2013).

The script was hosted on a server with MySQL as the database backend to save the survey response. The data stored in the MySQL only had anonymous survey responses. phpESP only allowed one response from each respondent and this was managed using cookies.

4.2.5 Email Reminders

The reminder emails for the post-intervention survey were managed using phpkobo, a free lead follow-up PHP script for business applications (*Lead Follow-Up Database Script (PHP + MySQL)*, 2015). phpkobo also uses a MySQL database at the backend. Customer relationship management (CRM) software addresses the various aspects of a business interaction with a customer. phpkobo did not have full CRM capabilities such as lead management and integrated analytics (Pittaway, 2007).

The emails of the respondents were independently stored in a text file after encryption that was used in phpkobo. Since email and survey data were managed by different applications, they were not logically linked. This ensured privacy of the respondents.

4.2.6 Sample Collection and Statistical Analysis

The sample size was calculated for a confidence level of 95% and a confidence interval of 10 using the formula (*Sample Size Formulas for our Sample Size Calculator - Creative Research Systems*, 2015): Sample Size = $\frac{Z^2 \times (p) \times (1-p)}{c^2}$

Where: Z = Z value (e.g. 1.96 for 95% confidence level) p = percentage picking a choice, expressed as decimal (.5 used for sample size needed) c = confidence interval, expressed as decimal

The study was conducted from June 2014 to February 2015. The survey questions are available in Appendix D. The statistical analysis was done using R version

3.1.2. The respondents were randomly assigned to two groups. The control group viewed a static webpage and the intervention group viewed SUNBUC along with the static webpage. Both groups answered the same survey once at the beginning of the study (June to November) and 3 months after the intervention (October to February). (See Figure 4.1) The mean duration of sun exposure was ranked as in Table 5.2 and compared between groups to ascertain whether SUNBUC made any statistically significant difference in duration of sun exposure. Factors indicating individual sun protection behaviour such as sunscreen use and wearing of hat were ranked on a scale from 1 to 5 (1 = NEVER 2 = RARELY 3 = SOMETIMES 4 = OFTEN 5 = ALWAYS). These factors were not individually analyzed, as the composite score was more likely to be representative of the sun safety behaviour.

The respondents were asked about the number of skin examinations performed by themselves and health professionals. The response was compared to assess if SUNBUC made respondents do skin examinations more frequently. In order to evaluate the effect of information provided by SUNBUC on perceived control over behaviour, a question specifically designed for this purpose was used and compared between those who used SUNBUC and those who did not get access to it.

4.2.7 HiREB approval

The Student Research Ethics Application for the study protocol and the usability testing was approved by Hamilton Integrated Research Ethics Board (HiREB) on 20th June 2014 with the REB number *14-399-S*.

Chapter 5

Results

5.1 Usability Test

Five respondents were chosen at random for the usability test that included a System Usability Scale (SUS) questionnaire (Appendix C) and think-aloud methodology. Four men and one woman between the ages of 23 and 36 participated in the usability test. The SUS response from the usability test is depicted in Table 5.1 with scores for the negatively worded subtracted in brackets.

SUS	Resp: 1	Resp: 2	Resp: 3	Resp: 4	Resp: 5
1	2	3	2	2	1
2	1 (3)	1 (3)	0 (4)	1 (3)	2 (2)
3	3	3	4	3	2
4	0 (4)	0 (4)	2 (2)	0 (4)	1 (3)
5	1	1	2	2	2
6	2 (2)	2 (2)	1 (3)	1 (3)	0 (4)
7	4	3	4	2	2
8	1 (3)	1 (3)	0 (4)	0 (4)	1 (3)
9	2	4	2	2	2
10	1 (3)	2 (2)	2 (2)	1 (3)	1 (3)
Score * 25	67.5	70	72.5	70	60
MEAN SUS	68				

Table 5.1: The SUS response from usability test

The mean SUS score obtained was 68 indicating average usability (Mirkovic, Kaufman, & Ruland, 2014). Below are the common themes that emerged during think aloud usability test. The number in brackets indicates the number of respondents who made the comment.

1. Small font size and unattractive front page. (3 out of 5 users commented)
2. Hamilton not in the list of cities. (2 out of 5 users commented)
3. No explanation for "unexposed". (1 out of 5 users commented)
4. The purpose of the webpage on the right is not clear. (2 out of 5 users commented)
5. The skin type explanation will be helpful where the value is displayed. (1 out of 5 users commented)
6. What to be done after using the app is not clear. (1 out of 5 users commented)

Based on the above comments, the following changes were made:

1. Background colour changed to beige.
2. Font size increased.
3. "Unexposed area" changed to "areas not exposed to sun."
4. The steps to be followed to participate in the study were highlighted in red.

The following messages were added:

"Only the major cities are listed above. Choose your nearest city from the list. e.g. if you are from Hamilton, please choose Toronto."

"Fitzpatrick skin type is a skin classification system ranging from very fair (Type 1) to very dark (Type 6)."

"Find out your skin type and the time required to develop sunburn below. The webpage on the right provides additional sun safety information."

5.2 Statistical Analysis of the survey

The calculated sample size for detecting a 10% difference with 95% confidence was 96 (*Sample Size Formulas for our Sample Size Calculator - Creative Research Systems*, 2015). The total number of participants was 101 for baseline survey (48 controls, 53 intervention) from which 94 (46 controls, 48 intervention) responses were obtained at final survey (3 months after the preliminary survey) with 7 (7%) dropouts. The study was conducted between June, 2014 to February, 2015. Since snowball sampling is not truly random, non-parametric statistics methods were used for analysis. The questionnaire is attached in Appendix D.

5.2.1 Weekday sun exposure pattern (Question 1)

The first question was: *"In the past 3 months, how many hours are you outside per day between 10 AM and 4PM on WEEKDAYS?".* The question required the respondents to rank their average sun exposure from 1 (30 minutes or less) to 7 (5-6 hours) as per Table 5.2. See Figure 5.1 for the plot of the number of responses for control and intervention group before and 3 months after intervention.

Rank	Exposure Time
1	30 minutes or less
2	31 minutes to 1 hour
3	1 to 2 hours
4	2 to 3 hours
5	3 to 4 hours
6	4 to 5 hours
7	5 to 6 hours

Table 5.2: Ranking of sun exposure times.

The null hypothesis was that respondents who had access to SUNBUC and who did not have access to it would have the similar duration of sun exposure at the time of final survey. Kruskal-Wallis rank sum test used to compare groups gave a chi-squared value of 4.46 with a p-value of 0.22 and a median rank of 2. The

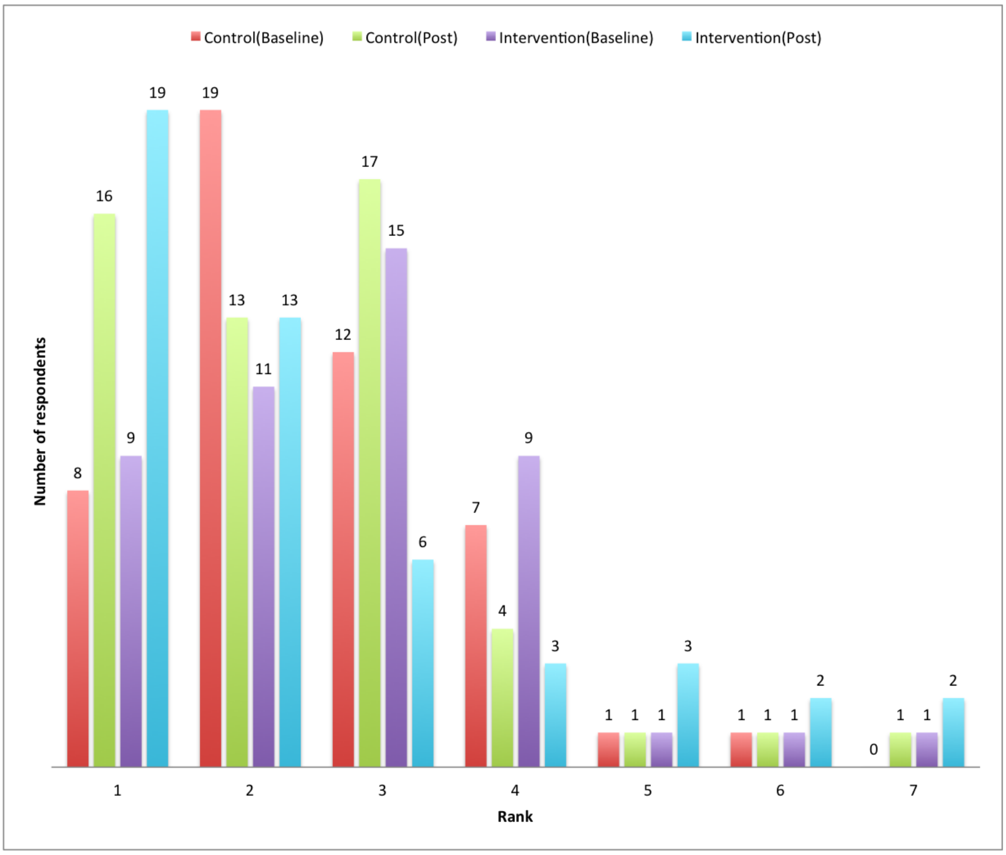

Figure 5.1: The weekday sun exposure pattern. Total responses n=195

results indicated that the null hypothesis was true, and there was no significant difference in weekday sun exposure between control and intervention groups before and after the intervention.

5.2.2 Weekend sun exposure pattern (Question 2)

The responses to the question: *"In the past 3 months, how many hours are you outside per day between 10 AM and 4PM on WEEKEND DAYS?"* were similarly ranked from 1 to 7 (See 5.2). See Figure 5.2 for the frequency plot of the responses.

Kruskal-Wallis rank sum test was used to test the hypothesis that SUNBUC would reduce the duration of sun exposure. The test gave a chi-squared value of 21.5 with a p-value of 8e-05 and a median rank of 4. The result showed a statistically significant difference between one or more groups represented by baseline

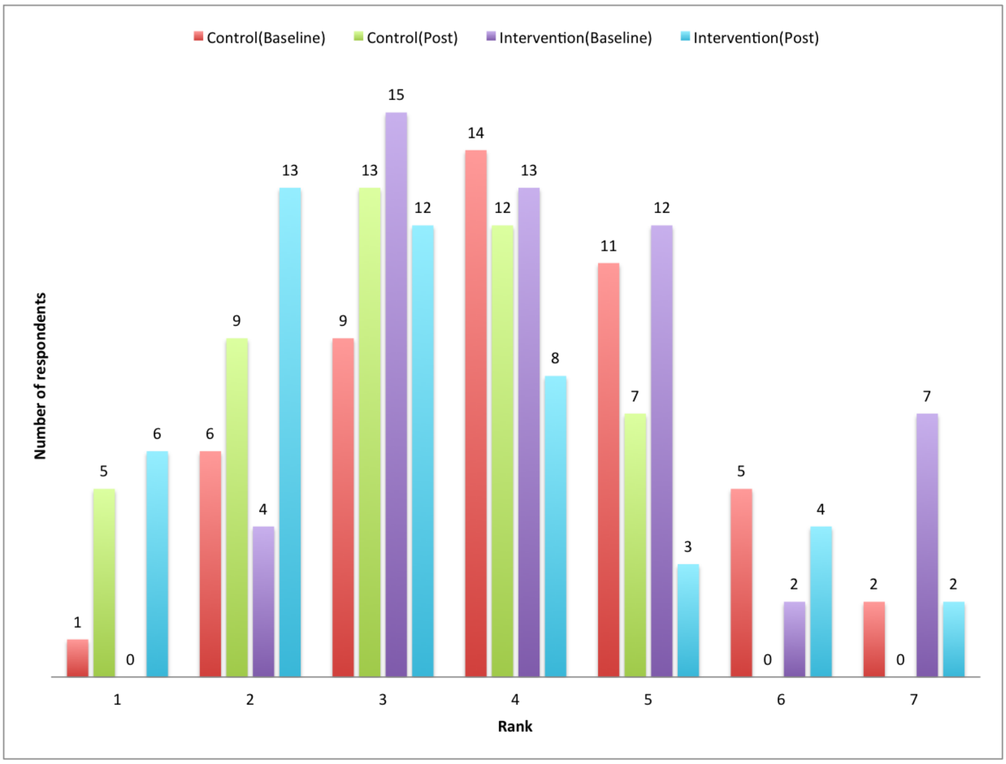

Figure 5.2: The weekend sun exposure pattern. Total responses n=195

response for controls, response after 3 months for controls, baseline response for intervention, and the response after 3 months of intervention. A pairwise comparison was performed using Wilcoxon test and the results are summarized in Table 5.3. The pairwise comparison showed that there was a statistically significant difference between baseline responses and post-intervention responses. However, there was no difference between SUNBUC users and non-users. The significant difference between baseline and post-intervention scores for both groups could be related to seasonal changes as explained in the discussion.

5.2.3 Red OR painful sunburn (Question 3)

The question asked was: *"In the past 3 months, how many times did you have a red OR painful sunburn that lasted a day or more?"*. Twenty-five out of 101 respondents reported 1 or more painful sunburn within the prior 3 months during the baseline survey conducted between June to November. Thirteen out of 94 re-

	Control Group three months after viewing static webpage (N=46)	Intervention group three months after using SUNBUC (N=48)	Baseline for Control group (N=48)
Intervention group three months after using SUNBUC (N=48)	0.69		
Baseline for Control group (N=48)	0.002*	0.002*	
Baseline for Intervention group (N=53)	0.0005*	0.0004*	0.69
**significant at 95%* CI			

Table 5.3: P-value obtained on pairwise comparison between groups for weekend sun exposure

ported sunburn within 3 months during the repeat survey conducted from October - 2014 to February - 2015. Data are summarized in figure 5.3.

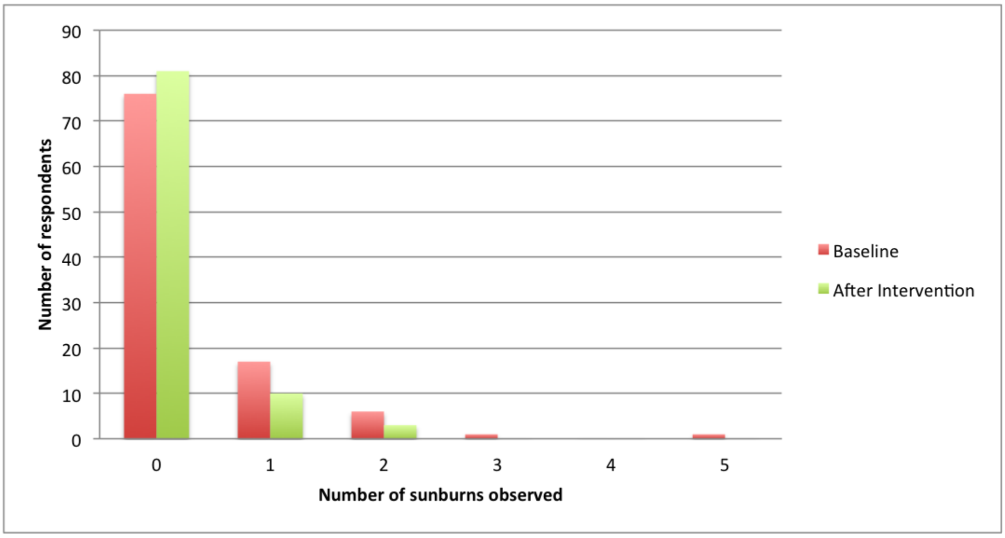

Figure 5.3: Frequency of reported sunburn. N (pre=101, post=94)

5.2.4 Sun safety behaviour (Question 4)

Sun safety behaviour was assessed using 6 questions on the frequency of usage of sunscreen, shirt with sleeves, wear hat, stay in shade, wear sunglasses, and time spent in the sun to get a tan. The responses were measured using a Likert scale from 1 to 5 (1=Never and 5=Always). Since time spent in the sun to get a tan negatively correlates with sun safety behaviour, the score was subtracted from 5 to be comparable with other values. The results are depicted in Figure 5.4.

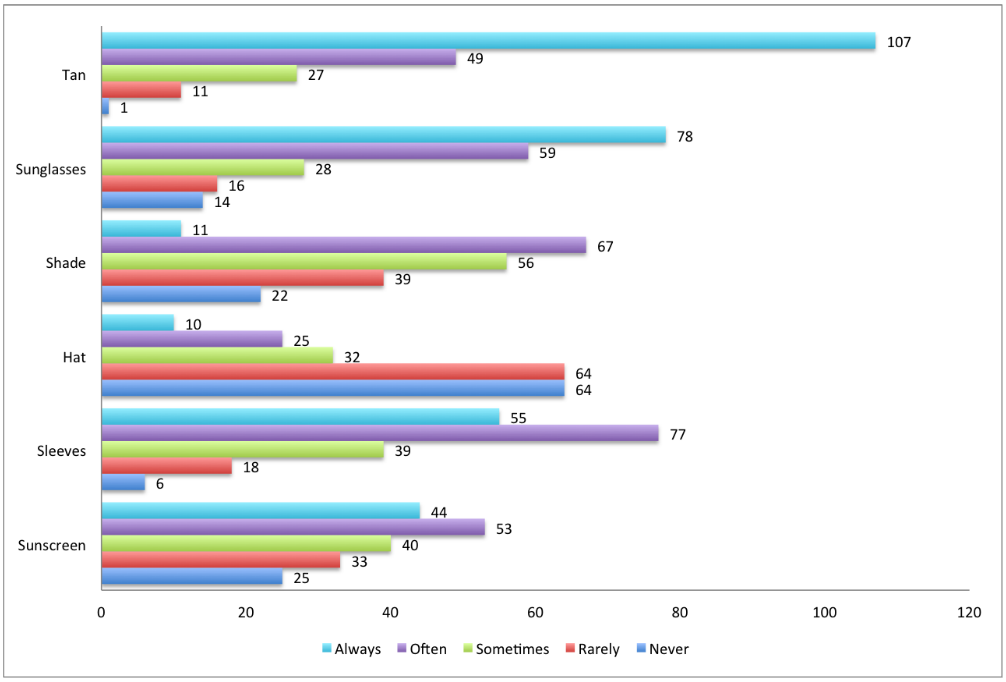

Figure 5.4: Sun protection behaviour

The groups were not compared for individual components such as sunscreen use. The hypothesis was that SUNBUC would have a positive impact on the cumulative sun safety behaviour score. Hence, the sum of Likert scale scores were compared between groups using the Kruskal-Wallis rank sum test. The p-value obtained was 0.3 indicating that there was no statistically significant difference in sun safety behaviour between the responses for control and intervention groups.

5.2.5 Self and professional skin examination (Questions 5-7)

The respondents were asked whether they conducted a self-skin examination and/or a skin examination by a healthcare professional. Responses are tabulated in Table 5.4 and Table 5.5 respectively. The hypothesis was that SUNBUC users would be more likely to perform skin examination. Chi-square test did not show any significant difference between control and intervention group for responses to both these questions.

Professional Examination	**Control Group**	**Intervention Group**	**Total**
No	34	33	67
Yes	12	15	27
Total	46	48	94
Test	**Statistic**	**Degrees of Freedom**	**P-Value**
Chi Squared	0.106	1	**0.745**

Table 5.4: Comparison of the number of professional skin examinations for the control and intervention groups

Self Examination	**Control Group**	**Intervention Group**	**Total**
No	40	41	81
Yes	6	7	13
Total	46	48	94
Test	**Statistic**	**Degrees of Freedom**	**P-Value**
Chi Squared	0	1	**1**

Table 5.5: Comparison of the number of self skin examinations for the control and intervention groups

Those who did self-examination were asked to mention the number of examinations they performed. Out of the 13 respondents who did self-examination, 9 did only once in 3 months, 2 did it twice, one respondent did it three times, and one did not answer this question.

5.2.6 Impact on theory of planned behaviour (Question 8)

To measure the perceived behaviour control, the users were asked to grade their agreement or disagreement with the statement: "If you wanted to, it would be easy for you to perform sun protective behaviours every time you go in the sun for more than 10 minutes in the next 2 weeks". The responses to the question were scored on a Likert scale of 1 (Strongly Disagree) to 7 (Strongly Agree). The frequency distribution is shown in Figure 5.5.

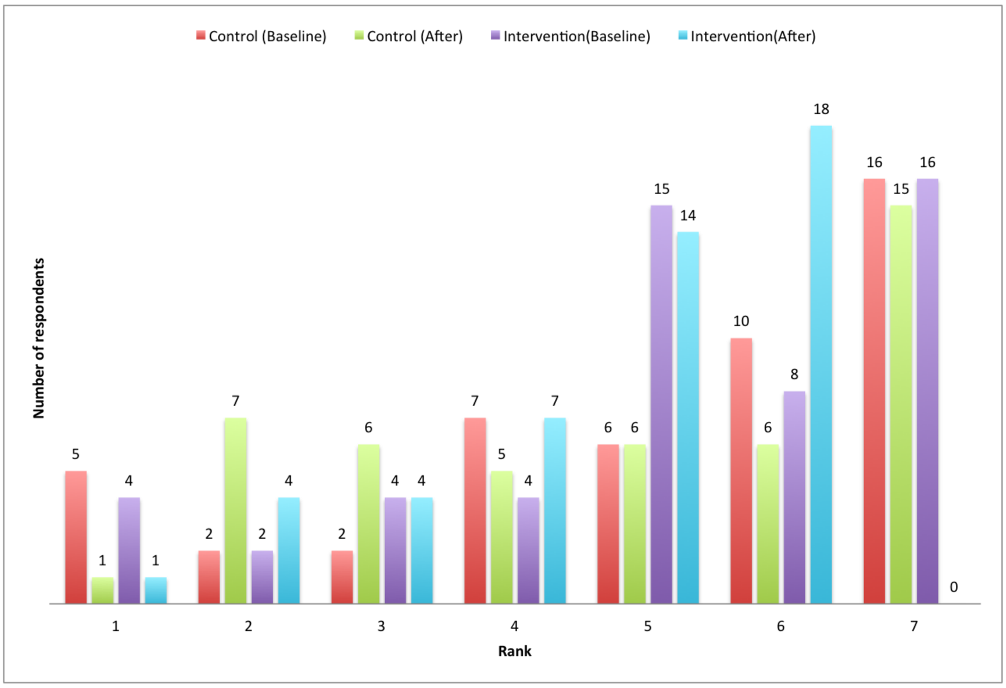

Figure 5.5: Response to perceived behaviour control related question

The median score for perceived behaviour control (PBC) for SUNBUC users was 6 while it was 5 for non-users. Wilcoxon rank sum test was used to test the hypothesis that SUNBUC improves perceived behaviour control (W=854.5, p=0.052). Though SUNBUC users showed better PBC, the difference fell just short of statistical significance.

In summary SUNBUC users did not show any statistically significant difference in any of the parameters measured related to sun safety from the control group.

Chapter 6

Discussion

No significant difference was observed between the intervention and control groups for duration of sun exposure during weekdays at basline and at 3 months. Weekend sun exposure pattern showed a significant difference in the duration of sun exposure during the baseline survey and after 3 months for all participants. However there was no difference between the control and intervention groups. The study started in the beginning of summer and the follow-up survey of some of the respondents was completed in winter. The difference in sun exposure duration between baseline and 3-month surveys is more likely to be due to the change of season. The absence of any difference between the control and intervention groups indicates that the tool had no impact on sun exposure. A protective effect has been reported for regular weekend sun exposure which could be mediated by photo-adaptation; a progressively decreasing response to same doses of irradiation. (Field & Newton-Bishop, 2011).

Six factors such as, application of sunscreen, use of hat, and sunglasses were recorded to measure the sun protection behaviour [Appendix D]. Responses to these factors were not individually analysed as these factors are related and the cumulative score is more likely to reflect the sun protection behaviour. Instead a sum of the responses as a single measure of sun safety behaviour was compared between the groups. No statistically significant difference was observed between the groups.

Twenty-five out of the 101 (25%) respondents observed one or more red and painful sunburns within the previous three months: This fell to 13 out of 94 (14%) post intervention respondents. This reduction in number of sunburns over time may be related to the change of weather during the study period. Painful sunburns are implicated in the pathogenesis of skin cancers (Kennedy, Bajdik, Willemze, De Gruijl, & Bouwes Bavinck, 2003). Five serious sunburns could increase the skin cancer risk by 80% (NHS Choices, 2014). Only one respondent reported more than 5 sunburns during our study.

Healthcare, information technology, and business management converge in eHealth; the emerging speciality that deals with electronic exchange and analysis of healthcare data (DeLuca & Enmark, 2000). This study is an attempt to explore and obtain insights on diverse aspects of eHealth with a specific focus on users as opposed to providers.

The adoption of health information systems by clinicians is suboptimal in spite of various governmental incentives to encourage adoption. However the number of patients seeking online health information has always been on the rise (Tonsaker et al., 2014). This has led to a proliferation of healthcare Apps that can be accessed using a variety of devices including smart mobile devices, bringing information to the fingertips of users (Ventola, 2014). However effective use is limited to only a handful of popular apps (Obiodu & Obiodu, 2012). The biggest concern in the healthcare consumer App industry is reliability, accuracy and usability (Johnson, 2006).

The system design of the sun safety tool was based on simplicity. The application calculated the skin type based on the user's response, retrieved the daily UV index value for the city of residence, and displayed the time required to develop sunburn to the users in an individualize manner. The control group viewed a random webpage displaying sun safety information. This was required to ensure blinding and seek more or less equivalent treatment of study groups. The intervention group viewed the study tool that delivered tailored information and a random webpage side by side in frames. The exposure to random webpage for both groups ensured that any detected effect could not be attributed to the static sun safety information on a webpage. A similar study that delivered online tailored sun safety information and subsequently measured a range of factors such as sun safety behaviour and sunscreen use reported that such online delivery of sun safety information could be informative, complete, and personally relevant (de Vries et al., 2012).

Sun safety assessment is difficult since it involves various factors such as sun avoidance, sunscreen use, eye protection and self and professional skin examination. Few studies have used validated survey instruments for assessing sun safety behaviour (Oh et al., 2004). A south Asian study reported the use of a validated questionnaire for the assessment of sun exposure for conducting research on vitamin D deficiency (Humayun et al., 2012). The regional validity of questionnaires developed in other geographic regions need to be ascertained. We used a validated questionnaire developed in a workshop of skin cancer prevention investigators from the United States (Glanz et al., 2008). Only the adult questionnaire was used for this study. Minor changes were made to the questions to accommodate the three-month study period.

User acceptance is essential for the success of any eHealth application (Vélez, Okyere, Kanter, & Bakken, 2014). A usability test of the study protocol including the questionnaire and the sun safety tool was performed using think aloud method (Jaspers et al., 2004) and System Usability Scale (SUS) questionnaire (Brooke, 2013) on 5 users. The mean SUS score obtained was 68. Improvements were made to the interface as per the feedback obtained during the think aloud study. Previous eHealth interventions have reported SUS scores of over 75 (Heinonen, Luoto, Lindfors, & Nygå rd, 2012; Kobak et al., 2011). A SUS score of 68 and above is considered good or above average (Bangor et al., 2008).

Buller et al. conducted a randomized controlled trial to assess the impact of a smartphone application called Solar Cell on a sample of 604 adults (Buller et al., 2015). Solar Cell was different from SUNBUC in being a mobile app for android devices. Solar cell provided a wide range of information such as sun protection advice, alerts to apply or reapply sunscreen, hourly UV index, and Vitamin D production. The time and location information was directly obtained from the phone. Solar Cell was successful in demonstrating a small yet significant reduction in sun exposure time. However sunscreen use and change in the number of sunburns over 3 months did not show any differences. SUNBUC is a web application providing information only on time to develop sunburn. SUNBUC's limitation in availability and content compared to Solar Cell may be responsible for its lack of impact on sun safety behaviour.

Many of the recent studies on tailored eHealth interventions for a variety of health benefits have failed to demonstrate a significant positive impact on health outcomes. (Antypas & Wangberg, 2014; Makai et al., 2014; Thorsteinsen, Vittersø, & Svendsen, 2014). An eHealth intervention for the chronic care for frail older people failed because of low acceptance (Makai et al., 2014). Another study on eHealth intervention for increasing physical activity showed no statistically significant effect on the users physical activity (Thorsteinsen, Vittersø, & Svendsen, 2014).

There are studies that reported a positive effect of online eHealth applications on health behaviour change as the Solar cell study (Buller et al., 2015). Aurora, A mobile-phone-based social emotion recording and sharing system was successful in encouraging emotional awareness, emotion sharing, and socially supportive behaviour (Gay, Pollak, Adams, & Leonard, 2011). Baranowski et al. identified 25 articles that demonstrated positive health-related behaviour changes from playing certain video games (Baranowski, Buday, Thompson, & Baranowski, 2008).

In this study, 27% of respondents underwent a full body examination within 3 months of the survey, while 13% did self-examination. There was no significant difference between the control and intervention groups in professional or self-examination in the final survey. A randomized trial of tailored skin cancer prevention messages called project SCAPE demonstrated a moderate effect on self-examination for messages sent through mail. The mailed message in SCAPE included skin self-examination instructions and practice tools (Glanz, Schoenfeld, & Steffen, 2010). SUNBUC did not provide any instructions or tools for skin examination.

It is important to understand the causal psychological and social processes and intermediate outcomes related to the eHealth intervention to understand its impact (Pingree et al., 2010). A question was included in our survey to assess the impact of the sun safety tool on perceived control over health behaviour as per TPB. The intervention group showed a trend towards a higher score for perceived control compared to the control group. However the difference fell short of statistical significance with a p-value of 0.052. A meta-analysis of 40 experimental and quasi-experimental studies has established the differential benefits of tailored web-based interventions over non-tailored approaches (Lustria et al., 2013). Tailored health communications customized for the user are found to be more effective in engaging individuals than generic information in areas ranging from promotion of immunization (Kreuter, Caburnay, Chen, & Donlin, 2004) to colorectal cancer screening (Marcus et al., 2005). Personally relevant tailored information is more likely to be remembered (Dijkstra & De Vries, 1999) and is perceived positively by healthcare consumers (Brug, Oenema, & Campbell, 2003). Providing feedback in the form of tailored messages reflect TPB by influencing perceived behaviour control. TPB based models have been found to be effective in promoting physical activity levels (Compernolle, Vandelanotte, Cardon, De Bourdeaudhuij, &

De Cocker, 2015) and self-management of chronic obstructive pulmonary disease (Voncken-Brewster et al., 2013).

Many websites offer information on sun safety such as the American Cancer Society(*Be Safe in the Sun*, 2015), Melanoma Research Foundation (*Melanoma Research Foundation — Research. Educate. Advocate.*, 2015), Canadian Cancer Society (Canadian Cancer Society, 2015) and Skin Cancer Foundation (*Prevention Guidelines - SkinCancer.org*, 2015). There are many websites offering Fitzpatrick skin type estimation services such as Canadian Dermatology Association (*Know Your Skin Type – Canadian Dermatology Association*, 2015) and the Skin cancer awareness project (*Skin Cancer Awareness and Sun Safety Education*, 2015). However, no freely available online resource that offered tailored information on the time required to develop sunburn as in SUNBUC was found on web search until 2013.

There are several eHealth apps available that offer health information. However not every useful application becomes popular or widely used as consumers may be overwhelmed by the choices available. Hence consolidating efforts by collaboration with teams working on similar solutions is the needed. Health applications on mobile platforms (mHealth) have shown tremendous growth in recent years though there is still a chasm between scientific and commercial faces of mHealth (de la Vega & Miró, 2014).

6.1 Limitations

Our study has several limitations. The biggest limitation is the inability to reach the vulnerable population. Sun protection is likely to be most effective in childhood in reducing skin cancer risk. A meta-analytic review of 33 studies on eHealth interventions for paediatric health promotion showed that behavioural theory based eHealth interventions were more beneficial than solely educational eHealth interventions (Cushing & Steele, 2010). Unfortunately web based interventions such as ours cannot easily target children though there are instances of its successful use in children as in this web based tailored smoking prevention program to discourage children from starting to smoke (Cremers, Mercken, Candel, de Vries, & Oenema, 2015). Music videos, computer games and mobile phones may also be useful in the delivery of health interventions in this age group (Norman & Skinner, 2007).

Our study was started in the beginning of summer in Canada. Our follow-up survey was planned three months after the initial survey. Some of the follow-up surveys were conducted during fall and winter. Theoretically this would be applicable to both control and intervention groups and is unlikely to have an effect on our objective. More experimental evidence is required to generalize our results for other geographic regions. The change of seasons resulted in a significant difference in weekend sun exposure time during the course of the study.

The absence of a mobile interface was a major limitation of our tool. Since we had to display the 'time to burn' app and a static web page side by side using HTML frames, the application was not accessible on mobile browsers. Only a single iteration of usability test was performed. No screen capture of responses were captured during the usability test.

The UV Index data for Canada was not available as a web service. A customized PHP script for web scraping weather Canada's daily UV index page was created for capturing real time UV Index data. Web scraping is known to be unreliable and any potential changes to the page can break the script (Glez-Peña, Lourenço, López-Fernández, Reboiro-Jato, & Fdez-Riverola, 2014).

When the UV index of a region is 0, theoretically the time required to burn is infinity. However 0 is an approximation and UV index may never be absolutely zero. Hence if UV index of 0 is encountered, time to burn is calculated based on UV index of 1. The snowball sampling employed is not truly random making inferential statistics less reliable.

6.2 Future Plans

6.2.1 Plans to improve the tool

The tool will be more useful if it offers a wider range of tailored sun safety information. If the tool has a mobile interface, availability of sun safety information while on the street, it may be more acceptable. An attempt will be made to consolidate efforts on mHealth ventures on sun safety; this project will be converted to an open source project and pushed to public repositories such as github for collaborative development.

6.2.2 Improvement in study protocol

A more comprehensive usability testing with multiple iterations would have been helpful in improving the tool. A wider geographic coverage would make the results more generalizable. Feature rich open-source survey management software tools such as LimeSurvey (project Team, 2011) may have been more efficient in managing the email reminders and data collection.

Chapter 7

Conclusion

The incidence of melanoma, a highly aggressive skin cancer is on the rise. With the ever-increasing senior population, skin cancers are likely to have a major impact on healthcare spending in countries such as Canada. Though several factors contribute to the melanoma risk, protection from harmful UV radiation may the single most significant and easiest to implement method to reduce the risk. eHealth interventions may be important in bringing positive behavioural changes in healthcare including sun protection.

An innovative web-based tool was created that provided users with vital tailored information needed to encourage UV exposure control. A web-based study was conducted to assess the impact of this tool on sun safety behaviour. The study failed to demonstrate any significant change in sun safety behaviour between those who used the tool and those who did not. However many of the respondents who used the tool felt that the information gave them more control over their behaviour. We recommend a consolidated open source approach to eHealth tool design so that the high numbers of eHealth apps in the same domain can be avoided, with users having access to high quality apps at little or no cost.

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Appendix A

JavaScript code to calculate Fitzpatrick skin type

```
<!--Fitzpatrick code starts here-->
<!--Include reference to jQuery in the header -->

<script type="text/javascript">
//Function to rank response to each question
function getGroupValue( rbs )
\{
    for ( var r = 0; r < rbs.length; ++r )
    \{
        if ( rbs[r].checked ) return Number(rbs[r].value);
    \}
    return 0;
\}
//Function to calculate the total score
function getScore(form)
\{
```

```
    var total = 0;
    for ( var q = 1; q <= 8; ++q )
    \{

        total += getGroupValue(form["question" + q]);
    \}
   if ( total < 7 ) stype = "1";
else if ( total < 13 ) stype = "2";
else if ( total < 19 ) stype = "3";
else if ( total < 25 ) stype = "4";
else if ( total < 31 ) stype = "5";
else stype = "6";
input.skintype.value=stype;

document.getElementById("Score").innerHTML =
    "Your total score is " + total + ",

    and so your Fitzpatrick skin type is " + stype;
}
</script>
```

Appendix B

PHP code to calculate time to burn

```
<!--Time to burn -->

<?php
//Get the UV Index for the city
\$city = \$\_POST['city'];
//Get the skin type of individual
\$skintype = \$\_POST['skintype'];
if(\$skintype)\{
        \$scale\_factor\_array = array(
                1    => 1.4,
                2    => 1,
                3    => 0.7,
                4    => 0.6,
                5    => 0.5,
                6    => 0.4,
        );
```

```
        if(!\$city)\{\$city=1;\}//correct if uv index =0
        \$base\_med\_rate = (3 * \$city)/7;
        \$scale\_factor = (1/\$scale\_factor\_array[\$skintype]);
        \$time\_to\_burn = \$scale\_factor/\$base\_med\_rate;

        \$hour = floor(\$time\_to\_burn);
        \$min = round(60*(\$time\_to\_burn-\$hour));

        //Display time to burn as HTML
        echo "<span style=\verb+\+
        "font-weight: bold; color: red;\verb+\+">";
        echo "<p><h1><b>Time to burn =
        \$hour hour(s) \$min minute(s). </b></h1></p>";
        echo "<p><i>UV Index of your region: =
        \$city. Your skin type: \$skintype </i></p>";
        echo "</span>";
\}
?>

<!--Time to burn ends here -->
```

Appendix C

Questionnaire for skin type calculation

A. What is your eye colour?

1. Light blue, Light Grey, Light Green
2. Blue, Grey or Green
3. Hazel or Light Brown
4. Dark Brown
5. Brownish Black

B. What is your natural hair colour?

1. Sandy Red or Light Blond
2. Blond
3. Chestnut/Dark Blond/Light Brown
4. Dark Brown
5. Black

C. What is your natural skin colour before sun exposure?

1. Ivory White
2. Fair/Pale or Reddish
3. Fair with Beige tint
4. Olive or Light Brown
5. Dark Brown or Black

D. How many freckles do you have on areas not exposed to sun?

1. Many

2. Several
3. Few
4. Incidental
5. None

E. How does your skin react to the sun?

1. Always Burns, Blisters and Peels
2. Often Burns, Blisters and Peels
3. Burns Moderately
4. Burns Rarely
5. Never Burns

F. Does your skin tan?

1. Never
2. Seldom
3. Sometimes
4. Often
5. Always

G. How deeply do you tan?

1. Hardly or not at all
2. Light Colour Tan
3. Reasonable Tan
4. Tan Very Easily
5. Turn Dark Brown Quickly

H. How sensitive is your face to the sun?

1. Very sensitive
2. Sensitive
3. Normal
4. Resistant
5. Never Had a Problem

Appendix D

Survey Questionnaire

Sun Exposure Assessment Questionnaire

For each question listed, please select the one answer that is the best response to the question.

Questions marked with a * are required.

*1. In the past 3 months, how many hours are you outside per day between 10 AM and 4PM on WEEKDAYS(Monday-Friday)?

*2. In the past 3 months, how many hours are you outside per day between 10 AM and 4PM on WEEKEND DAYS(Saturday & Sunday)?

*3. In the past 3 months, how many times did you have a red OR painful sunburn that lasted a day or more?

*4. For the following questions, think about what you do outside on a warm sunny day. Please choose the best response. 1 = NEVER 2 = RARELY 3 = SOMETIMES 4 = OFTEN 5 = ALWAYS

	1	2	3	4	5
How often do you wear SUNSCREEN?	○	○	○	○	○
How often do you wear a SHIRT WITH SLEEVES that cover your shoulders?	○	○	○	○	○
How often do you wear a HAT?	○	○	○	○	○
How often do you stay in the SHADE or UNDER AN UMBRELLA?	○	○	○	○	○
How often do you wear SUNGLASSES?	○	○	○	○	○
How often do you spend time in the sun in order to get a tan?	○	○	○	○	○

*5. Have you EVER had your skin checked for skin cancer from head to toe by a health professional?

○Yes
○No

*6. In the last 3 months, have you or a partner examined your entire body, including your back, for skin cancer?

○Yes
○No

7. If your answer to previous question is Yes, how many times? (Write number in the box)

*8. If you wanted to, it would be easy for you to perform sun protective behaviours every time you go in the sun for more than 10 minutes in the next 2 weeks: 1 = Strongly Disagree 7 = Strongly agree

Submit Survey

Appendix E

SUS Questionnaire

	Strongly disagree				Strongly agree
1. I think that I would like to use this ballot frequently.	1	2	3	4	5
2. I found the ballot unnecessarily complex.	1	2	3	4	5
3. I thought the ballot was easy to use.	1	2	3	4	5
4. I think that I would need the support of a poll official to be able to use this system.	1	2	3	4	5
5. I found the various parts of this ballot were well integrated.	1	2	3	4	5
6. I thought there was too much inconsistency in this ballot.	1	2	3	4	5
7. I would imagine that most people would learn to use this ballot very quickly.	1	2	3	4	5
8. I found the ballot very awkward to use.	1	2	3	4	5
9. I felt very confident using the ballot.	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this ballot.	1	2	3	4	5