Digital Health Innovation for Consumers, Clinicians, Connectivity and Community
A. Georgiou et al. (Eds.)
© 2016 The authors and IOS Press.
This article is published online with Open Access by IOS Press and distributed under the terms of the Creative Commons Attribution Non-Commercial License 4.0 (CC BY-NC 4.0).
doi:10.3233/978-1-61499-666-8-48

Promoting UV Exposure Awareness with Persuasive, Wearable Technologies

M. Sazzad HUSSAIN, Liam CRIPWELL, Shlomo BERKOVSKY and Jill FREYNE
Health and Biosecurity, CSIRO, Epping, NSW, Australia

Abstract. Current methods to promote awareness of the sun's ultraviolet (UV) radiation have focussed on delivering population level information and some location-based reporting of UV Index (UVI). However, diseases related to excessive (e.g. sunburn, skin cancer) or insufficient (e.g. vitamin D deficiency) exposure to sunlight still remain a global burden. The emergence of wearable sensors and the application of persuasive technology in health domains raise the possibility for technology to influence awareness of sufficient sun intake for vitamin D production, as well as preventing risk of skin damage. This paper presents a personalised solution to promote healthy, safe sun exposure using wearable devices and persuasive techniques.

Keywords. UV exposure, wearables, persuasive technology, mHealth, HCI

Introduction

The World Health Organisation (WHO) estimates that each year 2 to 3 million non-melanoma skin cancers and 132,000 melanoma skin cancers occur worldwide [1]. The problem is particularly acute in Australia, which has highest rate of skin cancer in the world. According to Cancer Council Australia[1], more than 434,000 people are treated for non-melanoma skin cancer each year, with 12,000 cases diagnosed with melanoma in 2012 and 2,200 incidents of death in 2013. UV radiation, associated with long exposure to sunlight, can cause sunburn, which damages skin cells, leading to the development of cancer. Public health campaigns have highlighted risks of UV radiation in an effort to change behaviours and minimise exposure [2].

UV exposure impacts human biological processes in positive ways as well. The WHO reports that a greater annual disease burden worldwide is likely due to lack of adequate sun exposure [3, 4]. Moderate exposure to the UV radiation is necessary for production of vitamin D. Lack of UV exposure can pose risk of osteoporosis and other chromic disease from vitamin D deficiency, certain types of cancer, and even psychological disorders [3]. Vitamin D insufficiency and deficiency is a prevalent condition in Australia [5, 6]. Long periods of indoor work, the rise in popularity of technology-based interaction and computer games can easily prevent outdoor activities resulting in insufficient daily UV dose. Moreover, sunlight in general plays an important role in the regulation of sleep-wake cycles, which impact mood, cognitive function, and overall wellbeing [7].

---

[1] http://www.cancer.org.au

The WHO has called for public health policy to decrease the burden of diseases associated with excessive and insufficient UV exposure [3]. In this work we present our technology response – a personalised persuasive mobile app that exploits real-time sensing to assist an individual to understand their current UV exposure risks and rewards. We propose that meaningful information that takes into account personal relevance and the surrounding environment could be more persuasive than generic information.

The emergence of wearable sensor technology and the popularity of smartphone applications (apps) have spiked a trend for self-monitoring/regulating in a variety of health and lifestyle applications (e.g. fitness tracking). These applications enhance user experience and deliver high degree of personalisation by considering objective (i.e. wearables), as well as subjective (i.e. user preferences) measures. Recent wearable devices, such as the Microsoft Band[1] and SunSprite[2] use embedded UV sensors to objectively measure current UV exposure levels. On the other hand, persuasive technologies [8, 9] have aimed to influence and reinforce positive attitude and behaviour change (e.g. healthy lifestyle) through interactive communication, advice and social influence medicated by computers. Systems that incorporate persuasive technologies with personalisation are likely to have higher impact on behaviour change (e.g. smoking cessation, physical activity) [9]. We believe that these new commercial sensors, when paired with intelligent persuasive apps have the potential to promote awareness of UV exposure, to support healthy life.

In this paper we present our technology solution, a work-in-progress mobile app that integrates with the Microsoft Band and considers persuasive technology as part of the design principle. The aim is to promote the balance of getting sufficient sunlight to stay healthy and avoiding excessive UV exposure to avoid sunburn.

1. Background

1.1. UV Radiation

Environmental factors that influence UV radiation include, time of the day, geographical location, altitude, and ground reflection [1]. UVI, a scale from 0 to 11+, with five exposure categories, is the primary indicator of the intensity of UV radiation for a given location and time. UV affects people of different skin tones and eye colour differently, specifically in terms of physiological effects and risk of sunburn. The Fitzpatrick questionnaire has been shown to reliably classify a person's skin type [10]. Knowing the UVI and skin type can be used to determine how long it will take for the exposed skin to start burning (*Time to Burn*).

Minimal Erythemal Dose (MED), is the amount of time it takes for the sun's UV radiation to cause skin reddening or marginal sunburn [6]. MED can be adjusted to skin types to estimate the *Time to Burn* that can range from 'some burn' to 'all burn' (please see [11] for detailed description). For example, under UVI 7 (i.e. high), people with fair skin types are likely to reach 'some burn' in 20 minutes and 'all burn' in 40 minutes, whereas people with darker skin types are likely to reach those risks in 40 minutes and 90 minutes respectively. MED can also be used to determine vitamin D production, and

---

[1] https://www.microsoft.com/microsoft-band/en-au

[2] https://www.sunsprite.com/

as with burn rates a persons skin type will impact vitamin D production levels [6]. For example, people with dark skin require approximately six times more UV exposure than someone with light skin to produce same amount of Vitamin D [6]. UV radiation is absorbed by any part of the body that is exposed to direct sunlight. Therefore, skin coverage, including clothing, sunglasses or use of sun protection factor (SPF) will impact the amount of UV radiation that a person is exposed to, and subsequently the amount of Vitamin D produced and their risk of sunburn. SPF reduces both the positive and negative impact of UV exposure. Use of SPF on exposed skin increases the amount of time that an individual can spend in the sun before reddening occurs. On the other hand, use of SPF or having too much of the body covered (i.e. clothing) limits the production of vitamin D because they act as UV radiation filters and reduces the dose. The "Rule of Nines" assessment [12] of the Total Body Surface Area (TBSA) is used to determine how much of the body is uncovered.

1.2. Technological Solutions

With the popularity of wearable devices growing, we are seeing new and diverse sensors being included in commercial wearable technologies. We detail two wearable technology solutions promoting the awareness of UV exposure. SunSprite is a personalised technology platform (app and wearable device) that promotes the positive nature of obtaining sufficient sunlight. The clip-on wearable is solar powered, has both ambient light and UV sensors, and displays progress towards a sunlight goal using LED indicators. The device integrates with an app (Android and IOS) to communicate sunlight exposure through visualisations. The Microsoft Band contains numerous sensors including an ambient light sensor and a dedicated UV sensor. The Band detects the current UVI activated by the user through a button press and held under direct sunlight. The Band has a large display, which can be used to communicate with the wearer.

In this work we set out to incorporate sensor technologies, use UVI information, personal user information, and add to these the intelligence of personalised persuasive interventions, in order to develop a prototype. Our proposed technology solution uses established methods to estimate vitamin D production rates, and the rate at which skin burns for an individual, using information, such as skin type, clothing and use of sunscreen. It monitors sun exposure levels, through UV and light sensors embedded in wearable devices to determine a user's progress toward a daily Vitamin D target, and toward unsafe exposure levels. This information is communicated to individuals using visualisations and messaging as part of the personalised persuasive approach.

2. Proposed Technology Solution

Our technology solution is an app that uses wearable sensor technologies with persuasive interventions to influence behaviour change. In the next section we present the system overview and features of the proposed app.

2.1. System Overview

The prototype comprises a wearable sensor, in this case a Microsoft Band, and an Android app. The primary function of the Band is as a source of UV information pertaining to the location of the user and as a method of communication with the user.

The functions of the app consist of user profiling, including skin type profiling, collection of data on SPF usage and TBSA coverage, and sensor data processing, to produce visualisations and messaging for communication to the user.

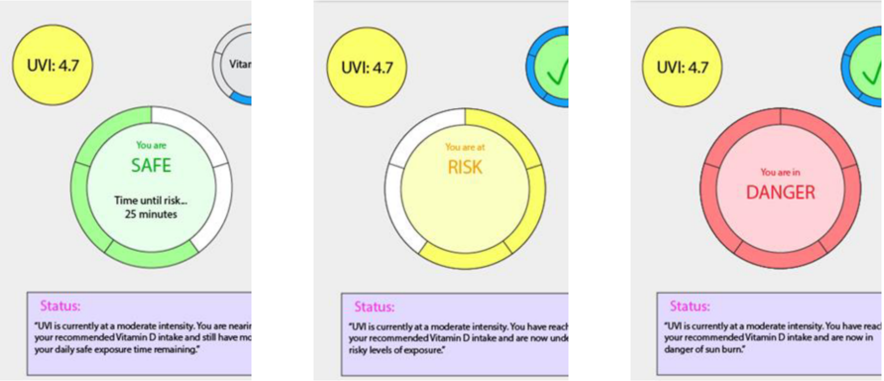
The app collects self-reported information to personalise the information for each individual user. Users complete the Fitzpatrick questionnaire to determine their skin type. Knowledge of skin type determines the individual's MED and subsequent vitamin D absorption rates and time to burn, as detailed previously. This information forms the core of the user profile, along with information on age and gender. The user profile is used to determine MED targets and thresholds for daily sun exposure for each user, based on the location's UVI. The app also collects self-reported information on the use of SPF and clothing on a daily basis or more frequently if provided.

Progress toward targets and thresholds is calculated in the app using information gathered by the wearable sensors, specifically the current UVI and whether the user is currently indoors, in the shade, or outdoors and exposed to the sun. The app records progress toward a Vitamin D target and *Time to Burn* with each episode of UV exposure. A rule-based notification manager processes a continuous stream of sensor data and updates the information displayed on the app, and the generation of persuasive text messages. The messages are displayed as status summaries in the app and on the Band display.

2.2. Features and Messaging

The app consists of four screens. The profile information is collected when a user registers (first screen) with the system. Users are prompted to enter coverage and SPF information on a daily basis and to update this information throughout the day (second screen). The remainder of the app focusses on the communication of personalised information based on sensor readings. The landing page or homepage of the app (third screen) aims to communicate three key UV related information to the user. The first is the current UVI, second the *Time to Burn*, and third progress to vitamin D target (see Figure 1).

The current UVI indicator is located in the top left corner of the screen, and changes colour based on UVI intensity. Here we aim to show users how UVI changes in different locations and at different times of day. The personalised *Time to Burn* information is presented visually as part of the persuasion technique. Three phases are used to represent this; SAFE, RISK, and DANGER. Estimated based on the *Time to Burn* range as described in previous section, the time until risk (i.e. SAFE) represents the countdown in minutes before reaching 'some burn'. The RISK phase represents the time range from when the individual starts 'some burn' up to 'all burn', which is followed by the DANGER phase. This information is presented with a progress dial visualisation, which gradually changes colours from green to red, according to UV exposure dose. Figure 1 gives mock-ups of the app's homepage with examples for the three phases. Progress towards a daily Vitamin D target is located in the top right corner of the screen, and also follows a progress dial concept. When the app determines sufficient UV exposure to satisfy the users daily Vitamin D production the dial completes and the achievement is noted.



Status:
"UVI is currently at a moderate intensity. You are nearir your recommended Vitamin D intake and still have mc your daily safe exposure time remaining."

Status:
"UVI is currently at a moderate intensity. You have reach your recommended Vitamin D intake and are now unde risky levels of exposure."

Status:
"UVI is currently at a moderate intensity. You have reac your recommended Vitamin D intake and are now in danger of sun burn."

(a) (b) (c)

Figure 1. Proposed features with *Time to Burn* indicator a. SAFE, b. RISK, and c. DANGER

A brief description of the current status is presented in a text form at the bottom of the screen (as *Status*). These messages are also communicated to the user via push notifications sent to the Band. Upon receiving a notification, the Band vibrates and displays the *Status* providing a practical solution for informing the individual about their status. In addition to the daily visualisations and messages, the app features historical summaries (fourth screen) for sunlight exposure (e.g. individual's indoor vs outdoor behaviour), UVI changes (at a specific location), *Time to Burn* incidents (e.g. days reaching RISK, DANGER) and vitamin D completes (e.g. days reaching full progress). This information is presented using graphs, which allow individual to reflect back to their behaviour and make adjustments if required. Most of the visualisations are under progress, and in future we also intend to build rule-based messages to provide description of the historical summaries.

3. Discussion and Conclusion

We have proposed a personalised technology solution for promoting healthy and safe sun exposure behaviour with the use of smartphones, wearable devices, and persuasive techniques. The tailored information based on environment sensors (e.g. UV and light) and personal profiling (skin type, clothing, use of sunscreen) has the potential to encourage a wide range of population towards good practice in sun exposure behaviour.

A number of target groups would benefit from our proposed app. The widest target group is the general population that are seeking to avoid sunburn without diminishing vitamin D levels, but there are other groups that are more at risk due to requirements to spend time outdoors, such as gardeners, traffic wardens, parks and wildlife staff and construction workers; and those who spend large amounts of time indoors, such as office and shift workers. Sun exposure is also an important treatment for people with some mood and sleep disorders.

Our work-in-progress app uses the Microsoft Band to sense UV and light. The UV sensor in the Band collects UVI readings in response to an action by the user, a limiting factor for use in this type of real-time system. We implemented a work around to this issue by allowing the app to pull UVI data from meteorology sources over the Internet and promoting users to perform the sampling action with the Band only when necessary (e.g. high UVI, poor Internet connectivity). Our challenge in using other devices, such as the SunSprite was the availability of a software development kit (SDK). Our technology will easily adapt to other commercial wearable devices on the market or in development through SDKs.

A number of challenges remain in order to understand the potential of our proposed technology solution in the community. We have presented techniques to determine time based targets and quotas for sun exposure, and use of sensors to determine personalised progress toward these quotas. However, getting accurate sensor data is challenging, but more importantly, key challenges remain around getting reliable self-reported data on skin type (e.g. sensitivity to sun or number of freckles) and sun protection behaviour (e.g. clothing and sunscreen use throughout the day). These factors, including ground reflection from the individual's environment, and even family history, can be important predictors of how UV exposure affect individuals, which is a sensitive issue for designing technology that aim to deliver personalised information. It is unlikely that a system will know every aspect of an individual, therefore, a feasible approach would be to design such systems that do not intend to deliver clinical interventions but act as suggestive tools for individual on how sun exposure may impact their health and guide behaviour changes from that knowledge.

Our future work will include; testing the accuracy of sensors and algorithms used to predict safe and harmful UV exposure levels; followed by evaluations (e.g. user acceptance, feasibility and usability studies) to determine the appropriateness and impact of the communication of our persuasive technology with real users.

References

[1] "Global solar UV index: a practical guide," World Health Organization, Switzerland 2002.

[2] R. B. Harris and D. S. Alberts, "Strategies for skin cancer prevention," *International Journal of Dermatology,* vol. 43, pp. 243-251, 2004.

[3] R. Lucas, T. McMichael, W. Smith, and B. Armstrong, "Solar ultraviolet radiation: global burden of disease from solar ultraviolet radiation," World Health Organization, Switzerland 2006.

[4] M. N. Mead, "Benefits of sunlight: a bright spot for human health," *Environmental Health Perspectives,* vol. 116, pp. A160-A167, 2008.

[5] "The burden of brittle bones: costing osteoporosis in Australia," Access Economics Pty Limited, Osteoporosis Australia 2001.

[6] A. J. Samanek, E. J. Croager, P. Gies, and E. Milne, "Estimates of beneficial and harmful sun exposure times during the year for major Australian population centres," *Medical Journal of Australia,* vol. 184, pp. 338-341, 2006.

[7] R. S. Schwartz and J. Olds, "The psychiatry of light," *Harvard Review of Psychiatry,* vol. 23, pp. 188-194, 2015.

[8] B. J. Fogg, *Persuasive Technology: using computers to change what we think and do*. USA: Morgan Kaufmann, 2002.

[9] S. Berkovsky, J. Freyne, and H. Oinas-Kukkonen, "Influencing individually: fusing personalization and persuasion," *ACM Transactions on Interactive Intelligent Systems (TiiS),* vol. 2, pp. 9:1-9:8, 2012.

[10] T. B. Fitzpatrick, "The validity and practicality of sun-reactive skin types I through VI," *Archives of Dermatology,* vol. 124, p. 869, 1988.

[11] "Interpreting UV Readings," Davis Instruments Corp, CA, USA 2010.

[12] G. A. Knaysi, G. F. Crikelair, and B. Cosman, "The rule of nines: Its history and accuracy," *Plastic and Reconstructive surgery,* vol. 41, pp. 560-563, 1968.