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SPLASH: Smart-Phone Logging App for Sustaining Hydration Enabled by NFC

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Abstract
Maintaining good hydration is crucial for adequate physical and mental performance for all human beings. In this paper we present SPLASH, an Android app that enables users to set daily goals and to keep track of their liquid intake through a combination of smart-phone NFC technology and NFC-tagged cups. We conducted several experiments to verify the robustness of the technology, which indicated that the selected NFC tags had acceptable robustness, operational distance and good penetration ability to meet the intended requirements for monitoring hydration. To further assess the feasibility of our concept, we evaluated SPLASH with ten users who gave feedback on its usability. We discuss the current prototype's advantages and limitations, as well as possible improvements and potential capabilities. At the end of this paper, we propose additional healthcare application scenarios for our concept.

Author Keywords
Hydration; NFC; app; logging.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Figure 1: SPLASH allows users to log drinks using NFC-enabled smart-phones to read NFC-tagged cups.

Introduction

Water is a key constituent of the human body, as it is the basis for fluids that perform vital bodily functions. For example, fluids such as blood supply cells with nutrients and oxygen and remove metabolic waste from those cells; urine allows the body to get rid of soluble wastes; sweat facilitates regulation of body temperature; cerebrospinal fluid cushions the brain and the central nervous system [6]. In the human body, water is continuously lost through natural biological processes but, if these losses are not replaced, dehydration occurs. Dehydration causes many adverse functional and metabolic conditions, and in extreme cases can be fatal. A comprehensive review of the effects of poor hydration on the body is available in [12]. Conversely, it is also possible to consume excessive amounts of water, which leads to low levels of sodium in the blood and can have equally harmful effects.

Despite the widely acknowledged importance of hydration, there is no consensus as to how much water a person should consume per day. The European Food Safety Authority (EFSA) suggested that adequate water intake values depend on the person's gender, age, activity as well as their environment [8]. Young adults tend to need more water than children and older adults, and men tend to need more water than women. This lack of consensus can be attributed to the fact that monitoring water intake is a relatively new research area. Consequently, there are many gaps in knowledge, data sets are fairly incomplete, and measurement techniques have mostly not been validated [12, 13].

In this paper we offer SPLASH (Smart-Phone Logging App for Sustaining Hydration) as a proof of concept approach to measuring people's daily liquid consumption, in an accessible and affordable way (**Figure 1**). SPLASH is an Android app that leverages the NFC technology available in smart-phones to enable users to keep track of their liquid intake. We describe the development of the app, including experiments and a usability study conducted to verify the robustness of our approach. We then discuss the advantages and limitations of the current prototype, with a view to identifying potential application scenarios. In the following section, we begin with a critical review of existing technological approaches to monitoring hydration.

Related Work

Mobile technologies are a promising platform to deliver health interventions. This is attested by the increase in research and development in the field of mobile health (mHealth), which aim to empower individuals to adopt healthier behaviours. For example, there are mHealth interventions to support the management of mental illness [1], sleep [2], diabetes, hypertension, and asthma [4]. There are also mHealth interventions for logging activities that are difficult to track automatically, such as diet [e.g. 14], emotion [e.g. 11], and wellbeing [e.g. 3]. These type of interventions generally use strategies such as tracking and feedback, goal setting, social influence, and gamification, to encourage people to adopt healthier habits.

Current technological approaches to tracking hydration include smartphone apps, wearable devices, and smart vessels. Using smartphone apps to monitor hydration has the advantage of providing a low cost solution with multiple functionalities, which users can tailor to their individual needs and preferences. Smartphones possess

App requirements
Allow user to manually log liquid intake.
Allow user to set their daily goals.
Allow users to input their personal information e.g. gender, age, and weight.
App to calculate and suggest daily goal based on user's details.
Allow user to log drinks through NFC interface.
Allow user to program NFC tags for different types of drink and vessel capacity.
Interface to view daily and weekly charts of consumed liquids.
Logged information to be securely stored in phone's persistent memory.

Table 1: List of requirements for SPLASH app.

a number of features that make them a particularly promising platform for health interventions including text messaging, camera, automated sensing, and internet access, which facilitate clinician involvement and use social influence and entertainment [7]. Apps, such as iDrated, Waterlogged and Daily Water, allow users to set their daily goals, log drinks manually, and receive feedback on their daily and weekly progress. Many of these apps also include reminders and a social media component, which are intended to serve as a motivators to maintaining good levels of hydration. However, each log requires multiple operations, ranging from unlocking the phone, opening the app, tapping to log, choosing a vessel, and selecting an amount. Assuming a typical goal of 6 to 8 glasses of water per day, having to repeat these operations a corresponding number of times could be tedious and adherence could dwindle.

There has been a growing interest in wearable devices for various healthcare purposes, though few of these can monitor hydration in real-time. A recent wearable device launched by KENZEN has the ability to continuously monitor hydration, in addition to levels of lactic acid to measure endurance and glucose to measure calorie consumption. The ECHO H2 Hydration Smart Patch[1] has two components: the H2 Smart Patch, which is a disposable biochemical sensor that is attached to the users calf or abdomen; and the ECHO Monitor, which receives data from the smart patch and processes it in real-time. The system can communicate with a number of smart devices via low-energy Bluetooth, to allow users to instantly monitor their performance and physiological indices. While this system is not yet commercially available, one potential drawback from the users pertains to the need to attach the smart patch directly onto skin. It is foreseeable that this will not be acceptable to all users, since adhesives can leave residue after use and may cause skin irritations.

One promising solution in contrast to wearable technology is the application of smart technology to drinking vessels, such as glasses or bottles. Examples of these include BluFit (smart water bottle) and Vessyl[2] (a smart cup), which are equipped with sensors to monitor various aspects of drink consumption and synchronise this information with other devices to provide feedback to users. Neither of these products is as yet available on the market. While they have the potential to provide richer information about hydration, such as identifying the type of drink and estimating calories, these solutions will be more expensive than simple app-based approaches. Furthermore, users will likely be limited to using a single container for all beverages. It is therefore apparent that there remains a need for a reliable and accessible approach to monitoring hydration, which can be incorporated into clinical as well as domestic settings.

SPLASH

We developed SPLASH to allow users to set daily drinking goals and monitor their progress, in a convenient and accessible way using NFC technology according to requirements summarised in **Table 1**. We used NTAG213 29mm, round NFC tags with a clear plastic adhesive face [9], and developed the app in Android Studio 1.2.2.

[1] http://www.kenzenwear.com/

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

Tested Feature	Result
Operational transmission range	~14mm
Effect of hot content	No influence.
Effect of cold content	No influence.
Penetration through glass	Yes. Tested up to 6mm thick glass.
Maximum bend angle of the tag before becoming unreadable	120°
Penetration through metal	No.
Interference with other tags	No, unless two tags overlap.

Table 2: Results of experimental tests on NTAG213.

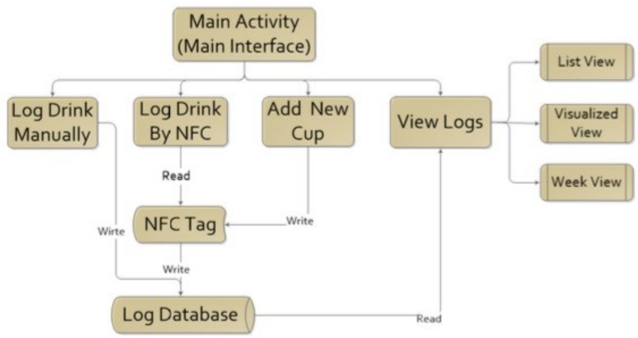

Figure 2: Flow chart of the SPLASH app.

Since adequate NFC support started in Android 4.1 (API level 16) with support for "creation of MIME and external type NDEF records"[3], the minimum SDK version was set to level 16. **Figure 2** provides an overview of app's functionality. In this section, we detail the evaluation of our approach.

Suitability of NFC

Near Field Communication (NFC) technology is a derivative of ISO 14443 RFID standard and it operates at 13.56MHz, which is available internationally (unlicensed radio frequency ISM band). It provides a two-way communication channel and, hence, information can be both read and written to an NFC tag. A study on the suitability of NFC for medical device communication where a transponder was implanted into human tissues, found this technology to be robust and have sufficient communications range [5]. It has been noted that NFC's operating range is 10cm or less (subject to field strength of initiator device) [10], which is one of the properties verified for the selected smart-phone and NFC tags (**Table 2**). Moreover, field-powered devices provide unique robustness to a radio-based attack and the only area of concern highlighted in [5] was an insufficient set of privacy properties of the NFC protocol. However, since tags in our proposed scenario do not carry any sensitive information, this is not seen as a barrier to this approach.

Cups contain liquids of varying temperature, so we conducted experiments to verify if this affected the NFC communication. Tests were also conducted to find the maximum angle to which NFC tag can be bent before it becomes unreadable. To judge the practicality of embedding NFC tags into cups, penetration tests through different materials (metal and glass) were performed. Results of these tests are presented in **Table 2**. In short, the operational range was found to be around 14mm and not affected by either extremely hot or cold cup content. The selected tags were found to be readable when bent up to 120° and hence deemed suitable for typical cups and glasses. Tests also revealed that a single-layer of 6mm clear glass did not block the signal, which suggest NFC tags can be embedded into cups and glasses. This would prevent tags from being exposed to detergents and physical damage, perhaps even making them suitable for dishwashers. As expected, the signal did not penetrate through metal. Due to the short communication range, NTAG213 would not suffer from interference from other NFC labels.

User interface

The main screen presents four choices: log a drink, add a cup, check logs, and settings (**Figure 3**). In Settings,

[3] http://developer.android.com/guide/topics/connectivity/nfc/nfc.html

Figure 3: The SPLASH main screen presents the user with four choices: log a drink, add a cup, check logs, and settings.

users can log gender, age and weight. SPLASH recommends a daily target based on this information, which can be overridden manually by the user. The LOG A DRINK feature allows the user to log drinks manually, for example for shop-bought drinks. The ADD A CUP option allows users to program new NFC tags with attributes specified by the user, such as name, volume and drink type. This information is formatted into NDEF records, encapsulated into NDEF messages and written into the NFC tag. Once an NFC tag has been programmed, the user is able to tap it against their phone to log drinks. Tapping wakes up their phone and SPLASH, which presents them with an NFC Log Screen. Here they are prompted to choose between 1/4, 1/2, 3/4, and full cup. This information, in combination with the volume associated with that particular vessel via the programmed NFC tag, allows the app to estimate the amount of liquid ingested. CHECK LOG function links to a screen that summarises liquid intake, which can be visualised in three different ways: Day List, Day Chart, and Week List/Chart view.

Evaluation

We conducted a preliminary usability study to gather users' initial feedback on SPLASH.

Task

Participants were given a brief introduction to the aims of the project and they each gave written informed consent to participate. The participants were given a smartphone with SPLASH installed, a set of cups/glasses with attached NFC tags, a task sheet, and a questionnaire to complete at the end of the study. The listed tasks covered all the functions and features of SPLASH: (1) personalising the user settings, by entering age, gender and weight; (2) logging half a cup of water using a pre-programmed NFC-tagged cup; (3) programming an NFC-tagged cup; (4) logging a drink manually; and (5) reviewing and deleting past logs. They were observed performing these tasks on their own and completed a feedback questionnaire, which comprised eight multiple choice questions and three open-ended questions.

Participants

Ten participants (seven male, three female), aged between 18 and 45, took part in the study.

Results

Nine participants completed the tasks successfully; one participant found SPLASH crashed when he tried to tap the NFC tag to add a new cup. This crash was caused by a bug, which was subsequently fixed. All participants agreed or strongly agreed that their overall impression of SPLASH was very positive. They also reported that SPLASH provided clear instructions and was easy to use, and that they immediately understood every function tested. Suggested improvements to SPLASH included storing data in the cloud for long-term monitoring, analysing users drinking patterns to provide personalised notifications, and allowing further customisation of SPLASH based on lifestyle and habits. These suggestions were beyond the scope of this stage of the project, but may implemented in future iterations of SPLASH.

Discussion

Dehydration may seem a trivial and easily solved problem, yet it remains a poorly understood area of healthcare. This has been attributed to a lack of effective approaches to monitoring hydration, which would facilitate clinical studies with specific user groups

[12]. Technologies available for this purpose have several drawbacks: apps for manual logging often require time consuming interactions; wearable sensors can be perceived as intrusive and may not be acceptable to all users; smart vessels are still not commercially available and will be expensive solutions that require drinks to be taken from one dedicated container. We argue that it is possible to leverage the NFC technology available in smart-phones to create an affordable and simplified app-based approach to self-recording liquid intake. We introduced SPLASH as a proof of concept, which overcomes the aforementioned limitations of existing technology. Many smart-phones and other devices are currently NFC-enabled, thus users do not have to buy dedicated devices such as smart cups or bottles. The current version of SPLASH suggests a daily target based on the user’s age, gender and weight. We acknowledge that this may not be an accurate recommendation, given that further work is necessary to better understand the factors that determine individual hydration needs. We merely present this to demonstrate the potential of future versions of the app. We see SPLASH as a useful tool to conduct future hydration research, which could inform empirical calculations and lead to more appropriate liquid intake recommendations.

We found that NFC technology is accessible and performed well with different temperatures, in the presence of some moisture, on round surfaces, and through 6 mm glass. NFC tags are low cost and easily programmable. We therefore envisage that NFC tags could both be printed into cups and bottles as well as manually attached to existing vessels, as seen in **Figure 1**. Other possible health-related applications include recording food and calorie consumption, and allowing users to keep track of their medication. Indeed, NFC technology has the potential to empower users to cater for their individual requirements through customised and customisable applications. Likewise, we feel the user interface could move beyond smart-phones, in light of the emergence other smart devices featuring NFC communication. As with existing apps, SPLASH could integrate social media as a way to motivate users to drink more and log more. Another area to explore could be to make SPLASH proactive by utilising timely prompts to notify the user to drink less or more.

Conclusions and Future Work

The work reported in this paper has proved that an NFC-based approach to logging liquid intake is appropriate and has the potential to be more widely applied. We introduced SPLASH as a proof of concept approach to logging liquid intake, which comprises an app and NFC technology. The usability study showed that SPLASH was easy to understand and to use, even the first time round. We plan to conduct a long-term user study that will involve more diverse demographics, in particular older adults who are arguably an important target demographic and who often present specific usability requirements. Future iterations of the app will also be capable of monitoring caffeine, alcohol and sugar intake, in connection with logging different types of beverages. This could be applied in conjunction with Recommended Daily Intake (RDI) information to support the dietary needs of specific users, such as people with diabetes or high blood pressure. We are particularly interested in using SPLASH in a clinical trial with renal patients, to better understand hydration research.

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References

1. Jakob E. Bardram, Mads Frost, Károly Szántó, Maria Faurholt-Jepsen, Maj Vinberg, and Lars Vedel Kessing. 2013. Designing mobile health technology for bipolar disorder: A field trial of the monarca system. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '13), 2627-2636.
2. Jared S. Bauer, Sunny Consolvo, Benjamin Greenstein, Jonathan Schooler, Eric Wu, Nathaniel F. Watson, and Julie Kientz. 2012. ShutEye: Encouraging awareness of healthy sleep recommendations with a mobile, peripheral display. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '12), 1401-1410.
3. Bentley, Frank, and Konrad Tollmar. 2013. The power of mobile notifications to increase wellbeing logging behavior. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '13), 1095-1098.
4. Heather Cole-Lewis and Trace Kershaw. 2010. Text messaging as a tool for behavior change in disease prevention and management. *Epidemiologic Reviews* 32, 56-69.
5. Eric Freudenthal, David Herrera, Frederick Kautz, Carlos Natividad, Alexandria Ogrey, Justin Sipla, Abimael Sosa, Carlos Betancourt, and Leonardo Estevez. 2007. Suitability of NFC for medical device communication and power delivery. In *Engineering in Medicine and Biology Workshop 2007*. IEEE, 51–54.
6. Ann C Grandjean and Sheila M Campbell. 2004. *Hydration: Fluids for life*. (2004).
7. Predrag Klasnja and Wanda Pratt. 2012. Healthcare in the pocket: Mapping the space of mobile-phone health interventions. *Journal of Biomedical Informatics* 45, 1, 184-198.
8. Nutrition EFSA Panel on Dietetic Products and Allergies (NDA). 2010. Scientific opinion on dietary reference values for water. EFSA J 8, 3.
9. NXP Semiconductors. 2015. *NTAG213/215/216 Product data sheet*. http://www.nxp.com/documents/data_sheet/NTAG213_215_216.pdf (accessed 13 January 2016).
10. Sixto Ortiz Jr. 2006. Is near-field communication close to success? *Computer* 39, 3, 18–20.
11. John P.Pollak, Phil Adams, and Geri Gay. 2011. PAM: A photographic affect meter for frequent, in situ measurement of affect. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (CHI '11), 725-734.
12. Barry M Popkin, Kristen E D'Anci, and Irwin H Rosenberg. 2010. Water, hydration, and health. *Nutrition Reviews* 68, 8, 439–458.
13. David R. Thomas, Todd R. Cote, Larry Lawhorne, Steven A. Levenson, Laurence Z. Rubenstein, David A. Smith, Richard G. Stefanacci, Eric G. Tangalos, John E. Morley, and Dehydration Council. 2008. Understanding clinical dehydration and its treatment. *Journal of the American Medical Directors Association* 9, 5, 292-301.
14. Christopher C. Tsai, Gunny Lee, Fred Raab, Gregory J. Norman, Timothy Sohn, William G. Griswold, and Kevin Patrick. 2007. Usability and feasibility of PmEB: A mobile phone application for monitoring real time caloric balance. *Mobile Networks and Applications* 12, 2-3, 173-184.