Routledge
Taylor & Francis Group

Journal of Technology in Human Services

ISSN: 1522-8835 (Print) 1522-8991 (Online) Journal homepage: http://www.tandfonline.com/loi/wths20

Improving the Well-Being and Safety of Children with Sensors and Mobile Technology

Matti Kinnunen, Mari Ervasti, Mirjami Jutila, Susanna Pantsar, Adama M. Sesay, Satu Pääkkönen, Marianne Mäki, Salman Qayyum Mian, Harri Oinas-Kukkonen, Michael Oduor, Liisa Kuonanoja, Jukka Riekki, Anita Juho, Petri Ahokangas, Maritta Perälä-Heape, Hanna Kotovaara & Esko Alasaarela

To cite this article: Matti Kinnunen, Mari Ervasti, Mirjami Jutila, Susanna Pantsar, Adama M. Sesay, Satu Pääkkönen, Marianne Mäki, Salman Qayyum Mian, Harri Oinas-Kukkonen, Michael Oduor, Liisa Kuonanoja, Jukka Riekki, Anita Juho, Petri Ahokangas, Maritta Perälä-Heape, Hanna Kotovaara & Esko Alasaarela (2016) Improving the Well-Being and Safety of Children with Sensors and Mobile Technology, Journal of Technology in Human Services, 34:4, 359-375, DOI: 10.1080/15228835.2016.1250028

To link to this article: http://dx.doi.org/10.1080/15228835.2016.1250028

Published online: 01 Dec 2016.

JOURNAL OF TECHNOLOGY IN HUMAN SERVICES
2016, VOL. 34, NO. 4, 359–375
http://dx.doi.org/10.1080/15228835.2016.1250028

Routledge
Taylor & Francis Group

Improving the Well-Being and Safety of Children with Sensors and Mobile Technology

Matti Kinnunen[a], Mari Ervasti[b], Mirjami Jutila[b], Susanna Pantsar[b], Adama M. Sesay[c], Satu Pääkkönen[c], Marianne Mäki[c], Salman Qayyum Mian[a], Harri Oinas-Kukkonen[a], Michael Oduor[a], Liisa Kuonanoja[a], Jukka Riekki[a], Anita Juho[a,d], Petri Ahokangas[a], Maritta Perälä-Heape[a], Hanna Kotovaara[a], and Esko Alasaarela[a]

[a]University of Oulu, Oulu, Finland; [b]VTT Technical Research Centre of Finland, Oulu, Finland; [c]Kajaani University Consortium, University of Oulu, Kajaani, Finland; [d]Prince Mohammad Bin Salman College of Business & Entrepreneurship, King Abdullah Economic City, Saudi Arabia

ABSTRACT
The well-being and safety of children and young people are important aspects in all contexts of everyday life. In particular, a feeling of insecurity might be a problem when being alone. Bullying is also common among school-age children and teenagers. Hence, there is a great need for personalized support systems to resolve these problems. This article describes a new area of research in sensor and social web development to help indicate children's insecurity in their daily environment. Deeper integration of sensors and the social web would allow us to foresee drastic changes in communities and new social–ethical scenarios will emerge.

ARTICLE HISTORY
Received 21 April 2016
Accepted 14 October 2016

KEYWORDS
Child; measurement; safety; school; social media; support

Introduction

Health and well-being are determinants of an individual's quality of life. This includes both physical and mental health. Increasingly, both health and well-being are being approached from a preventative and early detection perspective instead of an illness perspective (Ilves, 2012). In addition, the ongoing paradigm change in health care is contributing to the provision of personalized health services (Ahokangas, Perälä-Heape, & Jämsä, 2015). It has been determined that early detection and prevention of different forms of ill-being is worthwhile, leading not only to improved quality of life, but also to cost savings in society as a result of decreased healthcare costs (Kim, Strecher, & Ryff, 2014). Children's and young people's experience of safety in different daily circumstances is an important aspect of well-being. Bullying and a continuous feeling of insecurity can significantly increase the prevalence of mental illness and depression (Archer & Cote, 2005). This ill-being of children and youngsters may continue for years and can result in social exclusion.

CONTACT Matti Kinnunen matti.kinnunen@oulu.fi University of Oulu, P.O. Box 4500, FI-90014, Oulu, Finland.
Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/wths.

Therefore, it is important to prevent and stop all kinds of bullying already at an early stage. Friends, family members, relatives, and other trusted adults have an important role in this mission.

Research on children's safety is an active and growing area of research attracting both academic and commercial interest. According to a UNICEF survey on trending mobile technologies for child protection (Mattila, 2011), the most promising application areas relate to data collection, awareness raising, violence reporting, family tracing and reunification, and birth registration.

Technology can be utilized to provide a safer and more pleasant environment for children and young people to grow up in. Most mobile phones have access to the Internet and they support sharing of data between people. Different types of sensors are already included in mobile phones (e.g., acceleration, gyro, temperature, humidity) and it is easy to use them to track human behavior and to record changes in the surrounding environment (Macias, Suarez, & Lloret, 2013). Indicators of stress can be detected in human physiological signals such as voice, heart rate, galvanic skin response (GSR), and facial expressions (Boucsein, 1992; Hayre & Holland, 1980; Lang, Greenwald, Bradley, & Hamm, 1993). Different sensors have been developed and used to monitor stress based on GSR (Bakker, Pechenizkiy, & Sidorova, 2011) as well as electrodermal activity (EDA; Setz et al., 2009). Combining information from sensors like GSR, electrocardiography, temperature, and acceleration (3D) can be suitable for monitoring both physiological and psychological stress levels (Bakker et al., 2011; Ertin et al., 2011).

As these different devices can record physiological signals from the human body (Chan, Estève, Fourniols, Escriba, & Campo, 2012) and transform these signals into interpretable information via web-based applications, a promising new way of detecting the safety and well-being of children has opened up (Kinnunen et al., 2016). Hence, new possibilities for a variety of consumer applications and services that utilize the data are arising and new means for intervention are appearing.

Fluent and safe data transfer is a key issue in developing solutions for sensors and the social web. The principle of dual connectivity was recently introduced in the SEWEB (Sensors and the Social Web) concept (Kinnunen et al., 2016). Combinations of sensors and the social web are motivated by various factors like publishing and updating one's own personal data on the social web to increase real-time awareness of other users as well as measuring the context and environment where the users currently reside (Aggarwal & Abdelzaher, 2011). Several research papers have already discussed potential application areas where sensor data and web information can be used together, including "CenceMe" to infer the presence of users (Miluzzo et al., 2008), "HeartLink" to indicate well-being and physiological performance (Curmi, Ferrario, Southern, & Whittle, 2013), lifestyle management systems (Pavel, Callaghan, & Dey, 2012), location-based search engines (Shankar, Huang, Castro, Nath, & Iftode, 2012), sensor-driven social sharing at workplaces (Efstratiou et al., 2012), and various online applications (Jabeur, Zeadally, & Sayed, 2013).

The aim of this work was to launch a new area of research in connecting sensors and social web development to help indicate not only children's insecurity in their daily environment but also early signs of marginalization of youngsters. The motive, moreover, is to provide them with valuable help and support from trusted people in challenging situations via social web applications. Improving these factors of well-being can have a significant social and economic impact. This article exploits the general concept of utilizing a multisensory system and the social web for safety applications described in (Kinnunen et al., 2016).

Seweb challenge

Scenarios of challenging situations

Different challenging situations involving the physical safety of children and mentally stressful situations were studied and discussed. Brainstorming sessions were organized where people discussed different themes. Six different challenging situations were identified, and six different textual descriptions of scenarios were written (Mian, Oinas-Kukkonen, & Riekki, 2015). An example scenario of a challenging situation is described here. A traffic safety scenario (Figure 1) deals with two challenges at the same time. The first is about teens becoming overconfident when they follow the same route on a daily basis (e.g., "from home to school") and beginning to pay less attention to obstacles, pedestrians, cyclists, and motorists than usual (Figure 1a). Their

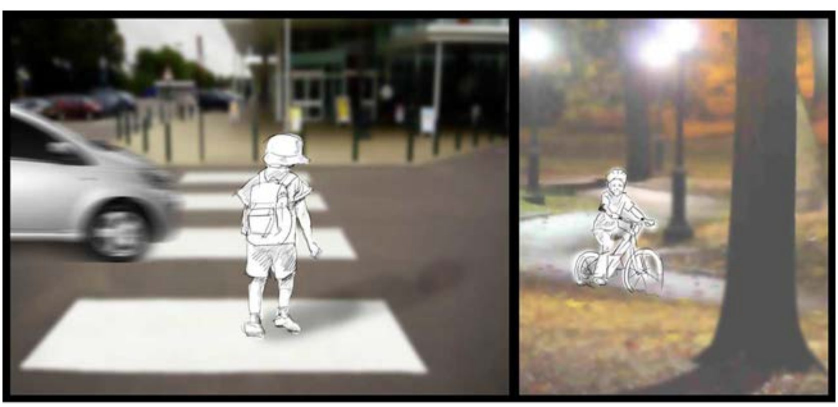

Figure 1. Traffic safety scenarios: (a) overconfident teen, (b) unusual situation and altered routine route.

focus may be shifted away from observing traffic and the environment, which may have potentially dangerous consequences. On the other hand, any unusual situation that forces a child to alter the daily routine route may bring stress and challenges to the child (Figure 1b).

It was discovered that different user groups (children, young teens, adults/ parents) need different variations of the application, including different combinations of service features. User interfaces as well as application features must be carefully specified. For example, the older the child is, the greater is the need for independence from the parents and the sense of responsibility for his or her own life (not to be monitored by parents) together with trust shown by adults.

Challenges

The challenges faced by child safety applications have been identified by several authors (Czeskis et al., 2010; Fraser, Rodden, & O'Malley, 2006). Some of these challenges are typical for location-based service related solutions: preserving privacy, ensuring trust, and policymaking when third parties (e.g., authorities) access users' private information. However, other challenges in this group are exclusively domain related: balancing the child's freedom with parental control and personal safety goals conflicting with human values (perception of safety, trust, human development, and privileged relationships between parents and children). The latter occurs as parents want to both keep their kids safe and support their teens' maturation and growing independence. Technical challenges include developing energy preserving solutions (battery life is limited on most smartphones), security of private data, and dissemination of this data in case of an emergency. Finally, it is a challenge to detect all necessary situations with the required accuracy.

Safety vest

Wearable sensors were investigated as a part of the SEWEB concept to enable wireless monitoring of children's activity. A safety vest prototype was designed from available off-the-shelf components (Jutila, Karhula, Rivas, & Pantsar-Syväniemi, 2015a) constituted of parts from LilyPad Arduino (Buechley, Eisenberg, Catchen, & Crockett, 2008) and Adafruit's Flora (Adafruit flora). These boards are used for integrating and collecting data from sensors, which data are then sent wirelessly through a radio module to a gateway device. The sensor components are connected and sewn together on the fabric with a conductive thread (Jutila et al., 2015a). The vest includes global positioning system (GPS), accelerometer, and temperature sensors and an XBee radio. Many different body movements can be recognized, based on the accelerometer data (Aminian & Najafi, 2004), to provide and gather information about, for example, a child's activity level and behavior, which can be utilized by numerous applications. The basic identified activity modes can usually be categorized as walking, running, sitting/staying still, or using some form of transportation. The implementation of the vest has some limitations in the way the movement data are gathered compared with wearable systems embedded with sensors, for example, on the arms and/or legs. With arm and leg sensors, other more specific user activities can also be recognized, such as eating, using stairs, falling, and lying down. On the other hand, the components in our prototype vest are attached to a separate piece of fabric in order to more easily test and identify a suitable place for the sensitive components to guarantee the best system functionality and wearability (Jutila et al., 2015a).

The gateways/routers are implemented using Raspberry Pi (Raspberry pi foundation) and Intel's Galileo (Intel Galileo), which are small computers suitable for covering both indoor and outdoor spaces because of their size and cost (Jutila et al., 2015a). The gateway provides the basic set of functionalities to work as an IoT gateway that delivers the data to a cloud and also to our safety service applications. Detecting whether the child's location is inside the allowed indoor and/or outdoor area is based on the Received Signal Strength Indicator (RSSI), which uses an algorithm based on a weighted centroid localization method (Blumenthalk, Grossmann, Golatowski, & Timmermannk, 2007). The location is weighted towards the gateway(s) that receives the best RSSI, and thus the algorithm robustly gives us a rough estimation of the area where the vest is. Experiments show that the well-known RSSI-based indoor localization algorithms can have errors of several meters (Goldoni, Savioli, Risi, & Gamba, 2010; Zanca, Zorzi, Zanella, & Zorzi, 2008). However, this is suitable for our purposes. To support special use cases where the mobility and portability of the gateway are required but battery life does not need to be very long, for example, during sports classes and preschool/school trips, other radio modules with a wider range (GSM, 3G, and Wi-Fi) can also be used in the gateway(s) and the vests. Besides having the capabilities of lightweight computers, Raspberry Pi and Intel Galileo can also host multiple sensors and implement intelligent reasoning algorithms for decision making.

Using a safety vest will offer solutions to issues regarding children's outdoor activities, going outside the preschool/school premises (trips, sports, arriving to school the area/building, etc.), children's disappearances from the preschool/school, and guardians' picking up children from the preschool/school. More detailed information about the vest's implementation is presented in a recent publication by Jutila, Rivas, Karhula, & Pantsar-Syväniemi (2014, Jutila, Karhula, Rivas, & Pantsar-Syväniemi, 2015b). The basic functionalities of the vest have been tested, but more concrete large-scale real-time measurements and analyses will be done in a future study.

Safety of children—a school pilot

The existing participatory design tools were exploited to collect and share information about the everyday contexts in which children feel most unsafe. Hence, the collected information was used to specify the desired situation-aware safety service and the technologies required for its digitalization (Pantsar-Syväniemi et al., 2014). As a result of the participatory codesign process, a safety service application was constructed to answer the growing needs of enhancing the safety of children, especially in home–school transition. A pilot was organized in a primary school environment to test and evaluate the general service concept and to collect user experience data for analysis using existing technology.

The application is built around the information provided by (a) GPS devices ("safety sticks") and (b) Radio Frequency Identification (RFID) tags (attached to key chains) carried by the school pupils; both devices are used to determine a pupil's current location. The difference between the two devices is that GPS is used for pinpointing the student's location outdoors where GPS is more reliable, whereas RFID tag readings are used when the student is indoors and GPS may be inaccurate. RFID readings provide the student's indoor location data in a school building via RFID reader devices located strategically in congestion points, such as narrow corridors and doorways, to minimize the chance for a misread. The pupils' own smartphones were utilized for collecting information about their movements between their home and school through a (c) smartphone application provided by a local telecom operator. Furthermore, (d) safety indoor wristbands were given to pupils diagnosed with diabetes. This service offered indoor position tracking on school premises by collecting information on the pupils' location inside the school building. Safety wristbands had an alarm button that the pupil could press when in need of help and, thereby, alert the school supervisor (the alarm was sent to the supervisor's mobile phone; Jutila et al., 2015a).

The application provides a GUI (Graphical User Interface) to the pupils' teachers and parents through which they can monitor the children's last known locations. Teachers and parents have separate levels of access to the pupils' location information; teachers are only shown whether the pupil has arrived or left the school area (based on GPS) and if his/her RFID tag is registered in a certain space (corridor, classroom, etc.) in the school building. Teachers are also shown pupil absence notifications left by parents for their children. A notification removes an alert of a missing pupil from the teacher's view on the GUI. Parents have more comprehensive access to the location data; they are shown the same data as teachers, but in addition, parents are shown their children's current and previous locations on a map. Also, the application uses the pupils' home location information to determine if a pupil is at a classmate's house and shows the parents the name of the classmate the pupil is visiting. However, this requires the classmate's parents to have enabled their home's location to be publicly available to other parents.

The technical design of the safety application consists of a role-specific (teacher, parent) GUI and server software that provides an interface for the GUI to read the different information, such as pupil class information, school location, pupils' home locations, and pupil GPS and RFID data. Server software also provides an interface for the GPS and RFID reader devices to store pupils' location information and RFID readings. The GUI is an HTML5 web application run in a web browser and the server software is a Java-based web application run on a Tomcat web application server. The application data comply with a specific semantic model designed for the school domain, and the data are stored semantically in a Virtuoso Resource Description Framework (RDF) database (see Figure 2).

The safety application was tested in a 3-month field trial during the spring of 2014 at a local primary school in northern Finland. The trial included 59 pupils between the ages of 7 and 10 from eight different classes, eight class teachers, and 57 pupils' parents. Not all pupils in the selected classes were included, as some of the parents did not give permission to include their child in the trial. Each pupil was given an RFID tag which they were instructed to attach to their backpacks for the best reading reliability. Five special GPS devices configured to store location data on a server were rotated among the pupils on a weekly basis, and the pupils who had a GPS-enabled smart-phone were connected to the server via a mobile application. The target

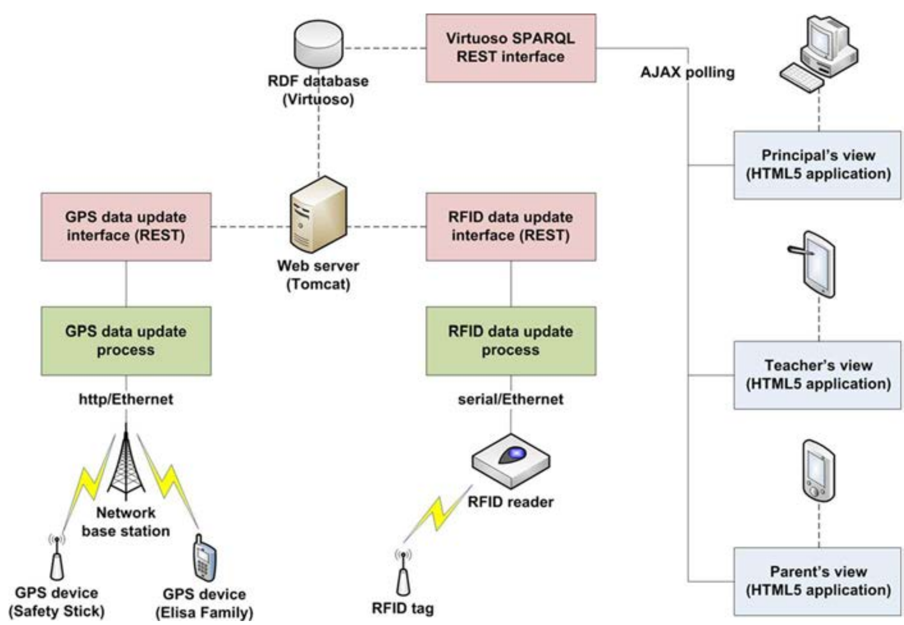

Figure 2. Safety-of-children school pilot system (GPS = global positioning system).

school was set up with five RFID reader devices which covered three entrances to the school building.

After the pilot, user feedback was collected from the children, teachers, and parents. They evaluated the feasibility of such a safety service application and provided improvement ideas and feature suggestions. Findings from the safety service field trial have been reported in more detail in Jutila and colleagues (2015a).

Qualitative user experience insights gained from the children's interviews and the questionnaires directed to the parents and teachers were further complemented with quantitative log data on usage of the safety service system. The field study findings revealed that, for children at this age as well as for their parents, the concept of being monitored by technology is not something they reject but possibly welcome. Furthermore, even though the children themselves did not benefit directly from using the system, they valued the fact that they could actively help teachers and parents by creating useful and valuable information.

Sensors and the social web

The SEWEB concept (Kinnunen et al., 2016) includes several important subthemes related to the safety of children. These are a personal safety network, notifications, a challenging situation, context and sensor data, and a communication channel. To more deeply investigate the potential of sensors, graphical user interfaces, and the social web and to advance the safety service application, also other scenarios different from the school environment were used. A low-fidelity paper prototype was used to validate these themes and to understand the interaction between the user and the prototype, as described in Mian, Oinas-Kukkonen, and Reikki, 2015.

The low-fidelity prototype mockups were developed using a typical iPhone 4s user interface with the theme being safety of children. Complete interaction flows of the scenarios were created on paper to be used in an experiment. The aim of the paper mockups was to verify the validity of the concept and to collect usability feedback to determine the level of detail required for a possible high-fidelity prototype design. A 4-hr-long user experiment involving five participants from the field of information technology was conducted with the objective of acquiring feedback. The participants with diverse gender and cultural backgrounds were in no way related to the project; however, they had experiences with similar projects. To better understand the requirements, a storyboard technique was used to draw user interfaces in collaboration with the participants as a study setting. The experiment was focused on the participants as the users of the mockups, their context of use, and the flow of events in the chosen scenario. The experiment revolved around a scenario where children and young adults finding themselves in any kind of challenging situation can contact a trusted person in their network for help. Each interaction flow was discussed, remarks were noted, merged, and deliberated during the experiment. Additionally, the discussions were recorded until the participants reached a consensus on the reliability of the flows.

The findings from the experiment verified the validity of the concept of using sensors and the social web for challenging situations. In addition, the findings provided a few refinements to the paper mockups and certain design guidelines for creating a high-fidelity prototype:

1. The reaction time for a user in certain challenging situations can be very short; therefore, the system should have quick options such as one-click notification or an instant snapshot of anybody's status.
2. Interactive feedback in terms of short status updates both to the user and his/her network contacts is of high importance. Providing automatic messages, status updates, pop-up alerts, and real-time notifications can help the user in a challenging situation, and also updates the network contacts.
3. As the theme of the scenario revolves around security against any kind of physical danger or challenging situation, provision of sufficient information is always the key. To understand the severity or the magnitude of the challenging situation, the context is extremely important.
4. Most of the primary users in the envisioned scenario were young children. Therefore, the system's behavior should be clear and simple. On the other hand, though children should have maximum control of the system in terms of achieving their goals, certain aspects should only be controlled by trusted network contacts.
5. The nature of the prototype is such that utilization of the user's context and personal information requires strict privacy rules. With children it is not such a constraint as with young adults; some degree of approval is needed from them for their information to be shared only with the people they trust.

The results of the user experiment were utilized in refining the user interface. At this stage, the focus was on textual communication and locations of group members. A conceptual application was developed to help children form groups, communicate between group members, and find each other in challenging situations like those described earlier. Moreover, a proof-of-concept prototype of this application was demonstrated. To better understand the technology and implications of its usage in real-world settings, a prototype was created. A conceptual user interface of this application is shown in Figure 3. The application shows the relative locations of group members in the upper part and messages sent between the group members in the lower part. This application could be improved by graphically presenting more detailed contextual information about group members' situation (like stress level). Such information could be produced by, for example, the new sensor solutions, although privacy issues should be addressed first.

Figure 3. Conceptual UI for sharing locations and chatting within a group (UI = user interface).

Discussion

The environment in which children are growing up has changed dramatically during the last decades due to increased material wealth. At the same time, the overall welfare of children has decreased due to increased mental and physical safety risks. New technology has already made it possible to monitor children, notably through their cellphones. Due to parental concern over their child's safety, particularly in an urban environment, cellphones are being acquired for young children (Pantsar-Syväniemi et al., 2014). Although cellphones and especially the latest generation of smartphones already enable methods for tracking children's mobility, there are some cases and situations where additional safety services could be useful.

Different sensor and social web technologies were exploited in the development of new kinds of digital services, thereby, answering the growing need to increase the safety and well-being of children and young people. As a result of the comprehensive participatory codesign process (Pantsar-Syväniemi et al., 2014), a SEWEB safety service concept was designed to answer the growing needs of increasing the safety of children. The findings gained during the design process confirmed the need for remote monitoring, especially on the way to school, which usually causes safety concerns among schoolchildren and their caretakers. Age appeared to be a very critical factor of acceptance of the system, and parents and teachers agreed that the safety service is most appropriate for the youngest schoolchildren, age 7–10. In addition, to increase the usability and acceptance of the safety service system, the portable safety service components should be designed to be easy and unobtrusive to carry along.

Sensors can be used to measure the user's well-being and emotions, whereas social media could be used to improve emotional stability via interactions with other people. It is also possible to create online support groups to help ill-being or excluded children, where adults, medical professionals like psychologists, or other trusted people could react to feedback provided by sensor data measuring an individual's physical and mental state. It can often be difficult to ascertain whether a child is experiencing excess and above-average stress in his or her school/home life, and also for children to express or convey the amount of stress they are under. Therefore, the availability of noninvasive, point of care/home diagnostic devices for stress monitoring—both physical and biochemical—would be advantageous tools for parents and caregivers to use in the comfort of a safe and caring environment. The ability of these devices to dynamically interact with social media environments and secure networks would open opportunities and ways to identify children who are at risk at an early stage, to enable safeguarding interventions if needed and give children a platform where they can access and discuss their situation (i.e., support groups). The dual connection perspective is a core dimension of the Social Sensor Web framework (Mian et al., 2016) and can completely change the way we think about new solutions for children. The point of care cortisol sensor and device can currently detect high physiological concentrations of cortisol in saliva, which are related to having high levels of stress (Sesay, Micheli, Tervo, Palleschi, & Virtanen, 2013). Future challenges for this technology would be in improving the dynamic range of concentrations to accurately monitor low stress levels and in developing data transfer and software interfacing for mobile applications.

It is important to embrace and exercise the real needs, desires, and requirements of the customers in the field when designing novel applications and offering new technology solutions. The needs of the intended user groups must be clearly kept in mind and already taken into account in the concept development and design phase (Pantsar-Syväniemi et al., 2014). Interaction systems for children are usually designed by adults who often have very little or no idea of children's needs and desires (Kelly, Mazzone, Horton, & Read, 2006). Several authors (Alborzi et al., 2000; Kelly et al., 2006) have determined that involving children in product development is beneficial. Previous study findings reveal that children value being able to participate and be active in design, use, and evaluation processes (e.g., Ervasti, Kinnula, & Isomursu, 2010; Kelly et al., 2006; Pantsar-Syväniemi et al., 2014).

A business model is seen as a concept and a unit of analysis (Zott & Amit, 2010) built around a business opportunity (Teece, 2010; Zott, Amit, & Massa, 2011). It answers questions like what is a firm's product and service offering to customers, what is the value proposition, and how, where, and with whom is the firm planning to accomplish it in practice and why they think it is profitable. The business potential of the SEWEB concept can be estimated using a business model approach and conceptualization (Ahokangas et al., 2014). It represents a unique style of questioning the future with the intent to transform organizations and society.

From the perspective of commercial and practical feasibility, the key question is who should cover the costs of the safety applications, and with what kind of business model, as the applications may require the involvement of public service providers (e.g., school), families (children and adults), associations (e.g., parent associations), and companies providing such applications and their maintenance. Also, the funding structures and organization of activities related to child safety may vary considerably in different countries, thereby creating challenges for applicable business models in commercializing the applications.

Parents could be the paying customers of the SEWEB "Kid Safety Solution App," which would include remote monitoring, location information, alarm notifications, and dual-way communication features for the children, with the value proposition of providing important knowledge about their child's security and well-being. Differentiation from other solutions could include the expandability of sensors connected to the app and the shareability and traceability of the collected sensor information, also over time, as the data would be stored in a cloud. The key operations of the business would include app development and services related to the app, and the basis of the competitive advantage of the SEWEB business includes the sensors combined with social media, also allowing schools to have access to the children's data.

The utilization of technologies are still gaining popularity and it can be expected that these technology environments will be improved in the coming years, as Internet of Things standardization bodies are working on developing protocols, systems, architectures, and frameworks. The current vest prototype is designed to mainly provide safety-, behavior-, and activity-related information about the user, but as future work, the vest could be made more appealing from the children's point of view and designed to also include some gaming and socializing applications alongside the safety-related features. The technicalities of the vest do not restrict embedding other sensors in the vest as well, or involving other end-user groups, such as older people, besides the children. One great challenge in implementing smart clothing is energy consumption, because wearable sensor systems consume a lot of battery power.

Future challenges of SEWEB include three paradoxes that related to the social web user's identity both online and offline. These paradoxes concern privacy, identity, and credibility (Oinas-Kukkonen & Oinas-Kukkonen, 2013). First of all, people have a need to both share (some of) their information and ensure their privacy, which creates a privacy paradox. Especially when children are involved, the need to understand the risks involved in information sharing—whether it happens automatically or manually—is crucial. The identity paradox relates to the fact that even when people are online as themselves, without pretending to be someone else, a social web profile cannot fully and genuinely represent the person behind the online profile. The credibility paradox states the fact that no one can rely on who or what kind of person there actually is behind an online profile or pseudonym, no matter how convincing the person seems to be on the web (Oinas-Kukkonen & Oinas-Kukkonen, 2013). What comes to the privacy paradox and the need to share information while ensuring privacy, users should be able to easily choose who can access and see their shared sensor data. Even though we live in the web era, it is not clear to all how the web truly works and not everyone is fully aware of the fact that practically everything one shares on the web possibly stays there forever for somebody to find. Thus, privacy aspects need to be taken into account at the very beginning of the design process of a new sensor system.

The proposed concept has large-scale potential and can be used in different application areas (Kinnunen et al., 2016). School bullying is increasing and tools need to be developed to detect and prevent school bullying (Ye, Ferdinando, & Alasaarela, 2014; Ye, Ferdinando, Seppänen, & Alasaarela, 2014). Cyber bullying—either overt or relational—is considered an extension of the traditional form of bullying, but with its own defining characteristics. The characteristics of cyber bullying can be considered from both the psychological (in terms of its effect on the victims) and technological perspective (the measures in place to detect and help in mitigating its effects). Location-based data with combined information about well-being status and environmental data opens possibilities for human behavior tracking applications also in the areas of well-being at work. The SEWEB concept also offers good possibilities to develop personalized health promotion applications and services. In addition, older people could benefit from safety applications, for example, by increasing and lengthening their possibilities to enjoy independent and safe living.

Conclusion

Sensors and mobile technology provide the basis for a new platform to support the safety of children and young people. To increase the usability and acceptance of the safety service application, sensors and wearable/portable technology should be designed to be easy and unobtrusive to carry along. Deeper integration of sensors and the social web (e.g., two-way communication) would allow us to foresee drastic changes in communities, and new applications and new social-ethical scenarios will emerge. However, an unobtrusive and pleasurable user experience (both hardware and software) nonetheless remains a high-priority goal in advancing towards acceptance of such applications. Future safety and well-being services will succeed only if they respond to end-user needs, fit into the context of everyday usage, provide value for users, and from a commercial and cost-of-use perspective, are viable to be launched.

Funding

The authors would like to thank TEKES (the Finnish Funding Agency for Innovation) for financial support of the SEWEB project (40027/13, 40028/13).

References

Adafruit Flora. (2016). *Wearables/flora*. Retrieved from http://www.adafruit.com/flora

Aggarwal, C., & Abdelzaher, T. (2011). Integrating sensors and social networks. In C. C. Aggarwal, & T. J. Watson (Eds.), *Social network data analytics* (pp. 379–412). New York, NY: Springer.

Ahokangas, P., Matinmikko, M., Yrjölä, S., Mustonen, M., Posti, H., Luttinen, E., & Kivimäki, A. (2014) *Business models for mobile network operators in Licensed Shared Access (LSA)*. Proceedings of IEEE International Symposium on Dynamic Spectrum Access Networks (DYSPAN, pp. 263–270), McClean, Virginia.

Ahokangas, P., Perälä-Heape, M., & Jämsä, T. (2015). Alternative futures for individualized connected health. In S. Gurtner & K. Soyez (Eds.), *Challenges and opportunities in health care management* (pp. 61–74). Cham, Switzerland: Springer International Publishing.

Alborzi, H., Druin, A., Montemayor, J., Sherman, L., Taxén, G., Best, J., … Hendler, J. (2000). *Designing story rooms: Interactive storytelling spaces for children*. In Proceedings of the Symposium on Designing Interactive Systems (DIS'00, pp. 95–104), Brooklyn, New York.

Aminian, K., & Najafi, B. (2004). Capturing human motion using body-fixed sensors: Outdoor measurement and clinical applications. *Computer Animation and Virtual Worlds*, *15*(2), 79–94. doi:10.1002/cav.2

Archer, J., & Cote, S. (2005). Sex differences in aggressive behavior. In R. E. Tramblay, W. W. Hartup, & J. Archer (Eds.), *Developmental origins of aggression* (pp. 425–443). New York, NY: Guilford.

Bakker, J., Pechenizkiy, M., & Sidorova, N. (2011). *What's your current stress level? Detection of stress patterns from GSR sensor data*. In Proceedings of the 2011 IEEE 11th International Conference on Data Mining Workshops (ICDMW '11, pp. 573–580). IEEE Computer Society, Washington, DC. Retrieved from http://dx.doi.org/10.1109/ICDMW.2011.178

Blumenthalk, J., Grossmann, R., Golatowski, F., & Timmermannk, D. (2007). *Weighted centroid localization in zigbee-based sensor networks*. Processing IEEE International Symposium Intelligent Signal Process (pp. 1–6), Madrid, Spain.

Boucsein, W. (1992). *Electrodermal activity*. New York, NY and London, UK: Plenum Press.

Buechley, L., Eisenberg, M., Catchen, J., & Crockett, A. (2008). The LilyPad Arduino: Using computational textiles to investigate engagement, aesthetics, and diversity in computer science education. Processing SIGCHI Conference Human Factors in Computing Systems (CHI'08, pp. 423–432), Florence, Italy.

Chan, M., Estève, D., Fourniols, J. Y., Escriba, C., & Campo, E. (2012). Smart wearable systems: Current status and future challenges. *Artificial Intelligence in Medicine*, *56*(3), 137–156. ISSN 09333657, doi:10.1016/j.artmed.2012.09.003

Curmi, F., Ferrario, M. A., Southern, J., & Whittle, J. (2013). *HeartLink: Open broadcast of live biometric data to social networks*. In Proceedings of the 2013 ACM Annual Conference on Human Factors in Computing Systems (CHI '13, pp. 1749–1758). ACM, New York, NY. Retrieved from http://doi.acm.org/10.1145/2466110.2466231

Czeskis, A., Dermendjieva, I., Yapit, H., Borning, A., Friedman, B., Gill, B., & Kohno, T. (2010). *Parenting from the pocket: Value tensions and technical directions for secure and private parent teen mobile safety*. In Proceedings of the 6th Symposium on Usable Privacy and Security (SOUPS '10). New York, NY. Retrieved from http://doi.acm.org/10.1145/1837110.1837130

Efstratiou, C., Leontiadis, I., Picone, M., Rachuri, K. K., Mascolo, C., & Crowcroft, J. (2012). *Sense and sensibility in a pervasive world*. Pervasive Computing 10th International Conference (pp. 406–424). Retrieved from http://dx.doi.org/10.1007/9783642312052_25

Ertin, E., Stohs, N., Kumar, S., Raij, A., Al'absi, M., & Shah, S. (2011). *AutoSense: Unobtrusively wearable sensor suite for inferring the onset, causality, and consequences of stress in the field*. In Proceedings of the 9th ACM Conference on Embedded Networked Sensor Systems (SenSys '11, pp. 274–287). ACM, New York, NY. doi:10.1145/2070942.2070970

Ervasti, M., Kinnula, M., & Isomursu, M. (2010). User experiences with mobile supervision of school attendance. *International Journal on Advances in Life Sciences*, *2*(1), 29–41.

Fraser, K., Rodden, T., & O'Malley, C. (2006). Home–school technologies: Considering the family. In Proceedings of Interaction Design and Children (IDC'06, pp. 153–156), Tampere, Finland.

Goldoni, E., Savioli, A., Risi, M., & Gamba, P. (2010). *Experimental analysis of RSSI-based indoor localization with IEEE 802.15.4* (pp. 71–77). Wireless Conference EW European, Lucca, Italy.

Hayre, H. S., & Holland, J. C. (1980). Cross-correlation of voice and heart rate as stress measures. *Applied Acoustics*, *13*(1), 57–62. doi:10.1016/0003-682x(80)90043-2

Ilves, T. (2012). *Redesigning health in Europe for 2020. European Union 2013, Belgium*. Retrieved from http://ec.europa.eu/digital-agenda/en/news/eu-task-force-ehealth-redesigning-health-europe-2020

Intel. (2016). *Intel Galileo*. Retrieved from http://www.intel.com/content/www/us/en/do-it-yourself/galileo-maker-quark-board.html

Jabeur, N., Zeadally, S., & Sayed, B. (2013). Mobile social networking applications. *Communications of the ACM*, *56*(3), 71–79. doi:10.1145/2428556.2428573

Jutila, M., Rivas, H., Karhula, P., & Pantsar-Syväniemi, S. (2014). *Implementation of a wearable sensor vest for the safety and well-being of children*. Conference on Body and Sensor Area Networks BASNet 14'. Hasselt, Belgium.

Jutila, M., Karhula, P., Rivas, H., & Pantsar-Syväniemi, S. (2015b). End-to-end safety solution for children enabled by a wearable sensor vest. *Journal of Ubiquitous Systems & Pervasive Networks*, *6*(1), 33–39.

Jutila, M., Strömmer, E., Ervasti, M., Hillukkala, M., Karhula, P., & Laitakari, J. (2015a). Safety services for children: A wearable sensor vest with wireless charging. *Personal and Ubiquitous Computing*, *19*(5), 915–927. doi:10.1007/s00779-015-0838-z

Kelly, S. R., Mazzone, E., Horton, M., & Read, J. C. (2006). *Bluebells: A design method for child-centred product development*. In Proceedings of the 4th Nordic Conference on Human–Computer Interaction (NordiCHI'06, pp. 361–368), Oslo, Norway.

Kim, S. E., Strecher, V. J., & Ryff, C. D. (2014). Purpose in life and use of preventive health care services. *Proceedings of the National Academy of Sciences*, *111*(46), 16331–16336. doi:10.1073/pnas.1414826111

Kinnunen, M., Mian, S. Q., Oinas-Kukkonen, H., Riekki, J., Jutila, M., Ervasti, M., … Alasaarela, E. (2016). Wearable and mobile sensors connected to social media in human well-being applications. *Telematics and Informatics*, *33*(1), 92–101. doi:10.1016/j.tele.2015.06.008

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, A. O. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology*, *30*(3), 261–273. doi:10.1111/j.1469-8986.1993.tb03352.x

Macias, E., Suarez, A., & Lloret, J. (2013). Mobile sensing systems. *Sensors*, *13*, 17292–17321.

Mattila, M. (2011). *Mobile technologies for child protection: A briefing note*. UNICEF WCARO, Dakar. Retrieved from http://www.unicef.org/wcaro/english/mobile_technologies_for_child_protection.pdf

Mian, S. Q., Mäntymäki, M., Riekki, J., & Oinas-Kukkonen, H. (2016). *Social sensor web: Towards a conceptual framework. In social media: The good, the bad, and the ugly*. Proceedings of the 15th IFIP WG 6.11 Conference on e-Business, e-Services, and e-Society, I3E 2016, September 13–15, Swansea, UK.

Mian, S. Q., Oinas-Kukkonen, H., & Riekki, J. (2015, August 9–12). *Leveraging the usage of sensors and the social web: Towards systems for socially challenging situations*. 6th Scandinavian Conference on Information Systems (SCIS 2015, pp. 44–60). Oulu, Finland. Vol. 223 of the series Lecture Notes in Business Information Processing.

Miluzzo, E., Lane, N. D., Fodor, K., Peterson, R., Lu, H., Musolesi, M., … Campbell, A. T. (2008). *Sensing meets mobile social networks: The design, implementation and evaluation of the CenceMe application*. In Proceedings of the 6th ACM Conference on Embedded Network Sensor Systems (SenSys'08, pp. 337–350). ACM, New York, NY. Retrieved from http://doi.acm.org/10.1145/1460412.1460445

Oinas-Kukkonen, H., & Oinas-Kukkonen, H. (2013). *Humanizing the web: Change and social innovation*. Basingstoke, UK: Palgrave Macmillan.

Pantsar-Syväniemi, S., Ervasti, M., Karppinen, K., Väätänen, A., Oksman, V., & Kuure, E. (2014). A situation-aware safety service for children via participatory design. *Journal of Ambient Intelligence and Humanized Computing*, *6*, 279–293. doi:10.1007/s12652-014-0225-z

Pavel, D., Callaghan, V., & Dey, A. K. (2012). *Supporting wellbeing through improving interactions and understanding in self-monitoring systems*. In J. C. Augusto, M. Huch, A. Kameas, J. Maitland, P. McCullagh, J. Roberts, A. Sixsmith, & R. Wichert (Eds.), Ambient Intelligence and Smart Environments, Volume 11: Handbook of Ambient Assisted Living (pp. 408–433). Amsterdam, the Netherlands: IOS Press. doi:10.3233/9781607508373408

Raspberry pi foundation. (2016). Retrieved from http://www.raspberrypi.org

Sesay, A. M., Micheli, L., Tervo, P., Palleschi, G., & Virtanen, V. (2013). Development of a competitive immunoassay for the determination of cortisol in human saliva. *Analytical Biochemistry*, *434*(2), 308–314. Epub 2012, Dec 19. doi:10.1016/j.ab.2012.12.008

Setz, C., Arnrich, B., Schumm, J., La Marca, R., Troester, G., & Ehlert, U. (2009). Discriminating stress from cognitive load using a wearable EDA device. *IEEE Transactions on Information Technology in Biomedicine*, *14*(2), 410–417. doi:10.1109/titb.2009.2036164

Shankar, P., Huang, Y. W., Castro, P., Nath, B., & Iftode, L. (2012). *Crowds replace experts: Building better location based services using mobile social network interactions*. PerCom 2012 Proceedings (pp. 20–29). Retrieved from http://dx.doi.org/10.1109/PerCom.2012.6199845

Teece, D. (2010). Business models, business strategy, and innovation. *Long Range Planning*, *43*(2–3), 172–194. doi:10.1016/j.lrp.2009.07.003

Ye, L., Ferdinando, H., & Alasaarela, E. (2014). Techniques in pattern recognition for school bullying prevention: Review and outlook. *Journal of Pattern Recognition Research*, *9*(1), 50–63. doi:10.13176/11.586

Ye, L., Ferdinando, H., Seppänen, T., & Alasaarela, E. (2014). Physical violence detection for preventing school bullying. *Advances in Artificial Intelligence*, *2014*, 9. Article ID 740358. doi:10.1155/2014/740358

Zanca, G., Zorzi, F., Zanella, A., & Zorzi, M. (2008). *Experimental comparison of RSSI-based localization algorithms for indoor wireless sensor networks*. Proceedings of the Workshop on Real-World Wireless Sensor Networks (pp. 1–5), Glasgow, Scotland.

Zott, C., & Amit, R. (2010). Business model design: An activity system perspective. *Long Range Planning*, *43*(2–3), 216–226. doi:10.1016/j.lrp.2009.07.004

Zott, C., Amit, R., & Massa, L. (2011). The business model: Recent developments and future research. *Journal of Management*, *37*(4), 1019–1042. doi:10.1177/0149206311406265