A proposed data-driven health-care monitoring system using near field communication

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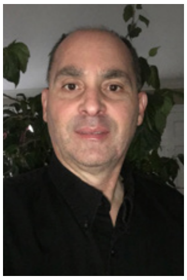

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is a serial entrepreneur, in addition to receiving honours for both his research and his business accomplishments. He has received a Forty Under 40 Award, was a finalist in the Executive Management Awards and has received awards from Intel Excellence in Computer Science, Grace Murray Hopper Prize and many other honours. He received an undergraduate research award while completing his bachelor's in science and business administration at Shippensburg University. A certified project management professional, experienced in project management and business development, he has managed multiple cross-functional infrastructure and cloud software solution initiatives. He is a co-inventor of patent application PCT/US2016/020497, a networked computer system for remote radio frequency identification (RFID) device management and tracking. He has written several books on topics of technology, leadership and entrepreneurship. While currently pursuing a Master of Business Administration degree, he is also managing data collection between his businesses in order to research and monitor trends in emerging technology. The objective of this research is to use the analytical data from these projects to determine an effective approach to determining technical changes that enhance access to information and improve the human experience. He is a business and technology evangelist, with a life's mission to share knowledge with others.

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Abstract Caregivers and healthcare professionals need better methods to provide data-driven treatment options. One way to accomplish this is to create a data-driven health-care monitoring system to collect data in a timelier and more efficient manner. The data can then be analysed and utilised to create a more focused treatment plan. Our research study proposes a data-driven health-care monitoring system using near field communication (NFC)-enabled devices to collect data and transmit it to a secure location; the data are then analysed and used by a healthcare professional to maintain or modify a patient's treatment plan. Specifically, we envision the use of this technology to monitor activities performed by autism patients. The results of this research should help determine whether the improved method of data collection affords a healthcare professional the opportunity to better assign activities that can boost the cognitive ability of the patient on the autism spectrum. Researchers also believe that this method of data collection increases accuracy, which will ultimately increase the quality of patient care and therapy.

KEYWORDS: data-driven treatment, near field communication, health-care monitoring system

INTRODUCTION

Therapists for children with autism have limited time, generally only a few hours a week, to conduct and assess activities designed to help increase the cognitive ability of their patients.[1] It is important for a patient's caregiver to reinforce the activities and lessons that were addressed by the therapist during these sessions throughout the remainder of the week. Currently, a limitation that exists for outpatient reinforcement and therapy is the time gap between caregivers and educators updating the therapist on the patients' progress with at-home or classroom activities. To address this time gap, we propose a data-driven health-care monitoring system that uses near field communication (NFC)-enabled devices to wirelessly collect and analyse data. With the use of NFC sensors, secure data collection and analysis of data, therapists can determine appropriate approaches to increase effectiveness in helping the patient overcome cognitive limitations and increase social interaction. As part of this proposed research project, a therapist will give their patient a task to do at home or school. The patient's caregiver and/or educator will use an NFC sensor in the form of a wristband worn by the patient to complete a short questionnaire on the patient's progress at each attempt of an activity. The wristband facilitates data entry and upon being touched by an NFC-enabled reader device, establishes a secure network connection that provides caregivers or educators quick and secure access in order to log progress. We contend that this approach should provide greater accuracy since data are being logged at the time when the event or task occurs and not hours or days later.

With data collected between therapy sessions, a therapist working on building their patients' cognitive skills will be able to better determine the next activity for the patient to complete, by basing it on the collected and analysed data. If the data indicate that the patient struggled with the original task, then a simpler task may be assigned. In contrast, if the patient's attempts were successful, then a different and possibly more difficult activity could be assigned. As a patient advances through their specific programme, the therapist is always aware of their patient's progress and can determine the next best course of action. Other studies report that it is beneficial to support individualised health care for family members at home by tracking patients' health information.[2–6] This type of streamlined secure data collection and reporting with the use of wireless sensors could lead to major achievements and help move a patient to a higher level of functioning on the autism spectrum. With these types of patients, social interaction in addition to successful accomplishments could lead to behavioural change and increased cognitive ability.

There is value in a caregiver's involvement in understanding and helping to treat a patient.[7] But how is this best realised? We argue that our proposed data-driven health-care monitoring system has value in collecting and analysing data, and it also increases the participation of the caregiver. This active participation should provide a more accurate assessment since the task results would be evaluated at the time of participation and not collected later. The feedback would be valuable to the therapist because it would give consistent data about the effectiveness of treatment. Therapists could then make necessary changes to the plan of care if the results showed that the current interventions were not effective. Most often, therapists approach this 'blind', and only after a lengthy interview with the caregiver do they know if improvements are occurring at home. Therefore, therapists could spend a lot of time and money on treatment that is really not working. With the feedback provided through this data-driven health-care monitoring system, it should be easier to identify what works and what does not, fine-tuning their intervention and adding value by reducing the amounts billed to insurance companies for methods that, to date, are unknowingly ineffective. This reduces wasted treatment time and may ultimately help increase the cognitive function and social interaction/programme of the patient on the autistic spectrum.

NEAR FIELD COMMUNICATION TECHNOLOGY

NFC is a subset of RFID (radio frequency identification) technology, but RFID cannot be read with consumer devices, such as smartphones or tablets. RFID is also a long-range frequency; in contrast, NFC operates on short-range frequency. NFC is a technology that allows a tag to interact with a smartphone within almost touching distance of the tag. To use NFC, a user would touch a smart device such as a phone to the NFC tag, and from there the connection would automatically load data to the phone. In our proposed health-care monitoring system, touching the phone to the NFC tag will launch a web interface within the device's browser. This was the best approach to the study rather than using a stand-alone mobile application. While a mobile application can collect data, these applications tend to be much more difficult to secure. Given the sensitivity of the data and patient privacy, security is crucial.[8,9] An NFC tag can be configured to go through multiple security checks and verifications with the touch of a reading device. Our proposed system had read-only tags with a tokenised authentication process across a secure socket layer (SSL), which encrypts all interaction or traffic between the health-care monitoring system and connecting devices. With this configuration, if a patient lost their wristband, it could be remotely disabled so that the data could not be accessed. For those on the autistic spectrum, the process of touching a smartphone to a tag is much easier than scrolling through a mobile application, which could create additional distractions. The simplicity makes it easy to implement and utilise as a routine throughout the day.

NFC has three distinct modes, namely 'read', 'write', and 'emulation'. For this study, the read and write functions are used. The emulation mode is most commonly used for payment in systems such as Android Pay, Apple Pay, Samsung Pay and many others. Since NFC requires a very close proximity to work, it provides great security benefits that are necessary within the healthcare vertical. Where long-range scanners can read RFID, NFC does not function in that manner.

NFC tags are affordable and come in a variety of form factors, such as bracelets, stickers, key chains and rings, and many other common forms, simplifying implementation for most use cases. The tags in this study average to approximately US$0.45 per unit. We will use a round plastic tag for durability, with an adhesive and a layer of ferrite to allow the tag to work on metal objects without any radio frequency interference. Tags in the sticker form factor can be as low as US$0.12, with bracelets averaging around US$1.20 per unit. This technology has been around for several years. Apple, within the last year, added NFC support into their most recent devices, joining the ranks of many other phone manufacturers who support the technology and increasing the accessibility of engaging with NFC.

INTELLECTUAL MERIT

Statement of objectives

The initial study will comprise working with 15 patients who suffer from autism. The patients' caregivers will help report daily progress through NFC sensors, which will store and analyse the data within a specialised data management system. The method of data collection and reporting uses a proprietary technology with US patent application US 15/058,965 and patents pending internationally. There is no other way to accurately carry out this research without the use of this proprietary method. The primary goal of this research is to increase reporting accuracy between patient visits with their therapist by measuring progress instantly after completing an activity. Therefore, our research question is: does the increased accuracy of data collection afford the therapist the opportunity to better assign activities that can boost the cognitive ability of the patient on the autism spectrum? An additional goal is to create documented research as it relates to the use of NFC in health care. Some current research studies[10,11] discuss electronic health-care applications with medication management. Other studies[12,13] apply technology to improve patient privacy. No studies, however, exist with a quantitative networked computer system to analyse data.[14] The data collected from this research can be used for future studies and research exploring this technology and its relevant uses in healthcare.

Methods

A web-based software application was developed using PHP and SQL database, which was designed to sort groups of data and allow data to be added, modified and measured. This software solution establishes connections between the therapist's user interface, the NFC sensor and the payload that would be delivered on interaction with the NFC sensor. This can be thought of as a folder, or grouping, of NFC sensors that relate to a specific patient. A therapist will first create a file for the patient within that software application. The software allows a therapist to create tasks and write them to an NFC sensor. The interface to do so is depicted in Figure 1.

New tasks can be created easily from the dashboard within the system. A therapist would access a desired patient's folder and would click on the plus (+) symbol to create a new task. The task creator enters a link to content that they have posted online in the form of a universal resource locator (URL), as depicted in Figure 2. Once a task is added, using an NFC encoding application such as NXP's TagWriter, a therapist would scan the generated quick response (QR) code and then touch their phone to an NFC sensor to write the data to it. This will allow the patient to access the task at any time by touching the NFC sensor with an NFC

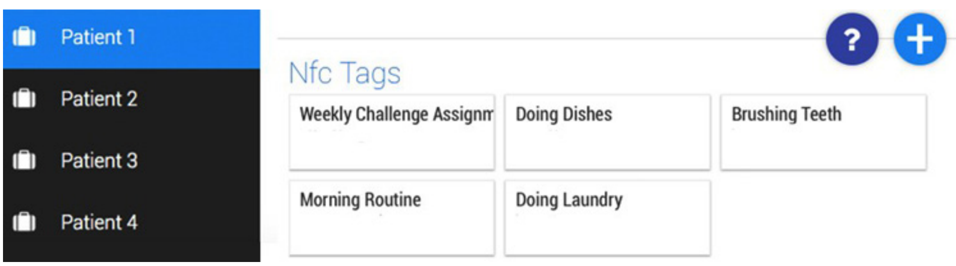


Figure 1: Provider dashboard to organise patients and associated tasks

Figure 2: Interface to add a new task

reader such as a smartphone or tablet. Since the system is cloud based, a therapist can change the content on the sensor remotely to modify the task. This data-driven task modification method allows the therapist to modify treatment based on the actual data being reported. A tremendous advantage to the cloud-controlled health-care monitoring database system is that the therapist does not need to re-encode the sensor to make changes.

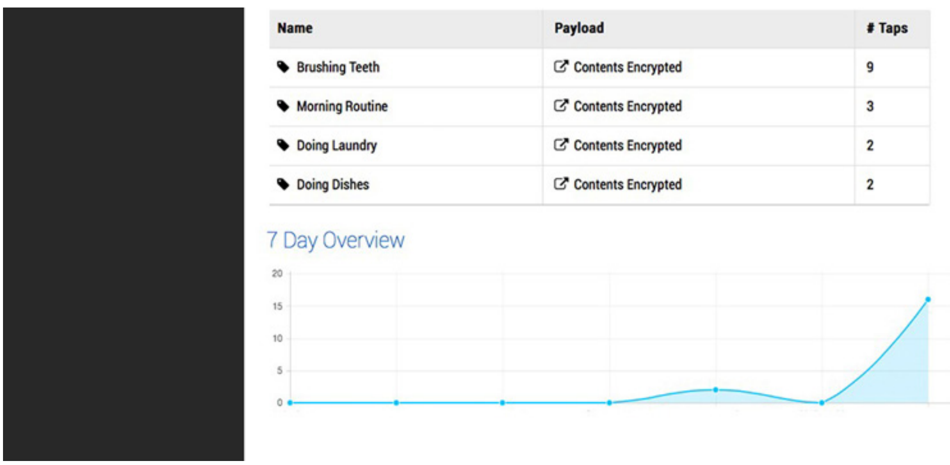
Once an NFC sensor containing a link to the associated task has been encoded, the therapist will give the NFC sensor to the patient's caregiver, with instructions on where to place it within the home. In addition, a brief overview of the task assigned will be provided. Once an NFC sensor is placed, patients can access the task by touching their phone to the NFC sensor. For example, if the task or assignment is to do laundry, then the caregiver would place the NFC sensor on the washing machine in the home. After touching their device to this sensor, the patient will begin the task, as depicted in Figure 3. Although Figure 3 depicts a single task, a therapist can provide multiple tasks to a caregiver by providing multiple NFC sensors.

Throughout the week, a therapist can view metrics about what tasks the patient has initiated with their smartphone and when and how frequently they access the tasks and supported materials such as instructional videos. Figure 4 depicts the data metrics and provides a snapshot of the patient's activity routine. Task attempts are tracked, and the therapist can view when and how often the patient attempted tasks.

The caregiver would be given NFC sensors to place in their home or an educational facility to report on the patient's progress with everyday tasks, such as getting dressed or brushing their teeth. To collect data, every patient would be provided with a wristband with an NFC sensor embedded. The use of this sensor is to allow the caregiver to easily report progress as tasks are completed. When the caregiver, who is reporting on the outpatient's progress, touches their smart device (phone or tablet) to the wristband worn by the patient, they are prompted to enter a secure code that is specific to that caregiver. This prevents the patient from accessing and changing the recorded data. The caregiver would then answer a question or a series of questions related to the patient's progress with the task, which is unique to a specific patient, as depicted in Figure 5. These questions, crafted by autism experts and therapists, will determine the best messaging to get accurate data. Therapists can then compare these data with the information reported by the caregiver, through the interface prompted by the wristband, to see how the patient is progressing with the assigned tasks.

If a therapist concludes that ample progress has been made for a particular patient, then the therapist can create additional tasks for that patient. This is realised using the specific patient's dashboard and file. A therapist would supply additional NFC sensors to the caregiver for the following week. If the patient did not show significant progress, the therapist can directly address those tasks during their

Figure 3: Patient engagement



Name	Payload	# Taps
Brushing Teeth	Contents Encrypted	9
Morning Routine	Contents Encrypted	3
Doing Laundry	Contents Encrypted	2
Doing Dishes	Contents Encrypted	2

Figure 4: Patient usage dashboard for a therapist

Figure 5: Caregiver reporting through NFC-enabled wristband and smartphone

sessions or try to determine what stumbling blocks the patient encountered to help identify subsequent therapy. Over time, the therapist will have access to a collection of reports and a view of the different tasks assigned as well as the patient's progress. The therapist will also be able to note whether the patient went back and tried previous tasks again. This type of data provides a view that therapists currently do not have, which may help make treatment decisions easier and more effective.

Patient privacy must also be considered, and other researchers argue that patient privacy is fundamental and must be ensured in any electronic health-monitoring system.[15,16] To that end, the proposed data-driven health-care monitoring system will use an NFC sensor that contains a hashed or obscured data set, which cannot be linked to a specific patient in any way. This type of technology used for patient identification is very useful.[17] As the data are entered, a data integration system will determine how it is processed and logged. Each patient in the data system will have a human identification number (HID), which ensures privacy since there are no names, social security numbers or any other information to identify the patient. Each task or activity will be sorted inside the data integration system with another identifier called the PID (package identifier). The obscured data stored on the NFC sensor will send both the HID unique identifier and the PID to the centralised data management system. When prompted by a user touching a smart device to the sensor, the data management system will then return a series of questions. As the caregiver enters the requested data, the information is encrypted and sent back to the centralised data management system, where it will be stored. Once data are stored, it will log metrics for the HID, the activity and the reported data. These data will then be presented to the therapist through an encrypted user interface, where they can review the data and determine the next step in the treatment. The process is depicted in Figure 6. NFC sensors in the home or educational facility can then be updated remotely with the next level of tasks for the patient to work towards achieving. This will streamline the process and provide metrics for therapists to determine progress, while also simplifying the implementation process of the caregiver since the sensors will only need to be placed once.

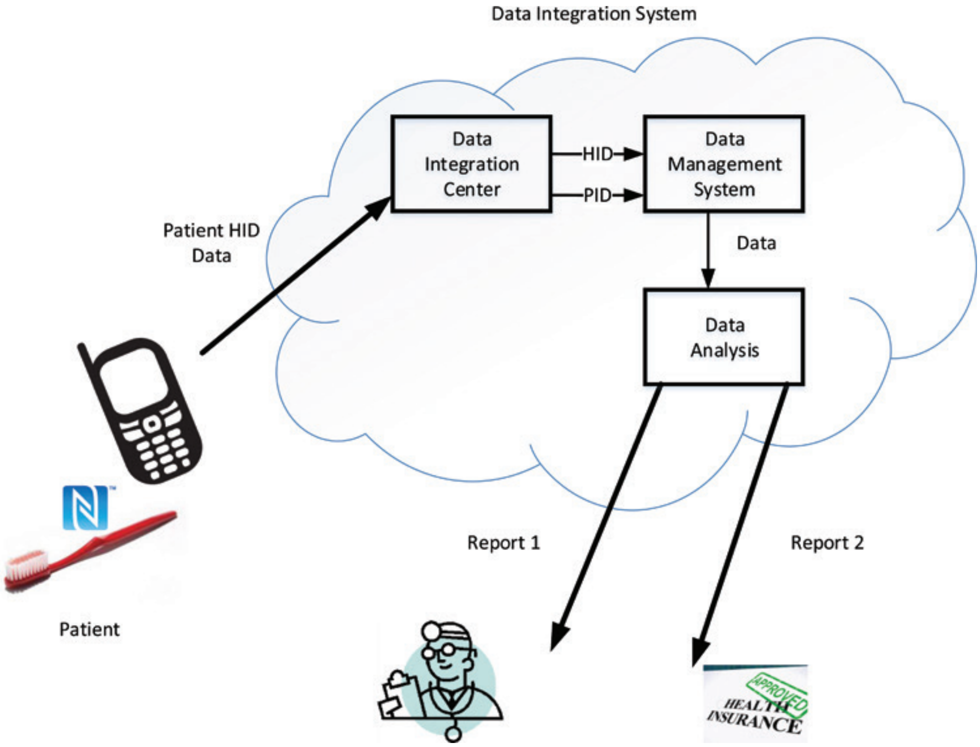


Figure 6: Process of data collection

This process will use multiple redundant data centres where traffic is secured with modern cryptology and a 256-bit AES encryption on the data. If an NFC sensor is lost, the therapist can remotely destroy it to ensure the highest level of privacy and compliance. Additional security measures include the use of an extended validation SSL certificate, HTTPS packet transmission, TLS 1.2, Server side RSA Certificate with AES with 128 bit keys and SHA256. The SHA-256 algorithm generates an almost unique, fixed size 256-bit (32-byte) hash. Hash is a one-way function — it cannot be decrypted back, further enhancing the level of data security and compliance.

BROADER IMPACT

The broader impacts of this proposed data-driven system are twofold. The first involves the ability to apply the system to monitor other types of health-care programmes, for example, diabetics monitoring, weight management monitoring and 'did you take your' prescription medication monitoring, just to name a few.

Another impact of this study affects the relationship between therapists and insurance providers. Recent regulations require therapists to be more accountable and detailed in showing patient progress to the payer (insurance provider) to provide payment for continued treatment. Currently, owing to their limited time with their patients, therapists have a difficult time documenting and logging patient progress. All the while, insurance providers are trying to implement processes to audit patient outcomes to make a determination of payment. The proposed data-driven health-care monitoring system should lead to more accurate data, which should lead to more accurate determinations for the overall plan of care for a patient.

These data will enable a therapist to make necessary changes to the plan of care of a patient in a more timely manner with the intended outcome of improving the patient's progress. This addresses the audit and patient outcome concerns of insurance providers.

Therefore, opportunities exist within the healthcare network for the data collection platform to be implemented into an electronic health record system as research rounds continue. Two electronic health-care record providers, Fusionwebclinic and NextGen, have already expressed interest in this health-care monitoring system since this will help enable better measurement of the patient's progress.

CONCLUSIONS

This paper proposes a data-driven health-care monitoring system to collect data in a timelier and more efficient manner. The data collected can then be analysed and utilised to create a more focused treatment plan for patients. Our research study proposal realises this system using NFC-enabled devices and corresponding software to collect data and transmit that data to a secure location, which is then analysed and used by a healthcare professional to maintain or modify a patient's treatment plan. The results of the initial pilot study should help determine whether the improved method of data collection affords a healthcare professional the opportunity to better assign activities that can boost the cognitive ability of the patient on the autism spectrum. The researchers also believe that this method of data collection increases accuracy and will ultimately increase the quality of patient care and therapy.

This type of system places a high value on caregiver involvement and participation, which should provide a more accurate assessment of a patient. Coupled with the fact that the proposed system ensures patient privacy, the researchers have already received favourable reviews from two electronic health-care record providers. Insurance providers need better methods to audit patient outcomes, and the proposed data-driven health-care monitoring system is a major leap in that direction.

Author's note

In loving memory of Shadow.

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