Full-Length Article

Music Playing a Role in Medical Interoperability

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Abstract

This article outlines interoperability, the exchange of information between distinct systems, specifically regarding how it applies to music in medicine. Interoperability is of growing importance in the increasingly high-tech medical world whose machines, monitors, and devices often utilize acoustic alarms. Additionally, this article expands on the definition of interoperability to include the integration of music such as music therapy with clinical medicine. Despite barriers pertaining to cost and infrastructure, the future of medicine is bright with the expanded, continued application of interoperability.

Keywords*: Interoperability, Health Information Technology, medical alarms, music principles, patient safety*

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Introduction

This article discusses how interoperability, the exchange of information between distinct systems, can be utilized in various medical settings to enhance patient care. High-consequence industries such as medicine require coordination and clear communication to ensure success. In the constant buzz of medical settings, important patient information can easily get lost or may not be communicated quickly enough. Devices that utilize aspects of information exchange amongst distinct devices help to bridge these gaps and facilitate effective communication.

Interoperability

In this 21st century world, human life has become intertwined with technology. Technology is the purposeful application of knowledge that produces some form of superior operational capacity; yet it is pervasive and wildly diverse. Its electronic form maintains a large proportion of all technology, and for the most part, engages with one or more sensory system to create a human-centered interface for the presentation of information. In the realm of medicine, these electronic technologies define a new practice of medicine known as digital health, which can be taken one step further to interoperability.[1] By its formal definition, interoperability is the "ability of a system or a product to work with other systems or products without special effort on the part of the customer."[2] The information that can be accumulated and processed in an interoperable system yields data that better represent the patient as it takes more aspects of the patient's physiology into account. Following the logic that more input information yields better output data, an interoperable system can establish a far more comprehensive image of a patient's well-being. In other words, interoperability allows medical devices to communicate and analyze data such that outputs, or, for example, alarms, represent real-time changes in the patient's health.

The capacity of a system to integrate various digital health tools to effectively minimize outputs is one, nuanced description of interoperability. Broadly, interoperability requires a platform through which distinct medical devices can share information and benefits from the implementation of standards. However, medical devices may not all be using the same "language." To cross this barrier, an implementation of standardized input and output styles for distinct devices may boost interoperability and limit the variation between devices' data. Ideally, medical devices would be standardized for input and output in such a way that presents electronic information in the same form, allowing multiple platforms to be connected and deliver information in the same "language."

One application of interoperability in the medical setting is in regulating medical alarms. Currently, patient monitoring is a concerted effort of multiple devices, each with a unique threshold for alarm. However, in an interoperable system, the indication for an acoustic alarm would not be a single, numeric threshold but rather the result of the accumulation and processing of the information from each of the connected devices. An alarm system incorporating multiple parameters has the ability to make more robust conclusions leading to alarms that are stronger indicators of patient's physiology as well as the suppression of false alarms.[3] By making the indication for an alarm more complex and comprehensive, the

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overall hospital background noise made up partly of false alarms should logically be reduced. This noise reduction will allow for clinicians to better focus their attention on their patient while also trusting that the alarms they hear are significant. Medical devices' underlying purpose is to allow clinicians to study and modify patient care knowing that deviations form a set of 'normal' parameters will trigger an alarm. Interoperability holds the potential to progress medical device alarms towards this goal.

As knowledge of such benefits of interoperability has increased, so have the structures that define it and the companies that supply devices to support it. The Integrated Clinical Environment (ICE) is a universal term that defines the broad building blocks that are necessary in an interoperable system.[4] ICE, in effect, is a set of standards outlining how to integrate information from devices from different manufacturers in order to provide better, safer patient care.[5] With this outline to interoperability provided, it is only a matter of software engineers developing these 'middleware' programs and platforms before interoperability can become universal. For reference, middleware systems are the software programs with the ability to integrate data from multiple sources, such as distinct medical devices, and integrate them to provide a singular output stream according to a set definition of 'normal' parameters.

Motivated by the need for increased device synchronicity, the Office of the National Coordinator for Health Information Technology (ONC) prepared a guide to interoperability published in 2014 with the aim to provide a roadmap for continued advancements in interoperability.[6] As newer machines, treatments, and monitors are introduced to medicine, the need to integrate and organize their information and alert systems has increased. Habituation and desensitization are frequent obstacles faced by some hospital departments, especially those that are of higher intensity levels such as Intensive Care Units.[7] The body has a remarkable way of adjusting to continuous stimuli so that they become less noticeable over time. This is exactly what happens to those who spend a significant amount of time in hospitals with regards to the noise of its alarms. Clinicians are familiar with the high volume of false alarms in the medical setting, a factor linked directly to desensitization.[3] Furthermore, overlapping sounds can be indiscriminable; strict segregation and sequencing of alarm sounds via higher order information processing, such as interoperability, may relieve clinicians of this issue.[8] These aspects of current alarm failures indicate that device interoperability may see the largest positive impact in high-consequence medical environments, but may also be efficacious in a wide range of medical settings.

Hayhurst et al found that half of all nurses witnessed a medical error due to a lack of medical device coordination; a clear and fatal flaw of current US healthcare settings.[9] Medical device coordination refers to the shared information between these devices; a lack thereof may cause their alarms to risk being repetitive or false. With interoperable medical devices, medical alarms may be coordinated such that, based on multiple parameters, more extreme physiological changes induce stronger, more noticeable alarms and smaller physiological changes that do not represent detrimental changes to patient health may not trigger alarms at all. In this way, combining information from multiple different systems and processing it altogether may benefit clinicians' understanding and interpretation of alarms so as to improve patient care. With the potential to improve performance and increase accuracy, interoperability will revolutionize how patients receive medical care.[10] According to Dave Cassel, director of Carequality, an interoperability initiative with the goal of understanding the technology and the policies interoperability requires, "many physicians are connected to one data sharing network or another. If you connect just a few of these networks together, we are on the cusp of a quantum leap in interoperability."[6]

There are currently multiple programs to enhance or provide interoperability being developed around the world. Examples include the US-American "MDPnP" system, the Japanese "SCOT" and the German OR.NET programs.[11-13] Each of these interoperable platforms is simultaneously creating distinct pathways to provide interoperability.[14] In other words, these distinct programs are all attacking the issue of interoperability from different corners of the world, at the same time. Take, for example, the US-American MDPnP system that is associated with Massachusetts General Hospital and is exemplary of an effective interoperability program. MDPnP stands for 'medical device plug-and-play' and describes a platform that various devices from different manufacturers can simply connect to in order to establish interoperability. The MDPnP program convenes large-scale meetings with experts in disparate fields ranging from engineers to medical device vendors to the US Food and Drug Administration (FDA).[13] Interdisciplinary programs such the MDPnP program are key in the medical community's pursuit to obtain total interoperability as they are taking the lead in this aspect of medicine's future.

It is important to note that, despite the development of the aforementioned programs, there are currently no comprehensive, universal middleware systems in place to serve as the communication backbone of interoperability.[4] These ICE-defined middleware systems are necessary to integrate the various sources of data from the connected interoperable devices and process them into one, streamlined alarm indicator. While there is ongoing research into middleware, such as the development of interoperability platforms like iLandis, the journey to full interoperability has yet to be and will likely never prove to be easy. According to Hayhurst et al, the largest obstacles currently facing hospitals' transition to fully interoperable clinical spaces are poorly defined standards, incompatible systems, and unhelpful medical device vendors who are hesitant or unwilling to invest their resources in developing interoperability.[9] There are no medical or governmental incentives driving investments into interoperability nor are there incentives for medical device companies to develop systems with integrable data streams.

It is necessary that all healthcare professionals continue to be involved in the development and advancement of interoperability. Specifically, the end-user must be involved in the product development and usability testing to offer input on how to create the most acoustically ergonomic devices that are maximally user-friendly.[15] To continue, interoperability applies not only to medical devices, but also to electronic health records (EHR). Then, too, would general practitioners benefit from interoperability as it relates to accessing their patients' information collected at other medical facilities.[15] In other words, the continuing research and application of interoperability must incorporate all of the clinicians who will be using these platforms on any basis. Otherwise, the hospitals and systems applying interoperability will never reap the maximum benefits of their digital health tools.

The future of interoperability lies in the goal of continuing to integrate all technologies in hospital departments in addition to using advanced computer processing programs to understand the various informational inputs and in order to dictate which alarms should sound and when. While more machine-based, this type of advanced interoperability creates awareness of the patients' status and needs more holistically by combining and assessing a wide range of factors at any given moment. As Underwriters Laboratories principal engineer Anura Fernando concisely summarizes: "we will have achieved interoperability when we stop talking about it."[9]

Interoperability of Medicine and Music

There are several opportunities to increase interoperability in medicine, some of which include incorporating the basics of one everyday element – music. The combination of science and art has increased in parallel with support for various interdisciplinary programs. Music and medicine, both cardinal representations of art and science, respectively, can work together in several avenues to improve and advance the practice of medical care.

At present, music is already implemented into medical care for various avenues of treatment. It has been shown to help with pain management for people suffering from chronic pain, indicating a possible non-pharmacological pain management option.[16, 17] Amidst the national opioid crisis, the application of any non-pharmacologic treatment for pain should be welcomed and spread.[18] Additionally, collaborative songwriting has been used with Prisoners and ICU Patients to successfully relieve anxiety and depression, as well as Post-Traumatic Stress Disorder (PTSD) and Post-ICU Delirium Syndrome (PICS) symptoms.[19-21] The process of writing lyrics and music allows the release of emotion and memory in a cognitive stimulating fashion. In parallel, the therapeutic process and music activates an improvement in motor function through strengthening multiple sensory pathways. This is especially beneficial for Parkinson's Disease (PD), as rhythmic auditory stimulation has been shown to improve gait in PD patients, but can also be applicable with other patients (e.g. cerebral palsy, chronic stroke).[22-25] Medicine has already proved to be open to integrating music, but there is a wide range of opportunity for improvement.

Medical Alarms

One opportunistic avenue in which to utilize music principles, such as pitch, rhythm and amplitude envelope, is in auditory alarms design. The acoustic environment of the hospital is a constant symphony of medical alarms, yet the lack of integration of basic music principles into auditory cues highlights a missed opportunity to utilize interoperability.[26, 27]

Current medical alarms are designed to adhere to the standard of the International Electrotechnical Commission (IEC) 60601-1-8, which has resulted in poor utilization of known acoustic features and uninformative alarms.[28-32] In accordance with this standard, medical alarms have a uniformed number of pulses, rhythm and octave.(33, 34) Although health care professionals are expected to learn and remember every signal and meaning, uniformity in sounds depletes the uniqueness of alarms, making it almost impossible to decode information of varying nature and importance.[34, 35] Wee and Sanderson found that alarms standardized to the IEC 60601-1-8 were only identified with 100% accuracy by 1 out of 22 nurses, even with mnemonics and training.[36] Additionally, Edworthy et al showed that new auditory icons outperform the IEC 60601-1-8 standard in both recognizability and localizability.[34] As such, the current alarms prove to be hard to learn and distinguish for healthcare professionals, yet there is room for improvement.

Structural changes to alarms, such as the amplitude envelope, may help decrease these deleterious effects. A sound's amplitude envelope is its change in amplitude over time. For example, clicking wine glasses will create an amplitude envelope with rapid onset and exponential decay. Currently, most medical alarms have a flat amplitude envelope characterized by rapid onset, a sustained period, and rapid offset. In contrast, most naturally occurring sounds, a yell or the previously described wine glasses clicking, have a percussive amplitude envelope characterized by a rapid onset, then continuous exponential decay. While the flat amplitude envelope presents a novel, synthetic warning sound, the auditory system is optimized to process a symphony of natural sounds – most consisting of percussive amplitude envelopes.[37] In fact, when utilizing percussive amplitude envelopes for alarms, researchers observed an improvement of recall in a memory task, as well as decreased perceived annoyance, when compared to flat amplitude envelopes. In addition, Schutz et al showed that amplitude envelope promoted learnability of tones.[28] These data suggest that structural adjustments to auditory alarms using music principles may result in alarms that are less aversive, easier to learn, and more recognizable; further leading to improved patient and provider outcomes.[28, 37]

The Operating Room (OR) is one area of the hospital that is not only saturated with alarms signals, but also music.[38] It has been shown that background music playing in the OR can relax the surgeon and improve their performance.[39-41] However, it has also been shown that this music can interfere with communication and overall performance of the room, specifically affecting anesthesiologists.[42-45] This is a prime example of where interoperability of medical devices can assist in ameliorating the interfering effects of music on communication and performance. For example, researchers have developed a device called the Canary Box (Figure 1) that is linked to both the music and a patient monitor during a patient's surgery. By using vital sign algorithms, the Canary Box mutes background music in times that require focus and clear communication.[42] The dynamic nature of this device linking technology allows for the incorporation of music's benefits and effective communication.

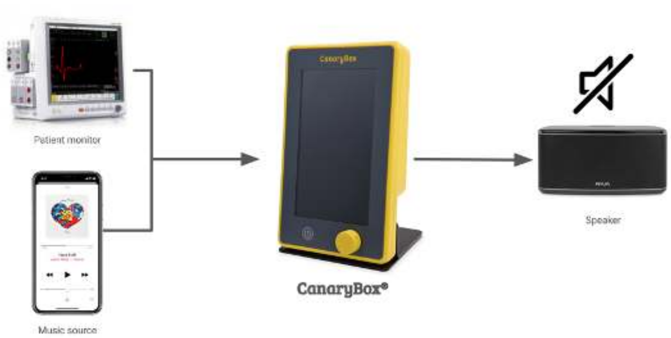

Figure 1. *The Canary Box Design [46]*

"Smart" Emotion

Beyond alarm design, music can play a role in relaxation and proactive care. One important concern in medicine is the risk of physician burnout, which not only affects the medical professional, but may also have residual effects on patient care and safety.[47] Since music activates neural pathways similar to those associated with euphoria and reward, it can be employed to improve mood and induce positive feelings, especially in stressful times.[48] For example, by using pre-recorded musical stimuli, physicians showed significantly reduced burnout symptoms after 5 weeks, which were maintained over a long time period.[19] Similarly, hospitals can be as stressful for patients, but when exposed to musical intervention while in the ICU, patients showed reduced systolic blood pressure and mean arterial pressure, as well as an increased sense of wellbeing.[49] Both examples show a clear improvement for emotional and physiological factors of providers and patients.

With future research, smart, interoperable devices may be able to track and comprehend human emotions in real time. A possible "smart" device could utilize constant emotional and physiological monitoring and change music to match the needs of the patient or provider. For example, such a device may play serene music when the user's emotions register as stressed or upset. Research has shown to recognize emotion through EEG readings from the commercial Emotiv EPOC device (San Francisco, CA), making EEG a possible route of monitoring for a "smart" device.[50, 51] For some patients or austere settings, an EEG may be too invasive or expensive. Another possible physiologic sign to be used in this device could be heart rate variability (HRV), the physiological variation in the duration of intervals between sinus beats. HRV is considered an index of emotional regulation and self-regulatory strength, and can be measured by a simple heart rate monitor or pulse oximeter.[52-54] A device that is in tune for both patients' and providers' emotions may alleviate stress and improve patient outcomes.

From devices that work together, to devices that work with the user, there are various avenues of improvement that exist in the interoperable medical world.

Challenges of Health Information Exchange

While interoperability can seem to be an obvious improvement to medicine, there is some caution for companies to collaborate and create interoperable devices, both due to concerns of manufacturer and patient security.

From the economic standpoint, this reservation has resulted in a large proportion of relevant electronic health data to not be easily accessible, restricting the optimal integration and exchange.[20] As it is, biotechnology networks for data exchange are classified into two categories – commercial and free; however, the networks in the "free" category are usually financed indirectly through institutions, ultimately classifying those as commercial as well.[55] Fortunately, connecting healthcare data has been facilitated by the 2009 Health Information Technology for Economic and Clinical Health Act (HITECH Act) and the 2010 Patient Protection and Affordable Care Act (PPACA) by encouraging the use of the EHR – opening the doors for data exchange and interoperability.[56,57] Additionally, groups such as MDPnP, mentioned earlier, are working to increase their cooperation with devices of various manufacturers. With optimal implementation, the EHR allows a medical professional to understand a patient's medical history and provide effective medical treatment, regardless of provider or location. As such, the EHR is one crucial step toward health information interoperability.

However, there are many concerns and limitations beyond business boundaries for the use of the EHR and other interoperable devices. One concern is the lack of standardized data implementation into the EHR (e.g. different codes to be used in different hospitals). Fortunately, the HL7 Common Terminology Service and Fast Healthcare Interoperability Resources, two resources that normalize terminology across the EHR and improve the process of aggregating and sharing clinical data.[58]

Additionally, the main concern that medical information faces is maintaining the security of patient health information (PHI), which is any information that can be tied to an individual. This importance is enforced under Health Insurance Portability and Accountability Act (HIPAA). There are many requirements that HIPAA enforces, but the overall goal is to safeguard PHI, usually resulting in all medical technology to be encrypted.[59] HIPAA is essential to ensuring proper patient safety, and should be considered for all medical technologies.

While HIPAA is important, it brings many challenges to the development of technologies that seek to open exchange of data between devices and healthcare networks. To ensure security and adopt interoperable technology, it is important to include, among other key features, a third-party certification of compliance and a secure network that will verify and protect all PHI and other clinical information.[60] These considerations will be imperative for all device developers and collaborators to incorporate into their design.

With the necessary restrictions and enforcements to protect PHI, the exchange of information in the biotechnology sector can be difficult to change and innovate. In just one case, HIPAA was found to have increased confidentiality and privacy, but also adding uncertainty, cost, and delay to human subjects health research.[61] With these technologies, clinical data approaches a more standardized and distributable structure, but many improvements are still needed to ensure proper data exchange and patient security.[62]

Conclusion

Technologies that enable interoperability across health care networks will likely provide for improved medical treatment and clinical research. Research groups have successfully created interoperable devices and platforms, such as the Canary Box and MDPnP, yet barriers to widespread data exchange remain. While patient privacy and outcomes should remain as critical concerns, developing new technologies and devices that promote interoperability can bridge gaps in communication – between both individual providers and large scale networks. Interoperable technology incorporating music with medicine can serve as an example of the successful and opportunistic innovations working to improve and advance the practice of medical care.

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