Technological Considerations for the Delivery of Real-Time Child Telemental Healthcare

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Abstract

Objective: In recent years, rapid advances in the sophistication and accessibility of new technologies for consumer use have been leveraged to meaningfully expand the scope of mental health services for youth. However, despite many potential benefits inherent in applying new technologies to improve the accessibility and quality of care, organizations and private providers looking to expand their services with telemental health (TMH) service options may find the broad range of software packages and hardware options daunting.

Methods: We summarize key considerations for adopting a videoteleconferencing (VTC) system, and provide recommendations for institutions and providers planning to launch TMH services at varying levels.

Results: Although there is currently no single combination of VTC software and equipment that works best for every provider, certain factors such as cost, ease of use, and system functionality contribute to the setup that may serve as the “best fit” for practitioners’ and clients’ needs.

Conclusions: Careful consideration of these system characteristics and their bearing on institutional functioning, quality of services, and client satisfaction and privacy prior to VTC installation can proactively reduce difficulties after TMH implementation.

Introduction

THE PAST DECADE HAS WITNESSED enormous advances in the uses of technology to meaningfully expand the accessibility and scope of children’s mental healthcare. With the rising ubiquity of Internet access and the rapid advancement of technological innovations available for consumer use, the healthcare sector, including mental health practitioners, has rushed to implement technology-driven strategies and systems to reduce traditional barriers to care (Nelson et al. 2003; Myers et al. 2007; Comer and Barlow 2014). Alongside this push to incorporate growing communications technologies in mental healthcare provision, the past decade has seen a gradual decrease in the cost of such systems, further improving the acceptability and feasibility of telemental health (TMH) practice for many organizations and private providers. For practitioners and institutions hoping to adopt a TMH system, however, choosing from the vast array of options may seem daunting. Selecting a system that is not appropriate for an organization’s needs, either by failing to perform adequately or by overreaching the needs of specific service provision, may result in lost financial resources, wasted staff time, and frustration for practitioners and clients alike. This article reviews

available technologies and important decision points in determining the Internet speed, equipment, software, and staffing needs necessary to launch a successful TMH practice.

Throughout, we use the term “provider site” to refer to the site from which TMH services originate (typically referring to the site at which the TMH practitioner is located), and we use the term “patient site” to refer to the location at which the client receives care. The patient site may refer to the patient’s residence in scenarios in which TMH services are delivered to clients in their homes (e.g., Comer et al. 2014; Comer et al. 2015; see also Crum and Comer, in press), but the patient site most commonly refers to a health center separate from the provider site or client residence. Further, videoteleconferencing (VTC) refers to the use of secure videoconferencing software and equipment to hold synchronous, interactive meetings that incorporate audio and visual streams of data across the patient and provider sites. In contrast, face-to-face (FTF) refers to services in which the patient and provider meet in the same room or setting, as is more commonly seen in traditional healthcare provision.

Initial deliberation on the appropriate technology package for a TMH practice should focus largely on the TMH services that the provider hopes to establish. The package is mainly composed of 1)

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the hardware used to provide services, 2) the necessary software including, but not limited to, the VTC platform, and 3) the network connection needed to connect sites. These components create the “ecosystem” within which TMH practice occurs. An additional—but no less important—consideration for an organization implementing TMH practice is the existing infrastructure’s ability to manage and maintain this ecosystem once the system and the TMH practice are established. This includes the ongoing maintenance of equipment and the management of regular updates to software and hardware to ensure that the ecosystem within which services are provided stays current with changing service demands and with changing regulations and policy in TMH practice. With these considerations in mind, providers can choose from any number of options across a spectrum of organizational structures to best suit their needs. At one end, a company focusing primarily on mental health service provision may develop and implement a TMH ecosystem, obtaining its own hardware, software, and technical support, adhering to a business model similar to that of a traditional private practice or healthcare center. At the other end of the spectrum, a healthcare organization may opt to select a third-party technology-only company that provides the necessary equipment, connection, and both on- and off-site information technology (IT) support staff in order to reduce the burden on the existing infrastructure. Both options and all points in between come with important strengths and weaknesses, and different models fit best depending upon a provider’s current status and future goals.

Technology Selection and Implementation

Selecting components for the technological ecosystem of TMH practice involves balancing quality, reach, and accessibility of service on the one hand with the costs of purchasing equipment, training practitioners, and necessary technical support, on the other. Prospective TMH providers must carefully weigh these costs and benefits. Regarding equipment systems themselves, the primary determinants of up-front costs can be divided into those relating to end-points (e.g., hardware and software needs at the provider and patient sites) and connectivity. Large, free-standing systems with high definition (HD) audiovisual (AV) equipment at both end-points will require substantially higher costs than standard setups using consumer desktop systems and cameras. Furthermore, institutions hoping to utilize high bandwidth connections through T1 or T2 lines or other commercial point-to-point systems will have substantially higher costs than those who can make use of commercial Internet services offering lower shared bandwidth speeds.

These decision points have a direct impact on the cost of adopting a TMH ecosystem and determine the quality of the services provided. Most TMH needs can be met with a variety of solutions ranging in cost and complexity, each with its own pros and cons. For example, whereas making minimal modifications to current systems will keep installment costs low, continued use of older setups not originally built with TMH provision in mind may result in significant tradeoffs (e.g., poor connections resulting from low bandwidth, insufficient resolution of existing displays). Further, whereas modifications to the provider site such as the acquisition of new desktop systems or the upgrade of existing equipment may seem obvious, it is also important to consider the needs of the patient site and the means by which to ensure the availability of quality equipment for client use, especially if TMH services are to be delivered to the client’s home or an independent institution (e.g., school).

Although no “best configuration” exists that cuts across all clinical applications (Polycom 2012; Computer Technology Documentation

Project 2015), a number of concepts and operations needed in VTC are similar throughout TMH settings. Table 1 provides a brief overview of major component characteristics, categorized broadly by high and low base cost. It is recommended, however, that practitioners and institutions hoping to implement TMH services review this article in its entirety, as the considerations required in selecting TMH hardware and software, and the end cost of the system as a whole, far exceed the item-by-item cost and summary.

This section begins with an overview of various software and hardware options before turning to connectivity issues in selecting the appropriate bandwidth, all with these concepts in mind. Special focus is given to desktop or computer-based applications because of their broad and intuitive appeal, relatively easy implementation, and growing popularity. Software and equipment should be tested before purchase, and consumers should consider the importance of the “bottleneck effect,” in which a system’s weakest parts limit its performance capabilities and functionality. Broadly speaking, weaker or more inexpensive components to the VTC system may reduce the quality of calls overall. An expensive, sophisticated VTC software package may be wasted if implemented on a system with poor network connectivity, just as an HD display at one end-point is useless if low quality cameras are used at a connecting point. In general, TMH providers should consult IT, privacy, and security specialists when developing their program, in addition to reviewing the guidelines set forth subsequently in this article.

VTC software applications

Current VTC software offers a range of services, add-on functions, and operations. Considering the software that best fits an organization’s planned TMH service provision first can help narrow down subsequent decisions regarding hardware by indicating what equipment is most compatible with the proposed application. VTC software can be characterized as either standards-based or consumer-grade applications (Polycom 2001). Standards-based applications connect existing VTC end-points and systems complying with open (i.e., nonproprietary) standards defined by the International Telecommunications Union standardization sector (ITU-T) and other standards-issuing bodies (National Institute of Standards and Technology 2001). Such standards are made publicly available and allow for communication among products from different manufacturers who adhere to the same standards. Alternatively, consumer-grade software applications only communicate

TABLE 1. KEY TELEMENTAL HEALTH SERVICE COMPONENT CHARACTERISTICS SUMMARIZED AND SORTED BY RELATIVE COST

<i>Component</i>	<i>Low cost</i>	<i>High cost</i>
Videoteleconferencing (VTC) components		
Software	Consumer-based	Standards-based
Codec	Software-based	Hardware-based
Network connectivity	Low bandwidth (≥384 kbps recommended)	High bandwidth
Microphones	Dynamic transducer	Condenser transducer
Video		
Displays	Lower resolution	Higher resolution
Cameras	Built-in system cameras	External cameras with added functions

through public networks such as the Internet. Connections can be made from any personal computers running the manufacturer's software, but do not allow for interface among software clients from different manufacturers without additional functions that accommodate standards-based encoding and decoding because the protocols used to communicate between end-points is typically proprietary.

Another important point of differentiation across standards-based and consumer-grade applications is the management and storage of data, especially given unique concerns regarding client confidentiality and privacy associated with healthcare (see Comer and Barlow 2014). Standards-based applications generally utilize freestanding systems that encrypt communications, incorporate firewalls, and are largely more secure. In contrast, whereas providers using consumer grade systems can themselves set up firewalls and protections to their equipment and networks, the VTC applications themselves are typically less secure. Additionally, servers and computers connecting systems running consumer-grade clients are maintained and controlled by the application manufacturer, typically off-site. It is essential to understand that in general, VTC connections running through the Internet such as those accessed using a software client are utilizing infrastructure located elsewhere, typically through third-party servers. It is possible that third-party servers, such as those implemented and maintained by VTC software manufacturers, may store data from VTC calls for product development or troubleshooting purposes. Therefore, whereas some consumer-grade VTC options may meet Health Insurance Portability and Accountability Act (HIPAA) (United States Department of Health and Human Services 2006) compliance in handling electronic protected health information (ePHI), others may not. Conversely, although standards-based applications provide greater security, they are more complicated to set up, restrict access or require additional infrastructure when connecting to points outside of firewalls, and carry a higher overall cost.

Regardless of the privacy and security provided by the software itself, additional considerations regarding data management, network security, and administrative and equipment-related procedures are essential to maintaining client confidentiality. Further, some standards-based systems may not accommodate robotic or mobile platforms capable of navigating between rooms, allowing individuals conferencing in to follow movement throughout a larger space (Telehealth Technology Assessment Center 2013). In other words, increased security typically increases costs and decreases flexibility of use and overall TMH acceptability, feasibility, and, ultimately, accessibility. For some providers hoping to extend TMH services into individual clients' homes using VTC, the use of a standards-based application may not be feasible. Other providers planning to utilize VTC to communicate between set provider and patient sites, such as major hospitals planning to provide services remotely to smaller offices across a large campus, may prefer the increased control and privacy of a standards-based system while incurring little or no disruption in use because of the lack of system flexibility.

In addition to gaining an appropriate understanding of the ability of various VTC options to meet functional needs, providers should consider the cost of applications as well as the pairing of appropriate hardware and software. Whereas standards-based applications may support higher definition video and higher quality audio and may come with more advanced functions, a hardware system with a poor microphone, inadequate speaker system, lower resolution display, or slow network speeds limits providers' and clients' ability to fully utilize expensive features. Conversely, selecting a

low-end consumer-grade VTC client may preclude users' ability to fully access the capabilities of high-end equipment. Furthermore, providers should determine whether they prefer a hardware- or software-based codec. The codec encodes and decodes audiovisual data sent between devices (Telehealth Technology Assessment Center 2013). In other words, the codec packages information from the camera and microphone and sends that data from an end-point (such as the provider site), and unpacks data received from other end-points (such as the patient site) to show on screen and play through speakers. Previously, hardware-based codecs were the industry norm. Such devices were often designed as small stand-alone products similar to a router or cable box used in a private residence with the sole purpose of sending and receiving data for VTC connections. Hardware-based codecs typically provide better AV quality, but are again typically more expensive and may require additional infrastructure and higher connection speeds to meet their full potential. The advancement of software-based codecs in recent years has allowed organizations hoping to utilize VTC to connect with users outside of a dedicated network via computers and mobile devices without requiring additional equipment (e.g., users with the same software connected to the Internet). Using a software-based codec may result in some AV quality loss, but is less expensive to implement and has more flexibility in use, allowing more devices to connect at different locations.

Network connection

When reviewing potential network options, organizations may find references to bandwidth most common among connection characteristics to discuss. Bandwidth speaks to the rate at which data is transmitted over an online connection. It is typically measured in bits per second (bps), indicating the number of bits—the smallest measure of data—transmitted each second of use. Because VTC involves the live exchange of AV information, it can require large amounts of bandwidth for seamless operation. The minimum bandwidth for simple programs is typically 128 kilobits per second (kbps). The maximum bandwidth for more complicated systems approaches 5 Megabits per second (Mbps) (Spargo et al. 2013), and the American Telemedicine Association's Practice Guidelines for Videoconferencing-Based Telemental Health recommend at least 384 kbps (Yellowlees et al. 2010). The exact amount of bandwidth needed varies based on the functions and equipment in use, including requirements set by the VTC software manufacturer, video resolution at both ends of communication, the number of end-points participating in each call, and usage of bandwidth by simultaneous calls or other network systems. Organizations hoping to contact external institutions or clients in their homes may need greater bandwidth to maintain stable calls with high AV quality. Such systems may also face limitations based on the bandwidth available to external end-points. Although these considerations make the optimal amount of bandwidth difficult to determine, institutions can implement quality of service (QoS) tools to work toward more efficient use of existing bandwidth. QoS tools work to reduce moment-to-moment traffic by prioritizing certain transmissions over others. For example, QoS systems may work to moderate flow by sending VTC content in real time, reducing updates for asynchronous communication such as e-mail to times when more bandwidth is available. Although QoS tools add to the cost of a VTC system overall, they may improve the quality of VTC calls and allow for reductions in cost paid directly to increase bandwidth.

Spargo et al. (2013) provide a step-by-step guideline to approximating bandwidth needed for effective TMH practice. First,

they recommend starting by modeling various transmissions between end-points, and estimating their frequency and data size. Although this may prove challenging if practitioners plan to connect to external end-points, obtaining a rough understanding of VTC-related traffic originating at the provider site can still provide insight into the minimum bandwidth needed. Second, the authors advise that providers consider non-TMH use of the network connection, including current office systems, electronic medical records (EMR) and other clinical data management systems, voice over Internet protocol (VoIP) use, and nonclinical VTC such as conference calls and administrative meetings. Included in these additional factors is network burden associated with cloud computing. Recent years have seen a rise in popularity of cloud computing, which distributes technological resources or functions to “the cloud” (i.e., on-demand access to computing services and resources via a public, private, or hybrid network [National Institute of Standards and Technology 2011]). Whereas one example of cloud computing might be the use of an EMR system shared across the private network of a medical campus, other applications include the provision of essential administrative software for remote access. After ascertaining the total bandwidth required to accommodate traffic identified in steps one and two, step three is to add the data used by these operations. Fourth, this sum should be subtracted from the current bandwidth available. The remaining difference roughly represents the bandwidth needed to maintain appropriate business functions with the added stress of VTC services. This process is meant to provide an approximation and is not extremely precise, but it reasonably estimates the amount of increased bandwidth needed for potential TMH providers entering the field. Although extensive overestimation may lead to increased cost wasted on unused bandwidth, a gross underestimation can cause “packet loss” that then impacts the quality of communication. Throughout VTC communication, AV data is sent between end-points in what are commonly referred to as “packets.” Packet loss results from an inability to properly transfer outgoing data packets and receive incoming data packets, typically because of high traffic on overburdened networks with insufficient bandwidth. Although some packet loss is expected and helps to optimize VTC calls over stressed networks, extensive loss causes noticeable disruptions, poor AV quality, and frequent dropped calls.

Audio

Depending upon the TMH services provided, crisp, seamless audio may be even more important than a strong video signal. Although connectivity plays a major role in determining the audio quality for end users, selecting equipment for both audio input and output can significantly impact the clarity of VTC calls. Additionally, just as software and hardware interactions are important, the interplay between select hardware components can mean the difference between a well-functioning high-end system and an unbalanced setup in which expensive equipment is not used to its fullest because of limitations caused by lower end parts selected to cut cost.

As the primary audio input device used to capture sound in VTC, an appropriate microphone for use in VTC contact plays a central role in determining the overall call quality. Consumers can differentiate microphones for use in VTC across three major domains: Output type, transducer properties (dynamic or condenser [Spargo et al. 2013]), and polar pattern. Output type describes the way in which the microphone connects to the computer, mobile device, or

other VTC system, and “outputs” audio data to the system. Most microphones not connected to a computer’s direct line-in port or microphone input use universal serial bus (USB) outputs. Although USB outputs are typically automatically detected and easy to use with most systems, they may prove problematic with older computers with poor processing capabilities struggling to manage audio from an external microphone in addition to a live video stream. Although most modern computers can handle this, practitioners should be mindful of their intended VTC use when selecting microphones for use. Low income and/or rural homes hoping to communicate remotely via TMH services may lack the most up-to-date systems, precluding the use of more sophisticated microphones. Alternatively, microphones using a direct line-in or microphone input (usually a 3.5 mm connection) may be too quiet or lose quality over time. Advances in Bluetooth technology over the past decade have also resulted in the development of energy-efficient, inexpensive Bluetooth microphones and headsets that may be attractive to organizations planning to take advantage of VTC on mobile devices. When selecting from Bluetooth devices, conducting test trials with planned equipment systems to ensure compatibility and ease of use may save time and resources spent troubleshooting difficulties after the initial installation.

Interested users can find both transducer types in USB and direct varieties (Spargo et al. 2013). Dynamic microphones typically incorporate more rugged design and can withstand a reasonable level of physical shock, exposure to moisture, and loud noises, but are less sensitive to sound in comparison with condenser microphones. Because of their durability, dynamic microphones may be best if providers expect daily use. Moreover, although expensive high-end condenser microphones may provide crisp, high-quality audio, the difference may not be noticeable to users over a VTC call, especially when audio quality is limited by insufficient bandwidth or VTC software capabilities. Unlike most dynamic microphones, condenser microphones need an external power source typically provided by a battery or by the computer via the USB or connecting cable, which may limit portability and systems’ available field time.

Lastly, TMH providers should select microphones based on polar pattern and intended use. Polar pattern describes a microphone’s sensitivity to sounds arriving at different directions relative to the equipment’s position. Practitioners planning to hold VTC calls during which users remain relatively still (such as at a desk) should consider using unidirectional microphones, especially if multiple calls may be initiated from the same space such as a call center at a provider site. Using omnidirectional microphones in such a setting might create communication difficulties because of unnecessary pickup of background noise. Alternatively, omnidirectional microphones may be essential if users at either or both end-points are expected to move throughout a space during a VTC call, or if speech from multiple users in the same room needs to be heard (e.g., observational assessments, conference calls, *in-situ* parent coaching [see Comer et al., in press; Crum and Comer in press]). Selecting a unidirectional microphone for these tasks may lead to difficulties hearing necessary audio at other end-points. Additionally, echo cancellation may help reduce feedback and acoustic echo by using software algorithms to “subtract” noise from an audio stream. Even these systems, however, only provide a limited degree of support and may be especially limited in cheaper equipment. Microphone placement and echo cancellation can significantly affect users’ decisions regarding the appropriate polar pattern to select, as both impact the overall audio quality in a VTC session.

Video

As previously described, codecs handle the encoding and decoding of audiovisual data transmitted across VTC systems. Although consumer-grade VTC systems may utilize closed-source, proprietary codecs, standards-based systems implement nonproprietary encoding and can thus connect to other standards-based systems across different manufacturers. A complete understanding of video codecs is not essential to the selection of VTC systems and software, but a cursory understanding can help potential consumers better weigh options. At present, the most commonly used standards-based VTC system is H.264. With the rapid advancement of VTC technology, video standards remain an ever-shifting, evolving concept. As such, older standards such as H.261 and H.263 exist and are at times still in use. As a result, organizations planning on entering the TMH market and using newer standards-based systems should discuss compatibility issues with older systems and consider the use of an intermediary translator device that would allow computers using different encoding standards to connect.

Displays. Major considerations in selecting the appropriate display for VTC revolve primarily around screen size and display resolution. As with other equipment components, there is no “right answer” as to the appropriate size for use. Providers should consider a number of factors including the patient population, preexisting equipment available, and camera resolution (use of a low-resolution camera will nullify the benefits of purchasing a high-definition display). Higher resolution and larger screen displays allow for clearer video images (as long as network speed and related equipment allow), which may provide considerable benefits when working to discern facial expressions, identify the differences between various physical and behavioral symptoms (e.g. pointing out tic behaviors and other small motor movements), and making other detailed observations. Alternatively, higher resolution can also help increase visibility when the setting of one end-point is a larger space.

Larger screens will require higher resolution to maintain a clear image. Selecting screens with higher dimensions also allows for better use of various video functions such as screen sharing and picture-in-picture. Screen sharing allows users at one end-point to display the contents of their desktop for other users to view, letting participants view and potentially edit digital documents in real time (see Comer et al. 2014 for an example of this TMH practice). Some VTC software also includes keyboard and mouse “takeover” functions, through which users at one end-point can give users at other end-points control of their keyboard and mouse functions. This operation can facilitate troubleshooting and general IT support as needed. Picture-in-picture, now a common feature in VTC software packages, allows users to view other VTC participants in smaller windows below the main display or to see the feed from their own camera, typically below a larger window showing the main speaker. Smaller screens can make such functions difficult to use. Increased screen size and resolution does, however, require higher bandwidth because of the increased volume of video data transmitted across the network. Decision makers should also consider screen placement in purchasing displays. Bigger flat screen displays can be mounted on the wall, requiring little space and allowing for multiple people in one room to clearly view and participate in the VTC call, but lack mobility. Smaller displays can be placed on carts for greater flexibility of use, reducing the need to dedicate space to TMH services. This may be especially important at smaller sites with limited space shared across a variety of programs.

Cameras. Although many modern computers, laptops, and mobile devices have built-in cameras, organizations may still consider the purchase and use of external USB webcams as needed. As with microphones, cameras play a major role in determining the AV quality of end users utilizing VTC services, but still rely on a strong network connection for optimal use. High-end cameras can capture HD quality video, but users may still find that they receive choppy or pixelated images if the computer using the camera has a low grade central processing unit (CPU) that struggles to process, compress, and transmit the video stream in real-time. Similarly, providers faced with bandwidth limitations may experience significant AV disruptions when attempting to stream HD video, and may need to make decisions to prioritize clear audio versus image quality. Additional functionality such as remote pan-tilt-zoom (PTZ) operations enable practitioners at the provider site to follow clients at the patient site as they move throughout a space and zoom in to see facial expressions and other small nonverbal cues.

Conclusion

The decision to implement and pursue TMH practice comes with a number of considerations in terms of the purchase, installation, and ongoing maintenance of a VTC system. As previously discussed, privacy also continues to be an important issue in TMH. Institutions should work to maintain HIPAA compliance by using VTC systems, data storage, and other associated systems that have met appropriate standards. Further, organizations should consult with available references and guidelines (United States Department of Health and Human Services 2006) as well as specialists qualified to evaluate VTC programs for HIPAA compliance. It is critical to be sure to follow guidelines regarding agreements made between healthcare providers and business associates who may handle or come in contact with ePHI (United States Department of Health and Human Services 2013). Decisions regarding the implementation of various consumer-grade VTC components may hinge on organizational standards and limitations for each TMH provider, but should always be made with client confidentiality, privacy, and security in mind. Moreover, institutions moving forward with such programs must gain a solid understanding of the services they will provide, their target population, and the needs of those individuals in order to best accommodate for those service factors proactively with VTC components and auxiliary systems such as EMR.

Given the rapidly rising role of TMH in the delivery of care, practitioners and organizations will increasingly need to prepare mental health providers to manage minor technical difficulties, especially those most common in practice. Although brief provider trainings and familiarity with equipment in use may aid in reducing the number of sessions disrupted by system failures, technical support should also be made available. The degree to which additional IT staff are needed within an organization again depends upon the complexity of the VTC system, the resources available at both the patient and provider sites, the comfort level and technological literacy of existing administrative and technical staff in troubleshooting potential issues, and the urgency with which issues need to be resolved. Prompt technical support may aid in reducing the number of dropped VTC calls or sessions prematurely terminated because of equipment difficulties, but practitioners should implement backup plans such as follow-up calls or in-clinic appointments to ensure a high quality of care. Extensive testing of VTC equipment prior to purchase can help providers better understand current technologies' abilities to meet their needs as practitioners and mental health organizations. Importantly, technological

problems and disruptions during the conducting of TMH—even minor ones—can seriously offset therapeutic alliance and client engagement, both of which are important for effective care.

Technological advances continue to innovate and expand health-care delivery at a rapid pace, and providers and organizations must work to stay current. Many providers are already leveraging technological innovations to meaningfully address problems of poor care accessibility and regional workforce shortages in expert mental healthcare. As TMH becomes an increasingly indispensable component in the larger portfolio of mental health delivery options, appropriate technology selection and implementation are at the heart of ensuring the quality and security of TMH care for affected youth.

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