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JASA ARTICLE

Virtual audiology education tools: A survey of faculty, graduate students, and undergraduate students[a)]

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ABSTRACT:
Due to global shifts at educational institutions from in-person courses to online formats caused by the COVID-19 pandemic, the current study aimed to estimate whether currently available virtual audiology education tools are helpful for acquiring necessary audiology skills and knowledge from the perspective of both educators and students. Therefore, a remote survey was developed and distributed to faculty and students in undergraduate communication sciences disorders and graduate audiology programs. Although participation was somewhat limited, the trends observed in the survey results suggested that the majority of both educators and students found the subset of virtual tools easy to use, that these tools improved teaching methods and learning outcomes, and that these tools would likely be used again. © *2022 Acoustical Society of America*. https://doi.org/10.1121/10.0010530

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I. INTRODUCTION

The COVID-19 pandemic rapidly shifted academic instruction from face-to-face to primarily online, virtual environments. For the field of audiology, among others, this shift meant attempting to determine ways in which clinical training could be adapted to meet the requirements of remote learning. Educators necessarily sought out and adopted online technologies for use in virtual classrooms, and students were shouldered with the task of learning hands-on practical skills through remote and largely virtual means. While this seemed like an abrupt shift from traditional teaching methods in March of 2020, undergraduate and graduate programs within communication sciences and disorders, speech-language-hearing sciences, and audiology have been using simulation techniques for many years. Hughes *et al.* (2016) split a sample of audiology students into two groups, one of which completed clinical training first with simulated patients and then in-person seminar training (group 1), while the other group completed the in-person seminar training first followed by the simulated patient training (group 2). Results suggested that, although significant improvement for clinical skill assessment was observed for both groups after the training regimens were completed, the order of the training sequence did not impact the value of the skill acquisition. In addition, both types of training resulted in equivalent skill improvement for these students in terms of gathering a case history and providing patient feedback. Hughes *et al.* asserted that this indicated there was no additional benefit added by asking the students to complete the training with simulated patients. However, the authors of the current letter to the editor argued that because both types of training resulted in equivalent skill improvement, simulation training (or the use of other educational tools) may be particularly useful during situations for which the in-person training cannot be completed, namely, during a global pandemic.

In recent years, simulations and other educational tools have transitioned to more thoroughly remote and virtual environments for specific training applications. In the long term, educational reformers and institutions should assess the value of virtual educational tools relative to more traditional in-person teaching techniques in a systematic fashion to determine which virtual tools improve skill acquisition above and beyond traditional in-person approaches. In contrast, the purpose of the current study was to estimate whether a subset of the currently available virtual audiology education tools is subjectively useful for acquiring the knowledge and skills necessary from the perspective of both students and educators. The goal was to determine, even after the pandemic has sufficiently subsided, whether these virtual tools may continue to be additionally helpful when combined with traditional methods of instruction. By remotely surveying both faculty and students in undergraduate communication sciences disorders and graduate audiology programs, the current proposal aimed to answer three questions:

(1) Which online virtual audiology educational tools are in use?
(2) From the faculty perspective, how well do those tools work, and would they recommend these tools for use again?

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(3) From the student perspective, how well do those tools work, and would they recommend these tools for use again?

II. METHODS

A. Survey

An online survey of educators and students in accredited audiology programs was developed and distributed across the United States. Specifically, the goal was to target individuals who have used virtual educational tools in their teaching (educators) or learning (students). All survey procedures were approved by the institutional review board at San José State University. The survey took only a few minutes, and participants were not compensated for their time. In the survey, participants were asked about virtual educational tools they have used in their teaching or learning. A list of tools was provided, with a space available for users to submit other tools not included on the list (see Table I). The list of tools was explicitly limited to those that could be utilized in an exclusively online environment. Once a tool was selected, the participant was asked to provide a rating of the tool in four different subdomains: (1) ease of use, (2) improvement to teaching, (3) improvement to learning, and (4) continued use. The rating scale included five possible selections: agree, slightly agree, neutral, slightly disagree, disagree. These subdomains allowed for examining whether these online tools are generally viewed as accessible, whether there was a correlation between student and educator perceived benefit, and the likelihood that these tools would be integrated into future coursework, regardless of an in-person or remote virtual teaching/learning environment.

B. Participants

Participants included educators (faculty members in an audiology, speech-language-hearing sciences, or communication sciences and disorders department), undergraduate students (enrolled in an audiology, speech-language-hearing sciences, or communication sciences and disorders program), and graduate students (enrolled in M.A./M.S., Au.D., or Ph.D. programs in audiology). Using a database provided by the Council of Academic Programs in Communication Sciences and Disorders (CAPCSD), which lists the associated programs and the accreditation status of each program (CAPCSD, 2022), an email list was developed that included department administrators' contact information. Using Qualtrics, a multi-branch survey was developed, and the survey was distributed to each institution of learning with a known undergraduate program in communication sciences and disorders ($n = 234$; also communicative/communication disorders, speech and hearing sciences, etc.) and Doctor of Audiology (Au.D.) degree programs ($n = 77$). Program contacts were encouraged to pass the invitation to any instructor of coursework related to audiology at the graduate or undergraduate level. To maintain anonymity, the participants were not required to provide any identifying information other than the designation of "educator," "undergraduate student," or "graduate student."

TABLE I. A list of the virtual audiology educational tool options used in the survey. The list in this table has been alphabetized and does not represent the order presented to survey participants.

	"Choose a virtual audiology education tool from the list below."
1	Avatar Audiometer
2	Theta audiology simulator (formerly CLASS)
3	CounselEAR
4	ESystem
5	Internet Institute for Speech and Hearing
6	WASP—Windows tool for speech analysis
7	Web Audio Playground
8	Other [ ]
9	None of the above

III. RESULTS

During data collection, 30 educators, 44 undergraduate students, and 24 graduate students consented to participate in the survey. Of the 98 total respondents, many did not complete the survey ($n = 41$) or chose "None of the above" ($n = 23$), suggesting by the latter group that many individuals who completed the survey were not actively using virtual educational tools. Thus, only 13 educators and 21 students (10 undergraduate, 11 graduate) either completed the survey or chose a response other than "None of the above" when asked to identify which virtual tools they had previously used. Given this sample size, the data were not sufficient to analyze comparisons among each tool. Instead, trends observed will be reported across all virtual tools for the subdomains assessed (see Table II).

A. Educator data

By selecting "agree" or "slightly agree," the majority of educators reported that virtual education tools were easy to use (10/13 = 76.9%), improved their teaching (9/13 = 69.2%), improved their students' learning (11/13 = 84.6%), and would likely be used again (10/13 = 76.9%).

B. Student data

By selecting "agree" or "slightly agree," the majority of students reported that virtual education tools were easy to use (14/21 = 66.7%), improved their instructor's teaching (16/21 = 76.2%), improved their understanding of the material (15/21 = 71.4%), and should be used again by their instructors (15/21 = 71.4%).

C. Distribution of technology

The most common virtual tool reported by all participants was Theta (formerly CLASS; 18.8%) (Morgan, 2022). In alphabetical order, virtual tools other than those listed in the survey (i.e., provided via the "other" option) included

TABLE II. Raw counts and percentage of respondents who selected each response category for each survey component, separated by educators (top) and students (bottom).

Educators	Agree	Slightly agree	Neutral	Slightly disagree	Disagree	Total
Ease of use	6 (46.2%)	4 (30.8%)	2 (15.4%)	1 (7.7%)	0 (0.0%)	13 (100%)
Improved teaching	8 (61.5%)	1 (7.7%)	3 (23.1%)	1 (7.7%)	0 (0.0%)	13 (100%)
Improved learning	8 (61.5%)	3 (23.1%)	2 (15.4%)	0 (0.0%)	0 (0.0%)	13 (100%)
Use again	8 (61.5%)	2 (15.4%)	2 (15.4%)	1 (7.7%)	0 (0.0%)	13 (100%)
Students	Agree	Slightly agree	Neutral	Slightly disagree	Disagree	Total
Ease of use	10 (47.6%)	4 (19.1%)	5 (23.8%)	2 (9.5%)	0 (0.0%)	21 (100%)
Improved teaching	10 (47.6%)	6 (28.6%)	5 (23.8%)	0 (0.0%)	0 (0.0%)	21 (100%)
Improved learning	10 (47.6%)	5 (23.8%)	4 (19.1%)	2 (9.5%)	0 (0.0%)	21 (100%)
Use again	10 (47.6%)	5 (23.8%)	2 (9.5%)	4 (19.1%)	0 (0.0%)	21 (100%)

AudiologyOnline (2022); AudSim Flex (2022); COMD Virtual Audiometer Suite (2021); and computational auditory models jsPsych (de Leeuw, 2021), Otis—The Virtual Patient (2022), Praat (Boersma and Weenink, 2022), and Visible Body (2022). While not all these tools can be used exclusively in an online environment, which was the primary focus for tools included in the survey, they may be able to be utilized remotely through a video conference call or other means of remote access.

After receiving input from survey participants, the authors found it prudent to provide a brief report on each technology to serve as a starting point for educators looking to incorporate online (or remotely accessible) technologies into their courses. Given the large number of potential tools, a brief description is provided for each, and the authors encourage interested readers to explore the links provided in Table III to learn more about each tool. The data for the table were collected by reviewing websites, obtaining demonstrations, and surveying representatives or owners of each tool for increased transparency. These tools will be compared in three categories: audiology clinical simulators (Sec. III C 1), demonstration/visualizations (Sec. III C 2), and specialty technologies (Sec. III C 3).

1. Audiology clinical simulators

Several of the listed resources in the survey were web-based audiometry simulators; however, survey participants also mentioned additional non-web-based simulation tools that are capable of being used for remote educational experiences. Specifically, the authors note that the two free-tier options, AvatarAudiometer and CounselEAR (Urban, 2014), are sufficiently developed to perform basic audiometric testing. Theta and the other simulators with fees or subscriptions offer additional features, more cases, and/or customizability. With the inclusion of downloadable simulation technologies, three other simulation programs were also identified and highlighted: Simulated Human Evoked Response Audiometry (SimHERA) (2022), Simulated Human Behavioural Audiometry (SimHBA) (2022), and

TABLE III. A comprehensive list of all virtual audiology education tools discussed throughout this work in alphabetical order (column 1, "Virtual audiology education tool") with the corresponding links to access them (column 2, "Online link").

Virtual audiology educational tool	Online link
AudiologyOnline	https://www.audiologyonline.com/
AudSim Flex	https://audsim.com/
Avatar Audiometer	https://www.avataraudiometer.com/
COMD Virtual Audiometer Suite	https://education.byu.edu/comd/virtual_audiometer.html
CounselEAR	https://www.counselear.com/Controls/Pages/Public/index.aspx?page=Simulator/Audiometer
ESystem	https://www.speechandhearing.net/laboratory/esystem/
Internet Institute for Speech and Hearing	https://www.speechandhearing.net/
jsPsych	https://www.jspsych.org/7.1/
Otis—The Virtual Patient	https://www.innoforce.com/en/products/otis-the-virtual-patient/
Praat	https://www.fon.hum.uva.nl/praat/
SimHBA	https://audiospeech.ubc.ca/simhba/
SimHERA	https://audiospeech.ubc.ca/research/brane/simhera/
SmartVS	https://smartvs.ihsys.info/
Theta audiology simulator (formerly CLASS)	https://audiologysimulator.com
WASP—Windows tool for speech analysis	https://www.phon.ucl.ac.uk/resource/sfs/wasp/
	https://www.speechandhearing.net/laboratory/wasp/
Web Audio Playground	http://webaudioplayground.appspot.com/
Visible Body	https://www.visiblebody.com/anatomy-and-physiology-apps/anatomy-and-physiology

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SmartVS (2022). While an exhaustive review of every simulation tool was not the focus of this letter, a concerted effort was made to include relevant features for a high-level comparison of audiology clinical simulators in Table IV.

2. Demonstration/visualizations

a. ESystem. ESystem (Huckvale, 2015) is a web-based tool that demonstrates concepts related to source/filter theory. Users can manually select source options from a provided list (sine, sawtooth, pulse train, white noise, upload your own audio, etc.) and then apply different filter characteristics, including high-pass, low-pass, band-pass, and vocal tract filters.

b. Internet Institute for Speech and Hearing (Huckvale, 2021). This website houses ESystem and WASP (Huckvale, 2019; described below) as well as numerous other web-based tools for demonstration and visualization of speech and other audio stimuli. Modules or programs are available that allow users to measure and manipulate pitch, view spectral cross-sections in speech, measure voice quality and pitch, synthesize speech, demonstrate effects of coarticulation, ripple tank demonstrations, amplitude and pitch displays, harmonic analysis and synthesis, real-time spectrum, real-time waveforms, and real-time spectrograms

c. Praat. Praat is a well-known tool for audio recording processing, analysis, and manipulation. Many tutorials and other works have detailed Praat's features, to which we refer readers for more thorough reviews (see Boersma and Weenink, 2022). As a brief summary, Praat can perform many different functions as a teaching tool including (but not limited to) spectral analysis, pitch analysis and manipulation, stimulus segmentation, waveform viewing, and filtering.

d. SimuCase (Calandruccio and Weidman, 2022). SimuCase provides a library of clinical simulations covering the areas of auditory processing, hearing and hearing loss, bone conduction and middle ear, otoacoustic emissions, hearing aids, and cochlear implants. The simulations are meant to improve students' clinical skills surrounding assessment, diagnosis, and intervention for virtual patients. Simucase also offers AudioLab, a licensed version of AvatarAudiometer (discussed in Table III) to complement their cases.

e. Visible Body. Visible Body software provides a detailed rendering of anatomical and physiological parts of the human body, including detailed renderings of the ear and speech mechanisms. Many universities already have active subscriptions to Visible Body for other anatomy-related coursework.

f. WASP. Users can record or upload audio and view the waveform and spectrograms. Users can also track pitch and zoom in and out of different segments of the speech signal.

TABLE IV. A comparison table of audiometry and other clinical/diagnostic simulation tools. Simulators are grouped by those included in the survey (row 2, "Author selected"), those mentioned by survey respondents via the "other" category (row 3, "Participant reported"), and other simulators that have come to the authors' attention (row 4, "Other").

Method of inclusion	Virtual audiology education tool	Educational pricing	Period	Web-based (no download)	Air conduction	Bone conduction	Masking	SRT/WRS/SAT	Tympanometry	Acoustic reflex thresolds (ART)	Otoacoustic emissions (OAE)	Evoked potentials	Otoscopy	Case history	Patient avatar/image/interaction	Automated scoring	Summary/report	Training mode/assistant	Psychometrics tracking	Student behavior analysis	Community case contributions	Patient response variability	Multiple language support
Author selected	Avatar Audiometer	Free	—	×	×	×	×																
	Counsel EAR	Free	—	×	×	×	×																
	Theta (CLASS)	$25	1 year	×	×	×	×	×	×	×			×	×		×	×	×	×	×	×	×	
Participant reported	AudSim Flex	$19.99	—		×	×	×									×	×	×					
	Otis – TVP	$168[a]	1 year		×	×	×		×				×	×	×	×	×	×		×		×	×
	Virtual Audiometer	$49	—		×	×	×	×	×					×	×	×	×						
Other	SimHERA	$125[a]	1 year		×	×	×	×	×	×	×	×		×	×	×	×	×	×		×	×	
	SimHBA	$45[a]	1 year		×	×	×	×	×	×	×			×	×	×	×	×	×		×	×	
	SmartVS	$150[a]	1 year		×	×	×	×	×	×	×	×	×	×	×		×		×		×	×	

[a]Variable pricing available for shorter/longer periods.

g. Web Audio Playground (Wilson, 2020). This tool allows users to drag and drop elements to create web-based audio demonstrations. Users can create audio sources from a list of options and manipulate those sources using modules (filters, gain nodes, etc.).

3. Specialty technologies

a. AudiologyOnline. AudiologyOnline is a parent site for continuing education in audiology. The site contains free and paid continuing education opportunities in a variety of formats (video, audio, etc.). The website also includes links to career opportunities, journal articles, group learning opportunities, and other tools that may be useful for teaching and learning online.

b. Computational auditory models. There are several computational models for auditory perception and processing. These models include outer, middle, and inner ear mechanics. While there is a learning curve to their use (usually requiring MATLAB programming), these models can demonstrate how audio information is simulated as it passes through various portions of the auditory system.

c. jsPsych. jsPpsych is a JavaScript online framework for presenting behavioral stimuli to complete research and other demonstration tasks online. jsPsych requires programming of "plugins" via JavaScript or the use of included or community-contributed plugins to create demonstrations or experiments.

IV. DISCUSSION

There is a trend in the observed results suggesting that this subset of virtual audiology education tools was perceived to improve teaching and learning experiences for both the educators and students who completed the survey. Although it is difficult to reach broader conclusions of this survey throughout all educational settings, this trend raises the possibility that the inclusion of virtual audiology educational tools may be additionally useful when combined with more traditional instruction for settings where there are limitations to in-person teaching and learning. The authors assert that, even under circumstances for which in-person education is a possibility, these virtual applications may help students practice their skills outside of class using methods that have not previously been available. For example, allowing students to practice masking during pure-tone audiometry and speech audiometry outside of the clinic, by way of a web browser, could reduce the amount of time that new students take when testing actual patients in the clinic. As institutions continue to develop and use virtual simulations for case history, otoscopy, audiometry, pediatric assessment (including visual reinforcement audiometry), immittance testing, electrophysiology, vestibular assessments, hearing aid fittings, cerumen removal, cochlear implant programming, and all other activities within the scope of practice for audiology, these virtual tools will hopefully assist budding clinicians, researchers, and educators as they integrate the skills acquired both virtually and traditionally. Since the results suggest that 23.4% of the respondents are likely not currently using any form of virtual audiology education tools, there is room to incorporate more of these resources into audiology programs across the country as the future rushes to meet us.

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