

Low Latency Audio Video Potentials for Collaborative Music Making Through Distance Learning

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Abstract:

The primary purpose of this study was to examine the potential of LOW LATency (LOLA), a low latency audio visual technology designed to allow simultaneous music performance, as a distance learning tool for musical styles in which synchronous playing is an integral aspect of the learning process (e.g., jazz, folk styles). The secondary purpose was to describe participant perceptions of the effectiveness of three technologies used to teach music: LOLA, PolyCom, and Skype. To achieve these goals, we isolated a classical masterclass, jazz lesson, and old-time fiddle session and described trends for these lessons across the three technology platforms. Participants rated the overall effectiveness of LOLA ($M = 4.25$) higher than PolyCom ($M = 3.06$) and Skype ($M = 2.80$). Participants shared their perception that LOLA was superior to other technologies for learning and teaching music. Implications for music teaching are discussed.

Keywords: collaborative musical styles | distance learning | music learning | music teaching | online instruction | technology

Article:

Technology is increasingly a major factor in education systems worldwide. As distance learning grows in prevalence throughout education, it is important for music educators to look at the technologies that best suit their highly collaborative and communicative teaching needs. Distance learning in music education has increased over the past two decades, but specific challenges to teaching and learning music online continue to exist. High-quality audio technology is necessary to transmit music with aural accuracy, and performers still may have difficulty adjusting to digitally transmitted sound. Furthermore, because music instruction frequently involves simultaneous playing, effective Internet lessons must be either conducted over a platform that allows for real-time playing together or significant accommodations must be made within each

lesson. Reducing the latency or “lag time” within music technology platforms is crucial for interactive music instruction, and remains an obstacle in distance learning.

Although synchronous online teaching has been largely successful, researchers have identified a number of issues that hinder effective music teaching and learning (Anderson, 2008; Brändström, Wiklund, & Lundström, 2012; Dammers, 2009; Kruse, Harlos, Callahan, & Herring, 2013; Lancaster, 2007; Maki, 2001; Riley, 2009). One of the most common issues identified is that of latency or delay (Anderson, 2008; Brändström et al., 2012; Kruse et al., 2013; Maki, 2001). For example, Maki (2001) found that early distance learning studies in Finland were a positive experience that satisfied students, but difficulties with delay prevented synchronous playing and singing. Additional issues such as video and audio quality, physical proximity, the ability to adjust students physically, eye contact, and modeling physical characteristics or positions have also been identified as challenges of online music instruction (Dammers, 2009; Maki, 2001; Orman & Whitaker, 2010; Riley, 2009). These issues do not prevent online music instruction but are aspects that need to be addressed to provide the most effective instruction.

Researchers have identified solutions to some of the aforementioned problems. For example, consecutive lessons were more successful for teacher and student after an “adjustment period,” where careful planning and deliberate communication techniques helped overcome the effects of latency (Dammers, 2009; Maki, 2001; Riley, 2009). Preparations such as e-mailing PDFs of music (Kruse et al., 2013), using multiple cameras and varying camera angles (Brändström et al., 2012), and incorporating multiple microphones (Maki, 2001) were recommended adaptations to increase lesson effectiveness. Delay remains an issue in present studies (Brändström et al., 2012; Kruse et al., 2013), but as bandwidth and network technology advances, music educators are increasingly looking to distance learning as a tool to help with many different styles of music education.

Collaborative and Creative Styles

Collaborative musical styles and styles that require synchronous playing pose specific challenges to online learning. Styles such as jazz or bluegrass are often learned by leader–follower interaction and informal group collaboration, or “jamming.” Musical expertise in these styles can be difficult to find in many geographic areas, and technology may be a solution to increase access to instruction. Online music platforms offer a variety of opportunities for synchronous and asynchronous learning (Dammers, 2009), and folk music communities have used these resources in a number of ways. YouTube videos and videos combined with discussions found on old-time/bluegrass Web sites, such as Banjo Hangout or Fiddle Hangout, have a strong following for informal music learning that includes jamming and improvisation (Kruse & Veblen, 2012; Waldron, 2011). YouTube videos aid in teaching and learning and engage participatory culture (Waldron, 2011) in online folk music communities. Many videos are geared toward beginners (Kruse & Veblen, 2012) and instruction is often held in conjunction with students frequently jamming and collaborating with their local folk music communities.

A number of professional bluegrass musicians have started their own fully online asynchronous schools of teaching, including Darol Anger (fiddle), Tony Trischka (banjo), and Mike Marshall

(mandolin). These online schools include a combination of visual and audio resources, instructional web videos, and direct video feedback from the artist when a student uploads a video of their own playing. Many other bluegrass musicians conduct regular synchronous lessons using Skype or similar platforms, including Jim VanCleve (fiddle), Adam Steffey (mandolin), Clay Hess (guitar), and many more.

Although significantly less common, jazz lessons and virtual schools are also available online, notably the virtual schools of John Patitucci (bass), Christian Howes (jazz violin), and Ed Byrne (trombone). Jazz at Lincoln Center also offers a number of instructional videos online, and many amateur and professional jazz musicians post instructional videos on YouTube. Although many of these online schools are popular and successful, asynchronous instruction is unable to address the interactive, real time collaboration that is essential to these musical styles.

Technology Platforms

Two technologies, Skype and PolyCom, are relatively common video-conferencing software programs that are used for music instruction. Teachers and researchers have explored the uses of these technologies in music, and schools have started to use Skype and PolyCom as distance learning tools over the past decade.

Skype

Across the mid-late 2000s, free audio–video conferencing software such as Skype became available for low cost synchronous distance learning (Dammers, 2009). Benefits of Skype (and similar technologies) include low cost and wide accessibility, but present challenges concerning the low quality of audio and video, a high latency, and audio “cutout” when multiple parties create simultaneous sound (Criswell, 2009; Dammers, 2009). Many classical and collaborative style professionals use Skype and similar technologies to teach private lessons on a regular basis.

PolyCom

Since 1999, some major conservatories have used the technology of PolyCom as a platform for high quality audio/videoconferencing and distance learning (Welsh, 2012). PolyCom is an audio/videoconferencing system founded in 1990 that serves a majority of finance, government, health care, and education institutions worldwide. PolyCom typically uses an H.323 codec, and is configured for multipoint video calls, movable camera angles, and presentation video channels—all features that are designed for business or academic voice conferencing (Nakai, 2011; PolyCom, 2014).

The Cleveland Institute of Music uses PolyCom and other software platforms to connect to a variety of distance learning locations, teaching programs including K–12, professional development, and conservatory lessons. The Manhattan School of Music also began using PolyCom as early as 1996 with H.323 and H.360 codecs, but adapted the technology in collaboration with PolyCom and Internet2 to allow for more accurate representation of the full range of musical sound (Orto & Karapetkov, 2011).

LOLA: Current Developments

Over the past decade, technology cooperation Internet2 has developed software specifically for music that reduces lag time to allow for real time performance. LOw LATency (LOLA) Audio Video, a new audio/videoconferencing software originally developed by the Conservatorio di Musica Giuseppe Tartini (Trieste, Italy) in collaboration with GARR, the Italian Research and Academic Network, and further developed by Internet2, was presented as early as 2005 and was fully released in 2011. This technology is the first, and currently the only one of its kind, to allow for latencies as low as 5 milliseconds (Nakai, 2011) and incorporates high quality audio and video. The software is free, but requires specific equipment with an estimated cost of US\$5,386 (M. Libera, personal communication, May 8, 2013). Simultaneous music performance via LOLA has been demonstrated at a variety of universities and locations, including a Paris–Trieste session at the Network Performing Arts Production Workshop in November 2010, Northern Illinois University/University of North Carolina at Greensboro collaboration in October 2011, a Northern Illinois University/New World Symphony (Miami Beach, Florida) collaboration in March 2012, and a Texas/California collaboration at the International Society for Technology in Education conference in June 2013.

Field tests of LOLA have primarily demonstrated music performance as opposed to teaching and learning. The GARR conservatory (Buso, 2011) and LOLA specialist Brian Shepard (2012) both stated that there is further work to be done at the network level to keep the technology usable. Although a small number of LOLA demonstrations have been presented at technology conferences, many more tests are needed to determine the effectiveness and usability in education settings. “[In] a master class where the teacher and student need to play together . . . [the] student can follow the teacher,” said Claudio Allocchio, lead developer of LOLA from GARR (Crimmins, 2012, para. 16). In this study, we sought to explore the benefits of LOLA in music education by investigating the use of LOLA, PolyCom, and Skype as teaching tools for classical, jazz, and old-time styles.

The primary purpose of this study was to examine the potential of LOLA as a distance learning tool for musical styles in which synchronous playing is an integral aspect of the learning process (e.g., jazz, folk styles). The secondary purpose was to describe participant perceptions of the effectiveness of three technologies used to teach music: LOLA, PolyCom, and Skype. To achieve these goals, we isolated a classical masterclass, jazz lesson, and old-time fiddle session and described trends for these lessons across the three technology platforms. The following research questions guided this study:

- **Research Question 1:** What are participant perceptions of the effectiveness of LOLA, PolyCom, and Skype?
- **Research Question 2:** Does LOLA provide a teaching environment that allows improvisation, jamming, and real-time collaborative playing?
- **Research Question 3:** Is LOLA audio/video perceived as more effective than other current higher-latency technologies used in the field?

Method

Participants

Prior to any participant interaction, we submitted this study for institutional review board approval and were deemed exempt because we were reviewing the effectiveness of a technology and were not asking the subjects for any personal information. Participants in this study included a professional classical violinist, a jazz saxophone professor, an experienced old-time fiddle teacher, and four university string students. The classical violin teacher was a member of the New World Symphony, a renowned U.S. symphonic orchestral academy. The jazz saxophone player and old-time fiddle teacher were, respectively, an associate professor in the jazz studies department and a string-specialist doctoral student at a major university in the southeast United States. All three teachers were successful in their field and had given a variety of lessons and seminars in their respective specialties. The four university students were undergraduate music performance and music education students. All four had received classical training and two had previous experience playing old time or jazz, in addition to the classical training.

Lessons

The professional classical violinist, jazz saxophone professor, and old-time fiddle teacher prepared and taught three consecutive lessons for their respective styles of music using LOLA, PolyCom, and Skype. Each lesson lasted approximately 30 minutes and the lessons were taught over a period of 3 days. Each day included one technology platform so that the experience with that technology was similar across musical styles (see Table 1).

Table 1. Lesson Organization.

Time (a.m.)	Day 1 (LO LA)	Day 2 (PolyCom)	Day 3 (Skype)
9:00	Masterclass	Masterclass	Masterclass
9:30	Old time	Old time	Old time
10:00	Jazz lesson	Jazz lesson	Jazz lesson
11:00	Focus group session	Focus group session	Focus group session

The jazz and old-time lessons included collaborative playing between parties at the two locations. The old-time lessons incorporated stylistic improvisation over a folk melody, whereas the jazz lessons focused on chord tone-based improvisation over chord changes. The classical lessons were taught in a masterclass style, with a teacher on one end of the technology and one student on the other end. For the old-time lessons, the teacher and university students interacted as a group ensemble at one technology site, whereas the professional violinist interacted as a virtual member of the group ensemble from the other site. For the jazz lessons, the university saxophone teacher led instruction while playing piano with a bass player and backing metronome as the rhythm section, and the professional violinist interacted as a student on the other end of technology.

Technology

Software versions for the lessons included LOLA 1.2, PolyCom HDX9006 version 3.1.1.3-36019, and Skype 6.4.0.833. LOLA uses a RME Hammerfall HDSP 9632 PCi audio card and a Bitflow ALT-PCE-AN1 video card with a Sony XCHR50 black and white camera and has the capability to run both the video and the audio fully uncompressed, which allows for lower latency but requires significantly more network space and stability (Buso, 2011; Conservatorio di musica G. Tartini, 2012). Unlike H.323 (the protocol for PolyCom) LOLA codecs allow for <5ms of latency, with audio/video buffers adding 0 to 1 milliseconds and network distance adding approximately 1 millisecond per 100 km (Buso, 2011). Latest network tests of LOLA in the United States have shown about 25 to 35 milliseconds of latency, whereas Skype and PolyCom often produce latencies well more than 125 milliseconds, depending on network configuration and bandwidth availability (Cisco, 2005; Skype Limited, 2011). A decrease in performance effectiveness has been observed at 60- to 80-millisecond latency (Schuett, 2002) and 106-millisecond latency (Bartlette, Headlam, Bocko, & Velikic, 2006). Because LOLA latency is typically less than 60 milliseconds, considerably lower than the reported latency of PolyCom and Skype, we were interested in user perception of delay and effectiveness across the three technologies.

Data Collection

This study used a mixed-method research design that included both quantitative and qualitative data. Data were collected via surveys, focus group sessions, and personal interviews to establish trustworthiness (Patton, 2002). Three areas identified in the related literature as interfering with the quality of online music instruction included collaborative playing (synchronous performance), audio quality, and video quality, and were included in the survey instrument. Participants rated survey items related to each of these three areas, as well as items related to personal experience, on a Likert-type scale, using 1 = *strongly disagree* to 5 = *strongly agree* as anchors. Open-ended questions at the end of each section of the survey were included to solicit any additional items that concerned the participants (see Table 2).

Table 2. Survey Questions.

Collaboration	
1.	The student was able to successfully play with musician/s at the other site.
2.	Playing with musician/s at the other site seemed organic or natural.
3.	This lesson was similar to having a lesson in-person.
4.	The student seemed able to develop a relationship with the teacher.
5.	The teacher was able to give specific feedback about the musical performance.
6.	The teacher did not seem distracted by the technology.
7.	Please include any additional comments about collaborating with the other parties:
Audio	
8.	I felt that the quality of the audio was sufficient for playing and communicating.
9.	Please rate the overall quality of the audio:
10.	I was able to clearly hear the tone of the musician/s at the other site.
11.	I was able to clearly hear the rhythm of the musician/s at the other site.
12.	I was able to clearly hear the articulation of the musician/s at the other site.
13.	Please include any additional comments about the audio of the lessons:

Video	
	14. I could clearly see the musicians/teachers at the other site.
	15. I felt that the video quality was sufficient for playing and communicating
	16. I was able to clearly observe the technique of the musician/s at the other site.
	17. Please rate the overall quality of the video:
	18. Please include any additional comments about the video of the lessons:
Personal experience	
	19. How familiar were you with the technology used in the lesson before your experience today?
	20. I was not distracted from playing or listening by the technology.
	21. I would use this technology in the future for receiving lessons.
	22. I would use this technology in the future for teaching lessons.
	23. Please use this space to comment on any additional aspects of the lessons and your experience today. If you feel that any of the technologies lend themselves to one method of teaching a style versus another (i.e., large group rehearsal vs. private lesson), please note that here:

The survey was administered to participants at the conclusion of each day so that they could rate their experience with the technology platform that was used that day across the three styles of music. Students and teachers also participated in a focus group at the end of each day when the experience was fresh. The three teachers were later interviewed following completion of the 3-day experience. Focus groups and interviews were purposefully open-ended to allow for freedom of commentary, but were guided by the three areas included in the survey instrument.

Results

Mean ratings were calculated for the three technology platforms across the three musical styles. Because of the small sample size, statistical analysis was limited to descriptive statistics, including only means and standard deviations. Tests for significant differences were not used. Participants rated the overall effectiveness of the three technologies as follows: LOLA lessons ($M = 4.25$, $SD = 0.77$), PolyCom ($M = 3.06$, $SD = 1.15$), and Skype ($M = 2.80$, $SD = 1.25$). When asked to rate the effectiveness of LOLA for each of the musical styles, participants rated the classical lessons highest ($M = 4.86$, $SD = 0.38$), followed by the old time lessons ($M = 4.00$, $SD = 0.58$), and jazz lessons ($M = 3.43$, $SD = 0.97$; see Figure 1). Participant ratings indicated that they were more likely to use LOLA in the future to teach or receive music lessons ($M = 4.32$, $SD = 0.84$), followed by Skype ($M = 2.88$, $SD = 1.15$) and PolyCom ($M = 2.75$, $SD = 0.86$).

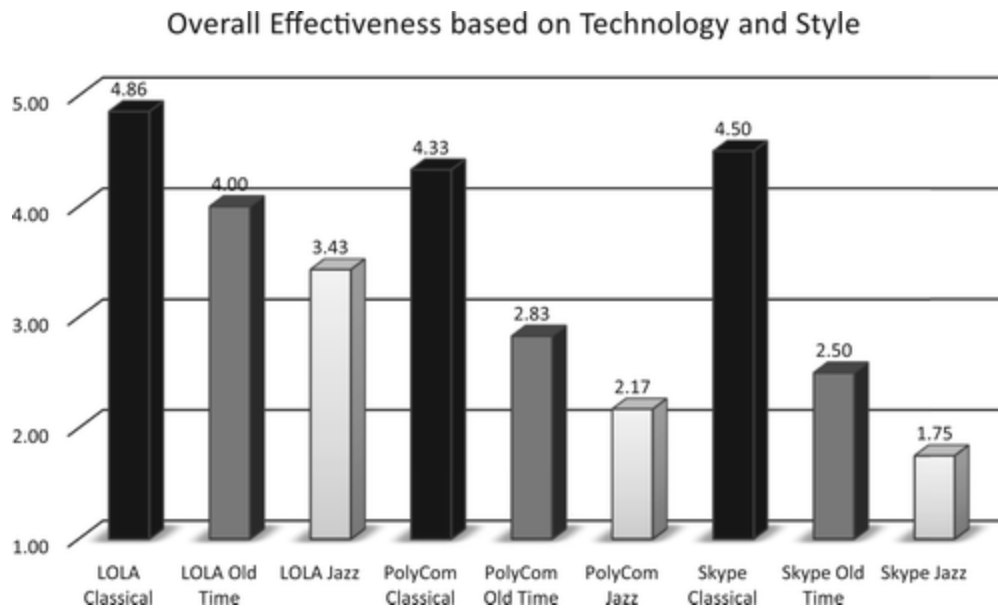


Figure 1. Participant ratings of each technology platform by musical style.

Emergent Themes

Data from the open-ended survey questions, interviews, and focus group sessions were coded separately to reveal emergent themes. For cross-verification, we triangulated the data by comparing the open-ended responses from the survey, focus groups sessions, and individual interviews (Creswell, 2013). Six themes emerged: Delay, Ability to play together, Audio quality, Audio cutout, Video quality, and Camera angle.

Delay

The most frequently mentioned theme in this study was delay. Delay was an issue during both the jazz and old time lessons because these lessons included synchronous playing. Participants noted that the delay of LOLA was substantially less than the delay that occurred during the PolyCom and Skype sessions. The following excerpts were taken from the focus group session at the end of the second day, which used the PolyCom technology.

The old-time instructor shared, “When you are trying to work collaboratively and you want everybody to be playing the same thing at the same time, you know, heterophonic music doesn’t really work if there’s a two beat lag.” This comment clearly outlined the difficulty of having a delay during musical styles that require a participatory culture. The jazz instructor added, “Well, I mean, the lag is a completely insurmountable problem. . . . I can teach her the melody fine as long as we are not playing at the same time.”

The instructors shared more of their personal experiences trying to adapt to the delay to make instruction more effective in the moment.

Old-time instructor:

[The delay] made me more self-conscious about what I was teaching, because it's like adapting instruction—when you're [the student] more than capable of doing these things, and I'm trying to figure out what I can do to make it better. There's nothing you can do about that lag.

New World Symphony violinist:

I think I would have felt the same thing. I didn't even bother trying to play the classical excerpts with [violin student]—I would have felt his lag. He would have been playing with me, but I didn't even bother because I thought, "Oh, it's just going to be horrible; he wouldn't get anything out of that."

LOLA enabled the most effective online teaching/learning environment with regard to collaborative playing. Below are excerpts from the focus group session that used LOLA:

Old-time instructor:

[Compared with other technology platforms] we were really able to get things done. . . . Like when I am doing a lesson on Skype, I have to play then wait to see if anybody heard what I did and then probably do it again . . . it seems like this [LOLA] is a lot more efficient.

Interviewer:

So you felt like it was more efficient, does everyone agree with that, or do people disagree with that? Does anyone think that it was less efficient or about the same?

Jazz instructor:

Nah, I think it is significantly more efficient. I've taught a lot of lessons both to my students here and to other students on Skype and on Google video chat and things like that, and most of the time the only thing that I can get done is have them play something for me, and I get to hear it. But as soon as I start talking they can't hear me, so they keep playing . . .

University participant:

The experiences that I have had teaching on Skype too and on Google have been very similar to what you just said, and it also freezes up a lot more. There will be times when I miss 30 seconds of what the person on the other end played.

Old-time instructor:

And collaborative work is just completely out of the question.

The instructors and university participants agreed that LOLA had provided their most positive experience to date with teaching and learning music in an online environment.

Participants from the jazz lessons thought that using the metronome significantly improved the ability to overcome delay during the LOLA lessons, and recommended the use of a metronome as a tool during future lessons.

Playing Together

Although LOLA was rated $M = 4.18$ for “successfully playing with musicians at the other site,” two major factors were identified by the teachers as interfering with the collaborative educational ability of LOLA: rhythm/time feel and pedagogical space. Responses from the jazz and old-time participants and teachers suggested that it was difficult or impossible to feel completely in time with the other party, even when the delay was minimal. This brief delay prevented the teacher and student from connecting rhythmically and establishing a groove with the student. The jazz instructor discussed this problem multiple times, first in the focus group session after the PolyCom lessons:

So much of teaching jazz involves rhythmic placement and rhythmic feel. I could hear that she was harmonically getting around what I was trying to give her, which is part of the reason why I steered so sharply in that direction. Unless she has a bass player on her end, or unless she has a metronome clicking on her end that I could hear, I have no idea whether she’s playing with the bass player with clarity on her end, or not. She may be behind the bass player the whole time on the other end, she may be ahead of him the whole time, it may feel terrible, but I can’t tell.

In an individual interview after all lessons had been completed, the jazz instructor noted that time feel in LOLA had problems as well:

There weren’t many problems with LOLA except once again, from a collaborative playing perspective. The delay, while really, really small, is enough to be distracting. I think you could get by with it, but due to the rhythmic nature and everything that we talked about—time feel and everything, with jazz. I think that it’s going to be impossible to completely feel comfortable saying, “Wow, that was really swingin’ . You had really good time,” when it’s not quite synced up.

Issues with simultaneous performance and playing together were also found in studies by Maki (2001) and Riley (2009). The majority of studies have ignored simultaneous performance altogether, not even attempting it as part of a lesson. Although the participants in the present study found the latency of LOLA to be more manageable than that of other technologies, total confidence in synchronous playing remained an issue across all three platforms.

Audio Quality

Overall, the participants were impressed by the audio and video quality of LOLA. However, some of the participants reported concerns that accurate assessment of tone and articulation was not possible because the tone quality was distorted. The violinist from the New World Symphony shared that, “The tone quality wasn’t perfect, and there was still some harshness to the sound, in sort of starts of articulation, so, like, a little bit harsh.” All three teachers referenced

trueness to original sound as an important aspect in teaching and learning, and again noted that delay was a much bigger issue than imperfections in sound quality.

The audio quality of PolyCom and Skype was rated lower than LOLA, and participants noted that the decrease in quality made it more difficult to assess students. One of the university participants shared on her survey that, “Levels were changing. Voice comes through strong; violin less so.” This issue was also discussed in the focus group sessions. Participants seemed much less satisfied with the range and timbre of the projected sound, and noted that both technologies were much less effective than LOLA at relaying the sound of the musical instruments.

Audio Cutout

During the focus groups, students and teachers remarked that the audio cut out during Skype and severely prohibited collaborative playing. The jazz instructor explained during a focus group session that, “It [cutout] defeats the whole purpose of her being able to hear what she’s [student] doing relative to what we’re doing, which is . . . 98.999% of what we’re doing over here.” Although the PolyCom participants did not observe a severe cutout, participants during the lesson did note some mild volume changes and echo issues. In the focus group after the PolyCom lessons, the old-time instructor spoke to the classical instructor/old-time participant:

In all three of the sessions, sometimes your audio would drop in dynamic, and then it would come back in. I noticed it more when we were trying to do our round-robin playing—there was a little bit of a lag, but it was also really, really quiet. I couldn’t hear you as well . . . did it happen on your end as well?

When the classical instructor began to reply, the audio drop was audible, and participants in the room nodded their heads in recognition. She could not hear a drop on her end, but spoke of other issues. “If I was too loud, I heard an echo of myself on the other side, sometimes.”

Instructors and students did not mention drops or cutouts for any of the LOLA lessons.

Video Quality and Camera Angle

The teachers also noted that they were unable to use educational strategies that involved physical space, such as adjusting a student’s position or using physical proximity to manage the classroom. The old-time instructor shared the following:

You can’t use pedagogical touch [with LOLA], especially if you’re working with young kids. You and that teacher on the other end have to be exactly pedagogically on the same page, which is rare. You can’t adjust their bodies or their bow holds. . . . If you’re trying to teach some new technical bow stroke where you need to be able to manipulate the student’s body—it would be very difficult to do something like that in a masterclass setting if you don’t have somebody whose body you can adjust.

Dammers (2009) found that the inability to adjust students physically was a difficulty in online music lessons, and it took both student and teacher time to adjust to using the camera effectively. Maki (2001) also observed this difficulty, and noted that teachers would adjust camera angle and zoom, get closer to the students' fingers, and then verbally adjust. Many students and teachers remarked that the camera angle made it difficult to assess and adjust any physical problems with the students. Participants had a positive response to the video quality and camera angle of PolyCom, but noted that many of the benefits of the video were negated by the increase in delay.

Although delay and audio quality were identified as problematic and participants were hesitant about the exclusive use of LOLA for teaching or rehearsing, participants indicated that LOLA far exceeded their expectations and prior experience using technology for music instruction. Furthermore, participants indicated that they would consider using LOLA in the future as a teaching tool for classical and collaborative music styles.

Discussion

Overall, participants described and rated LOLA as more effective than both PolyCom and Skype. Classical lessons were rated higher across the three technologies than old-time and jazz lessons. During the lessons that required collaborative playing, LOLA was perceived as more effective. These findings suggest that LOLA may be more effective as a technology used to educate across improvisational and/or collaborative playing-based musical styles. The decrease in latency found in LOLA seemed to increase perceptions of effectiveness for all the lessons. Furthermore, participants reported a preference for the superior audio and video quality of LOLA. The absence of physical space and proximity presented issues across all technologies, similar to findings of recent studies (Dammers, 2009; Riley 2009). Participants did suggest the use of multiple cameras and camera angles to address this issue.

Is LOLA an effective platform for jamming and improvisation? Within the focus groups and interviews, participants expressed optimism about many aspects of the technology but disagreed about their willingness to frequently use it for collaborative-based playing. LOLA's latency, however small, still presented a significant obstacle in the realm of true time feel and collaboration. Participants' unfamiliarity with the LOLA technology may have presented obstacles that could be easily overcome with additional use. While face-to-face music education remains optimal, especially in collaborative settings, LOLA has presented improvement in many of the difficulties that come with distance learning.

There were a number of limitations to the present study. The number of participants was small; therefore the results of this study should not be generalized. Differences between the mean ratings for each of the technologies were not tested for statistical significance, and may have been due to chance. Furthermore, without validity and reliability processes being completed on the survey instrument used in this study; it is unknown whether the data have potential respondent error. We did not control for presentation order, so it is likely that the order in which the participants experienced the technology affected their perceptions of effectiveness. Because visual experience is an integral aspect of audio-video conferencing, participants were aware of which technologies were being presented and may have had preconceived ideas about their

effectiveness. These limitations demonstrate a need for further research that addresses validity and reliability, controls for presentation order, includes a larger participant pool, and includes a wider variety of musical contexts.

Implementation of LOLA into any education setting will, at the present time, require a significant financial and time investment. Distance learning environments provide sustainable financial benefits that can frequently outweigh the cost of initial setup (Brändström et al., 2012) and educational institutions should consider the multigenre benefits of LOLA compared with other platforms when making decisions concerning music technology investment and establishing distance learning programs. In the present study, participants perceived LOLA as more effective than other technologies currently available for individual and group lessons. LOLA has the potential to increase opportunities for online music instruction, and may provide future opportunity for musical instruction in settings that require collaborative playing. As this technology becomes increasingly accessible, LOLA opens up a wide range of exciting possibilities in the field of collaborative music distance education.

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