

Kelly Murphey

2 January 2020

The Inclusion of Bone-Conduction Headphones in Theatre and Sound Design

This paper is an extension of ongoing research into bone conduction headphones and binaural recordings as used in theatrical settings. The objective of the research is to quantify and qualify the uses of bone conduction headphones in theatrical applications as an approach to theatre and sound design innovation. This will be achieved through a discussion of the background of bone-conduction technology, its current mainstream uses, and a presentation of current areas of theatre and sound design where application of bone-conduction technology can increase safety and present new possibilities in the realm of performance.

I. Why This Research is Important

The idea for using bone-conduction headphones in theatre originated as I began researching bone-conduction headphone technology as a project for a sound design class. Not knowing exactly how these headphones work, I sought out technical information that described how these headphones transmit sound, and what set them apart from air-conduction headphones. I was fascinated by the idea of sound transference through mediums other than traditional air-conduction, as found in speaker systems and most headphones; moreover, I noticed that because this sound transference happens through bone vibration, there was also little to no sound bleed, like what occurs with air-conduction speakers. More importantly, what stood out in my initial

research was the placement of the sound-producing mechanism, which is located in front of the ear rather than inside the ear. This presented a fascinating possibility: with their ears still open to ambient sounds, listeners can receive sound from multiple sources simultaneously. The implications of this dual-listening mode provide new avenues for sound, particularly in the areas of audience immersion into performances, a safer means of communication for technical crew members, and live, open-ear sound mixing for audio engineers.

Exploring ways to communicate and increase intimacy through sound design, theatre has continued to make creative and intelligent use of advancements in technology for live performance. Recent productions have made huge strides in sound innovation, particularly in the area of headphone theatre, like with Simon McBurney's *The Encounter*, and Nanna Karin-Schleimann's *Good for Nothing*, for example. Using audio technology to fully immerse the audience, sound design becomes more than a means through which a story is clarified; it becomes the vehicle through which the story can be experienced in an almost visceral way, bringing the audience closer than ever before to the story.

In this paper I'll highlight both the practical and the aesthetic aspects of utilizing headphones in theatre. From a practical standpoint, bone conduction headphones provide better live-mixing capabilities for those in audio engineering and assisting those with hearing impairments to participate on equal footing, and through open-ear listening, provide a safer means of communication for production crew members. From the standpoint of aesthetic considerations, bone-conduction headphones have the added flexibility of allowing the user to hear in two different modalities at once, which opens up the possibility of a deeper audience immersion in

performances through a curated sound design that employs both of these modalities simultaneously, resulting in a richer environmental landscape, and a deeper dive into the psyche of a story's characters. These attributes, coupled with ongoing research being conducted by the United States Army Research Laboratory (Henry), which includes improved BC microphone clarity and noise-cancelling capabilities within the microphones, has led to some exciting future possibilities in sound design and theatre.

II. Bone Conduction: Background

People hear through two manners of sound transmission: air-conduction and bone-conduction. The way our ears typically process sound is through the process of air conduction, which will henceforth be referred to as AC. A sound source sends compressions and rarefactions (vibrations of air molecules) through the air that in turn vibrate our ear drums. The ear drum sends these AC waves into the middle and inner ear which act as transducers, further processing the waves into signals that the brain can interpret as sound. When parts of this hearing chain fail, the processing of sound is impeded or, in worse-case scenarios, can irreparably cease to function.

All AC headphones, including on-ear, over-the-ear, and in-ear headphones, rely on the proper function of this AC hearing process. Bone-conduction technology was developed to circumvent parts of this process and is effective in some types of hearing loss. Bone-conduction, which for the purposes of this paper will be referred to as BC, is a process of sound transmission to the inner ear mechanisms produced by the stimulation of the basilar membrane due to pressure on either side of the membrane, through two means:

The first type of pathway short-circuits the middle ear and comprises three distinct mechanisms: cochlear fluid inertia, compression of the cochlear walls, and pressure changes exerted via cerebrospinal fluid. In the second type of pathway, the stimulus reaches the basilar membrane via the middle ear, either directly or via the outer ear (Dauman 209).

The origins of BC technology are still unclear, but it seems there are several sources of research conducted independently from one another by Vesalius (1515 – 1564), Fallopius (1523 – 1562), and Eustachius (before 1574), as well as Girolamo Cardano (1501 – 1576), although no reference to Cardano's work is seen in either of the other's work (Staab). It wasn't until the early 20th century that Hungarian biophysicist Gerg Von Békésy, between 1932 and 1949, was able to make great strides in understanding BC hearing. His research found three main modes of BC: labyrinth BC, or compression of the fluid in the inner ear forcing movement of the basilar membrane; skull BC, uses labyrinth BC as well as creating movement in the naturally-acoustic-producing ossicles in the middle ear to produce sound; and clinical BC, which passes vibrations through the jaw bones – the lesser effective of the three modes mainly because of the vibration-dampening soft tissues that comprise the jawbone–skull connection (Puria 2012, Békésy's three conceptual mechanisms of hearing by bone conduction sect, para. 1). This research has led to the use of BC technology in the development of hearing assistive devices, communication technology for the military that allows soldiers to remain highly cognizant of their surroundings, particularly in combat zones that are extremely loud and chaotic, and is also used in the athletic community as a safer music-listening device for runners.

III. Bone Conduction Technology: Mainstream Uses

In hearing-assistive technology, bone conduction is used in cochlear devices such as the Bonebridge implant, which takes external audio signals into an external processor and converts them into impulse signals that are transferred to the implant attached to the inside of the temporal bone, sending the vibrations to the inner ear. This technology can also be found in the ADHEAR cochlear device, which transmits the sound in a similar manner, but the transducer is on the outside of the skull rather than implanted. This technology does not work with all forms of hearing loss, but rather will only work in cases where the cochlea works and is not part of the hearing loss causation (*Bone Conduction Hearing Devices*).

The first mainstream use of this technology was seen in the United States Armed Forces. The Army has been conducting ongoing research to better understand the technology for the purpose of developing custom headsets for their troops. The Army currently employs the use of Invisio headsets with their troops as a means of two-way communication in the field (*Tactical Communication and Hearing Protection Systems*). The technology allows each of their soldiers to receive audio commands and keep an open line of communication while remaining aware of their surroundings:

Radio communication and hear-thru are separate with continuous and unimpeded hear-thru in both ears, even when transmitting.

INVISIO offers headset options that include in-the-ear and over-the ear hearing protection, 20 meters submersible and lightweight patrol headsets. The provided hearing protection is industry

leading and offers state of the art situational awareness. (*Tactical Communication and Hearing Protection Systems*).

BC technology has also been adopted by fitness and sports companies like Audio Bone, started in 2008, and Aftershokz founded in 2011, as a means of allowing a runner to listen to music while still being aware of the ambient sounds around them (Smith 2017).

Scuba divers have also found this technology helpful as a means of communication in deep sea diving. Logosease is an underwater wireless device developed by Casio that is worn by the diver on the mask. These devices pick up and interpret the voice in real time through the bones, even while the wearer still has the air regulator in their mouth. The reception range on these devices can reach up to 100 meters underwater, in depths up to 50 meters (*Product Specification* 2019). With underwater dives, communication with a partner is imperative to the safety of both divers.

Google Glass also used BC technology in their headsets in the form of a bone conduction transducer in the glass piece that sits directly behind your ear on the temporal bone (*Audio* 2020). These devices are mainly used in manufacturing industries like GE, AGCO, DHL Logistics and Sutter Health as a means of making the job easier for their workers. AGCO, for example uses them as a platform for their workers to see their custom builds and the safety inspections for those builds in the Google Glass display mechanisms.

In all of these mainstream uses, there seems to be a consistent factor of the user's safety that is considered, in that the wearer can remain aware of their immediate surroundings. The

implications of this can have a great impact on the theatre community; especially in areas of performance, stage management, audio engineering, and performance musicians.

Communication in theatre is very important for the success of a performance, both in the communication backstage and in the delivery of the story through sound to an audience. To understand where BC headphone technology might fit into the world of theatre, we must first look at previous iterations of headphone theatre.

IV. Headphone Applications in Theatre: Past and Present

Headphone use in theatre is not a new idea. It is commonplace for theatres to use AC headphones for the purposes of hearing assistance, audience engagement, and both backstage and front-of-house communication. More recently, headphone use has appeared in a genre of theatre called headphone theatre (Kendrick 64). Springing from the omnipresent use of wearable listening devices, these productions use headphones throughout the audience in an effort to more fully immerse them in a performance. In Lynne Kendrick's *Theatre Aurality*, she notes that "Sound may no longer be associated with passive immersion, nor indeed is sound considered to be the only sense that immerses. Yet in headphone theatre, sound is the material of immersion and listening is the primary means by which we experience it" (Kendrick 67). These performances are diverse, ranging from more traditional productions to performance art. In this section, I will explore the dialogue centered around headphone theatre; successes and shortcomings, found through reviews of performances that have utilized the technology.

The purpose of AC headphones is two-fold: to dampen or eliminate external sources of sound completely and send curated sound to your ears directly. This allows the listener to be as isolated from ambient sound as possible. While some productions, particularly performances like Simon McBurney's *The Encounter*, and Nanna Karin-Schleimann's *Good for Nothing*, have found ways to use this feature to their advantage, others seem to be hindered by the inherent isolation of AC.

In Matt Trueman's experience as a theatre writer for The Guardian in his article, "This Play May Contain Headphones," headphones create a noticeable separation between the participants as an audience, and their relationships to one another as a shared experience and to the performers.

...this latest wave of audio-instructed performance has left me cold.

Yes, they uncovered some interesting possibilities: I enjoyed the convergence of separate paths in *Hall*, where you suddenly realise the presence of other participants; and I liked the communing element of Speakman's so-called [*Subtle mob*], which involves sharing an experience with some, but not others, as if tuning into another frequency. But neither really delved into what it's like for the audience to encounter their surroundings in this new way

(Trueman 2009).

Trueman emphasizes this by describing the critical relationship between what we see and what we hear; moreover, we feel at odds when there is a disconnection between the sound and its source. This was more apparent in *Hall*, one of the three shows Trueman participated in as an audience member. In this eerie audio tour, he and other audience members were guided through a run-down site by silent performers. Productions like this lead to what he describes as a,

“curious experience: one that feels active, but is actually passive” (Trueman 2009). He sums up his thoughts: “In short, [audio-instructed performance] can't afford to ignore the headphones: the form cannot be readily separated from the content” (Trueman 2009).

In opposition to this, other productions like *The Encounter* by Simon McBurney/Complicite brings the audience what some, like Benedict Cumberbatch, have considered a ‘magical’ experience, one that is performed live in front of an audience each night (Gilmore 2016). The sound design by Gareth Fry uses binaural audio transmitted live through microphones in the ears of a dummy head on stage with McBurney. Fry uses a mix of this live binaural sound, prerecorded sound, and other live audio tools to take the audience on journey through the eyes and ears of Loren McIntyre, a National Geographic photographer, played by Mc Burney. Through this unique three-dimensional soundscape, *The Encounter* recreates McIntyre’s real-life interactions with an undiscovered tribe in the Amazon rainforest in 1969 fully immersing the audience in the story. Fry recalls in an article “Inside This Season’s Headphones-Required Broadway Must-See *The Encounter*” by Dan Gilmore, “It’s about reducing that distance and making it feel like, in one sense, Simon can come and whisper in your ear, but equally you can be onstage with Simon” (Gilmore 2016). For *The Encounter*, the choice to isolate the listener with AC headphones allowed him the ability to transmit a curated sound design while eliminating any unwanted external sounds.

In Nanna Karin-Schleimann’s sound design project *Good for Nothing*, an entirely improvised performance at the Danish National School of Performing Arts in Copenhagen, she utilized DPA’s still-experimental 4560 binaural headset microphones to give a headphone-wearing

audience a performance that, in her words, explored, “the relation between an individual enclosed experience and a collective and spatial experience” (*A Headphone Wearing Theatre Audience* 2019). Like *The Encounter*, this performance aimed to create something personal for the audience in an effort to allow them to feel more immersed in the story, rather than act as a passive observer. However, both of these performances did so to the exclusion of the ambience around them. What if there were a way to harmoniously include both the live ambient sounds that surround an audience and a curated sound design delivered through headphones? BC headphones have the ability to send clear vocal and tonal sounds directly into the inner ear without impeding the sounds coming from external outputs, allowing them both to be received equally. In the world of theatre, this feature can prove useful in the areas of performance as an integral part of audience engagement and can provide a safer means of communication between stage management and the rest of the production team.

V. Future Applications of Bone Conduction Headphones in Theatre

BC headphones in theatre applications could allow for improvements and greater flexibility in two areas of theatre: performance application and safety in communication. In the first section, I will explore the use of BC headphones in theatrical performances in theory and in practice to further qualify their practicality and artistic value. In the second section, I will explore the theoretical applications of this technology in the areas of communication during rehearsals and performances. Lastly, I will explain how this technology can theoretically help audio engineers during technical rehearsals and could possibly aid in other areas of sound production and monitoring.

A. Use in Performance

In our previous paper, *Bone Conduction and Binaural Sound in Theatre*, collaborator Jacob Henry and I postulated that BC headphones, when used as a replacement for AC headphones, could “create a new kind of immersive experience for live theatre performance” (Murphey and Henry 1). Speaking generally, we believed that we could enhance the audience’s engagement in a performance by giving them the opportunity to hear the inner thoughts of a character while at the same time hear the performer’s outer dialogue. Since an audience wearing BC headphones would be able to hear ambient sound through their ears, as well as the curated sounds sent through the device, we theorized that both types of sound could be layered into an overall sound design. The beta test for our postulation would be a short, twenty-minute performance where an audience of no more than twenty people would wear BC headphones that received the inner dialogue of a character, while additional ambient sound would be transmitted through AC speaker sources. The purpose of this beta test was two-fold: first, it was created to determine the successful reception of both BC and AC sound sources clearly by the audience members, and second, that the sound landscape that was created, along with the blending of the character’s internal dialogue, helped the audience feel more immersed in the performance. This arrangement gave the audience the rare opportunity of discovering the real intentions of a character, by hearing their innermost thoughts in combination with their outer dialogue. This theoretical idea was put into practice with Jacob Henry’s thesis project at Texas Tech University entitled *9 in the Morning*, in May of 2018. In this performance, the audience watched a solo performer struggle to recall the previous night’s events. The sound design included a blending of external AC ambient sounds through natural movements in the room, curated sounds through AC speakers, and the

character's inner dialogue transmitted through BC headphones. According to Shane Strawbridge of Lubbock Arts: News and Reviews, "What makes this production different—and worth spending the time to see—is the utilization of bone-conduction technology which allows the audience to hear both the words from the mouth of Woman and the voices inside her own head" (Strawbridge 2019). This relationship between the intent behind the thoughts and the delivery of the response to those thoughts would not be possible, nor as believable, if they were delivered through AC headphones.

In May of 2019, my research and its practical application in Jacob Henry's *9 in the Morning*, led to the creation of *Morning, Noon, Evening, and Night* (a collaboration with Jacob Henry and Matthew Schleif), a site-specific sound experience developed for the Prague Quadrennial. In this event, twenty BC headphones were used in conjunction with twenty wireless in-ear monitor systems and a single transmitter connected to a portable battery. This portable system, connected to a laptop, stored pre-recorded dialogue, containing the inner thoughts of our two live actors. This inner dialogue and sound effects were blended into the story's narrative and were transmitted through wireless belt packs to BC headsets worn by the audience. The sound experience was a live audio tour where the audience could watch and follow the two actors as they meandered through the PQ park grounds, using the environment, and all of the live, uncontrollable ambient sounds, to help tell their narrative. The structure of the technical elements and the environment allowed for flexibility in the development and delivery of the story so that no two performances were the same. Moments of unexpected sound pollution, like a train going by, or unexpected rain showers, would occur during moments of the performance at different times, so they could not be predicted. This caused the production team to create a sound delivery

platform that had to be just as flexible as the performers needed to be. From an immediate Survey Monkey survey after the performances, reviews rated the clarity of the dialogue from the performers and the sound through the BC headphones to be above average with average ratings between 7.25 and 10 out of 10 (Appendix A). These surveys were submitted to the audience after the performance by means of a paper handout with the names of the project and its contributors along with a QR code that was linked to the website where the digital survey could be completed. One anonymous participant recalled their experience in the survey, “This was amazing. A completely new way of storytelling - and it worked. I would LOVE to see more work like this. Even something with more of a one-act length. Or even a full show. It was immersive, exciting, and intimate in a way I've never experienced before” (Murphey, *Market Research 2019*). The success of *Morning, Noon, Evening, and Night* stemmed from the combination of the utilization of the technology to help enhance a deeper level of empathy for the characters and the forum in which this performance took place: an environment that was real, alive, and believable.

Both *9 in the Morning* and *Morning, Noon, Evening, and Night* could not have been performed successfully, or as safely using BC headphones. Our production was a response to Prague Quadrennial’s call for site-specific work, which we took as a perfect opportunity to debut this technology to an international audience. *Morning, Noon, Evening, and Night* was written and performed to showcase the technology’s ability to allow the site, the Quadrennial’s park grounds, to be experienced live in a special way. As previously discussed, AC headphones separate the listener from the outside sound influences and can even distort the relationship between the sound and its source. While allowing our audience to share the inner thoughts of the

characters, our use of BC headphones also discouraged them from becoming disassociated from their natural surroundings. Mobile and free to explore alongside our actors, the audience was encouraged to share in the same physical and psychological experience as the characters. The success of BC headphones in this respect can be applied to other areas of theatre; this ability to be tuned into fine sound detail while still remaining open and responsive to the changing physical environment could enhance the quality and safety of backstage communications.

B. Use as Backstage Technology

Stage managers and production crews during live performances and rehearsals depend on intercom systems, which are usually physically tethered to a network, to communicate within the vast network of people they are comprised of – these need to be wireless for ease of movement, and to lessen the chance of tripping or blocking movement. Little has changed since the introduction of the Clearcom belt pack of the 1960s, apart from making them wireless, which has freed up the user to walk freely within a certain range. Intercom systems have provided the necessary means for communication for stagehands, but with one recurring issue: the earpiece. Intercom headsets can create soreness from compression on certain parts of the skull, as well as create an uncomfortable soreness on the outside of the ear, along with unbalanced sound reception. Along with these two issues, there is also the matter of safety that arises with over-ear AC headphones: at least one ear is closed off to external sounds, even within their immediate surroundings. AC headphones in this instance are merely an impedance to hearing and not a complete nullification, but in the backstage environment, crew members need to remain aware of their surroundings and every second counts when it comes to safety.

For the purpose of clarity, there is an important consideration for using BC headphones that cannot be overlooked when implementing them as a replacement for AC headphones in an intercom system: is there a loss in vocal clarity with BC headphones? A study titled “Improvement of voice quality and prevention of deafness by a bone-conduction device”, led by Hyung-Woo Park, looked into bone-conduction system as a safer alternative to increasing the volume on mobile device handsets when used in noisy areas. The findings indicated that bone-conductions are a better, safer means of dampening ambient sounds and increasing vocal reception, citing, “Not only was the ambient noise neutralized with the anti-phase, but the incoming sound was amplified using in-phase signals” (Park, Conclusions para. 1 2014). Much like noise-cancelling headphones in the AC headphone arena, BC headphones employ the same technology to eliminate noise pollution so the listener can focus on what is being delivered. A clear signal helps improve the expediency in which a crew can do their job.

According to the article “Speedy Science: How Fast Can You React?” by Daisy Yuhas, the average human reaction time is between 150 to 300 milliseconds, hearing unimpeded. A study conducted by the University of Wisconsin, Madison entitled “The effects of audio and visual distractions on reaction time” shows that under the influences of either music, texting, or conversation increased a person’s reaction time by 1.58%, 94.94%, and 13.48% respectively when compared to a control set (Yuhas 2012). These numbers can translate to stage communication and the operation of moving stage parts in a direct way. When stage managers issue calls to move scenery, the command is communicated and interpreted by the listener on the other end and then processed before action occurs. Backstage crew requires quick reaction time to stage manager calls and a safe environment where they are keenly aware of the choreographed

movements of heavy parts. BC headphones can allow both of these areas of need to be addressed: open-ear awareness, and clear communication with the stage manager. The change from AC headphones to BC headphones in intercom systems is not difficult using the technology we have, currently.

Changing from traditional intercom headsets to BC headphones can be done using an XLR 4-pin, or 5-pin, in some instances with Telex systems, to 3.55mm female stereo jack adaptor. The same conversion can be done with walkie-talkie intercom systems by inserting two-way communication BC headphones like the Sports Titanium with the microphone included in the headset from Aftershokz. This configuration works similarly to any other in-ear two-way communication headsets. As David J. McGraw of “Stage Manager’s Kit” says, “You can hear your show while still being able to hear your director/designers/crew next to you. Moreover, you don’t have to pick which ear hears the headset feed and which hears the show feed. Plus, no more “swamp ear” after wearing cans for a 10 out of 12” (McGraw 2017). The freedom gained from having the ears open to external sound sources is a benefit to stage crews who monitor the movement of heavy equipment and scenery backstage. It can also present a much-needed solution to the issues that face audio engineers, and other front-of-house production members.

C. Use in Audio Engineering and Musical Theatre

Sound mixing is an art of blending decibel levels and frequencies of individual sounds to create the desired levels, sound quality, and balance appropriate for audio output. During rehearsals, and during performances, there is typically also a need to communicate with the rest of the

production team as well. Currently, sound engineers are left to switch back and forth between mixing headphones, or listening to live sound, and their intercom headsets. These issues can be resolved by introducing BC headphones in place of their intercom AC headsets, as is proposed for the backstage intercom systems. Not only would these headsets still allow open communication with the stage manager and other crew members, but it will also free up their ears to mix sounds with open ears, hearing them as their audience will in the house. Audio engineers that like to use AC headsets to monitor channels can still do so with the BC headphones being actively used. The two do not interfere with one another as they produce sound using two different means: one directly into the inner ear, and the other through the tympanic membrane and the out ear. This technology can also assist those that need to hear music and their part in the production of and contribution to that music.

Musical theatre performers rely on monitors during performances to help them keep tempo and stay in tune by following the accompaniment of a live or pre-recorded band. Monitors utilize AC, sound reproduced through speakers, and provide clarity and amplification to sounds when mixed correctly. Monitors can also create additional sound distortion and feedback when used in combination with microphones, which are worn by actors and other live musical performers. BC headphones would eliminate feedback concerns and would provide a safer means of monitoring real-time sound without the use of in-ear systems that can pose the threat of hearing. Musical directors and conductors would greatly benefit from these intercom systems as well, especially during rehearsal, and in some cases, performances. Speaking generally, this intercom configuration could enhance the communication with all members of the production team, while keeping their ears open to the real-time, in-house blending of sounds.

VI. Conclusions and Future Research

This paper proposes the inclusion of BC headphones into existing theatre technology for the purpose of expanding the possibilities of sound design innovations and alleviating current issues that arise from the use of AC headphones in intercom systems in both technical and performance applications.

Easily implemented with existing technology, the use of BC behind the scenes has the potential to eliminate current obstacles to efficient, safe communication. In environments where communication between production members is crucial to safely executing coordinated movement, the use of BC is predicted to boost the wearers' ability to hear voice communications while keeping them more connected to their environment. This could lead to reduced response time and increased efficacy in identifying and avoiding potential hazards. Elevating the level of safety for backstage crews by increasing awareness of their surroundings through open-ear BC headphones would be of great value and is a potential improvement to current safety protocols and best practices.

My research also suggests that the implementation of BC in performances could be a positive influence on innovations in sound design and storytelling. BC offers a tool for new areas of exploration in headphone theatre—increasing audience engagement with the story, maintaining connection with and making use of their ambient surroundings, as well as preserving awareness of other audience members as a participating collective.

Future research into the use of this technology in theatre applications could change the manner in which performances are experienced by an audience, further immersing them into the narrative. These experiences could inform or potentially modify the manner in which shows are written, directed, and performed—broadening the landscape of theatre and introducing new modalities of storytelling and audience perception.

Developers of BC systems are currently looking to improve upon the clarity and amplification of live vocal transmissions through the implementation of noise reduction technology in combination with amplified in-phase signals. With these improvements, the ambient noise received by the listener could be eliminated to allow clearer vocal and audio transmissions to be heard.

Further implementation of BC within the realm of theatre and beyond can be imagined in many arenas. BC technology could easily be explored in the area of verbatim theatre. In this genre where plays are written using the exact words spoken by interviewed individuals, the ability to share actual curated portions of interviews while melding them with the live performance could be of interest. In improvisational theatre, BC technology could be an effective enhancement both in troupe practice and audience participation. In a similar fashion, the use of BC could become a powerful tool in drama therapy. The BC headset, coupled with mic capabilities, could be used to play chosen recorded sound as well as real-time communication between participants and facilitators.

I will be conducting further research into the applications of BC headphones as a medium used in combination with cognitive behavioral therapies (CBTs) to help treat those with post-traumatic stress disorder (PTSD). Groups like Stephan Wolfert's DE-CRUIT, which help veterans with PTSD triggers through group therapy and reenactments from plays, use theatre to begin a dialogue that will help them understand the complex web of their traumatic experiences and the steps that will aid them with their own personal rehabilitation and a smoother transition back into civilian life.

Appendix: Survey for *Morning, Noon, Evening, and Night*

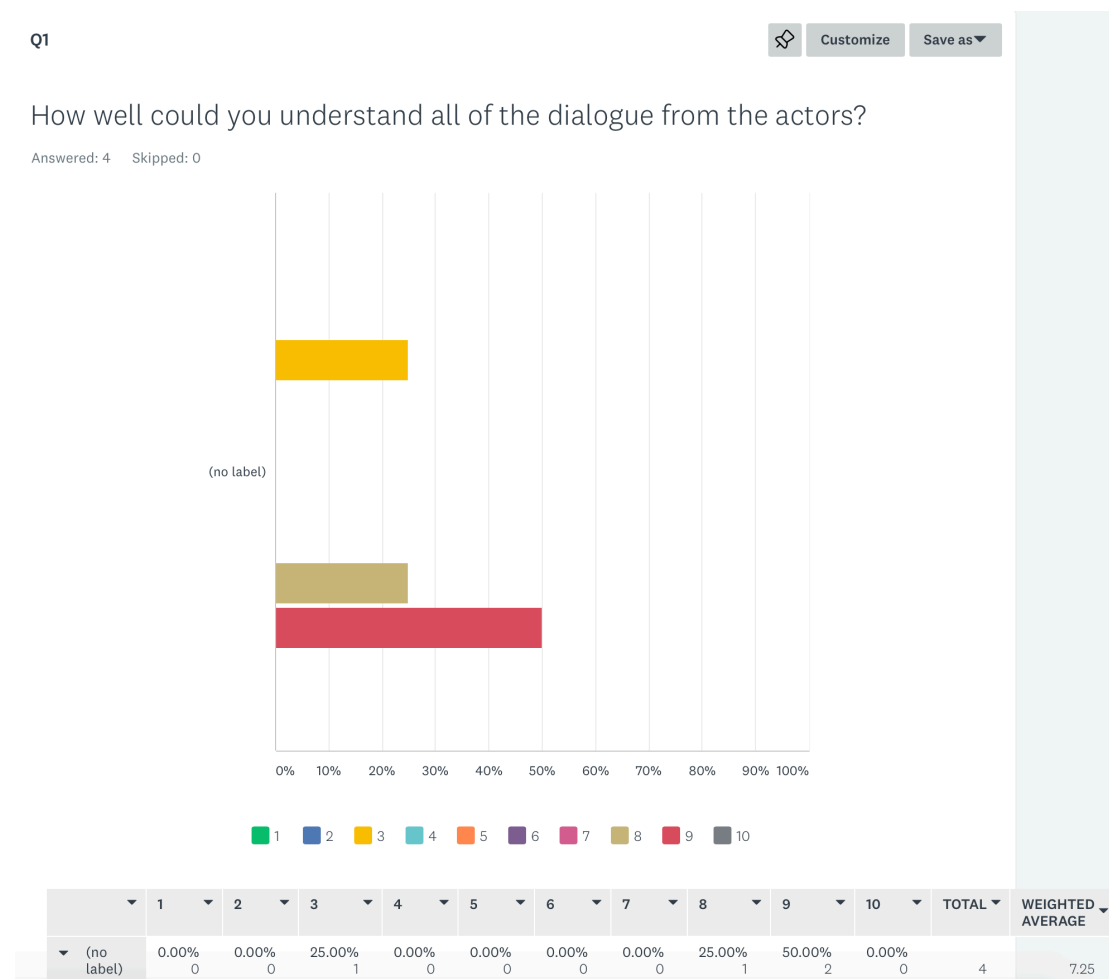


Fig. 1. Survey Question for *Morning, Noon, Evening, and Night*. Survey Monkey. Web. Market Research. Prague, CZ. 14 June. 2019. Unpublished Survey. Digital Image

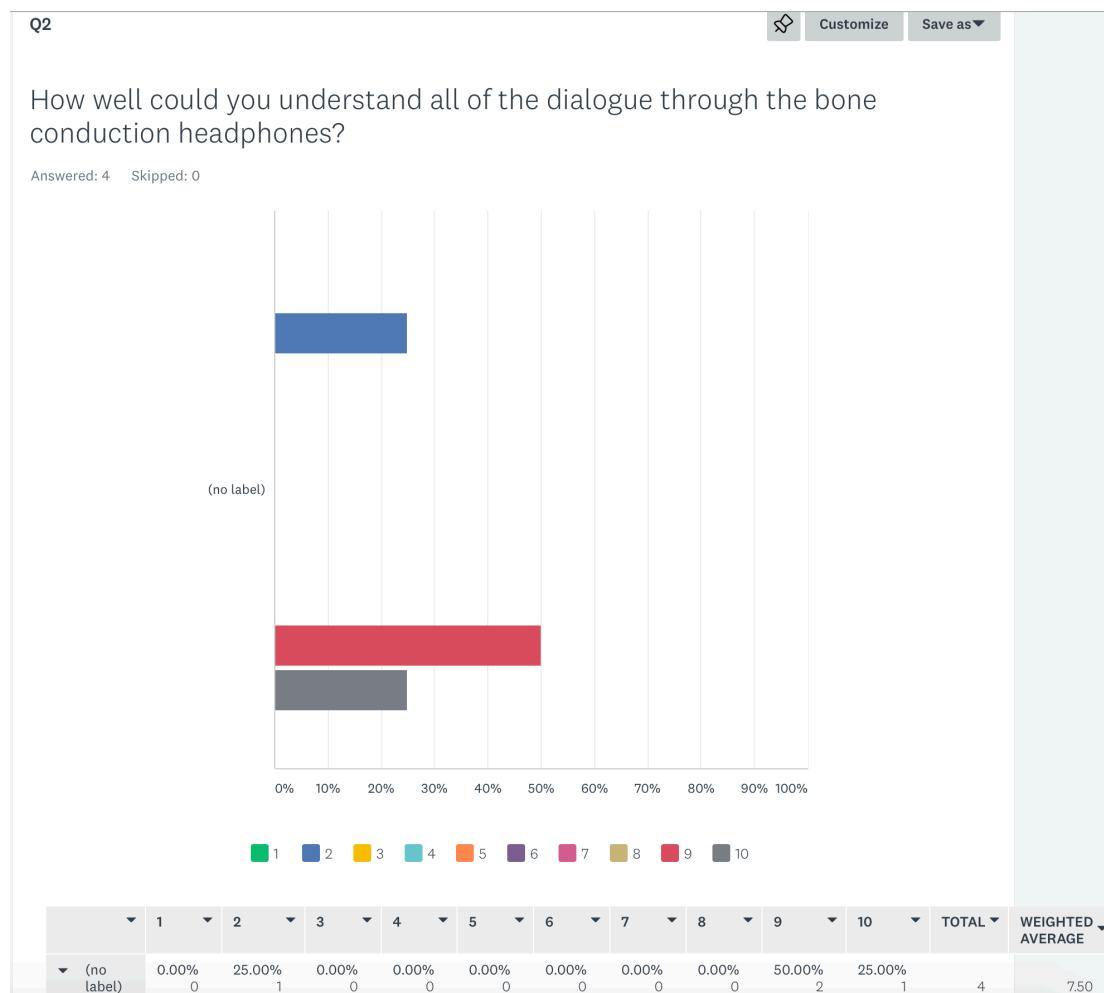


Fig. 2. Survey Question for *Morning, Noon, Evening, and Night*. Survey Monkey. Web. Market Research. Prague, CZ. 14 June. 2019. Unpublished Survey. Digital Image

Q3

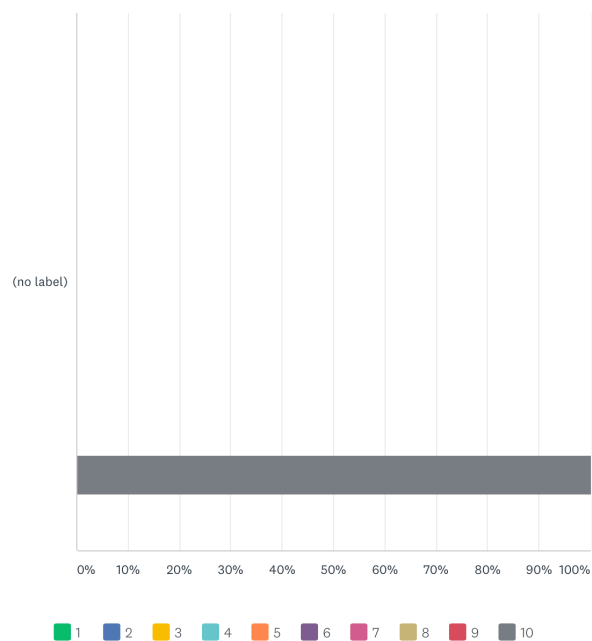


Customize

Save as ▼

How easy was it to follow the story?

Answered: 4 Skipped: 0



▼	1 ▼	2 ▼	3 ▼	4 ▼	5 ▼	6 ▼	7 ▼	8 ▼	9 ▼	10 ▼	TOTAL ▼	WEIGHTED AVERAGE ▼
▼ (no label)	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	100.00% 4	4	10.00

Fig. 3. Survey Question for *Morning, Noon, Evening, and Night*. Survey Monkey. Web. *Market Research*. Prague, CZ. 14 June. 2019. Unpublished Survey. Digital Image

Q4

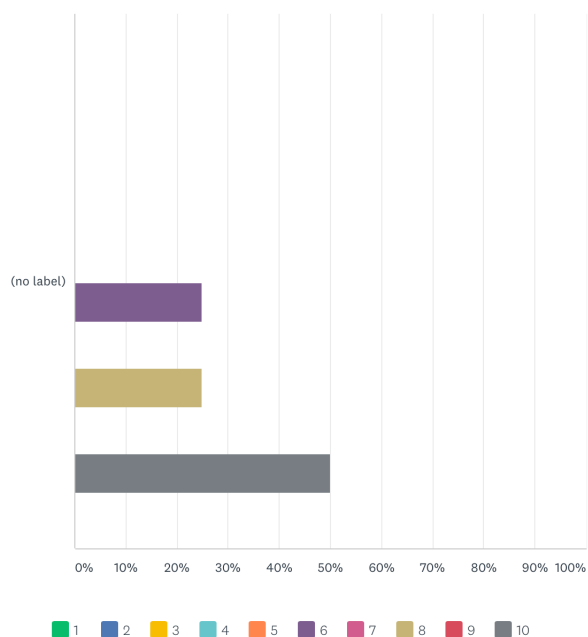


Customize

Save as ▼

How immersed in the story did you feel as an audience member?

Answered: 4 Skipped: 0





	1	2	3	4	5	6	7	8	9	10	TOTAL	WEIGHTED AVERAGE
(no label)	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	25.00% 1	0.00% 0	25.00% 1	0.00% 0	50.00% 2	4	8.50

Fig. 4. Survey Question for *Morning, Noon, Evening, and Night*. Survey Monkey. Web. Market Research. Prague, CZ. 14 June. 2019. Unpublished Survey. Digital Image



In your own words, tell us about your overall experience during the performance you attended.

Answered: 4 Skipped: 0

RESPONSES (4) WORD CLOUD TAGS (0) 

PAID FEATURE
Text Analysis lets you search and tag comments and see word clouds of frequent words and phrases. To get this feature, upgrade to a paid plan. 

UPGRADE [Learn more »](#)

☐ Apply to selected ▼ Filter by tag ▼  

Showing 4 responses

<input type="checkbox"/>	Beautiful setting for a mediocre park. Engaging short story. Was glad to see two different iterations.	7/6/2019 6:33 PM	View respondent's answers	Add tags ▼
<input type="checkbox"/>	First I was annoyed by the welk known Dispute Situation but than I focused on the form and the Idea and that was a funny experience	6/15/2019 4:18 PM	View respondent's answers	Add tags ▼
<input type="checkbox"/>	This was amazing. A completely new way of storytelling - and it worked. I would LOVE to see more work like this. Even something with more of a one-act length. Or even a full show. It was immersive, exciting, and intimate in a way I've never experienced before. So cool.	6/14/2019 10:26 PM	View respondent's answers	Add tags ▼
<input type="checkbox"/>	The experience was wonderful. Listening to music through the bone induction headphones before the performance started made the transition easier.	6/13/2019 6:53 PM	View respondent's answers	Add tags ▼

Fig. 5. Survey Questions for *Morning, Noon, Evening, and Night*. Survey Monkey. Web. Market Research. Prague, CZ. 14 June. 2019. Unpublished Survey. Digital Image

Works Cited

Anderson, Ellen, et.al. "The effects of audio and visual distractions on reaction time." University of Wisconsin- Madison. 11 May 2012.

jass.neuro.wisc.edu/2012/01/Lab%20603%20Group%2014%20FINAL.pdf

"About INVISIO." INVISIO, 26 Oct. 2018,

invisio.com/about/about-invisio/.

"Audio." Google Glass Help, Google, 2020, support.google.com/glass/answer/3311275?hl=en.

"Bone Conduction Hearing Devices." Hearing Link, 2017,

www.hearinglink.org/your-hearing/implants/bone-conduction-hearing-devices/.

"Bone Conduction: How It Works." Goldendance.co.jp, 22 Mar. 2019,

www.goldendance.co.jp/English/boneconduct/01.html.

Dauman, R. "Bone Conduction: An Explanation for This Phenomenon Comprising Complex

Mechanisms." *European Annals of Otorhinolaryngology, Head and Neck Diseases*, vol.

130, no. 4, 3 June 2013, pp. 209–213., doi:10.1016/j.anorl.2012.11.002.

"A Headphone Wearing Theatre Audience Experiences Truly Immersive Live Audio Thanks To

DPA's New 4560 Binaural Headset Mic." DPA, DPA Microphones, 9 Dec. 2019,

www.dpamicrophones.com/news/a-headphone-wearing-theatre-audience-experiences-truly-immersive-live-audio-thanks-to-dpa%E2%80%99s-new-4560.

Gilmore, Dan. "Inside This Season's Headphones-Required Broadway Must-See The Encounter." *Vanity Fair*, Vanity Fair, 8 Sept. 2016, www.vanityfair.com/culture/2016/09/the-encounter-broadway.

Henry, Paula, et.al. "Comparison of Bone-Conduction Technologies." Human Research and Engineering Directorate, Army Research Laboratory, ARL-TR-4705. Jan. 2009. www.researchgate.net/publication/313084101_Bone_conduction_communication_Applications_and_limitations

"Tactical Communication and Hearing Protection Systems." Invisio, 2018. <https://invisio.com/media/1165/invisio-product-brochure-art24383-7.pdf>

Kendrick, Lynne. *Theatre Aurality*, Palgrave Macmillan, 2018, pp. 64–67.

McGraw, David J. "Near Future Tech for Stage Managers." *Stage Directions*, Timeless Communications, 27 Mar. 2017, stage-directions.com/theatre-blogs/sm-kit/9375-near-future-tech-for-stage-managers.html.

Murphey, Kelly, and Jacob Henry. "Bone Conduction and Binaural Sound in Theatre". 16 Nov. 2017. Unpublished Research

Murphey, Kelly. Market Research. Prague, CZ. 14 June. 2019. Unpublished Survey.

www.surveymonkey.com/summary/OosxuChQC4Nrcxc6roIfJUIgeUj7scKGFOGqrYHq27I_3D

Park, Hyung-Woo et al. "Improvement of voice quality and prevention of deafness by a bone-conduction device." *Biotechnology, biotechnological equipment* vol. 28, sup1 (2014): S14-S20. doi:10.1080/13102818.2014.949041

"Product Specification - YAMAGATA CASIO CO., LTD." Logosease, 2019,
logosease.yamagata-casio.co.jp/en/product/.

Puentes, Lakisha. "How Bone Conduction Headphones Useful in Military Communication." *Medium, Medium*, 19 Dec. 2018, medium.com/@lakishapuentes/how-bone-conduction-headphones-useful-in-military-communication-fa271518179a.

Puria, Sunil, and John J Rosowski. "Békésy's contributions to our present understanding of sound conduction to the inner ear." *Hearing research* vol. 293,1-2 (2012): 21-30.
doi:10.1016/j.heares.2012.05.004
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3449028/>

Smith, Aryal. "The History of Bone Conduction Technology." *AfterShokz, AfterShokz*, 4 Mar. 2017,
aftershokz.com/blogs/news/the-history-of-bone-conduction.

Staab, Wayne. "Origins of Bone Conduction Hearing." Wayne's World, Hearing Health Technology Matters, 26 Mar. 2012, hearinghealthmatters.org/waynesworld/2012/the-origins-of-bone-conduction-hearing/.

Strawbridge, Shane. "REVIEW: 9 in the Morning by Jacob Henry." *REVIEW: 9 in the Morning by Jacob Henry*, Lubbock Arts, 29 Mar. 2019, shanestraw.blogspot.com/2019/03/review-9-in-morning-by-jacob-henry.html.

Trueman, Matt. "Warning: This play may contain headphones." The Guardian, 9 Dec. 2009. www.theguardian.com/stage/theatreblog/2009/dec/08/headphone-play-audio-theatre?CMP=share_btn_link

Yuhas, Daisy. "Speedy Science: How Fast Can You React?" *Scientific American*, Scientific American, 24 May 2012, www.scientificamerican.com/article/bring-science-home-reaction-time/.