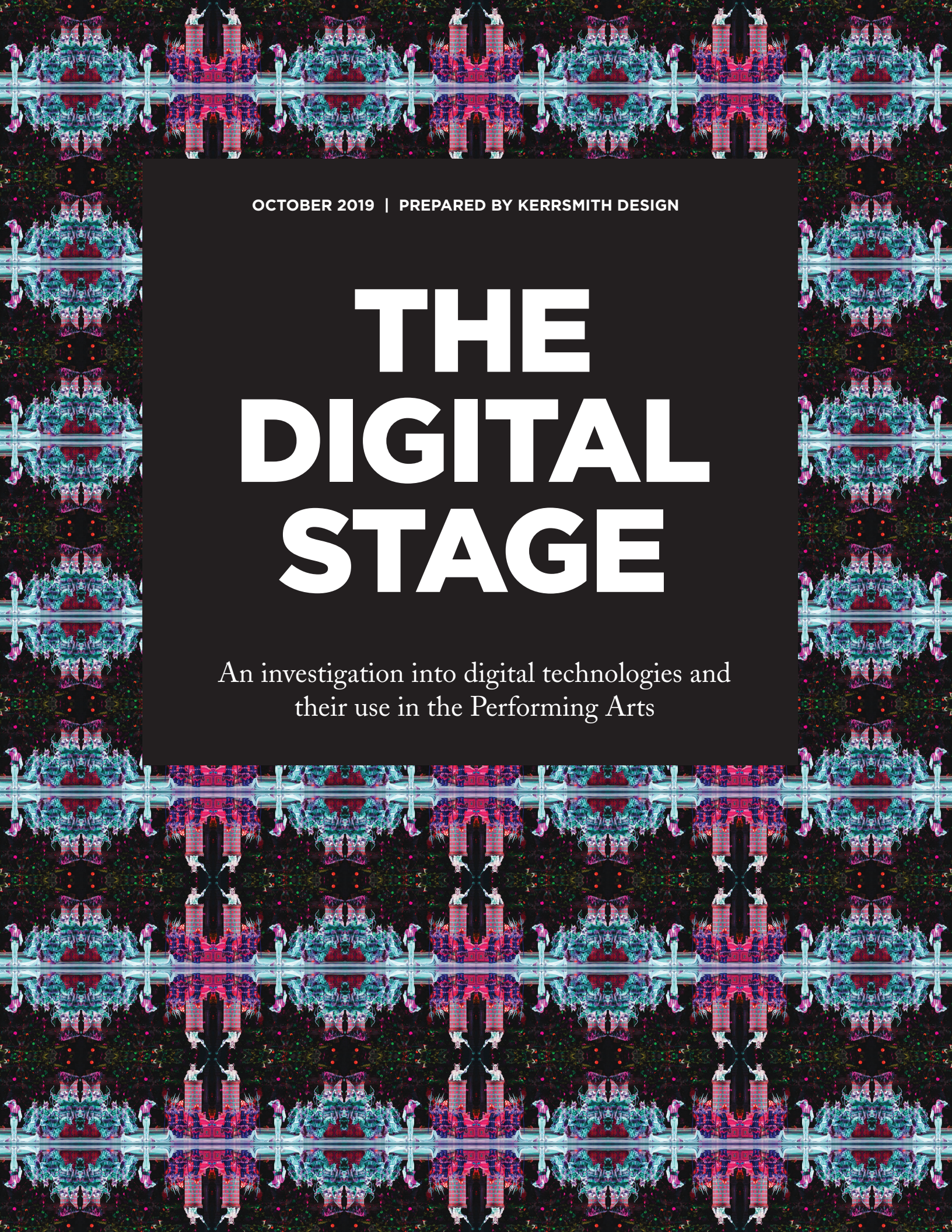
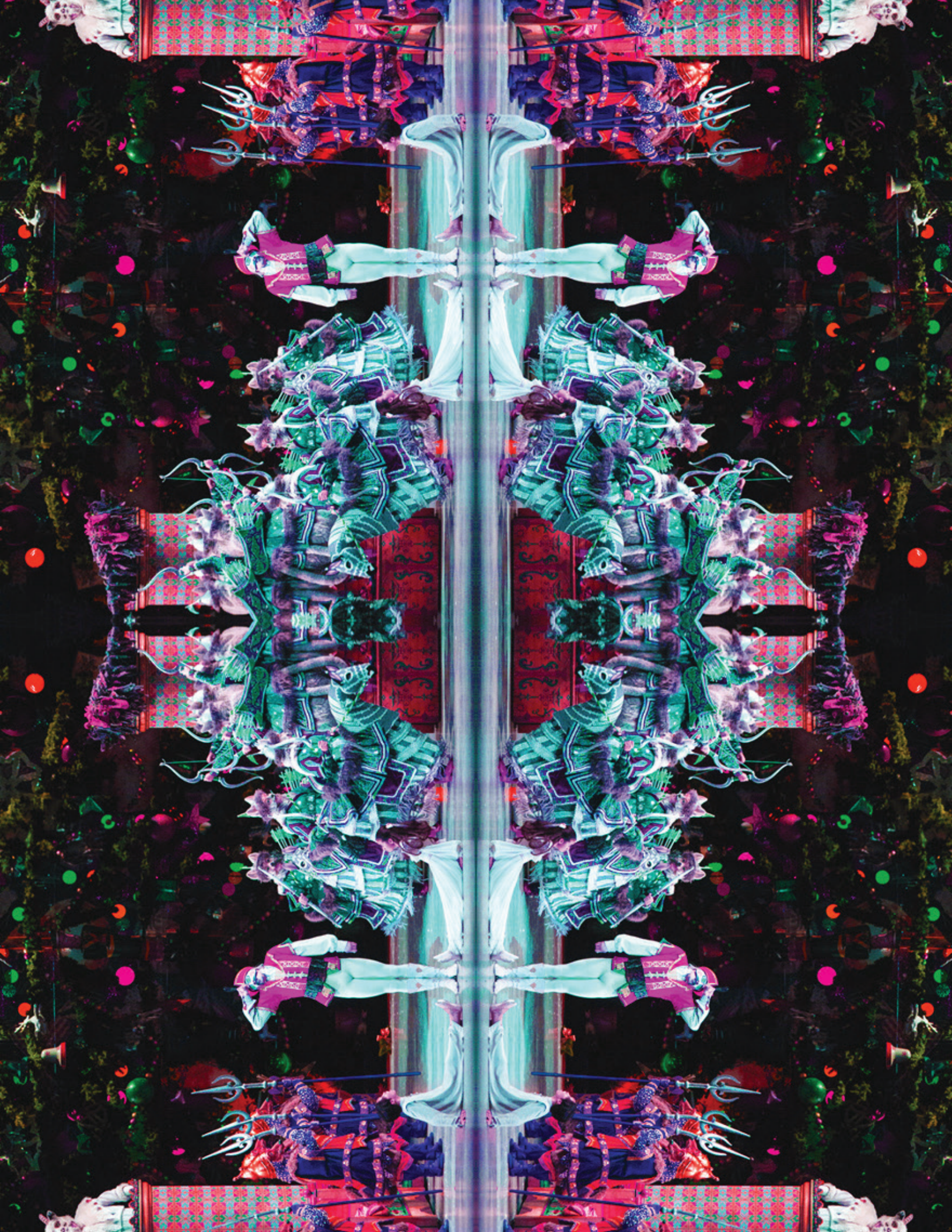


OCTOBER 2019 | PREPARED BY KERRSMITH DESIGN

THE DIGITAL STAGE

An investigation into digital technologies and their use in the Performing Arts



OCTOBER 2019 | PREPARED BY KERRSMITH DESIGN

THE DIGITAL STAGE

An investigation into digital technologies and their use in the Performing Arts

PREPARED FOR CANADIAN OPERA COMPANY,
NATIONAL BALLET OF CANADA, SCREEN INDUSTRIES RESEARCH AND TRAINING CENTRE (SIRT) AT SHERIDAN COLLEGE
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Image Patterns
Cover Image: Digital manipulation of an image of *The Nutcracker,* National Ballet of Canada, Photo by Karolina Kuras.
For a full list of images used in this document, see page 86.

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Contents

01

Background & Context

Background

In March 2019, Canadian Opera Company was awarded a grant from the Canada Council for the Arts' Digital Strategy Fund as the lead applicant of a broad initiative bringing together arts organizations, educational institutions and academics, technology partners, and experts in the digital sphere to understand and apply the opportunities presented by the digital age.

The project's aim is to understand the implications and applications of digital technologies, from both an audience engagement and an artistic/production perspective, in order to develop a new strategic framework for the use of digital technologies in the performing arts in Canada.

It is essential to understand, explore and proactively adopt new and emerging technologies, in order to ensure the long-term viability of the institutions and for the sector at large to remain relevant in a rapidly changing context.

KerrSmith Design was engaged to conduct an environmental scan of technologies currently in use, or being explored, by performing arts organizations across the globe. The following report represents results of that research.

Romeo and Juliet, National Ballet of Canada, Photo by Bruce Zinger

Context

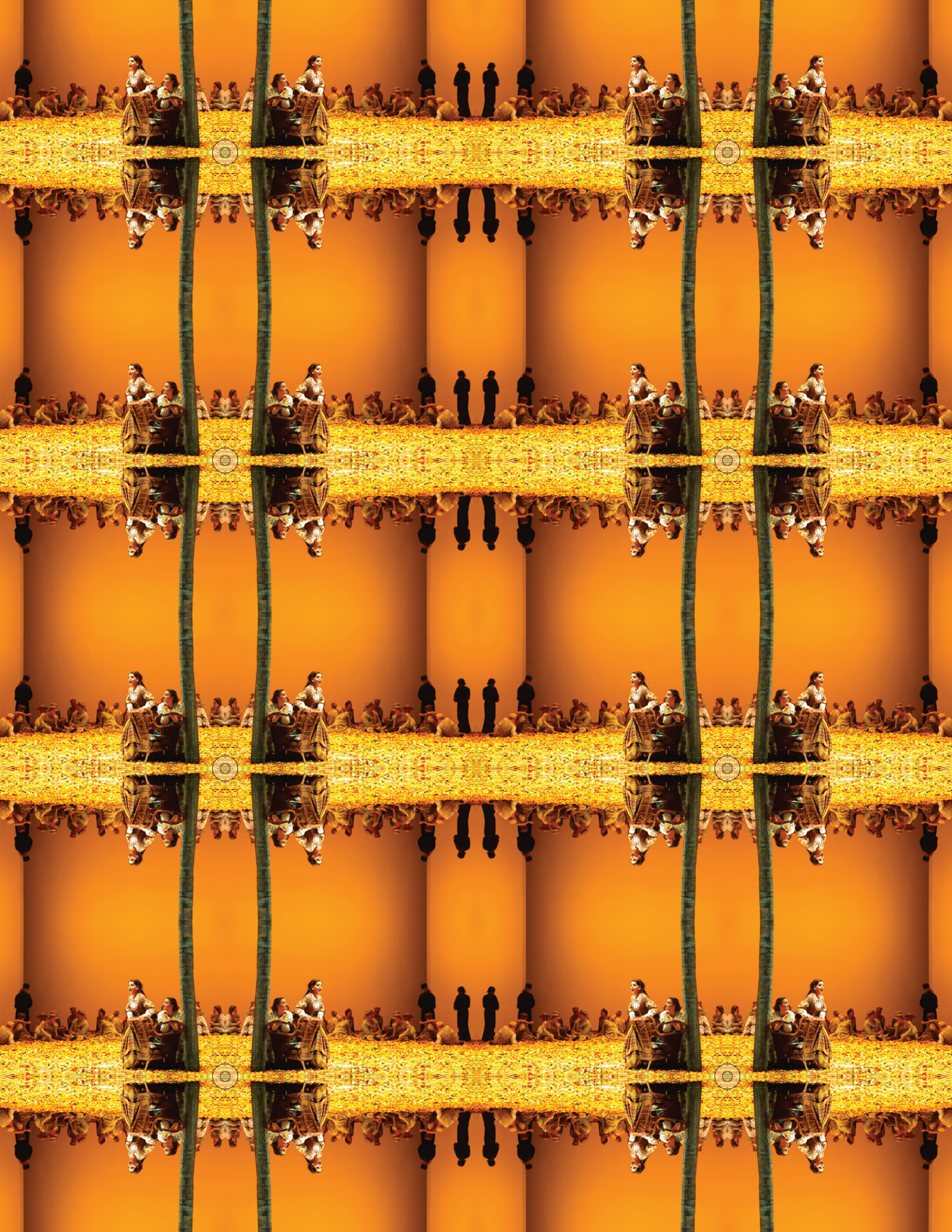
"The context within which Canadian artists and arts organizations operate is much changed. The broad adoption of digital technologies, high speed internet and mobile connectivity has served to blur the boundaries between individual arts disciplines and practices, the arts and cultural sector and other sectors, and how the arts sector conceives of and interacts with audiences and the public.

Digital technologies have long had an impact on the creation and production of artworks, whether in the form of software for scriptwriting, video editing, photo-manipulation, and programmable lighting arrays for the stage. But it was not until the advent of a globally distributed high speed internet that the transformative power of digital technology became clear. Mobile connectivity and the internet as a platform for creation, production, presentation and distribution have radically changed the way the arts are experienced in the world.

In this new environment, artists can collaborate more easily across vast distances, share their work with audiences around the world and be compensated for their creativity. Arts organizations can connect with their peers in other regions and countries, develop audiences across multiple platforms and extend their reach and/or their collections to audiences who may never cross their thresholds.

The proliferation of digital creation tools has facilitated a shift in the public from passive consumers of arts experiences to active engagers who often have their own creative practices. This fundamentally changes the relationship between artists and arts organizations and the public. Arts professionals are experts of their domain but they are now confronted with audiences who have deep expertise in finding and crafting their preferred interactions with the arts. For some, this shift in power from centralized decision-making to distributed expertise is troubling, leaving many unsure of their role in this new world. Others have embraced this new relationship, viewing the public increasingly as collaborators in the creation of art experiences with whom they might develop an ongoing relationship."

From *"Framework for a Digital Strategy Fund Learning Network"*
A document prepared for Canada Council for the Arts
by Helen Kerr (September 2018)



02 Methodology

Phase 1: Contextual Information Gathering

Expert Interviews
In depth, semi-structured, hour long interviews were conducted by phone and in-person with 18 sector experts and affected stakeholders in Canada, the United States and England. These professionals had knowledge in the areas of opera, dance, theater and music as well as creative, operational and organizational experience. They provided perspectives on the opportunities and challenges related to creating and producing performances that incorporate a wide variety of digital technologies currently, including the perceptions of those working in the field.

Literature Review
The research team augmented interview findings with a literature review of recent developments at the intersection of technology and the performing arts in order to more fully describe the use of emerging technical knowledge, as well as the repurposing of pre-existing technology for new effect. Using a breadth-first search technique followed by a depth search approach allowed for the identification of both well-used digital approaches and unconventional or disruptive ones. Case examples of various performing arts organizations were investigated along with relevant examples from adjacent industries or disciplines that incorporate performance into their expression such as fashion, popular music, visual art, media, retail, hospitality, athletics and politics.

Varduhi Abrahamyan and *Joyce El-Khoury* in *Eugene Onegin,* Canadian Opera Company Photo: Michael Cooper, 2018

Phase 2: Data Analysis

Interview Coding
All interviews were documented with detailed scribe's notes and information regarding the creation and the delivery of performances, as well as the reception of performance by audiences. This information was anonymized for data sanitation purposes, however identification of individual respondents was retained by the researchers should attribution, with permission, be sought at a later date.

Analysis of Data
Findings from both the expert interviews and literature/media review were collected into a limited access password protected database. This information was analyzed to identify iterative repetition of issues, challenges and opportunities, as well as to discern outlier applications.

Phase 3: Information Synthesis

Table of findings
Key technologies in use in the performing arts currently were gathered into a comparative table identifying attributes, including cost to incorporate, expertise required to deploy and impact on the audience experience. A more detailed description of the technology and example of its use were included. This information should be considered directional rather than definitive due to the vastly differing case examples and the compounding complexity of integrated use of technologies.

Report of Insights
Impactful implications of the use of these technologies were extracted from the research. This information will serve as a guide for deeper discussion with sector professionals in a symposium format in the near future.

03
Insights

As this research progressed, it became clear that the impacts of digital technology within the performing arts fall into three primary categories (outside of business operations):

A. Performance Creation
Creation of the performance itself, including the elements of the storytelling content, the artistry it embodies, and the environment it occurs within, increasingly is affected by the digital realm.

B. Performance Delivery
Delivery of the performance has been impacted over a longer period, with technology and stagecraft now fully intertwined and rapid change still to come.

C. Performance Reception
More recently, reception of and participation in the performance has been altered through more emphatic immersion by, and levels of interaction with the audience.

In each domain, there are early adopters who fully embrace digital innovation, there are practitioners whose work is being disrupted, and there are those wishing to preserve the most valuable elements of the existing art and craft forms.

The following insights should not be read as value assessments, but rather identification of potential implications that require strategic attention in an era of digital saturation. In each category, key insights are highlighted with associated technologies as case example.

Magic Flute: Michael Schade in *The Magic Flute,* Canadian Opera Company 2019, Photo by Michael Cooper

A. Performance Creation

1. Previsualization

Non-jurisdictional collaboration in the arts is now more possible through the incorporation of technology that has been widely used in other domains such as engineering and architecture. Pre-event roll-through of all elements of a performance is enabled and curation of core components could be achieved. Software such as Microsoft Azure and 3D modeling enable collaborators at a distance to work on the same piece, either in real time or asynchronously. This can streamline production and reduce travel costs and time. Creators are able to access one another and work fluidly, potentially resulting in new and unexpected outcomes. Producers and venue managers can mitigate risk by identifying possible problems ahead of time, potentially reducing insurance costs and optimizing logistics.

These are some technologies involved in Previsualization:

1.1 3D Modeling

The performing arts are borrowing techniques from the film industry where previsualization has been used to help to plan visual effects and meet budget requirements in movies. Architects and engineers have also used 3D modeling to effectively assess performance and functionality of buildings and infrastructure. Software programs such as FrameForge 3D Studio, Storyboard Pro, Moviestorm, Catia, AutoCAD and SketchUp have varying price points from free to several thousand dollars per user. Functional profiles that may be useful to determine how a performance unfolds prior to delivery can significantly impact operational efficiency.

1.2 Virtual Reality

Beyond end-user applications, VR can also be used to simulate a space or experience for performers and creators. Cirque du Soleil has benefited by previsualizing its complex and risk laden events. “We can create a holographic life size stage and use a trial and error approach to test our ideas before having to produce masts, lighting ridges, set elements, or acrobatic installations for real.”

https://www.itbusiness.ca/news/cirque-du-soleil-experiments-with-mixed-reality-to-test-creative-show-ideas/90374

1.3 Online Collaboration Tools

Performing arts organizations are increasingly operating in the same manner as many other contemporary creative industries; virtually. Digital collaboration tools, such as Slack, provide a real-time online platform for communication, resource sharing and collaboration. For example, Propared, a digital company dedicated to assist theatre, arts, and event managers in organization, used it to create a community entitled the Theatre, Event and Venue Managers Slack Group. This group allows for the connection and sharing of resources between theatre and production managers from around the world. Through this connection, these managers are able to find solutions to any production problems that may arise with assistance and others' previous experience, where previously they may have had to handle them alone.

Manhattan Theatre Club (MTC) utilizes an online platform called TheatreLink to encourage collaboration between students across long distances. TheatreLink is described as "a curriculum-based Web project that connects high schools around the world for a five-month period to create and study theatre together."
Students are able to collaborate on the entire creation process (writing, designing, presenting) across the world. Post-show discussions take place through live streaming and illustrates how much each student gets out of this process. TheatreLink is being used as an "enhancement tool"; traditional creation processes are still used, but this program allows for a more diverse audience and collaboration across cultures. MTC Education Program Director David Shookhoff explained, "now we have a multi-cultural element. When a school in Houston presented a play written in Johannesburg, South Africa, the school also got a student-produced video glossary of the Johannesburg slang used in the play."

https://www.huffpost.com/entry/tools-for-the-stage_b_4220134

2. Performance Optimization – Body & Voice

The use of wearable and motion tracking devices to observe and assess performers' movements in order for their actions to be optimized has migrated from athletic use and medical rehabilitation where integrated technology has been advancing quickly.

"Wearable sensing technology is a category of technology devices worn by subjects that allow continuous physiological monitoring with reduced manual intervention and at low cost."

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6198019/

Voice optimization is a core research domain in the tech industry as computers increasingly respond to voice search commands. Pitch-correcting and vocal processing Auto-Tune technology has been revolutionizing pop music for 20 years. Both allow higher levels of physical accuracy to be achieved, although there may be some diminishment of the idiosyncratic characteristics of individual performance. Overall, the expectation that performers can repeatedly reach optimal, or indeed flawless, levels of excellence in live events exerts a pressure that can take a punishing toll, pushing them to exceed their capacity.

These are some technologies involved in Performance Optimization:

2.1 Athlete Optimization System

Developed by Kitman Lab for the sports industry, this data collection and analytics program intersects with medical records to provide individualized alerts about potential for injury and has been adopted by some members of the dance community. Using machine learning and multivariate analysis to determine the process and drivers behind injury risk, the system is able to provide teams with actionable strategies for athletes and others. It is a costly service and requires near continuous monitoring of performance during rehearsals and performance, as well as interpretation of collected data.

"Kitman Labs has devised the Athlete Optimization System, which tracks stats during and after workouts. It collects data on acceleration and deceleration, physiological factors (stress, mood, sleep), biomechanical response, muscle fatigue and methods of recovery so that dancers can monitor their regimen."

https://www.dancemagazine.com/36988-2307060178.html

A. PERFORMANCE CREATION (CONT')

2.2 Motion tracking

Ensuring consistency of a performer's movements over multiple performances can be enhanced by using wearable devices to track motion, either on the body directly or embedded in their shoes and clothing.

"This has a wide range of applications such as in military, entertainment, sports, medical applications, validation of computer vision and robotics. Furthermore, it is also used in film making and in video game development. In many areas, motion tracking is often called motion capture, whereas in film making and games, motion tracking is commonly called match moving."

https://www.techopedia.com/definition/31558/motion-tracking

"Motion-tracking "E-Traces" are slippers that feature a small electronic device attached to the bottom of a dancer's shoe. The chip records a foot's pressure and movement, allowing the dancer to effectively "draw" their movements in a pattern of data strokes. Dancers can then use the app to interpret their movement, compare rehearsals and performances and make corrections."

https://www.dancemagazine.com/36988-2307060178.html

2.3 Auto-Tune/Melodyne

Long used as a suite of tools for vocal manipulation in the sound recoding studio, these technologies are now being incorporated into the composing process as a method to create previously difficult to achieve effects. Some vocalists use Auto-Tune as a guide to perfecting vocal calibration, timing and pitch.

"In 2010, Grimes used Auto-Tune as a kind of writing tool for the song Hallways, from her second album, Halfaxa. She took a vocal melody and made it jump up and down in random leaps of three or four notes. Then, using this as a guide vocal, she resang the herky-jerky Auto-Tuned melody in order to, as she once said, 'put the emotion back into it.' "

https://pitchfork.com/features/article/how-auto-tune-revolutionized-the-sound-of-popular-music/

3. Technology as Creative Collaborator

Pre-existing industrial technologies are being deployed as new instruments and media, but in emerging situations, the technology is becoming a self determining co-creator of content. As Artificial Intelligence and machine learning capacities increase, computers are beginning to compose music, to choreograph dance and to write passages of stories. Most examples are experimental at this point but some more mainstream performances are incorporating elements of computer-generated creation. Whether we change our perception of digital tools as full fledged collaborators remains to be seen.

These are some technologies involved in Technology as Creative Collaborator:

3.1 Digitized Dance Notation

This technology allows choreographers, such as British artist Wayne McGregor, to choose and connect pre-recorded stock movements. Some artists are creating their own unique 3D steps with The Motion Bank, a data collection company that uses Microsoft Kinect and motion tracking technology to record dancers' movements and generate an archived movement library.

"The tool works in real time as a camera watches dancers move in space. And it's not simply suggesting something from the archive—it can offer ideas that are totally original. It can be set to reflect a particular dancer's style, or even combine the styles of two different dancers to come up with a hybrid. 'I'm fascinated in how AI might actually develop the conversation around what is choreography, who has to make choreography, what are the potentials of choreography,' McGregor says"

https://www.dancemagazine.com/is-google-the-worlds-next-great-choreographer-2625652667.html

"Google Arts & Culture Lab is working on an artificial intelligence that would store hours of video to train an algorithm to detect patterns. It functions like predictive text - helping choreographers mix things up by suggesting thousands of other options that still fit with their choreographic style."

https://www.dancemagazine.com/is-google-the-worlds-next-great-choreographer-2625652667.html

3.2 Robotics/AI/Interactive Video

Robotics, Artificial Intelligence and Interactive Video are inspiring creatives to explore new ways of communicating ideas. The unique characteristics of these technologies allow an expression of relationship between creator and tech. Additionally, responsive AI and Robotics take on the role of a collaborator; as these technologies respond to the creator, it changes the nature of a performance.

"Gideon Obarzanek's *Glow* uses sophisticated interactive video technology to create an intensely moving duet of sole dancer and technological 'other'. With the use of a motion-sensing system and live-generated algorithms the technology fulfills its role of supportive partner as the dancer performs in a living responsive environment, with no two performances being exactly the same.

While this technologically intense work could be perceived as anti-humanistic, the choreographer, Obarzanek, chooses to highlight the analytical capabilities. When used sensitively, he argues that technology, like many diagnostic tools in our life, is capable of illuminating and embodying our abstract and internal relationships that would otherwise be invisible. There is the potential to explore this relationship and create new works highlighting the human and technological relationship."

https://dancemagazine.com.au/2010/11/dance-and-technology/

Holly Herndon used machine-learning software called Spawn, which is modeled after the human brain to assist in composing her album *PROTO*. "Neural nets are capable of "learning" patterns from large datasets, which they absorb as "training," then generating new material based on what they've learned." In this case, the new material is a melody or audio file.

https://www.spin.com/featured/ai-music-artificial-intelligence-feature-holly-herndon-yacht/

4. Magnified Multi-disciplinary Artists

Musicians that create stage sets; dancers that compose; playwrights that sing. While the world of the arts has long been multidisciplinary, more digital competency is translating to the ability to fully control the creative output without expert partners. In fact, creators with some technological competency are increasingly able to expand their repertoire across other disciplines with high levels of accomplishment. In some cases the technical producer is eliminated and the artistic creator has taken on the role using sampling or digital fabrication.

These are some technologies involved in Magnified Multi-disciplinary Artists:

4.1 Sound Editing and Design Software

These tools have been used in film and audio post-production industries for many years but are increasingly used in the performing arts.

"The internet has lowered barriers for sound designers to find the exact music and noises they need to move a production. However, "It has made us FAR more efficient, but the caveat is that it also introduces the possibility of what I'd call 'superfluous sound effects' — just because it's easy for us to add a sound effect doesn't mean it's the right choice for the show."

https://blog.ozobot.com/steam/how-technology-is-changing-theater-design/

A. PERFORMANCE CREATION (CONT')

4.2 Smart Gloves

Imogen Heap partnered with engineers and researchers to produce Mi.Mu gloves, a physical interpretation of sound and music, essentially turning the body into an instrument. The gloves allow for music to be played without the use of traditional instruments; these are gloves that put the power to create an entire musical composition right at her fingertips. This changes the relationship between music and performance, as well as make the creation of electronic music more intuitive. Heap's gloves enable electronic musicians to step out from behind their banks of gear to actually perform to their audience. Efforts to make the technology more affordable mean the ability to experiment with what the tech means for performance.

4.3 AI

"...Yamaha artificial intelligence (AI) technology enabled a world-renowned dancer Kaiji Moriyama to control a piano by his movements. The concert, held in Tokyo on November 22, 2017, was entitled "Mai Hi Ten Yu"' and was sponsored by Tokyo University of the Arts and Tokyo University of the Arts COI. Yamaha provided an original system, which can translate human movements into musical expression by using AI technology, as technical cooperation for the concert."

https://www.yamaha.com/en/news_release/2018/18013101/

5. New Types of Collaborations

At the opposite end of the spectrum, technologists are becoming more frequent collaborators with artists, especially as more complex digital tools with high expertise requirements are being re-purposed for the stage. As these tools become more popular, creators are finding the need to work with those whose expertise and decision making processes differ from their own. This collaboration of minds can change the nature of the artwork produced.

"Increasingly, these types of multidisciplinary teams are now the norm in creative arts practice, especially when driven by technological innovation. Whereas in some areas, such as animation, even from their earliest days, they have always required close collaboration between artists and scientists, poets and engineers (Ebert & Bailey, 1999), other more traditionally "underground" (i.e. not in the spotlight) creative pursuits, such as design and photography, are increasingly looking beyond the scope of their disciplines in a search for new alignments and partnerships which will facilitate new technologies and online opportunities. More recently, in professional practice, intersections between Information Technology (IT) and the creative arts have flourished, especially since the advent of Web 2.0 applications, new games development and a proliferation of technologically driven art-based projects. The cast of players includes designers, robotics and software engineers, researchers and theorists, but it might also incorporate digital photographers, illustrators, 3D model makers, musical composers, performers and more. The scope of this intersection is well known: Nowadays software, electronics, mathematics, robotic technology, genetic art, algorithmic art, led installations, and artificial intelligence in union with music, dance, sculpture and painting expression are used to involve the audience as part of an interactive dialogue with technology (Ahmed et al., 2009)."

https://files.eric.ed.gov/fulltext/EJ978981.pdf

These are some technologies involved in New Types of Collaborations:

5.1 Motion Capture

Gaming technology has begun intersecting with performing arts as elements from XBox Kinect suggest. "The trend appears to be towards ever more interactive sets, with effects triggered by actors live on stage.

For example, Knifedge is testing the use of Xbox Kinect cameras for this purpose (which detect movement for the purpose of video gaming), and chemically treated glass that turns opaque with an electrical charge, creating an instantaneous projection screen." These interactions are not possible without high levels of computer programming and digital manipulation.

https://howlround.com/technology-sound-design-eroding-collaboratio

5.2 Robotics

Choreographer Fredrik Rydman performed with a two meter (6.5 ft) tall, 900 kg (2,000 lb) industrial robot from digital technology pioneer ABB.

"Benke's path-breaking duet, set to an original score, is a unique reflection of the changing role of robots, automation technology and artificial intelligence in society. The ABB IRB 6620 robot with which he performed is more typically found in heavy manufacturing facilities, like automotive plants, where it performs spot welding and complicated assembly tasks in close collaboration with plant employees. It is one of ABB's biggest, strongest and heaviest industrial robots. ABB's latest advanced software, which is used in factories around the world, helps make this possible by enabling a collaborative robot like the ABB IRB 6620 to be aware of what is happening in its surrounding area and adjust its movements with incredible speed to keep people nearby safe. The software, called ABB SafeMove2, knows where a dancer is at all times."

https://new.abb.com/news/detail/6936/modern-dance-premiere-is-a-delicate-collaboration-between-human-and-abb-robot

5.3 Virtual Reality

Welsh National Opera, in collaboration with CAMERA and REWIND, created a virtual reality experience of *Madame Butterfly* and *The Magic Flute*. In a shipping container designed for the experience, audience members used Google Daydream View VR headset to experience scenes from the opera in a 3D virtual setting.

Computer scientists from CAMERA, the University of Bath's motion capture research centre worked with award-winning VR/AR content production agency, REWIND, on the project for Welsh National Opera (WNO).

https://phys.org/news/2017-10-latest-virtual-reality-technology-opera.html

5.4 3D Printing

Scenic designers have long held the practice of utilizing foamcore, wood, cardboard and paper to construct scale representations of their designs to help directors, actors and financial backers envision what they will eventually see on stage. This work requires fine motor skills and is time intensive. 3D printing has streamlined this process. Kacie Hultgren, who creates miniature models for theatre set designer, John Lee Beatty, explains that her models "take considerably less time, and they are made primarily of one material: Plastic. "Hultgren bought her first pinter in 2011, and the first show she used it on was the Roundabout Theatre Company's 2012 production of the farce *Don't Dress for Dinner.* She has used the printer on every show she's worked on since".

http://www.playbill.com/article/3d-printers-revolutionize-work-of-broadway-scenic-designers-com-214428

When Italian stage design firm Gio Forma was commissioned to design the set for a La Scala performance of Don Pasquale, they wanted the lead soprano to fly over their set of Rome in a 1950s era Lancia Aurelia B24. As it was too expensive and too dangerous to use a real car, and other construction materials would either take too much time to create or be too fragile to support the weight of a human body, the designers turned to 3D printing a life size replica of the famous car. "The car was 3D-printed to scale: 4.5 meters by 1.5m (14'9"x 4'11"), the actual size. It took 85 hours printing time and four days to assemble." Gio Forma partner, Florian Boje explained "It was impossible to hit the time frame with another technology"

https://massivit3d.com/blog/stage-design-just-got-easier-with-3d-printing

There is also the opportunity to create new aesthetics within the world of costume design. Oscar Winner Ruth E. Carter's 3D printed designs for the film *Black Panther* highlight a new method of costume design. The items are flexible and durable, allowing for travel and long lifespans of the costumes.

B. Performance Delivery

1. Automation of Staging

The work of musicians, designers, and technicians is being taken over in part or completely by automated processes: 3D printing, computer controlled lighting arrays, or set elements and stages automated by software. Examples include programmed lighting or machines to ensure correct timing, set automation utilizing motors, cable systems, and control software to execute the movement of set pieces. All these assist in creating smooth transitions and allow directors to have additional tools in their staging. With coming advancements, Artificial Intelligence may be used to streamline this process further. "Even on a smaller scale orchestrating the appropriate timing for lighting, sound, and movement can be a daunting task. Though error is not completely out of the picture when using automation, human error is far more common and can be costly to the immersiveness of a performance."

https://interestingengineering.com/engineering-the-stage-what-new-technologies-are-reshaping-performances

These are some technologies involved in Automation of Staging:

1.1 Computerized Control

The work of stage technicians has been intersecting with automated systems for decades and that is only increasing. Adaptation to the digital stage is underway as educational institutions such as the schools of Music and Theatre at Yale that offer interdisciplinary programs incorporating computer science, acknowledging the critical importance of advancing digitization in the arts.

03 INSIGHTS

"It is tempting to think that there is an 'non-technological' theatre tradition against which the kinds of computer-assisted performance discussed here might be measured. In most contemporary theater, however, computers control the media. Lighting is the most computerized of the theatrical media, followed closely by sound, sound sources, and electronic music. With video and other effects the computer is less involved, but its influence is growing. Sound and video will eventually migrate toward standard processes and technologies in the same way lighting technology has already done. The more the computer is involved in coordinating activities in media, the more difficult it becomes for the human participant to orchestrate what the computer does."

http://www.siliconatelier.com/intelligentstage/publications/cit/cit.html

"For students with a computing perspective, issues in these disciplines present interesting and substantive problems: how musicians use computers to compose; the limitations of current software tools used by artists; the types of analyses done by art historians; challenges in designing and using virtual sets in the theater; ways that virtual worlds might help to envision new forms of artistic expression; and lessons that can be learned from trying to create a robotic conductor or performer."

http://catalog.yale.edu/ycps/subjects-of-instruction/computing-arts/

"This may seem like an obvious example, but that is because automation can be very noticeable onstage as hydraulics lift in large props or set pieces. On a smaller scale, many traditional items in theatre rigging now rely on automatic timed responses from its tech. Follow-spots were previously operated by stagehands that illuminated the action on stage, but that practice is frequently substituted by automated digital follow-spots controlled from the tech booth.

Lighting cues are often programmed in sequential order over fifteen-second spans. Large props are often automated on rails, and they are timed digitally by stage management cues from backstage. Projections and video displays are currently very popular amongst theatre creators, and the many possible uses of this tech are just beginning to be explored."

https://www.theatreartlife.com/staying-still/4-ways-technology-changed-theatre/

B. PERFORMANCE DELIVERY (CONT')

1.2 Flexible Staging

The ability to configure the stage to accommodate new challenging performances and to enable maximum usage of the venue requires the ability to reconfigure space continually.

"When designing a new performing arts center, we constantly adjust our expectations about the technology that will come to inhabit the spaces that we shape. The reality of the acceleration of theatre technology systems development and automation means that whatever we see today will be superseded by something new in a matter of years—or even months. We often joke that the future arrives in a truck, but the reality is that day-one performance equipment is quickly replaced by new gear. The common denominator between all these things is the need to support them (and store them) within the infrastructure of The Shed. So, how do we anticipate the future? The Shed and its spaces must be able to accept, integrate, and incorporate new technologies when they become available. In order to achieve this, the infrastructural framework of The Shed is designed in such a way as to support technology that has yet to be even imagined. This means that the structural, electrical, and mechanical systems of The Shed are all designed for equipment that will one day be big, hot, heavy, and data- and power -hungry."

Throughout the building, we focused on designing power centers that would accommodate any type of lighting source (e.g. LED, tungsten) and any possible type of power (dimmed power, constant power) by maximizing the capacity and minimizing the effort required to distribute power throughout the venues."

https://www.livedesignonline.com/venues/shed-qa-fisher-dachs-associates

"For the arts district Theatre, (Dee and Charles Wyly Theatre) the challenge was to build a beautiful new structure while retaining the artistic freedom of the original "barn"... The 12-storey building has an advanced, automated "superfly" system, which allows both scenery and suspended seating balconies to be "flown," or lifted out of sight to create a proscenium stage, thrust stage, in the round and flat-floor configurations, essentially transforming the building into a "theatre machine."

...By investing in infrastructure that allows ready transformation and liberating the performance chamber's perimeter, the Wyly Theatre grants its artistic directors freedom to determine the entire theatre experience, from audience arrival to performance configuration to departure."

https://www.serapid.com/de/system/files/downloadae_issue_complete_wyly_theater_serapid_0_0.pdf

2. Eco-impact and Mitigation

The carbon footprint of live performances will soon be an issue that no one can ignore. The cost of flights, in dollars and impact, for performers and their full stage production to travel are increasing. Materials used for elaborate stage design may be toxic and, however frugal the designer, waste will be incurred. Audiences are more aware of the impact of entertainment as well, and increasingly opt to forgo longer travel to live events and seek out live-streamed versions as an ecological choice.

These are some technologies involved in Eco-impact and Mitigation:

2.1 3D Printing

3D printing, at the current stage, uses more electricity than other production techniques. However, it uses less manufacturing material, as it does not require "cutting away" excess material. This means energy is only used to produce usable material. There is an ability to print these items anywhere, reducing the need to transport objects and the emissions associated with it. Use of biodegradable and renewable materials ensures that recycling is possible.

2.2 Virtual Reality

Cirque du Soleil's use of virtual reality as a form of pre-visualization reduces travel needs. "Our creators can also visualize the same hologram, at the same time, regardless of where they are in the world, rather than coming to our creation studio in Montreal to take part in the creation process. They could move, add, remove or modify objects in the mixed reality while edits would be seen simultaneously by other users."

https://www.itbusiness.ca/news/cirque-du-soleil-experiments-with-mixed-reality-to-test-creative-show-ideas/90374

B. PERFORMANCE DELIVERY (CONT')

2.3 Voice Over Internet Protocol

Voice over IP providers such as Skype enable vocal, motion and instrumental coaching for non-collocated students and teachers. Video communication can be used to minimize travel, thereby reducing cost, time and carbon footprint for the performing artists and organizations. Lessons, coaching and choreography can be shared through online communication. "Students can watch dancers anywhere around the globe, take classes from an artist in Berlin or Beijing, or Skype with an alumna in Amsterdam—all of which they have done."

https://smtd.umich.edu/muse/2013/fall/Technology-Takes-the-Stage.html

2.4 LED Lighting

Light sources that require less power, heat management and optics could help develop the experience of the audience and theatre technicians. "LED technology has enabled smaller, lighter, less power-consuming fixtures while outperforming older technology, especially in output," says David Stewart UK sales manager at lighting manufacturer, GLP.

https://www.avinteractive.com/features/av-live/staging-a-spectacular-16-05-2019/

3. Technical Retrofitting

Older venues must intersect new technology with architectural history, oftentimes finding it difficult to raise funding for behind the scenes tech enhancement that is largely invisible to donors. Travelling companies may also experience difficulty with set up on different stages with varying levels of digital readiness. Much of the technology outlined in this report relies on designing for a specific space, using accurate digital models to represent both front and back of stage as well as power and data architecture. This means touring performances may need to adjust the previsualization of a performance (where possible) for each location, increasing costs. For example, projection mapping requires inputting dimensions of a performance space, as well as where projectors will be positioned in relation to it. This would change with each new location, requiring detailed prior technical knowledge and adjustments.

These are some technologies involved in Technical Retrofitting:

3.1 Wireless Technology

Using radio frequency or infrared frequency waves, wireless tools allow technicians to run performances without the use of cables and wires that may be impossible to insert into pre-existing architectural features. Some new materials may interfere with clear transmission of information.

“When working within historic performance spaces Paul Johnson, lighting director at creative studio Satore Studio, aims to retain the look and feel whilst incorporating the best new technology. He experienced the challenges associated with restoring listed buildings when helping redevelop the Bristol Old Vic in 2012, using new lighting and wireless technology: “Retrofitting a historic space can be complicated if you have to keep the existing look but this lends itself to wireless control to reduce new cable costs. Wireless technology should also be handled carefully in historic buildings as the thickness of walls can cause signal loss.”

..."In addition, remote control can be a critical requirement in many venues, so it's important that the mix system includes easily-configurable wired and wireless control options to complement the main surface."

Allen & Heath's customizable dLive and SQ mixers allow users to quickly create their own fader layout, custom assignments to buttons and rotaries, or selection of widgets on screen. The company also provides an extensive range of remote control and I/O options. A dLive console was installed in the 800-seat Madách Theatre in Budapest, Hungary. Hosting 350 performances a year, Madách needed a system that allowed for four independent mixing systems which could also work together, offered a high level of flexibility, large number of channels and a common language for inter-connections."

https://www.avinteractive.com/features/av-live/staging-aspectacular-16-05-2019/

3.2 Digital Archiving of Musical Scores

For many symphonies and operas with rich and long histories, each production produces paper copies of each musical score. The desire to archive every individual score introduces important considerations with regard to space and weight, in some cases necessitating structural reinforcement of floors and walls.

3.3 Media Servers

Media Servers are dedicated computers and/or specialized software that act as a central storage location for sharing media files. Servers can range from enterprise class machines that provide the video on-demand services of our favourite streaming platforms to personal computers dedicated to storing a family's videos, photos and music. For theatre productions, media servers store the images and videos that will be projected on stage. They also allow integration with other staging technologies such as lighting and sound.

https://www.thestage.co.uk/features/2017/video-getting-bigger-part-theatre/

4. The Digital Divide

Smaller companies, or those outside the most populous urban centers, may not have access to equivalent technologies or the infrastructure to enable their use. An underlying barrier to adopting many new technologies is cost. Smaller companies may not have budgets that can be easily directed to developing new methods of producing and performing. Typically, these organizations allocate existing resources to more traditional stagecraft. However, there is an opportunity for a communal "database" of tech to allow for experimentation for companies lacking access or funds.

"A report from TD Bank has analyzed the digital divide between Canadian locales. It predicts that superstar cities which attract highly paid tech workers will leave their smaller counterparts struggling: a trend that's already become apparent in the U.S.

The study notes that high-tech jobs are already clustering in a handful of cities. Five urban centres—Toronto, Montreal, Vancouver, Ottawa, and Calgary—account for approximately 70 percent of all digital services. … The study suggests four ways to counter that outcome, including teaching technology and computer literacy courses to kids as young as four, strengthening relationships between tech firms and universities, government matching of venture capital for companies, and building adequate infrastructure in smaller cities."

https://www.straight.com/tech/1285421/digital-divide-between-canadian-cities-will-likely-widen-says-report

These are some technologies involved in the Digital Divide:

4.1 Licensed Resources and Learning Management Systems (LMS)

The public education system in Canada is also facing a fragmented and unequally developing technology landscape. Some solutions in place are worth studying.

"A Learning Management System (LMS) is generally defined as an online system or platform that provides a centralized place to create, deliver, and manage a course or a learning module. The software can be hosted locally or institutionally, by the province or district, or it can be made available through web-based technology. LMS contain a standard set of tools that can be accessed by students anytime, anywhere, and via multiple devices."

…The Ontario Software Acquisition Program Advisory Committee (OSAPAC) works with the Ministry of Education to survey teachers in Ontario regarding their overall software requirements. They then consult with the Ministry of Education to confirm those requirements and an RFP or RFT process is initiated for requested software. Some general features looked for in software include the following.

- Commercially released;
- No more than three years old;
- Networkable;
- Available in Windows 2000, XP, Vista, Win7, Win8, Win8.1 and/or Macintosh OS X
- Available in English and French;
- Canadian made, or at least, provided by an exclusive Canadian distributor;
- From a company that is capable of providing regional training and support."

Licensed software is made available to all schools in Ontario. The complete list of licensed software is available at https://www.osapac.ca/dlr/.

https://publishers.ca/wpcontent/uploads/2019/03/DigitalTrendsandInitiativesinEducation.pdf

C. Performance Reception

1. Performance for Everyone

Breaking down barriers and enabling a wider section of the public to experience the performing arts is increasingly possible with new digital tools. Audience members with physical disabilities may engage through technologically facilitated sensory enhancement. Those who live at a distance or are less able to afford the prohibitive cost of attending a performance in person may participate through elevated livestreaming that incorporates multiple views and background explanatory storytelling.

These are some technologies involved in Performance for Everyone:

1.1 Augmented Reality
Audience members with hearing impairment can re-engage in music and theater using alternate senses. A/R headsets take sur-titling a step further by providing text based information in an integrated manner to stage performance.

"…The National Theatre is combining Epson's Moverio BT-350 augmented reality smart glasses – designed specifically for cultural and entertainment venues – with a software application developed by the National Theatre, Accenture and Stagetext to allow deaf and hard of hearing customers to read subtitles in their field of vision from any seat in the auditorium."

https://www.avinteractive.com/features/av-live/staging-a-spectacular-16-05-2019/

1.2 Mixed Reality Live Streaming

Borrowing from gaming platforms and exploratory uses of tech tools, augmented live streaming provides a new dimension for inclusion in performances.

"MR (mixed reality) technologies give artists the opportunity to create experiential spaces that would be impossible to create in real physical locations. They can also stretch the experiential distance between real and virtual spaces much further. Spaces that are in different physical locations can be inter-connected through the Internet when using networked MR technologies. With the MoCap (motion Capture) and real-time 3D technology used in *To be with Hamlet* the actors and audiences can be in different physical locations while the performance MoCap data is streamed live over a network.…This also means that audience and performers don't necessarily have to be in the same physical location to have a live, shared experience."

https://www.ietm.org/en/system/files/publications/ietm_fp_mixed-reality_march2017_1.pdf

"Videogaming livestreaming has become a staple of many people's lives, whether that involves just watching, or producing. For streamers who show virtual reality (VR), presenting a smoother and simpler mixed reality livestream just got easier with MixCast 2.0 from Blueprint Reality.

…"Blueprint Reality's roots in virtual, augmented, and mixed reality development run deep – we are creators and huge fans who want to bring the experience to the masses," said Tarrnie Williams, co-founder and CEO, Blueprint Reality. "MixCast 2.0 will expand the market for VR experiences through social sharing, live spectation, and by empowering a larger, more diverse community of content creators.""

https://www.vrfocus.com/2018/06/streaming-mixed-reality-without-a-green-screen/

1.3 Haptic Music

Although originally developed to augment the listening experience for any user, haptic sensors and user interface offers those with limited hearing the chance to enjoy musical sound more fully.

"Musical haptics is an emerging interdisciplinary field investigating touch and pro-prioception in music scenarios from the perspectives of haptic engineering, human–computer interaction (HCI), applied psychology, musical acoustics, aesthetics, and music performance."

https://www.researchgate.net/publication/324905088_Musical_Haptics_Introduction

"UK smart TV developers playAlong have released an app that turns your phone into a haptic feedback device for music. The app called BeatWare is a music player that uses patent pending Haptic (sense of touch) driver technology to give you a physical experience by using your smartphone. The idea behind the app is to create high-definition Haptic sensations that are in sync with your music."

https://www.soundonsound.com/news/feel-music-beatware-haptic-music-player

2. Boundary Busting Immersion

Audiences are experiencing deeply immersive performances, including those beyond the stage. New technologies and tools enable creators to design experiences that allow audiences to be deeply immersed in their narratives. In some cases, the traditional boundaries of the "stage" are expanded to encompass the audience, wherever they happen to be situated.

These are some technologies involved in Boundary Busting Immersion:

2.1 Holograms
A holographic image, created with photographic projection that appears to be three-dimensional and which can be seen with the naked eye, is being used in new ways, in new places. Although not a new technology, it is now being employed with higher fidelity and to more immersive effect with audiences taking more active roles in participating.

Luxury brand Burberry "celebrated the opening of their Beijing flagship store, and to commemorate they held a runway show with live music from Keane that featured a sensational virtual experience enhanced by Musion Eyeliner holographic technology. Burberry's Creative Director Christopher Bailey, incorporated projections of blasting virtual snowflakes and swirling umbrellas. Dozens of models walked across the catwalk where real-time video and generative computer graphics interacted with the models' movements and clothes, resulting in a hybrid spectacle where the physical and the virtual could hardly be distinguished."

https://www.vice.com/en_us/article/9ad8j3/clothing%E2%80%94a-platform-for-digital-artwork

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Japan's pop star hologram takes to the road. "Hatsune Miku is a virtual character created by Crypton Future Media. Originally, she was sold as the face of computer software that allowed users to generate their own music, with her as a vessel. Imagine GarageBand mixed with Sims performing your songs. Since Miku's creation, over 170,000 sounds have been created for her, garnering a grand total of over 100 million hits on YouTube. This spring, she embarked on a ten-city tour with a live band to showcase the most shared singles — almost all the shows were sold out"

https://www.wmagazine.com/story/hatsune-miku-crypton-future

"Late last year the Spanish government passed a law that set extreme fines for protesters convening outside of government buildings. In response to the controversial Citizen Safety Law, which will take effect on July 1, Spanish activists have staged the world's first ever virtual political demonstration. Organised by the group Holograms for Freedom, ghost-like figures holding placards took aim at the imminent draconian measures, arguing that holographic people are now afforded greater freedoms than their real-life counterparts."

https://www.independent.co.uk/news/world/europe/spains-hologram-protest-thousands-join-virtual-march-in-madrid-against-new-gag-law-10170650.html

Hologram theatres have been created to enable audiences to experience "live" performances from deceased performers. Early tests are being trialed for "beaming" performers/performances to multiple venues simultaneously. "Hologram USA has also partnered with the Laugh Factory to "beam" live sets from comedians into venues all over the country, like when Jimmy Kimmel was in Hollywood and Nashville at the same time." Alki Davi, owner of Hologram USA predicts the tech will be used in classrooms. "Imagine Einstein being beamed into multiple schools at the same time to give his take on his own theorems,"

https://www.lamag.com/culturefiles/months-delays-worlds-first-hologram-theater-finally-opening-hollywood/

C. PERFORMANCE RECEPTION (CONT')

2.2. 3D Spatial Sound

Beyond surround sound, where an array of speakers is located at specific places around a subject to provide multi-dimensional experience, 3D Spatial Sound, can come from all directions (including above and below) and all distances from the subject. It is the spatial location of a sound that gives it its three-dimensional and more naturalistic aspect. 3D Spatial Sound has been explored in multiple performance contexts, allowing audiences to feel located in relation to the sound.

MNTN Rocks software drove the IzzJazz's presentation of "*Paraesthesia*", an experimental and spoken word performance mapped as 3D audio. The presentation made use of spoken word, instrumental performance, and visuals presented on an array of 20 speakers. "The software enables immersive and complex 3D audio mixing, as sound can be distributed around an audio scene in real time, leading to beautiful and dynamic "sound paintings". The app can be added on to any regular production software, facilitating the mixing of surround sound and the design of speaker layouts.

https://www.electronicbeats.net/the-feed/this-ep-proves-surround-sound-tech-is-now-everyones/

"4DSOUND is transforming the listening experience. Created by composer Paul Oomen, the spatial sound system allows you to experience sound from all directions, using architecture as a new kind of 'instrument'. 'I have always been interested in the energy released through sounds,' says Oomen, who studied the work of scientist Nikola Tesla. 'I began to formulate ideas about the musical dimension of movement in space, applying them to my compositions for operas and theatres. Then I realised I needed a technological system which would allow me to use the spatial element in my music.'… Renovation works to the buildings have been designed to enhance the sonic experience. The industrial space has been stripped back to its shell, with the structural beams doubling as a grid for 4DSOUND system's 45 omni-directional speakers and 8 subs. Meanwhile, a heavy-duty polymer floor has been fitted to enable soundwaves to travel through the volume of the building uninhibited.

https://thespaces.com/inside-the-institute-of-spatial-sound-in-budapest/

3. Democratizing Performance

Perhaps the most disruptive change for audiences is the increasing participatory role they are playing in performance. No longer merely content to be passive receptors for an experience, many are seeking opportunities to self determine the outcomes. Direct engagement in evaluation rather than through a critic or creative involvement in the development of assets alter the structure of artist-audience relationships.

"The rising trend of co-creation reflects the evolving role of the audience in the creative process. At first sight, co-creation represents a movement towards democratizing the arts through a process where creativity is demystified and opened-up to participant engagement. In recent years, it has been accompanied in the performing arts by the growing popularity of interactive theatre and dance, often referred to as immersive or relational performance.

…Arvidsson (2008) argues that the progressive inclusion of consumers in the creation of value represents one of the most significant trends in contemporary society, while Leadbeater (2009) notes that cultural activity has undergone a seismic shift from production to or for audiences to creation with them. These assessments have almost become a truism, describing the defining features of a post-modern audience which engages in "active and expressive ways" to form a culture of "making-and-doing" (Brown et al., 2011, p. 4). Arvidsson links this trend with an oversupply of knowledge workers who have learnt to seek out self- expression and –realization through social production, while Payne et al. (2008) identify three concrete factors behind this shift: technological breakthroughs; changes in industry logics; and changes in customer preferences and lifestyles. In the performing arts, these factors can be seen in developments like live streaming (which has spurred initiatives such as National Theatre of Scotland's 5-Minute Theatre); a focus on appealing to diverse and younger audiences (e.g. Contact theatre's Freestyle Mondays); and personalized marketing."

http://eprints.whiterose.ac.uk/79370/1/Co-creating%20theatre%20-%20Authentic%20engagement%20or%20inter-legitimation%20-%20final%20draft.pdf

C. PERFORMANCE RECEPTION (CONT')

These are some technologies involved in Democratizing Performance:

3.1 Social Media
Using social platforms to both comment on and co-create content in the performing arts is on the rise. From the 2009 opera composed through social networking platform Twitter by the Royal Opera House, London, to Yorkshire Dance's co-created experimental program Respond, efforts to include audiences in creative decision-making are being explored.

"The project was launched as part of the Royal Opera House's (ROH) Ignite season and aims to get more people involved in the creative side of opera.

Alison Duthie, head of ROH2 said: "It's the people's opera and the perfect way for everyone to become involved with the inventiveness of opera as the ultimate form of storytelling.

"Expect the unexpected - who knows how the story will evolve, but get tweeting and you can play your part in your opera."

http://news.bbc.co.uk/2/hi/entertainment/arts_and_culture/8193917.stm

"In March 2014 the project consortium, comprising Yorkshire Dance, the University of Leeds and Breakfast Creatives, asked for the public's help to select two new dance projects to be commissioned specifically for the Respond project. In the course of one week, 1600 votes were cast from around the world from a choice of six artists' video pitches shortlisted from dozens of entries by a panel constituted by Yorkshire Dance. As a result of this public vote, two artists, Hagit Yakira and Robbie Synge, were selected to create their new pieces. In the meantime, the project team worked on developing and testing the online platform. The design and development of the Respond platform was heavily inspired by the American choreographer Liz Lerman's renowned Critical Response Process (CRP). The main challenges here were to translate CRP into a suitable online format that 'showed' rather than 'told'; and to make the platform appealing, interactive and 'sticky'… In December 2014, the two pieces, Robbie Synge's Douglas and Hagit Yakira's Air Hunger, were publically performed at Yorkshire Dance in Leeds.

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…The development of the cultural economy has been characterised in part by a growing culture of participation or "participatory turn" (Crawford, Gosling, Bagnall & Light, 2014). Ito (2007) relates this culture shift to the concept of "networked publics", which he invokes to explain how online audiences engage actively with media to the point where they co-create or even reinvent it. This provides an excellent illustration of what Cova (1999) calls "the linking value of consumption". An effective example of this linking value at play is provided by the growing global phenomenon of online book clubs, tellingly referred to by some developers as 'social reading platforms'. One analysis of such platforms illustrates how their developers "attempt to reduce notions of hierarchy [and] draw on the democratic potential of social media environments to present social reading platforms as social spaces that thrive on affinity" (Vlieghe & Rutten, 2013, n. p.)."

https://www.sciencedirect.com/science/article/pii/S0304422X15300383

Through a survey of 311 executives in major industries, Cognizant(2012) found that "organizations that structure their innovation processes by combining internal teams with customer input report higher satisfaction with a variety of innovation areas than companies that don't employ this structure".

https://pdfs.semanticscholar.org/13dd/fc8a2bfc266c2c3872edd657bc699300bee1.pdf

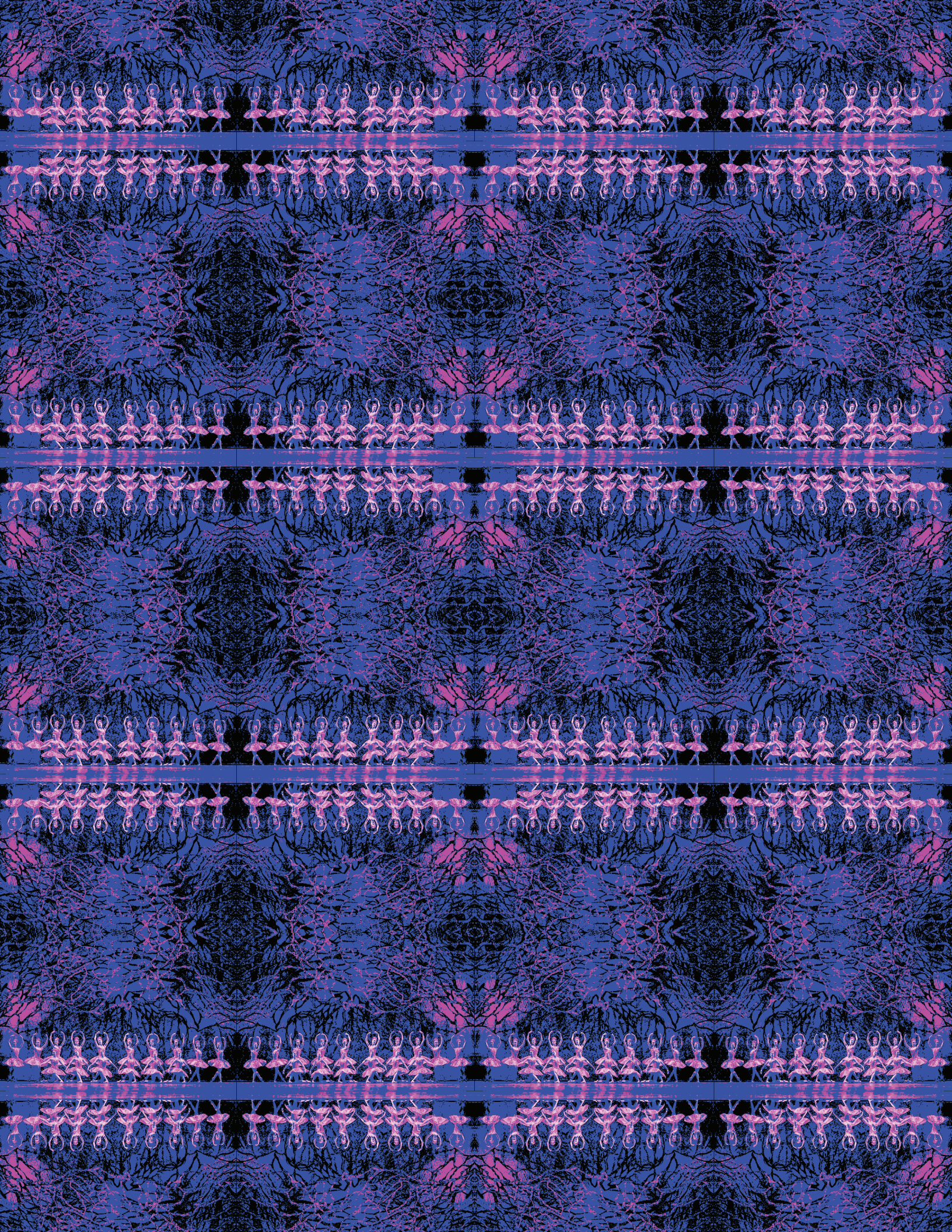
C. PERFORMANCE RECEPTION (CONT')

3.2 Augmented Reality

"…today's customers are not passive bystanders purchasing any product that an organization offers. Today's customers are better "informed, networked and empowered" (Prahalad&Ramaswamy, 2004b, p. 5). They are more capable of deciding which products or services they wish to purchase. They are able to interact and communicate with each other instantly utilizing current communication technology. In this context, customers have become known as actual co-creators of value as they contribute with their own knowledge and skills in the use and integration of products and services into their lives. Marketers recognised this trend shift by the late 90s and are now trying to understand the customer's value-in-use leading us here to discuss the provision and utility of better platforms for co-creation.

…In this paper, we argue that Augmented Reality technology, which links the digital and the physical world will enhance interactions that are of value to the organisation. By offering AR applications that allow and encourage instant co-creation of information and experiences through interactive elements such as dialogue and knowledge gathering, customers can gain added value from the offering through value-in-use. We also discuss how this convenience of dialogue and knowledge gathering can create a synergy of trust between the customer and the organisation due to the ability of customers to trigger the AR experience when they require further information or where additional understanding of the product practicality and usability is needed. We discuss this by outlining the various models of co-creation and propose a trust-based model that explains and promotes the unity of customers and organisations within the context of co-creation."

https://www.researchgate.net/publication/324976504_The_Role_of_Augmented_Reality_in_the_Interactivity_of_Co-Creation



04

Technology Attributes

The research identified thirteen important digital tools in use to enhance or simplify the creation, delivery and reception of performing arts around the world and across sectors. In some cases these technologies remain experimental or prohibitively expensive; in some cases they are widely, but unevenly, adopted due to cost, complexity of use, or difficulty in transporting them. This is not an exhaustive list, but illustrates important changes that will impact the performing arts.

The following pages provide an at-a-glance overview to provided comparative features, as well as a more detailed summation of each technology, its attributes and current use cases. Readers may use these references as a tool to assess the suitability of various technologies to their individual applications. Included are introductory assessments of the cost to adopt, the requirements of expertise and scale to incorporate and the potential impacts on artists, venues and audiences.

The Sleeping Beauty, National Ballet of Canada. Photo by Karolina Kuras

At-A-Glance

Technology \ Attributes	Relative Cost	Applicability Across Multiple Disciplines	Scalability (Business Operations)
3D Printing	$-$$$$$	Music, Theatre, Opera, Dance	Small, Medium, Large
3D Spatial Sound	$$-$$$$	Opera, Dance, Music, Theatre	Large
Artificial Intelligence/ Machine Learning	$-$$$	Dance, Stagecraft	Medium, Large
Augmented Reality	$$-$$$$$	All disciplines	Large
Holograms	$$$-$$$$$	Theatre, Opera, Dance	Medium, Large
LED Displays	$$$-$$$$$	Can be applied to most disciplines	Large
Motion Capture	$$$$-$$$$$	Can be applied to most disciplines	Large
Motion Tracking	$-$$$	Currently used for dance	Small, Medium, Large
Projection Mapping	$$$$$	Can be/is used across all disciplines.	Medium, Large
Sound Sampling Software (including Smart gloves)	$$-$$$$	Can be applied to most disciplines	Small, Medium, Large
Video Projection	$ - $$$	Can be applied to most disciplines	Small, Medium, Large
Virtual Reality	$$-$$$$	Can be applied to most disciplines	Medium, Large
Wearable Sensing Technology	$$-$$$$	Can be applied to most disciplines	Large

The following pages of this report look at each technology and its attributes in more detail.

Technology \ Attributes	Scalability (Production Design)	Easily Integrated Into Existing Technology Infrastructure	Level of Specialized Expertise
3D Printing	Small, Medium, Large	Moderate	Moderate
3D Spatial Sound	Large	High difficulty	High
Artificial Intelligence/ Machine Learning	Small, Medium, Large	Moderate	High
Augmented Reality	Small, Medium, Large	High difficulty	High
Holograms	Large	Moderate	High
LED Displays	Small, Medium, Large	Easily integrated into existing tech	Moderate
Motion Capture	Large	Moderate difficulty integrating into existing tech	High
Motion Tracking	Small	Easily integrated into existing tech	Moderate
Projection Mapping	Small, Medium, Large	Moderate	Moderate
Sound Sampling Software (including Smart gloves)	Medium, Large	Easily integrated into existing tech	High
Video Projection	Small, Medium, Large	Easily integrated into existing tech	Moderate
Virtual Reality	Medium, Large	High difficulty	High
Wearable Sensing Technology	Large	Easily integrated into existing tech	Moderate

3D Printing

Definition
3D printing, also known as additive manufacturing, is a process of making 3D solid objects from a digital file. In an additive process, objects are created by successive layering of material (often plastic) until the final form has taken shape. The opposite of subtractive manufacturing, where an object is cut out or hollowed out of the source material, 3D printing enables creators and designers to produce complex shape with less waste than traditional manufacturing methods.

Current Use Examples
- *Outside Mullinger*,
  John Lee Beatty (Set Designer)
- *Conversation With The Rain (Gesprek Met De Regen)*,
  Het Nieuwstedelijk (Theatre Company)

Saturation
Medium

Application Outside Performing Arts
Manufacturing of tools across disciplines

3D printing process
https://www.forbes.com/sites/bernardmarr/2018/08/22/7-amazing-real-world-examples-of-3d-printing-in-2018/#1f9f4b016585

Printing concrete columns for a dance performance
https://www.dezeen.com/2019/07/24/3d-printed-concrete-choreography-pillars-design/?li_source=LI&li_medium=recommended_movies_block

3D PRINTING TECHNOLOGY ATTRIBUTES

Relative Cost

$200-$100,000
Price varies depending on the material being printed and the size of the output. Plastic filament is the least expensive, while metal can be the most. Larger outputs require larger and more expensive printers.

Applicability Across Multiple Disciplines

Instrument fabrication, costume and set design in all performance disciplines. 3D printing can be used to reduce cost and time associated with traditional fabrication.

Scalability (Business Operations)

Small-large companies could feasibly use this technology, depending on size and cost of machine. Most often this will be an outsourced operation.

Scalability (Production Design)

3D printing can be used to create items as small as a button to as large as a full stage construction.

Easily Integrated Into Existing Technology Infrastructure

Discrete use typically applied outside of normal stagecraft techniques as an enhancement or precision tool.

Level of Specialized Expertise Required

More complex designs require the creation of an accurate 3D digital file before printing, or for extremely large objects that demand a 3D printer with a large build volume. It is therefore necessary to obtain training on proper use of a 3D printer, as well as fabricating 3D models.

Impact on Creative Process

3D printing makes set and prop design more precise and time-efficient.
Depending on material used, some costume elements can be more durable and flexible, allowing for longer lifespans. Opportunity to create new aesthetics within the world of costume design.

Impact on Audience Immersion

Minimal impact on audience immersion.

Geographically Transportable

Printer is not easily transported, however it is possible to print files anywhere an appropriate printer is located, resulting in less time, cost and emissions associated with transporting goods. Resulting products can be more durable, making transportation easier and safer.

3D Spatial Sound

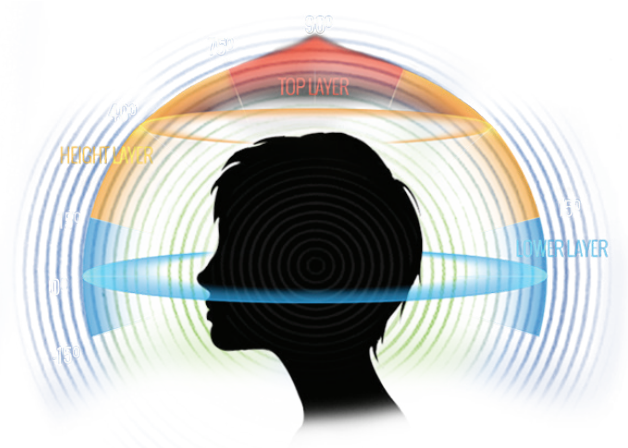
Definition
3D or Spatial Sound allows sound to be distributed in a 3 dimensional setting.
Audio focal points are projected and suspended in the air, and fixed to a specific location, enabling unique sound to be audible at that specific point.

Current Use Example
- *Spatial Sound: Story and Image*, Laurie Anderson and Arto Lindsay (Course instructors, Princeton)
- *Bjork Digital*, Vivid Sydney Exhibition, Marco Perry (Sound designer)

Saturation
Currently experimental

Application Outside Performing Arts
Contemporary art

Bjork soundscape
https://www.stormaudio.com/en/immersive-sound/auro-3d/



Spatial sound representation
https://www.arup.com/-/media/arup/images/projects/b/bjork-reverberation-chamber/1bjork_2000x1125_sacksco.jpg

3D SPATIAL SOUND TECHNOLOGY ATTRIBUTES

Relative Cost

$$-$$$$

Applicability Across Multiple Disciplines

Can be used to enhance the experience of opera, dance, music performances, and could be applied to theatre.

Scalability (Business Operations)

Large organizations, as this is still experimental technology and expensive.

Scalability (Production Design)

Large, currently still experimental. The idea of spatial sound would, in theory, reduce the need for many physical speakers.

Easily Integrated Into Existing Technology Infrastructure

This technology does not integrate into existing standard stage techniques; new systems are required.

Level of Specialized Expertise Required

High level of expertise needed.

Impact on Creative Process

"This method can generate and vanish the sound sources freely in air. These point sound sources can deliver private messages or music to individuals."* Creators would be able to compose soundscapes based on geography.

*https://digitalnature.slis.tsukuba.ac.jp/2016/08/holographic_whisper/

Impact on Audience Immersion

Enables immersive and complex 3D audio mixing and can distribute sounds around an audio scene in real time generating "sound paintings". The ability to distribute sound in a 3 dimensional setting means it is possible to single out sections of an audience to hear specific sounds.

Geographically Transportable

Currently experimental - in theory would allow for ease of transportation of a touring performance.

Artificial Intelligence / Machine Learning

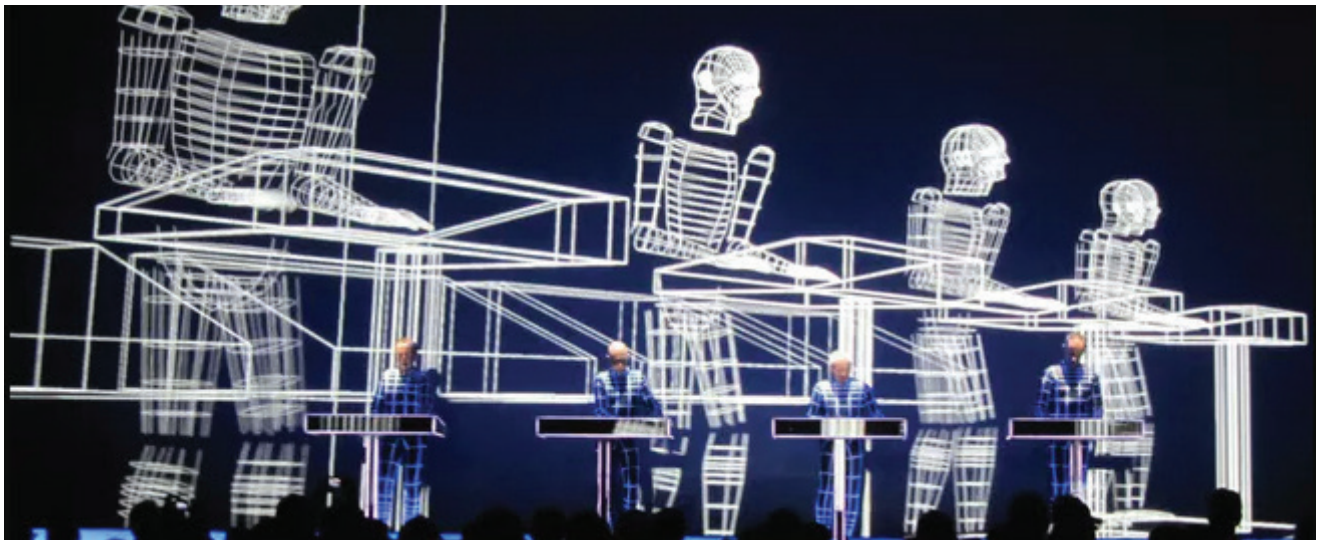
Definition
"Artificial intelligence (AI) is the simulation of human intelligence processes by machines, especially computer systems. These processes include learning (the acquisition of information and rules for using the information), reasoning (using rules to reach approximate or definite conclusions) and self-correction." *

*Rouse, M. What is AI (artificial intelligence)? (n.d.) In *WhatIs.com*.

Current Use Examples
- *Lifestyle of the Richard and Family,* Roslyn Helper and AI (playwrights)
- *Living Archive: a tool for choreography powered by AI,* Wayne McGregor (Choreographer)

Saturation
Medium

Application Outside Performing Arts
Used to control and develop programs across disciplines



AI used to compose music
https://www.inverse.com/article/31773-google-demo-magenta-magenta-nsynthogfest

ARTIFICIAL INTELLIGENCE / MACHINE LEARNING TECHNOLOGY ATTRIBUTES

Relative Cost

Front edge experimental uses are expensive as the set-ups are bespoke and the linked technology can vary. However, Google's artificial Intelligence education course is free; it is a matter of training a program to learn and function in the way a creator would want.

Applicability Across Multiple Disciplines

Currently being experimented with for use in dance and music. Machine learning is being used for behind-the-scenes construction and automation in the performing arts.

Scalability (Business Operations)

Medium-large companies currently using this tech. Advancements and experimentation usually conducted by independent creators. (i.e. choreographers with training in programming)

Scalability (Production Design)

Small-large. Can be used simply as a choreography tool, or to automate functions of stagecraft and staging.

Easily Integrated Into Existing Technology Infrastructure

Can be trained to recognize and understand existing tech; used to automate lighting and sound cues for theatre performance. (i.e. automated lighting as stage cues for actors)

Level of Specialized Expertise Required

High level; requires an understanding and educational background in computer science and coding. There are performance creatives with this experience.

Impact on Creative Process

Ability to train AI to assist in the creation process; "predictive" assistance with choreography, automate aspects of the behind-the-scenes of the stage.

Impact on Audience Immersion

As AI/Machine Learning is currently being used, audiences would not be aware of its use.

Geographically Transportable

Relatively easy to transport - requires transferring of files and an operator with an understanding of tech.

Augmented Reality (AR)

Definition
"Augmented reality (AR) is a type of interactive, reality-based display environment that takes the capabilities of computer generated display, sound, text and effects to enhance the user's real-world experience. AR combines real and computer-based scenes and images to deliver a unified but enhanced view of the world." *

* What is Augmented Reality (AR)? (n. d.) In *Techopedia.*

Current Use Examples
- *Codes 2.0*,
  MIDASpaces (Interdisciplinary Collective)
- *Scattered*,
  Motionhouse (Dance company)
- *Gulliver*,
  Sasha Kreindlin (CEO, ARShow)
- *U2's Innocence & Experience World Tour*,
  Es Devlin (Stage designer)

Saturation
Medium; being adapted by companies looking to experiment with immersion

Application Outside Performing Arts
Entertainment. Architecture, Archeology, STEM Education

AR performance - adding imagery to real life
http://www.illusionfactory.com/wp-content/uploads/2015/01/Meel-Mil-100s.jpg

AUGMENTED REALITY TECHNOLOGY ATTRIBUTES

Relative Cost

$$-$$$$$

Applicability Across Multiple Disciplines

Can be applied to most disciplines.

Scalability (Business Operations)

Currently only large companies with access to more resources could use this technology, due to the high cost required to produce it.

Scalability (Production Design)

In theory, augmented reality could be used to enhance experience through a phone or much larger screen.

Easily Integrated Into Existing Technology Infrastructure

Requires use of technology that is not traditionally used for the performing arts. Advancements allow for this tech to be used in real-time performance.

Level of Specialized Expertise Required

High level of expertise needed; created in collaboration with software engineers.

Impact on Creative Process

Timing becomes more significant than ever and is challenging. The writing process is done in cooperation with software engineers, each providing relevant expertise.

Impact on Audience Immersion

"The connection enables an exclusive viewing experience and for the first time allows a large number of people to take part, transforming it into a multi-participant entertainment form."*

*https://www.artsprofessional.co.uk/magazine/article/fantasy-reality

Geographically Transportable

The nature of the tech is to be easily transported, however depending on complexity and hardware used, this may not be the case.

Holograms

Definition
Created with the use of manipulated photographic projection, a hologram is an image that uses light diffraction to appear three dimensional to the naked eye. Holograms are generally a "photographic recording of a light field, rather than an image formed by a lens." *

* Wikipedia Contributors. (n. d). Holography. In *Wikipedia, The Free Encyclopedia.*

Current Use Examples
- *Michael Jackson ONE*, Cirque du Soleil
- *Meet Yourself*, Martine Jarlgaard (Visual Artist)
- *Symphony to a Lost Generation*, Adam Donen (Director)

Saturation
Medium

Application Outside Performing Arts
Entertainment, Art, Security, Experimental medicine

Use of Hologram to enhance performance
https://3d-imaging.co.uk/blog/royal-shakespeare-company-to-use-3d-motion-captured-holographic-avatars-in-the-tempest/

HOLOGRAMS TECHNOLOGY ATTRIBUTES

Relative Cost

$10,000-$62,000

Applicability Across Multiple Disciplines

Used in theatre, opera, dance.

Scalability (Business Operations)

Hologram technology is hard to access for smaller, less well endowed companies.

Scalability (Production Design)

Large - requires significant performance space and backstage capability.

Easily Integrated Into Existing Technology Infrastructure

Generally achieved using traditional staging tools; tech is generally inspired by the principals of historic "Pepper's Ghost" illusion.

Level of Specialized Expertise Required

High level expertise required.

Impact on Creative Process

Potential for new ways of thinking for representation of ideas/design of costume or sets, as well as character creation.

Impact on Audience Immersion

Enables an audience to experience performance in multiple locations simultaneously. There is an element of interaction with holograms, as they can feel lifelike.

Geographically Transportable

Not easily transported. Site specific set up required.

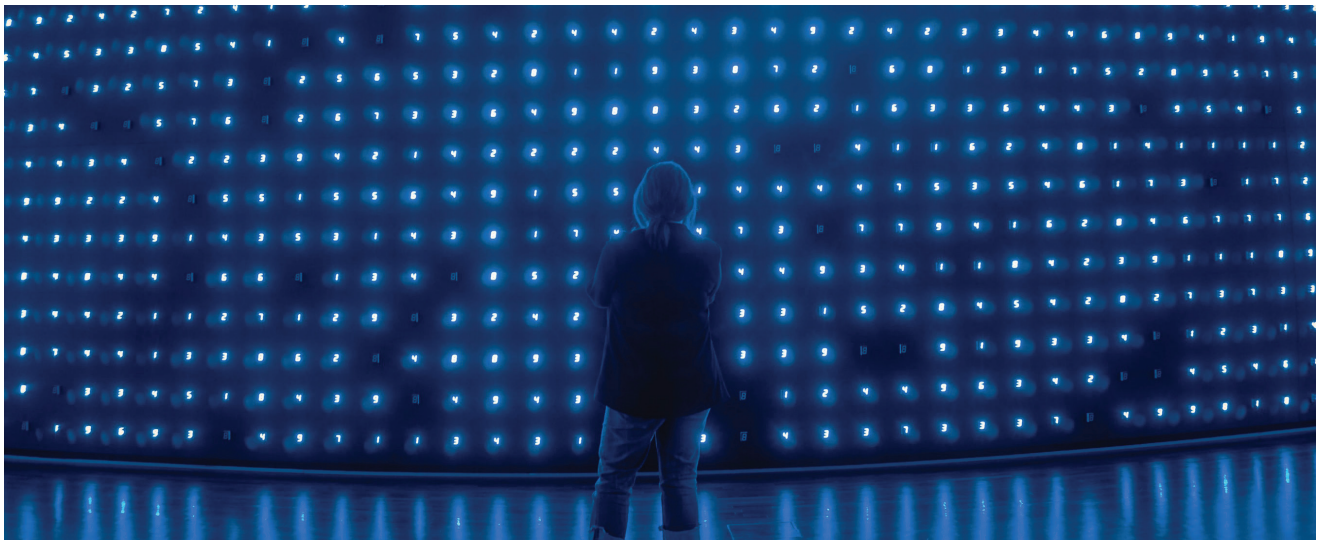
LED Displays

Definition
Light-emitting diodes (LEDs) are semiconductor light sources that emit light when a current flows through them. Widely used in our homes, LEDs have also played a big role in lighting up performances. LED displays can be as small as mobile devices or as large as video walls.

Current Use Examples
- *Reputation Tour*, Taylor Swift (Pop singer)
- *Formation World Tour,* Beyonce (Pop singer)

Saturation
Low, due to cost and availability

Application Outside Performing Arts
Entertainment, Art, Housewares



LED light display
Photo by Yeo Khee on Unsplash

LED DISPLAYS TECHNOLOGY ATTRIBUTES

Relative Cost

$17,000-$25,000 per square meter (depending on product selection, options, accessories, etc for video walls). With less resolution or pixel density, the price drops dramatically.

Applicability Across Multiple Disciplines

Can be applied to most disciplines. Care must be taken to ensure the sound and heat emitted by larger arrays do not interfere with performances.

Scalability (Business Operations)

Currently only large companies with access to more resources could use this tech at a large scale due to the high cost required, although smaller insertions are possible for smaller investments.

Scalability (Production Design)

Small-large, as the screens can be made to be any size needed.

Easily Integrated Into Existing Technology Infrastructure

Easily integrated into existing tech.

Level of Specialized Expertise Required

Would require moderate training and an understanding of how to utilize hardware and software effectively.

Impact on Creative Process

Potential for new ways of thinking for representation of ideas/design of sets and narrative.

Impact on Audience Immersion

Allows for an opportunity to show audiences higher detail of a show, or to provide seamless environments for a performance.

Geographically Transportable

Can be easily transported as larger displays can be broken down into smaller components.

Motion Capture

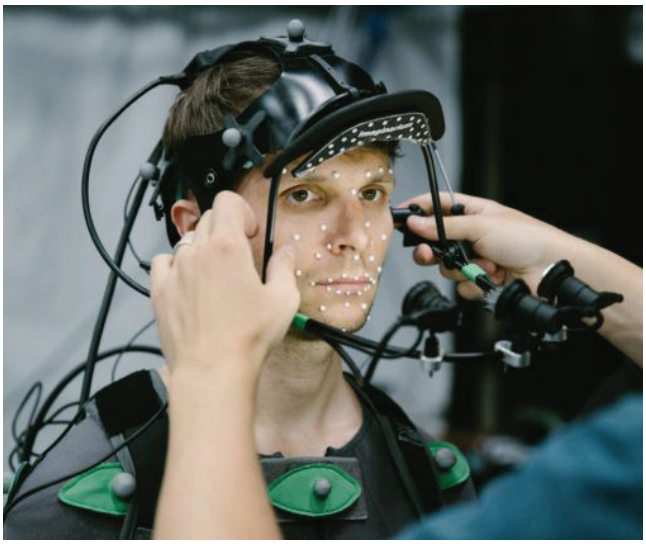
Definition
The act of digitally recording a performer's specific movements and translating them into a computer-animated image. This technology is often coupled with gaming software platforms to suggest a character moving in real time inside a digitized 3D modeled context. Motion capture refers to a non-real-time representation of an object's coordinates.

Current Use Examples
- *The Tempest*,
  Royal Shakespeare Company, UK
- *Creative Technology Gateway*,
  New Royal Theatre, UK, in partnership with University of Portsmouth

Saturation
Medium

Application Outside Performing Arts
Entertainment, Video Games

Andy Serkis demonstrating motion capture
https://3d-imaging.co.uk/blog/royal-shakespeare-company-to-use-3d-motion-captured-holographic-avatars-in-the-tempest/



Real-time motion capture digital avatar in The Tempest
https://arstechnica.com/gaming/2016/11/tempest-review-real-time-digital-avatar-performance-capture/

MOTION CAPTURE TECHNOLOGY ATTRIBUTES

Relative Cost

$4,000 /day plus $20 a second for data solving + re-targeting.
Costs depend on the scale of the video, and what services are required.

Applicability Across Multiple Disciplines

Can be applied to most disciplines.

Scalability (Business Operations)

Large organizations, due to pricing and expertise required.

Scalability (Production Design)

Large, due to complexity of technology.

Easily Integrated Into Existing Technology Infrastructure

Not easily integrated into existing tech.

Level of Specialized Expertise Required

High level of expertise needed, generally executed in collaboration with specialized experts.

Impact on Creative Process

Used to enhance Virtual Reality imagery. Advancements in this tech
mean it can be used to enhance and alter the appearance of actors in a live performance.

Impact on Audience Immersion

Encourages audience immersion and interaction through more realistic
movement in a digital setting

Geographically Transportable

Live performance tech not easily transported; pre-animated visuals require
only (large) file transfers.

Motion Tracking

Definition
Motion tracking assists in tracking the movement of objects and transferring the sensed data to an application for further processing. It includes capturing the motions of objects matching with its stored motion template. Motion tracking refers to a real-time data stream to control a process. In filmmaking and games, motion tracking is commonly called motion moving.

Current Use Examples
- *London Symphony Orchestra - Visualizing Motion and Music*,
  Tobias Gremmler (Musician and multimedia designer)
- *Orphe ONE smart shoes*,
  Orphe footwear, Japan

Saturation
Currently experimental

Application Outside Performing Arts
Entertainment, Video Games, Athletics

Motion tracking hardware integrated with dance costuming
https://www.domusweb.it/en/news/2014/11/20/lesia_trubat_e_traces.html

MOTION TRACKING TECHNOLOGY ATTRIBUTES

Relative Cost

$-$$$

Applicability Across Multiple Disciplines

Currently used for dance.

Scalability (Business Operations)

Small-large, depending on cost of training.

Scalability (Production Design)

Relatively easy to produce at small scale but still experimental.

Easily Integrated Into Existing Technology Infrastructure

Requires integration of Arduino tech and is easily integrated with current dance/performance equipment being used.

Level of Specialized Expertise Required

Would require moderate training.
Examples such as “e-traces involve an intuitive app to track results.

Impact on Creative Process

Allows for tracking of movement and pressure, resulting in dancers being able to interpret and compare rehearsals and performances, and possibly improve. Choreographers could use this to create more precise pieces.

Impact on Audience Immersion

Audiences would not be aware of its use, besides appreciating potentially stronger performances. Though the trackers are visible, they can be easily incorporated into costuming.

Geographically Transportable

This technology would be relatively easy to transport.

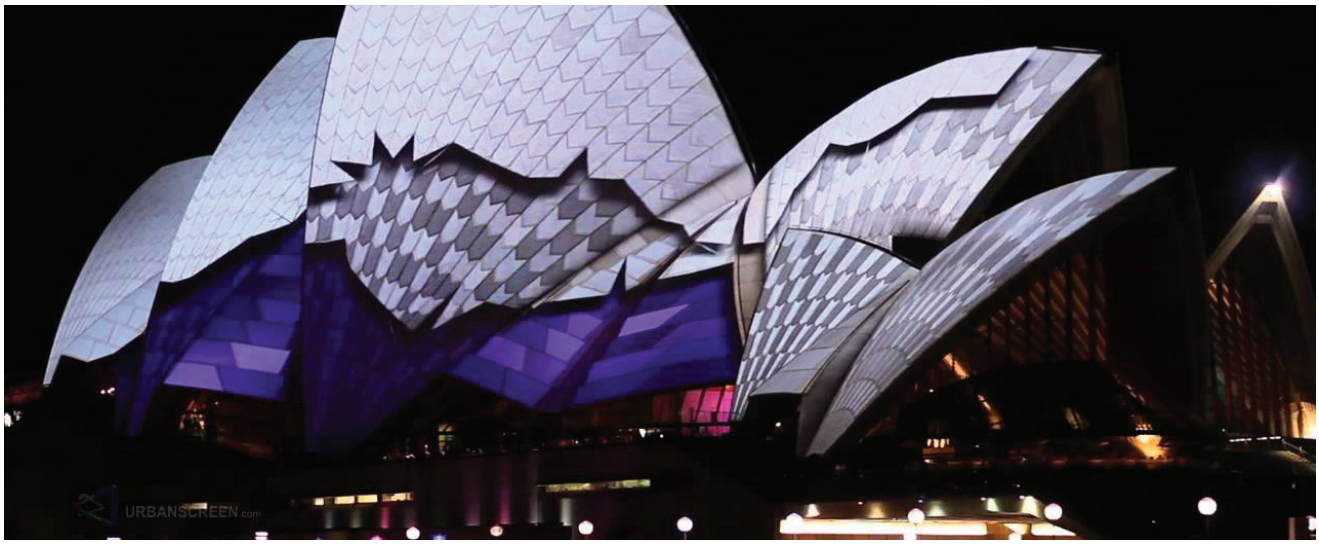
Projection Mapping

Definition
Also referred to as video mapping and spatial augmented reality, projection mapping, in simple terms, is the act of displaying an image on a non-flat or non-white surface. It can be achieved using everyday video projectors. Commonly used software include Lightform, HeavyM and Madmapper.

Current Use Examples
- *Pixel*,
  Adrien M/Claire B (Dance company)
- *The Curious Incident of the Dog in the Nighttime on Broadway*,
  Simon Stephens (Playwright)
- *Walt Disney Concert Hall Dreams*,
  Refik Anadol (Media Artist)

Saturation
Medium

Application Outside Performing Arts
Advertising, TV, film and tourism



Projection mapping used to transform Sydney Opera House
https://www.youtube.com/watch?v=eCeK8NBddIQ

PROJECTION MAPPING TECHNOLOGY ATTRIBUTES

Relative Cost

$10,000 for one-minute of 3D video, which covers the actual video production.

Applicability Across Multiple Disciplines

Projection mapping can be/is used across all disciplines.

Scalability (Business Operations)

Medium-large organizations and productions. Is used by more independent but well funded companies (e.g. Adrien M / Claire B, a French dance company).

Scalability (Production Design)

Small-large. It is possible to use this tech to alter the appearance of a small object or an entire set, depending on narrative or artistic needs.

Easily Integrated Into Existing Technology Infrastructure

Would require alternative software in order to digitally map the 3 dimensional space.
Requires conventional projectors.

Level of Specialized Expertise Required

Medium level skill in 3D modeling software, and access to a projector - scale is very important.

Impact on Creative Process

Allows designers to turn objects into a display surface for video media.
Can be adjusted and adapted to a variety of settings.
Can create the illusion that the stage is evolving or becoming a performer rather than a static setting.

Impact on Audience Immersion

Possibility for movement to be detected by both performer and audience, meaning the audience actively participates.

Geographically Transportable

Scale is very important. Position of projectors affects resolution of work.
Must have an idea of the space before mapping.

Sound Sampling Software (including Smart Gloves)

Definition
The act of converting live or pre-recorded analogue audio into digital signals and files. Used by sound designers to streamline the composition process. Live performers have adapted this technique to develop digital instruments.

Current Use Examples
- *Why Try* with Mi.mu gloves, Ariana Grande (Pop singer)
- *Opera Riparata*, Økapi (Turntablist)

Saturation
High saturation; sound sampling is seen in most theatrical performances, however, next level sampling is being introduced as a live instrumental element.

Application Outside Performing Arts
Popular music, TV and film

Imogen Heap Mi.Mu gloves
http://routenote.com/blog/these-gloves-could-change-how-we-make-music/

SOUND SAMPLING SOFTWARE TECHNOLOGY ATTRIBUTES

Relative Cost

$$-$$$$
Smart gloves: $3,220 for 1 pair

Applicability Across Multiple Disciplines

Can be applied to most disciplines.

Scalability (Business Operations)

Small-large organizations and productions.

Scalability (Production Design)

Small-large. Requires some time commitment as previous knowledge of sound/music theory as well as training in the technology. In the case of smart gloves, training is needed and gloves are relatively expensive for one pair.

Easily Integrated Into Existing Technology Infrastructure

Enhances current sound design software.

Level of Specialized Expertise Required

Would require high level training; but once users are experienced the tools are fairly easy to use.

Impact on Creative Process

Software allows sound designers to locate, download and construct soundscapes much more easily. Smart gloves (Mi.Mu gloves) are a new form of instrument; musicians can construct and manipulate new pieces in real time as a performance.

Impact on Audience Immersion

Sound design is a key factor for audience understanding of a performance; it aids in emotional "manipulation", or bringing an audience closer to a narrative.

Geographically Transportable

Relatively easy to transport - requires transferring of files and an operator with an understanding of tech.

Video Projection

Definition
Moving images that are projected onto a white screen provide immersive stage effects that augment live performance on stage. Used to integrate film, video or motion graphic elements into a live performance based on the needs of a specific show.

Current Use Examples
- *The Lehman Trilogy*, Es Devlin (Set Designer);
- *887*, Robert Lepage (Director, Playwright)
- *Dear Evan Hansen*, David Korins (Set designer)

Saturation
Extremely High

Application Outside Performing Arts
Pop culture; used in many of the performing arts

Video Projection theatre workshop
http://www.wsd2013.com/scenofest/performance-and-technology/

VIDEO PROJECTION TECHNOLOGY ATTRIBUTES

Relative Cost

$ - $$$

Applicability Across Multiple Disciplines

Can be applied to most disciplines

Scalability (Business Operations)

Small-large organizations and productions would be able to use this technology, provided they have access to video production equipment and projectors.

Scalability (Production Design)

Small-large depending on complexity of projection and availability of hardware

Easily Integrated Into Existing Technology Infrastructure

Video technology has been used in theatre for decades. The rate of integration into a range of theatrical production has increased significantly due to the ease of use and relative low cost of today's video projection technology.

Level of Specialized Expertise Required

Would require moderate training; there is a need to understand how to properly use projection hardware.

Impact on Creative Process

The ease and increased availability of this tech allows for creators to incorporate it into their productions; they are able to explore new ideas and methods of communicating with audiences. This would be a good alternative to projection mapping for smaller organizations with fewer resources as it involves less time and a lower cost to use.

Impact on Audience Immersion

Would allow creators to experiment with new methods of idea communication.

Geographically Transportable

This technology would be relatively simple to transport. It requires transfer of files and use of a projector and a screen.

Virtual Reality

Definition
"Virtual reality (VR) is a simulated experience that can be similar to or completely different from the real world. It allows for the ability to look and move around the artificial world, and interact with virtual features. Commonly achieved by VR headsets consisting of a head-mounted display with a small screen in front of the eyes, but can also be created through specially designed rooms with multiple large screens." *

* Wikipedia Contributors. (n. d). Virtual Reality. In *Wikipedia, The Free Encyclopedia.*

Current Use Examples
- *Dreams of "O"*, Cirque du Soleil;
- *Sibelius 5*, Philharmonia Orchestra (UK)

Saturation
Medium; being adapted by companies looking to experiment with immersion

Application Outside Performing Arts
Theme Park Amusements, Advertising, Architecture/Real Estate

Virtual Reality adding immersive element to performance
https://inspiration.samhoud.com/2015/11/europe-launched-first-virtual-reality-cinema/

VIRTUAL REALITY TECHNOLOGY ATTRIBUTES

Relative Cost

$700-$5000 (data gloves $499-$5000) or can be very expensive for more elaborate immersive experiences.

Applicability Across Multiple Disciplines

Has been used for theatre, opera, dance, and circus performance.
Can be applied to most disciplines.

Scalability (Business Operations)

Medium-large orgs and productions, usually in collabortion with a technology company

Scalability (Production Design)

Medium-large, depending on complexity of production.

Easily Integrated Into Existing Technology Infrastructure

Virtual reality hardware (glasses/goggles/gloves) required. Would need to be applied outside of normal stagecraft technologies.

Level of Specialized Expertise Required

High level of expertise needed for virtual reality as it requires knowledge of animation, coding and VR software/hardware.

Impact on Creative Process

Ability to co-create from many locations, reducing cost and time of travel; ability to reach creatives that may not have had access previously. “They could move, add, remove or modify objects in the mixed reality while edits would be seen simultaneously by other users.”

Impact on Audience Immersion

Allows viewers to interact with performance; move through a digital space, zoom in and focus on certain aspects, could even turn and see audience reactions.

Geographically Transportable

Required hardware to be transported: virtual reality glasses or goggles, data gloves.

Wearable Sensing Technology

Definition
A category of smart technology devices that can be worn on the body and incorporated into costumes, clothing or accessories. These devices typically interact with other technologies that control their output (for example, a wearable costume made of lights controlled by a switchboard on the chest). Such technologies can alter a performance by means of either audience immersion or performer aesthetics.

Current Use Examples
- *LED pulsating wristbands,* PixMob, Montreal
- *A Very Electric Christmas* with Electroluminescent (EL) Wires, Ian Carney (Artist director)

Saturation
Low

Application Outside Performing Arts
PixMob Video, Sports stadiums

Wrecking Crew Orchestra (Japan) uses electroluminescent wire to punctuate their performance
https://ichef.bbci.co.uk/news/640/media/images/78583000/jpg/_78583579_dancers.jpg

WEARABLE SENSING TECHNOLOGY TECHNOLOGY ATTRIBUTES

Relative Cost

LED wristbands cost $5-$10 per person, currently designed for large audiences of 500-100,000 people - other fitbit type tracking devices relatively cost effective.

Applicability Across Multiple Disciplines

Wristbands currently used for popular concerts, could be applied to contemporary theatre, opera or dance.

Scalability (Business Operations)

Currently used by large companies, as volume of tech is quite large.
As demand increases, the volume required to produce this tech will shrink.

Scalability (Production Design)

Wristbands used for large events for now, however cost is dropping due to availability and increasing audience interest in tech.

Easily Integrated Into Existing Technology Infrastructure

Easily integrated into current backstage technology.

Level of Specialized Expertise Required

Would require moderate training.

Impact on Creative Process

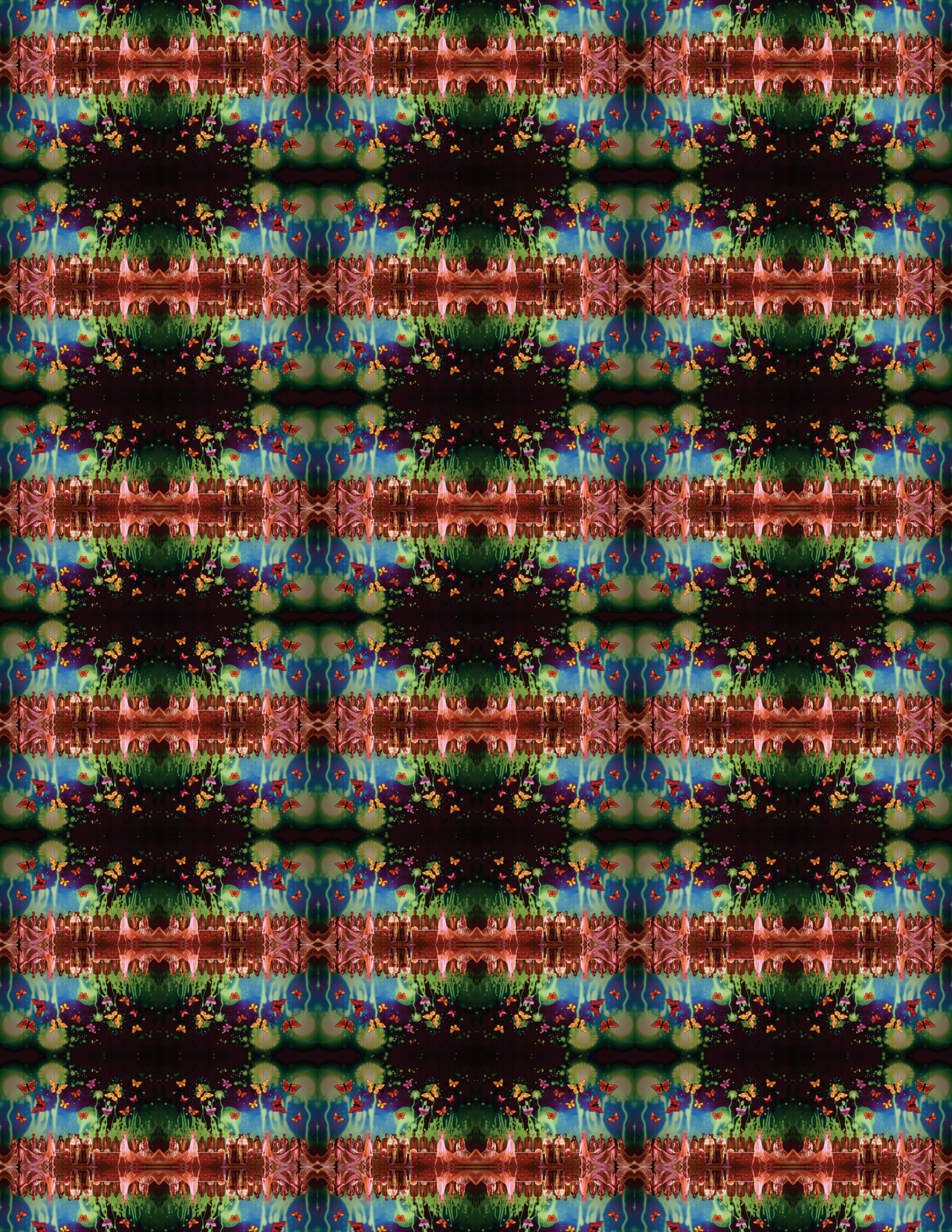
Multiple opportunities to include sensed data from performers in the creation process, or from audience members in the experience of the performance.

Impact on Audience Immersion

Increase in audience engagement; lights worn by audience create visual “soundscapes”, making the viewers part of the performance.

Geographically Transportable

Small in size, would be more easily transported.



05

Discussion & Conclusion

As digital technology rapidly evolves in all sectors and weaves into our lives in new ways, it is inevitable that there will be increasing impact on the performing arts. In addition to individual decisions about whether to introduce new digital technologies to performance, larger questions reflecting a shift in behaviour in the sector are arising. Opportunities for productive change, as well as disruptions of the status quo, are possible. Exploratory responses to these emergent conditions are offered for discussion here. Each has a series of implications for finance, labour, governance, legality and learning in the performing arts, and should be given serious attention.

On October 2, 2019, a group of 75 representatives from 29 performing arts organizations convened to receive the findings of this environmental scan research and to discuss the implications of digital technologies as they are incorporated into performance.

Cosi: Così fan tutte, Canadian Opera Company, Photo by Michael Cooper

1 – How might we share tools?

The inequality of technology distribution is likely to expand as concentration of Canada's population in large urban cores accelerates. The pace of progress in new experimental applications and tools is also increasing, especially as machine learning and data analytics improve. The introduction of 5G systems is likely to happen first in major centers. None of this is inexpensive.

A library system that provides both tools and service support on loan could be a step forward to enable smaller, less financially established or less digitally equipped organizations to participate in the digital transformation of the performing arts. A critical component to ensure success of this approach would be to include a "human library" element; essentially people on loan to provide assistance to those unfamiliar with the workings of new technology.

Roundtable Response

There was strong support for the notion of creating a collaborative space for sharing tools and knowledge across the sector. Despite the reality of competing for share of audience wallet between more established organizations and smaller, nimble and more digitally experimental ones, there was recognition that there is much to be gained from sharing. Digital literacy and confidence in tools is required. Examples of potential approaches included collectively owning software licenses, open-access learning modules, and shared tech help either through online support or in person advising.

2 – How might we work together?

Collaboration is a foundational competency in the current world. While the skills required to "put on a show" are intensely co-operative, the tools to work in a networked fashion are sometimes lagging. Co-working software is not always available, bandwith for applications may be insufficient and technical competency may be challenged, especially for the many organizations in tight financial circumstances. Hierarchy within the arts is also devolving as flatter organizations distribute decision making more fully, sometimes even co-creating with audiences as participatory involvement gains traction.

Transparent approaches to working together must be fostered and the collaboration tools to do so may need to be shared. Network creating and competency sharing efforts are required to build a more resilient sector in the face of so much change. Education for those unfamiliar or uncomfortable with online tools should be a priority.

Roundtable Response

The inter-organizational, cross-disciplinary round table discussions were much appreciated by participants as a first step towards breaking down silos and improving collective sectoral clout. Having an eco-systemic view of the challenges faced could help to reduce the sense of isolation that several people expressed. The need for funding to upgrade aging tech systems was raised, with several organizations expressing the inadequacy of current infrastructure. There is certainly a need to adopt collaboration tools, however several people identified that many first order problems are analogue in nature – finding the time to have structured conversations about how to navigate the rapidly changing context for creating and presenting the arts.

3 – How might we reduce our impact?

While the performing arts provide a means for audiences to understand their place in the world, to thrill to the transcendence of human performance and, sometimes, to escape the day-to-day, it is clear that opportunity comes with a cost. It is no revelation that we are living in times of dramatic environmental upheaval. As in all other sectors, creating, producing, and delivering performances has a carbon footprint that should be measured.

It is possible that the adoption of new technologies, especially those that measure energy use, reduce waste and limit long distance travel could greatly lessen the impact of performances. A method to inventory event emissions and waste, and to share best practice across organizations could create a sector wide improvement.

Roundtable Response

Audiences, and governments, are increasingly concerned about changing behaviors associated with climate change, while considering the implications for the current system. The conversation held regarding reducing carbon footprint was acknowledged to be just a starting point. Travel and touring in particular make large contributions to greenhouse gas emissions that are difficult to avoid. Carefully assessed carbon offsetting practices could be implemented. It was clear, though, that the issue should be authentically and holistically approached to ensure that "greenwashing" approaches are avoided.

Simply turning to digital solutions may not be enough, as the energy consumption of internet based activity is high. Beyond traditional production methods, digital carbon reporting to curtail emission should also be considered.

4 – How might we tell our stories tomorrow?

Perhaps one of the most vexing questions arising is tied to the human cost of adapting to a world transformed by information digitization and automation. In an on demand communications ecosystem, persistently fueled by content creation, ownership of output and likenesses must be navigated in new ways. As operational efficiencies mount with machine learning and robotics, the value of human decision-making and actions must be assessed. These are not easy conversations in a realm that has celebrated the best of what people have to offer as long as stories have been told.

A pro-active and open engagement of the full performing arts ecosystem is required, sooner rather than later, in order to build structural resilience and provide inclusive pathways to change.

Roundtable Response

Beyond the straightforward review of how tech is changing creation of content, little exploration of the implications of automation and performance digitization related to this difficult subject emerged. This conversation likely requires a more nuanced and carefully structured discussion of how all parties can mutually benefit from digital innovation.

5 – How might we bring others to the table?

In many ways, technology is changing our behavior, our values, and our very culture. Its intersection with the performing arts could be more intentional. Fields of learning that have been isolated are ripe for cross-over, and emerging partnerships between computer scientists and artists bring new thinking to both areas. As wealth has shifted to those who innovate in the digital realm and implement new platforms and products, a correspondingly monumental shift in support for creative performance has not yet taken place.

This disciplinary rapprochement should be encouraged to break down silos of knowledge and explore possibilities. Donor cultivation in the technology sector will require serious and objective self-assessment of the relevance of performing arts to a new audience.

Roundtable Response

Several participants related that they were very open to new kinds of collaborations with technology experts, but lacked the network to access partners or the technical competency to have a meaningful dialogue. Not knowing where to start can be debilitating. There was a sense that the technology sector is not interested, especially in the more classical disciplines. However this may be a misguided assessment and more opportunities to dismantle barriers may be in order.

The preceding five questions served as an introduction to these issues and suggest that there is appetite for more discussion across the performing arts. It is recommended that follow up, topic specific round tables with participants from across the performing arts be convened to dig deeper into the implications and possible actionable pathways to change that emerge.

Next Steps

This document is intended as an introduction to sector wide discussion about the implications and potential applications of existing technologies into the performing arts in Canada. In particular, the key opportunities should be considered for piloting on an experimental basis, with a robust assessment of their appropriateness for further adoption.

Horizon Scan

Following a facilitated exploration of the content of this document, a further exploration of emerging technologies likely to enhance and possibly disrupt performing arts over the next 10-20 years will be undertaken. The "Horizon Scan" will seek to identify digital innovations at the front edge of creative and technological practice that may point to new possibilities. This future-focused study is not intended as a predictive exercise, but rather a probe into conceivable, but embryonic, change. A summative report detailing findings will be prepared and shared with the sector.

Alice's Adventures in Wonderland, National Ballet of Canada , Photo by Bruce Zinger

Divider Pages: Image Sources

The divider pages in this document were created by digitally enhancing the colours, reducing, mirroring and repeating images to create patterns. The images below display the original unmanipulated photographs and manipulated patterns.

The Nutcracker
National Ballet of Canada
Photo by Karolina Kuras

The Sleeping Beauty
National Ballet of Canada
Photo by Karolina Kuras

Romeo and Juliet
National Ballet of Canada
Photo by Bruce Zinger

Cosi: Così fan tutte
Canadian Opera Company
Photo by Michael Cooper

Eugene Onegin
Canadian Opera Company
Photo: Michael Cooper

Alice's Adventures in Wonderland
National Ballet of Canada
Photo by Bruce Zinger

The Magic Flute
Canadian Opera Company
Photo by Michael Cooper

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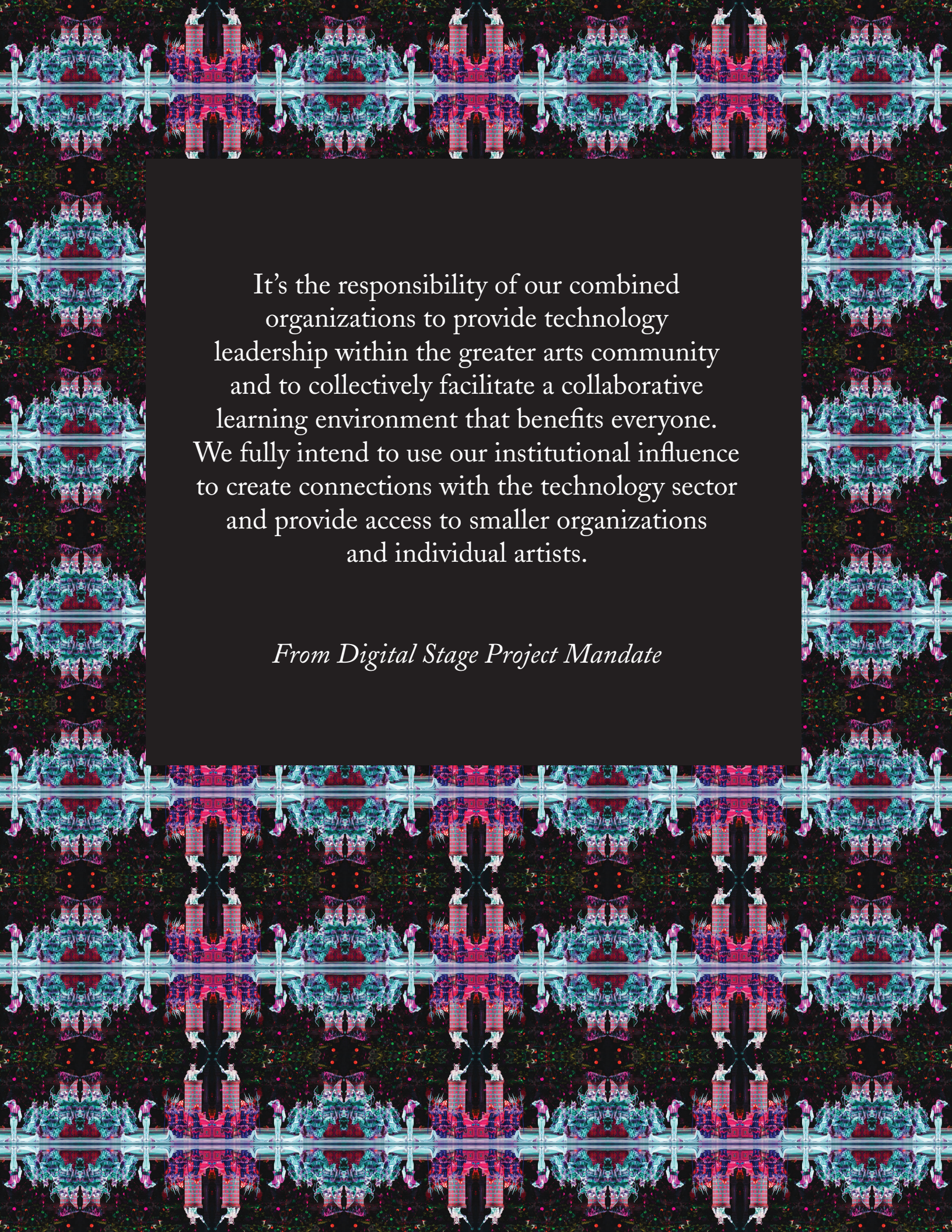

It's the responsibility of our combined organizations to provide technology leadership within the greater arts community and to collectively facilitate a collaborative learning environment that benefits everyone. We fully intend to use our institutional influence to create connections with the technology sector and provide access to smaller organizations and individual artists.

From Digital Stage Project Mandate