Spring 2018

An Investigation of Scenic Visualization Using Virtual Reality During Rehearsal

Cyrus Jian Bonyadi
cbonyadi@rollins.edu

An Investigation of Scenic Visualization Using Virtual Reality During Rehearsal

Cyrus Jian Bonyadi
Department of Mathematics and Computer Science, Rollins College
1000 Holt Avenue, Winter Park, FL 32789
cbonyadi@rollins.edu

Abstract—**In this paper, we discuss the use of virtual reality as a tool for actors during the rehearsal process and assess methods to implement and continue this research in future works. During the rehearsal process, the scenic design is normally introduced to actors close to the end of rehearsals. In introducing a virtual reality environment to train actors, we hoped to help them develop a better understanding of the design at an earlier point in the process. Our investigative pilot study involves two productions in a university theatre, where we render the scenic design of the production for which our actors are rehearsing. After rendering was finished, a treatment group of actors was permitted to explore and practice their movements in the virtual environment using an HTC Vive. The actors were then assessed on their confidence level at different points in the rehearsal process; the findings of this data are presented alongside interview anecdotes from the actors. We end with a discussion of potential struggles and extraneous variables that should be monitored in future studies along with the average trends found in our pilot study.**

CONTENTS

I. INTRODUCTION

In most theatres, scenic construction begins when rehearsal begins, so directors have the opportunity to make adjustments in the construction based on actors' feedback, resulting in fewer reconstruction costs later in the production. In academic theatres, this is especially the case, as the stagecraft department normally houses set pieces during productions, leaving them with little room to store future set pieces. Sets, or the parts of the scenic design separate from the stage itself, are not built overnight, and as a result, they are frequently finished far closer to the opening night of the show than the beginning of rehearsal. As a result, a majority of time during rehearsal is spent with tape outlines and props denoting set pieces. Rehearsing with impressions of an incomplete set may give actors false ideas of the end result, and their rehearsed behavior may be improper or unrealistic. It is thus important for actors to be able to visualize a completed scenic design without its full presence in their rehearsal space.

Various methods of scenic visualization currently exist. In addition to the aforementioned tape outlines and sparse set pieces, small models and rendered images, many of which have human scale, are frequently used. All of these existing methods require some spatial reasoning and imagination on the part of the actor, which can be limiting to those without the ability to visualize themselves in scale. As a result, actors are led to believe their actions are feasible, even when they may result in dangerous behavior.

At the theatre where this research was conducted, the most commonly recounted danger is with regard to changes in elevation. Whether the actors recounted experiences from a platform significantly higher up than anticipated, stairs narrower than usual, or a stage rake (or slope) steeper than expected, actors frequently feel endangered and struggle to continue their blocking unchanged after scenic load-in.

While much of this can be remedied by allowing actors to see and work with unfinished set pieces, the construction of some set pieces does not begin until late in the rehearsal process. Large platforms rarely have intricate detail, so they are frequently postponed until the end of the construction period. Enabling the actors to experience the set in VR would allow them to see and work with unfinished set pieces as though they were finished. Additionally, after the set pieces are loaded into the set, corrections must be made due to functionality or visual aesthetic. Having a pre-constructed set in a virtual environment would allow these alterations during the construction process.

Our case study aims to fill this learning gap by exploring the use of VR in two performances, though both consist of a similar methodology. Both case studies are academic performances on the main stage of Rollins College, The Annie Russell Theatre. Both productions are straight plays (non-musicals) with veteran directors. The first production, *Sense and Sensibility*, took place in the end of Fall in 2017, while the second production, *Women of Lockerbie*, took place in the beginning of Spring in 2018. In our analysis, we address the data separately as well as together, as productions have very few participants, resulting in smaller confidence levels. Additionally, to be able to continue this study on a scale large enough to get statistically confident results, the methods of data collection need to be refined and packaged into a format that is easily distributed.

II. Theatre Background

In the ancient art of performance theatre, modern technology is frequently only implemented to improve the audience experience; however, much of the performance and rehearsal process itself can be improved with technology as well.

Currently, the most commonplace use of technology in theatre is in stage managers' notes, which can be consolidated digitally to improve the ability to search and save time. By contrast, many designers prefer hand-drawn scenic designs to digital renderings, due to their innate artistic value (1). In beginning the implementation of technology throughout the rehearsal process, distaste for digital renderings in scenic and costume designs must be put aside so these designs can be made digitally available. Additionally, certain benefits granted by digital interaction may be useful to help the rehearsal process so that digital renderings become preferred to hand-drawn renderings.

During the rehearsal process, actors are required to practice a number of components of the final production. In the final rehearsals the complete show is practiced, yet directors frequently divide the final work into separate components to develop individual mastery. While **lines**—the content and manner in which words are spoken—must be practiced to near-perfection, **blocking**—the movements that are made during a performance—must also be mastered. While the actors are the performance component of a theatrical production, the final production would visually resemble the first rehearsal if not for the work by the theatre tech crew. The **tech** is all of the components of the final production that are not acting, including but not limited to scenic design, sound design, lighting design, costume design, stage management, and the people who help develop these components. Due to the limited crew size and physical scale of theatres, actors' rehearsals often begin well before the completion of the tech components, which causes both processes to frequently start concurrently. As a result, each component of tech has a **load-in**, or a point in the actors' rehearsal process where the component is integrated, at different times throughout the rehearsal process. Each load-in brings changes to the actors' rehearsal, as each presents new challenges, and the scenic load-in of **set pieces**, or the components of the set, tends to precede the highest number of changes to blocking. The use of VR would theoretically enable actors to experience the different levels, space, and lines of sight prior to scenic load-in, giving them more time to practice their movements and establish spacial awareness for their performance.

III. Related Literature

While VR in theatre has been used for audience interaction and design (2; 3; 4), in our literature overview, we could not find any projects that focus on the use of VR in theatre as a rehearsal tool for actors. By contrast, common uses of VR for surgeons and military personnel allow for practice and technique refinement before engaging in active combat or surgery (5; 6).

The difference in application for rehearsal versus audience participation is noticeable. In a fixed audience perspective, only a single view with facade renderings are needed, so an immense amount of detail can be included. To be used as a rehearsal tool, an entire virtual environment must be rendered, though at the expense of detail, as frame rates are important to maintain.

The utility of VR in these applications is normally dependent on certain conditions in the training process. These conditions include, but are not limited to: the ability to visualize the presence of oneself in a given environment, the ability to interact with a given environment to accomplish tasks, and the proportion of scale required. For example, in the research of historical teaching, an environment may not necessarily be to scale, but if a user is able to see oneself in the environment and interact with it, the information can be clearly conveyed (7). By contrast, in the field of medical research, many obstacles must be overcome like locomotive controls for visualization and interaction (5) and scale and material visualization of tissues in surgeries (8). Thus, it is necessary to capture the components of proper blocking in the VR environment in the theatre. These aspects include body, movement, and space (9), which we portray through repetition of experience in the space, the general space of the scenic design, the architecture and levels of the space, and the portrayal of stage pathways in the VR environment constructed.

While this work focuses on a training exercise, it is in the context of theatre, where VR research abounds. The existing research in the use of VR in theatre generally exists in two categories: (a) allowing an audience to view a production in VR and (b) allowing designers to view their work in VR. For audience use of VR (a), the goal of research has been to maximize the amount of tools and informational resources available without losing environmental detail (7), attempting to enrich the audience experience. In the realm of design (b), particular emphasis has been placed on the ability to visualize costume designs (2; 10). This work develops mesh editing to make costume representation in VR more accurate. This has a similar application to the research discussed in the following work, but does not analyze the impact of costume visualization on the rehearsal process. Additionally, this work is from 2004, when VR technologies were not as portable or efficient as they are today. Much like the use of VR as a rehearsal tool described in this paper, work in the use of VR to better visualize designs prioritized user functionality over detail in the VR environment (1). Aside from costume renderings (2; 10), work has been done to analyze the utility of allowing designers to visualize a design in VR alongside a scale model (3), but this is not directed toward the accessibility of actors, rather directed toward improving designer's abilities.

With the increased technology and decreased cost in headsets (11; 12; 13), a wide variety of VR environments have become available for use and research. Much of the current research is being conducted in the use of VR for teaching (7), military preparations (6), medical research (8; 5), and sports (14). Outside of these professions, little research was found regarding the use of VR for training. Where not used for training, VR is frequently found to be an attempt to improve the performance or experience of a profession. The use of VR in improving the performance or experience of tactile professions and the use of VR as a training tool in less tactile professions both seem to be lacking, alongside its augmented reality (AR) counterpart.

IV. Technology Setup

A. Hardware

Data was collected from actors and stage managers in this investigation. **Actors** were members of the cast who agreed to participate in this study, while the **stage manager** was the head stage manager, or the person in charge of relaying the director's notes and instructions to the tech and actors, for each production. A hard master list was kept by the research team corresponding each actor to a given participant number. As data was collected, the data was anonymized and stored under the participant number. This data was stored on a Rollins Blackboard server. After anonymization, identifiable information was destroyed. The processes for actors and stage managers is outlined below:

In recent years, companies have developed a wide variety of VR tools (15; 13; 11; 12). There are several types of VR tools available for use. Each type of VR tool enable the viewing and interacting with a virtual world. The most commonplace VR tools are those akin to Google Cardboard (13) or Daydream (15), wherein a phone is affixed in front of the eyes and the motion detection on the phone is used to simulate movement in the world. The Google Cardboard is a standalone **head set**, or the component of the virtual reality attaches to your head that enables you to view the virtual world. In addition to the head mount, the Google Daydream also has a **tracker**, which is a hand-held component that is replicated in the virtual world. Both of Google's products are based on a smart-phone platform; however, the HTC Vive (11) and Oculus Rift (12) are based on a computer platform. By using a computer rather than a smartphone, the Oculus Rift and HTC Vive provide a higher level of functionality and more features. Both the Oculus Rift and HTC Vive have two trackers, as opposed to the Google Daydream's one tracker. While all VR tools have the ability for **seated/standing-only** controls, meaning the user is in a fixed position, the HTC Vive has the ability to simulate **room-scale** controls, enabling the user to physically explore a space. For this research, the HTC Vive was selected, as it enables room-scale, which allowed actors to explore the virtual theatre.

While the HTC Vive was selected for its ease of use and room-scale features, a high end computer is required to run an HTC Vive. As a result, the quality and detail of the portrayed design had to be reduced to a minimum essence.

1) HTC Vive Components:

a) **Controller Unit:** This connects to your computer and to the headset via wires and provides the necessary ports to power and operate the Vive system.
b) **Headset (Figure 1):** This headset connects via a wire to the controller unit and mounts on top of your head. This piece of hardware has its location and orientation tracked to provide an image to the user via screens positioned in front of your eyes.

Fig. 1. HTC Vive Headset (11)

c) **Trackers (Figure 2):** These are the hand units with some level of control. The only controls allotted in this research were the ability to teleport from one location to another by activating a laser pointer by pressing the thumb button, and releasing it to be teleported to the laser-pointed location.
d) **Two Lighthouse Towers (Figure 3):** These are IR beacons that detect the relatively location to each other, the headset, and the trackers. This is what separates the HTC Vive from the rest of the

Fig. 2. HTC Vive Trackers (11)

VR units, as it enables room-scale: the ability to explore the simulation.

Fig. 3. HTC Vive Lighthouses (11)

To initialize the HTC Vive, a room-scale (Figure 4) setup must be performed. The implementation of room-scale allows the user's physical movements within a space to be recorded in the virtual environment, meaning they can explore the simulation. The minimum allotted space for room-scale is 2 meters by 1.5 meters. The maximum distance between lighthouse beacons for room-scale in the original HTC Vive is 5 meters (11). In both studies, the same room setup was used, allotting for a 7 feet by 5 feet play area.

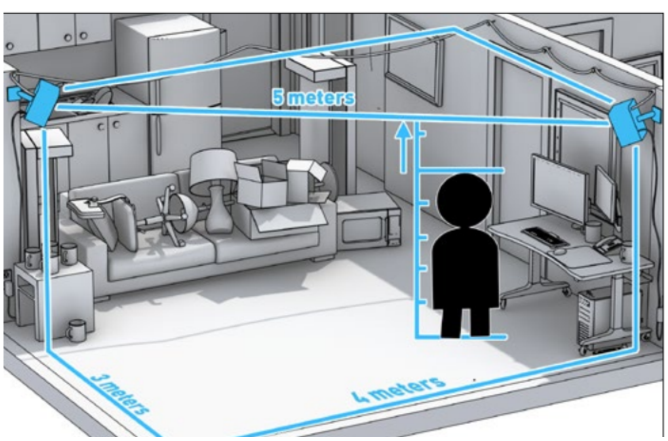

Fig. 4. HTC Vive Room-scale Maximum Setup (16)

B. Software

In order to make the implementation of VR environments ubiquitous for actors, the interaction code used must create tools that are as simple and easy to understand as possible. Several sample pieces of interaction code were written, tested, and modified before a "stock code" from a popular tutorial (17) was chosen for its portability and ease of understanding and use. Using this stock code, a basic interaction user interface (UI) can be created, enabling teleportation and movement tracking with easy-to-follow instructions.

To use this code, the room-scale setup (Figure 4) must be initiated on the HTC Vive. Following this setup, the system is ready for use. This interaction UI features a few common components for VR interaction. A blue grid box is bound to the environment of the room, the parameters of which align to the parameters established in the room-scale procedure of the HTC Vive, enabling users in the environment to know the limits of the real environment they are contained within. Laser pointers are attached to the trackers. The laser pointers place a target on the floor, which, upon release of a trigger, teleports the user to that target, giving them a new space to explore. It has been found that immediate movements like teleportation are less likely to cause motion sickness than gradual movements.

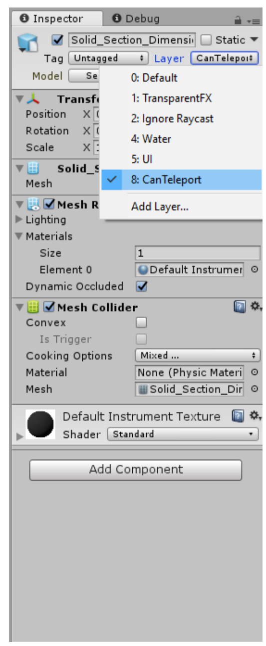

Fig. 5. Object Labels and Components—*Add the Mesh Collider component to objects using the "Add Component" button, then change the "Layer" to "CanTeleport."*

In this study, a .fbx rendering of the scenic design was imported to Unity. The **.fbx rendering** (file format) was created in the computer assisted design (CAD) software Vectorworks (18), which is free to academic institutions. Once imported to Unity through the assets folder, the entire .fbx rendering was given MeshCollider components (Figure 5), a component that enables the recognition of collisions with the aforementioned laser pointer. The labels of the objects corresponding to the floor of the stage were labeled "CanTeleport," a necessary change to enable teleportation. After this, the design was fully rendered in the space. At this point, the "head" and "hands" components were moved inside the theatre and positioned onto the stage, ensuring the simulation began with the user in the correct position.

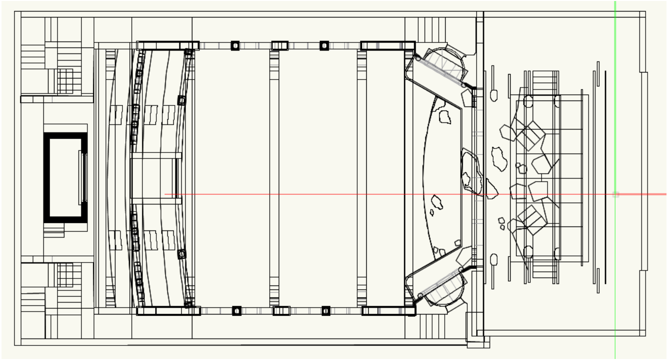

Fig. 6. Floor Plan for *Women of Lockerbie*. Floor plan by Lauren Cushman, Kevin Griffin, and Robert Miller of the Annie Russell Theatre Department at Rollins College.

C. Theatre Renderings

To fully apply VR technology, the existing theatre must be rendered into 3D. This process began with a two dimensional floor plan and elevation. A **floor plan** (Figure 6) is the top-down dimensions of a design, whereas an **elevation** (Figure 7) is a side view of a design.

To render components of the final design from the floor plan and elevation, certain design decisions must be made. Whichever side (floor plan or elevation) contains the most detail should first be rendered in 2D, then, its perpendicular components should be extruded into 3D. An example of part of the rendering process can be found in Figures 7 and 8. In the example of the door frame for *Sense and Sensibility* (Figure 7), the frame and doorway header were detailed in 2D. The individual components of the doorway header were cut out and extruded at different heights, and the final extrusion was rotated to stand on its end. Similarly, the triangle footers to the door frame were rendered from their side, rotated upward, and placed at the front and back of the doorway legs. The resulting 3D product, as seen in Figure 8, can be found in its full rendering in Figure 11 and its corresponding final construction on the left of the stage (stage right) in Figure 12. This final rendering is the component used in the virtual environment for the training simulation.

In addition to the scenic design, the floor plan contains details of the theatre like positioning of banisters, arches, and tech booths. These details are important to render alongside the scenic design so the participants are better able to visualize the space they are working in. Once the non-stage portions of the theatre was rendered and extruded into 3D, photos and measurements of some details in the facility were taken for reference. Without attention to specific patterns, only general shapes and colors were replicated to enable participants to gain a familiarity with the space in the simulation. For example, a tapered extrusion (trapezoidal from the side) was used in lieu of a detailed column capital (Figures 9 and 10). In reducing the amount of detail in the theatre, the simulation runs more fluidly while still maintaining the general aesthetic.

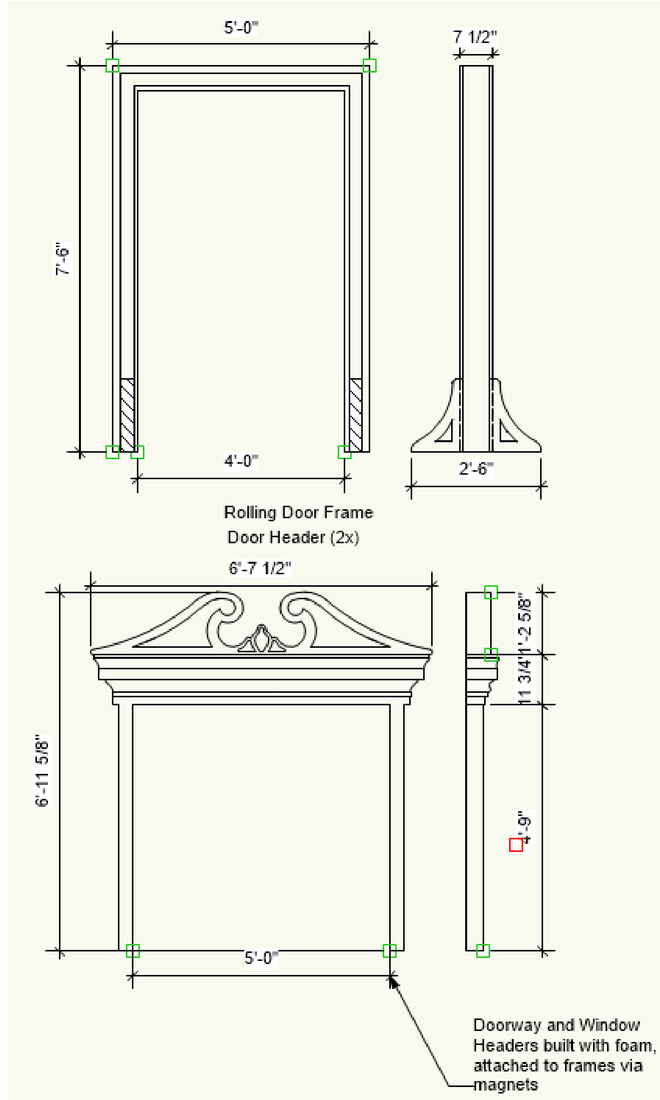

Fig. 7. Door Frame Elevation—*These elevation drawings were collected from the Technical Director (the head member of the tech crew) for Sense and Sensibility. In the production, they are used to scale to help the construction crew build the components of the scenic design. In rendering a virtual environment, they are used to scale to generate the dimensions of a 3D rendering of the scenic design. (Design by Lisa Cody-Rapport, initial rendering by Lauren Cushman, Kevin Griffin, and Robert Miller of the Annie Russell Theatre Department at Rollins College.)*

D. Set Renderings

Once the existing theatre is rendered, the scenes for a given production must be similarly put into the virtual space via Unity. The resulting scenic design and theatre must be exported to a .fbx rendering (Page 4).

For the production of *Sense and Sensibility* (Figures 12 and 11), none of the set pieces were static. As a result, multiple scenic designs were rendered for multiple environments to be experienced. The scenes portrayed were as follows: Ballroom, Barton Park Interior, Cleveland, Cottage, Dashwood Estate, Exterior Townhome, Garden, London Townhome, and the Opening Scene. Participants thus needed to move through several scenes to be fully immersed in the scenic designs involved in their performance. Through the design process,

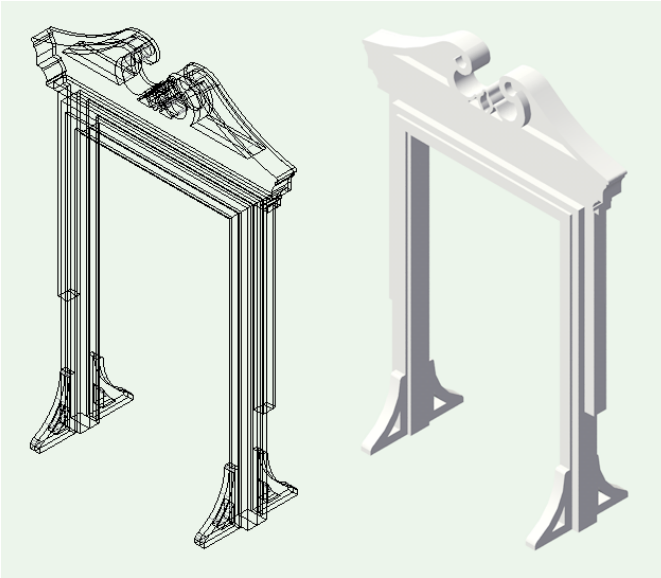

Fig. 8. 3D Door Frame Rendering—*These final renderings of the door frame and doorway header. On the left is a wireframe rendering, which is useful to quickly understand progress during the rendering process. The OpenGL rendering on the right is useful to generate an expectation of what will be seen by the users in the virtual environment.*

Fig. 9. Annie Russell Theatre Column circa 1990s (19)

several changes were made in both position and components of the scenic design: these changed elements could only be replicated in the virtual environment in their original design. For example, some platforms in *Women of Lockerbie* were constructed shorter than originally planned, but the virtual enviroment represented the original height.

In the indoor environments of *Sense and Sensibility*, it was important to pay attention to the smaller details like the sizes and scales of furniture. Specific table height and chair height were crucial in displaying the space to actors, and the ability to see the trackers within the simulation enabled a better understanding of scale.

Fig. 10. Rendered Annie Russell Theatre Column

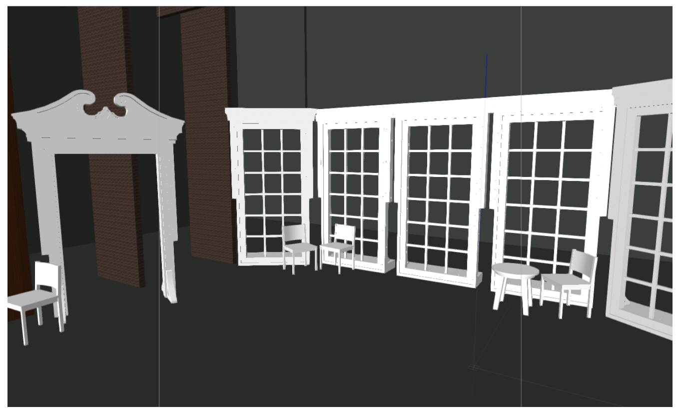

Fig. 11. Rendering for *Sense and Sensibility*

Fig. 12. Stage of *Sense and Sensibility*. Design by Lisa Cody-Rapport (20).

In the outdoor environments of *Sense and Sensibility*, it was important to pay attention to the larger set pieces. Door frames and lattice structures needed to be shown in higher levels of detail, but specific attention to brickwork and ambient lighting was far less important to enable interaction between actors and the set.

For the production of *Women of Lockerbie* (Figures 14 and 13), none of the set pieces moved. As a result, only one scenic design was needed to be rendered for the environment

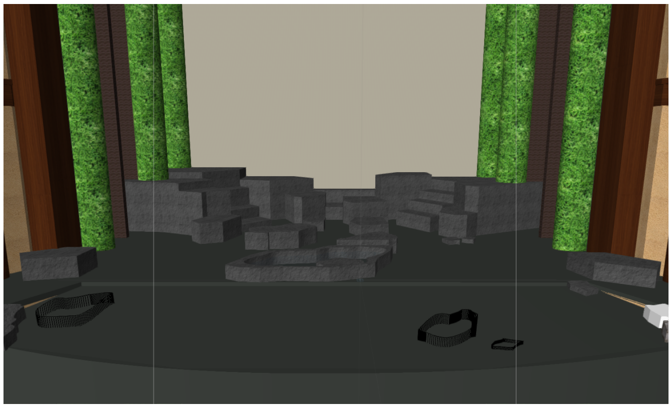

Fig. 13. Rendering for *Women of Lockerbie*

Fig. 14. Stage of *Women of Lockerbie*. Design by Lisa Cody-Rapport (21).

to be experienced. While the realized design had high detail with regard to foliage and texture, it was both necessary and important that the rendering contained less detail. To give actors better awareness of the surfaces that would be designed into the stage and ensure they were not obscured, this detail was removed. Physical changes in conjunction with ambient lighting can make it hard to see where the original scenic design can be found in the final production, but the final product simply builds on the original design. For this reason, rendering from the original design enables actors to recognize the structure of the final product.

V. Study Methodology

A. *Purpose and Timeline*

Much like most academic institutions' theatres, the Annie Russell Theatre typically has about an eight week rehearsal period. In the Annie Russell Theatre, the scenic design is loaded-in to the stage two weeks before the opening of the show (Figure 15), which, as previously mentioned, requires actors to change their movements to adapt to the change in the structure of the space.

As later discussed, it was important that we capture performance surveys (*S1* and *S2*) around both a baseline week (VR Treatment in Figure 15) and the week we wanted to observe

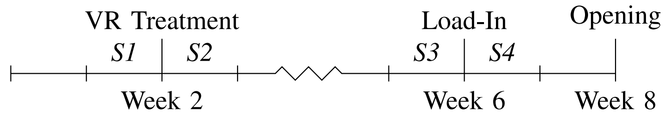

Fig. 15. Study Timeline—A typical production at the Annie Russell Theatre has 8 weeks of rehearsal. This timeline outlines when rehearsal started, when they ended, when the set was loaded-in to the space, and when the VR treatment was given. Additionally, the weeks of survey collection are are labeled *S* followed by the number survey they were

a change in effects (*S3* and *S4* for Load-In in Figure 15). The surveys we collected around each point were used to generate a measure for actors improvement rates.

B. *Participants and Recruitment*

1) Actors: By being a part of *Sense and Sensibility* or *Women of Lockerbie*, actors were recruited into the study. Informed consent was obtained from all participants in accordance with standard *IRB* guidelines.

TABLE I
Participant Demographics

	Treatment 1	**Control 1**	**Treatment 2**	**Control 2**
Male	2	2	0	0
Female	4	2	5	4
≤ 5 shows experience	3	1	3	1
> 5 shows experience	3	3	2	3
< 2 on current stage	4	2	3	1
Veteran to current stage	2	2	2	3
Supporting Role	4	3	3	2
Lead Role	2	1	2	2

Participants for this study had a wide range of experience, both on the current stage and in general, as shown in Table I. One member of the treatment group for *Women of Lockerbie* had participated in roughly twenty productions over eleven years, while another had only participated in three productions over four years. Additionally, one member of the control group for *Sense and Sensibility* had participated in roughly forty productions over fifteen years, while another had only participated in four productions over five years. This variance was simplified for ease of representation in demographics, but the ability to visualize a scenic design from tape marks on the floor could certainly have correlation to years of experience among other factors.

2) Stage Managers: By being a part of *Sense and Sensibility* or *Women of Lockerbie*, the lead stage manager was recruited into the study. Informed consent was obtained from all participants in accordance with standard *IRB* guidelines.

C. *Instruments and Data Collected*

1) VR Treatment: Roughly half of the participants were subjected to the VR simulation of the scenic design. To expose actors to the treatment, the VR environment was set up in a private room in the theatre. During a given rehearsal period, actors were asked to step aside and participate in the VR until the treatment group had experienced the environment. Many actors had never experienced VR before, so verbal guidance was given until they found their bearing.

In the first production, there were many scenes with different arrangements of set pieces, so a list was made of all of the actor's scenes. They were allotted a minimum of two minutes, and a maximum of five minutes to explore per each scene. A prompt was given to move through their blocking during their allotted time, which was heeded by some.

In the second production, only one scene existed, so actors were permitted as much time as they preferred, though all actors took between four and five minutes in the space. In their time, some practiced blocking, while some focused on visualizing the set on the stage for a later date.

2) Spatial Reasoning Test: For the first piece of data collected, participants were asked to take a spatial reasoning test based on questions sampled (22; 23). Data on both the number of correct responses and time to complete the test was taken. This data was initially intended to be collected at both the beginning and end of the rehearsal process, but in the end, the data was not included in our analysis.

3) Entrance and Exit Interview:

a) **Entrance Interview:** For the first show, this was a verbal interview that took roughly 5 minutes per participant. For the second show, this data was collected via Qualtrics survey. The electronic survey interview is preferred both for the sake of correct data collection and time constraints. This interview consisted primarily of the following questions:

i) How many years have you been acting?
ii) How many productions have you been in? At this institution? On this stage?
iii) What is your experience in the way load-in impacts your blocking?
iv) What do you know about virtual reality?

1) **Exit Interview:** Much like the entrance interview, participants were asked questions, and the first and second data collections were verbal and electronic, respectively. Additionally, in the first interview process, a final spatial reasoning test was conducted. No spatial reasoning test was conducted at the end of the second data collection.

4) Surveys: 7 point Likert Scale survey data was collected before VR treatment, after VR treatment and before scenic load-in, and after scenic load-in for both productions. These questions focused on self inquiry with regard to current performance, peer support, director support, and personal development (Appendix B).

In designing our experiment, we sought to minimize our disturbance to the rehearsal process while still capturing meaningful data. As a result, these surveys were collected over the course of a three-day period, and were encouraged to be recorded at a point that did not resemble either a high or low point of stress.

5) Journals: A copy of the stage managers' journals was transcribed for quantitative data about actors' notes, and the data was stored on the Blackboard server. The initial intention was to quantify the number of notes actors received relating to blocking, measuring a difference between the number of notes received after scenic load-in. These notes were not measured, but in future work, we hope to code and analyze the specific notes received by each actor at different points in the rehearsal process.

VI. Data and Analysis

To collect training data, certain precautions must be taken. Due to the fact people may have different internalized confidence levels, a single data point is insufficient to collect. Rather, we must collect two data points to change in improvement. As a result, we collected data before and after both the treatment and the load-in process. A sample response for the treatment response can be found in Table II.

A. Sample Raw Survey Data

TABLE II
SAMPLE SURVEY RESPONSE **BLOCKING** DATA FROM CONTROL GROUP PARTICIPANT 80 BEFORE AND AFTER THE TREATMENT PERIOD

Statement	Intake Response	Response After Baseline Week	Difference
During rehearsal, I feel comfortable moving on stage in front of others.	3 (Strongly Agree)	2 (Agree)	-1
I can easily visualize the set, even when I'm not on the stage.	2 (Agree)	1 (Somewhat Agree)	-1
I could be doing better in blocking. (Inverted)	0 (Undecided)	-1 (Somewhat Agree)	-1
I am better able to understand what the set looks like based on tape outlines.	2 (Agree)	0 (Undecided)	-2
Average	1.75	0.5	-1.25

Each participant's average change in score for each category of questions was recorded as the true data points. This final data was averaged between all participants, and the variance was taken. These data points, their average, and their variance are representative of the improvement for each group over a typical rehearsal week (VR Treatment, where the treatment group receives treatment and the control group does not) and the week of scenic load-in. These points of data are represented in the following section. It should be noted that these data points may be susceptible to the previously mentioned issues, as some actors may improve at a faster or slower rate than others.

Limited by time and financial resources, this study suffered from a lack of participants. While both productions had more participants than the typical eight, there were not enough to make statistically significant claims. In future work, many more productions should be used to find more conclusive results.

Additionally, not only do most productions only have a few actors, but without financial motivation, actors are inclined to suspend or terminate their participation prematurely. At two points in survey collection, up to 3 data points were missing from the control groups, accounting for the higher control variances (Table IV). Fortunately, only two participants were lost from *Sense and Sensibility* and only one was lost from *Women of Lockerbie*. The wide variance in the control group of *Women of Lockerbie* is due to a single participant who was particularly confident in their final abilities: a common problem in studies with small samples. In future studies, some financial compensation should be assured so that all participants complete the study.

B. Quantitative Analysis

TABLE III
DIFFERENCES IN AVERAGES OF PERCEIVED CHANGE IN **BLOCKING** ABILITY

	Treatment	Load-In	Improvement
Both Shows Combined	-0.250	0.361	0.611
	0.125	*0.250*	*0.125*
Sense and Sensibility	-0.500	0.214	0.714
	0.000	*0.167*	*0.167*
Women of Lockerbie	0.063	0.875	0.812
	0.500	*0.500*	*0.000*

**VR treatment group data above italicized control group data.*

Due to our small number of participants, our values cannot be statistically significant; however, we present a statistical analysis of the data available. We present an analysis on the combination of both shows in Table III in an attempt to mitigate non-blocking factors in the rehearsal process. The data could be combined as the values of measured improvement in blocking data between both shows were similar (Appendix A): increasing, lower starting rate for treatment group than control group, higher ending rate for treatment group than control group.

The seven point Likert scale survey questions in Appendix B were combined and averaged between the two productions. The questions were first aligned so positive outcomes were rated a seven, while negative outcomes received a one. Then, the questions were categorized into "Blocking," "Lines & Performance," "Characterization," "Director Relationship," or "Peer Relationships." The results of this data are indicative of a participant's perception of their own abilities in each category.

The difference between participants' responses before and after treatment were taken and averaged to determine an improvement amount, along with the difference between participants' responses before and after scenic load-in. These improvements were the final analyzed data points as they show the change in an actor's self perception regardless of different overall confidence levels between participants. This data suggests the impact of each rehearsal period on the participants. We use the "Treatment" value as a measure of a typical improvement week for each participant and the "Load-In" as a measure of how the actors improved over scenic load-in.

The final "Improvement" value in the fourth column of Table III is the difference between the standard rehearsal improvement rate and the improvement rate over the period of scenic load-in. To attain this value, we subtracted each participant's improvement amount over the "Treatment" period from their improvement amount over the "Load-In" period. This is our final value of measurement, as it may indicate how participants in both groups are affected by scenic load-in compared to a typical rehearsal period.

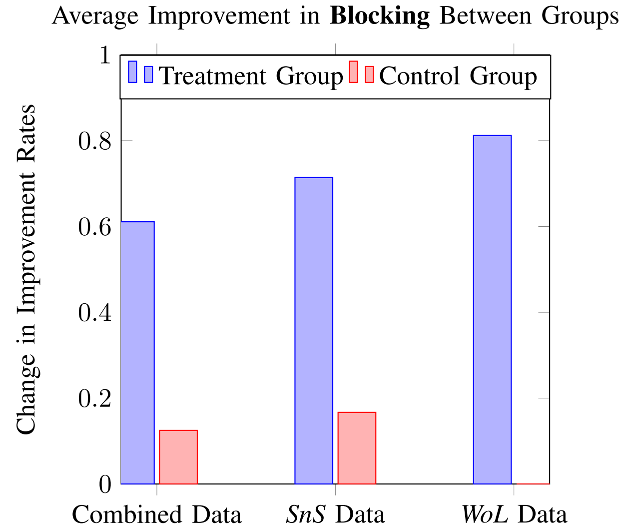

Fig. 16. A bar chart representation of the "Improvement" values found in Table III. These are used to measure the difference in an actor's improvement in the week surrounding scenic load-in and an actor's improvement in a typical week.

As can be seen in Figure 16, on average, the treatment group improved more over the scenic load-in process than the control group. While both the treatment and control group showed an average increase in confidence in blocking performance after load-in, those in the treatment group averaged a higher increase in their rate of blocking improvement than those in the control group. This improvement can be seen in the overall performance category as well, with those in the treatment group maintaining some improvements throughout the rehearsal process.

TABLE IV
VARIANCE OF PERCEIVED CHANGE IN ABILITY OF **BLOCKING**

	Treatment	Load-In	Improvement
Both Shows Combined	0.438	0.381	0.409
	0.854	*1.432*	*1.143*
Sense and Sensibility	0.563	0.030	0.296
	1.188	*0.083*	*0.635*
Women of Lockerbie	0.182	0.599	0.391
	0.333	*1.792*	*1.063*

**VR treatment group data above italicized control group data.*

The averaged blocking data shows a higher rate of improvement for the treatment group in both studies, with relatively low variance (Table IV), given the small sample size. With regard to characterization, both groups struggled to improve during the load-in process, with a similar rate of improvement (or lack thereof), showing some consistency in the overall performance changes of our participants. While director relationships have some variance, peer relationships improved for the treatment group but worsened for the control group (full data in Appendix A). While this data is not statistically significant due to our small number of participants, the descriptive statistics warrant further investigation with a larger number of participants. Moreover, the qualitative data found in the next section seems to support the aforementioned observations.

C. Qualitative Analysis

Our qualitative data comes from both the entrance and exit interviews, and the discrepancies between the groups in this data are presented in the following analysis.

1) Entrance Interview: The entrance interview included questions which sought to determine both participants' past cases where scenic visualization was difficult and the level of experience participants had with VR. Participants frequently cited instances with changes in elevation as the most difficult blocking they had experienced. Additionally, only three participants had extensive experience with virtual reality, and most just thought it was "really cool." The interview process also revealed that even within the participants who had experience with virtual reality, only one participant had used the HTC Vive (11), rather than a fixed position virtual environment tool like the Oculus Rift (12) or Google Cardboard (13).

When asked about past blocking experiences, several participants in both productions made mention of instances where key set pieces were "narrower" and/or "higher" than expected. In the interviews for *Sense and Sensibility*, Participant 64 discussed an instance with a "2 story set" where "the stairs were extremely thin due to how large [their] stage was, so there were like 18 girls who, every day, had to practice running up the stairs," as "tape did not help" the actors visualize how "dangerous" the stairs would be after they were installed. Similarly, in the interviews for *Women of Lockerbie*, Participant 10 discussed a far less dangerous instance where their theatre "borrowed some [smaller] set pieces and built the larger ones," so "having to imagine where trees would be was difficult, especially since the trees were much larger than anticipated." These stories were common, with seven other participants sharing similar sentiments.

When asked what impact using VR would have on the rehearsal process, all but three participants thought it would help. Only one participant opposed the use of VR, Participant 75 of *Women of Lockerbie*, who expressed a fear that VR "might give [them] false pretenses on what the set will actually look like." Similarly, Participants 24 of *Women of Lockerbie* and 96 of *Sense an Sensibility* remained skeptical, because, as Participant 24 said, "you cannot practice walking on [platforms] or running on them, and that is half the battle." As with most other participants, Participant 58 in *Sense and Sensibility*, who thought VR would help, expressed they believed it would allow them to "start to make more physical choices more comfortably and...make realistic physical choices" throughout the process, a similar sentiment to the motivation behind this research.

2) Treatment Response: During the treatment processes, as participants practiced their blocking, they were encouraged to verbalize their reactions. For *Sense and Sensibility*, participants were surprised by the look and size of the doors and windows they would be moving as part of their blocking. Similarly, in *Women of Lockerbie*, participants who had blocking involving the rearmost platforms were surprised to learn how high and narrow the platforms were, readying them to confront this challenge before the set was loaded into the space.

3) Exit Interview: The exit interviews included questions that sought to determine the difficulty of blocking in the current production, the utility of VR for the treatment group, and whether the treatment group would like to use the technology again.

For *Sense and Sensibility*, Participant 54 in the treatment group said she did not see the relationship between the VR environment and the actual scenic design until load-in, when "it just clicked" and she "felt like [she] had been [on the set] before."

A few participants in both productions also discussed frustrations with the directors' desires to change large components of blocking up to three times throughout the production, as said by participants 10 and 53 in *Women of Lockerbie* and participant 77 in *Sense and Sensibility*. In both productions, the sentiment of frustration with blocking changes came more frequently from those in the control group than from those in the treatment group, with three of the eleven participants in the treatment groups and six of eight in the control groups expressing difficulties with blocking throughout the rehearsal process. This disparity is made clear when participants were asked about the most difficult part of rehearsals for their show, between Participant 44 in the control group of *Sense and Sensibility* expressing "blocking in this show was a [obscenity] nightmare" and Participant 89 in the treatment group of *Sense and Sensibility* saying blocking "was not that bad."

Finally, when asked for additional comments, a majority of the participants in the treatment group expressed a strong desire to use VR again in future productions. For example, participant 89 in the treatment group for *Sense and Sensibility* expressed "I would love to do that with every production I think that would be so useful, especially if there were a set that had platforms."

4) Overview: In addition to the aforementioned interviews, to determine the unique difficulties in each show, participants were asked to rank their past experiences during productions in the entrance interview and the experiences with the current production in the exit interview. Participants were asked to rank blocking, director relationships, peer relationships, line delivery, characterization, and academic/external relationships in order from most to least difficult task of the rehearsal process. As a result of our small number of participants, no statistical significance can be determined, but in the beginning of both productions, the majority of participants ranked blocking at fourth (out of six) or below, while in the exit interview of both productions, the majority of participants ranked blocking as the most difficult task of rehearsals. To nearly all participants, the blocking in both of these shows was uniquely challenging, demonstrating the potential for an increased effect of the VR treatment. While the other variables shifted around, these shifts and the difficulty of blocking are reflected in our quantitative data and exit interviews.

VII. Discussion and Conclusions

In this paper, we discuss the actor's use of VR for scenic designs to help actors better prepare for their movements in a production, which may increase the use of digital renderings involving scenic designs. To this end, we discuss methods to analyze and test the benefit associated with a VR experience in the environment, including an analysis of a pilot study where use data was collected. Rather than investigating the impact on the creative process involved with digital designs, we are interested in the application of a technology to the benefit of the actors being better able to understand the stage before its final construction. As the training application is a relatively novel use of VR, there are still larger questions that our work attempts to present some solutions to:

1) How can the benefits of different training methods be analyzed and compared?
2) How can an actor's blocking (or motions on a stage in different scenes) be quantified?
3) When are the effects of VR as a training process realized for trainees?

Several attempts were made in this work to create templates to quantify answers to these questions. While the primary tools for data analysis were Likert scale self-assessment questions, we collected stage managers' notebooks, self-assessment on notes, and spatial reasoning tests were conducted and received. In future work, the stage managers' notebooks could be coded to assess the frequency of blocking notes given by the director per participant throughout the rehearsal process, as stage managers are frequently required to transcribe every note given by the director. Self-assessment on the notes received by the director can be checked against the stage managers' notebooks and may help point out inconsistencies in self-assessment. Additionally, rather than simply accounting for typical self-perception, a control variable going forward could be their spatial reasoning score. Those with higher spatial reasoning skills may be better able to visualize a scenic design without VR, whereas those with lower spatial reasoning skills may benefit more from VR as a rehearsal tool.

Due to having a lower number of participants, significant differences in our data cannot be measured. Any findings in this paper are limited to this investigative pilot study, and far more participants would be needed to reach any statistical significance.

While not statistically significant, our case study showed, on average alone, the treatment group handled the process of load-in with a higher comparative rate of confidence than our control group. This quantified data aligns with the qualitative data from the interviews conducted at the end of rehearsals, showing an improvement in blocking by the treatment group over load-in despite the perceived elevated difficulty of blocking in both performances studied. Additionally, participants in the VR treatment group both enjoyed the experience and felt it helped them, wishing to use the VR environment in future productions to help acclimate them to the scenic design at an earlier point in the rehearsal process.

While this work has obstacles, it is important to measure the effectiveness of using different technologies to improve performance in a wide variety of fields. While VR has been used for training purposes in high-stakes, hands-on fields and has been able to improve client experience in service fields, there is little research in the effectiveness of VR as a training tool in fields like theatre.

VIII. Future Work

Should this work be continued, several changes should be made to the data collection process. The interviews should be done with detailed forms to reduce transcription time or technology cost of automated transcription. Spatial reasoning tests should not be recorded, as the data could not be reasonably correlated to any other pieces of data. Finally, stage managers' notes should be used for more quantitative data.

Our Likert scale survey categories were established to help isolate the dependent and independent variables from possible extraneous variables. These extraneous variables like peer and director relationships should be moderated in future studies, as they may amplify or suppress the effects of the treatment rather unpredictably. Additionally, certain variables are expected to show little correlation, like characterization, so these should be monitored in future studies as indicator variables of data validity.

Collecting more data for statistical significance, proves difficult when working with theatre. Most shows only cast around eight people, so one solution would be to collect data from far more shows. While we collected data from two non-musical shows in a proscenium style stage, data should be collected from many genres of productions on multiple types of stages. Another solution going forward would be to collect more baseline points of data. In our study we only used VR treatment at one point with two surveys around that point. If we had another weekend of VR treatment after *S2* (Figure 15) with another survey in the following week, we could create a better baseline to measure the improvement rate over time, though this requires far more collaboration with the theatre and its personnel. Should more data be collected, we believe more conclusive results on the effectiveness of a VR environment as a training tool for actors during the rehearsal process.

Should the continuation of this work demonstrate a significant improvement in the ability for actors to improve their blocking abilities, VR training may improve more than average theatre performance. The use of virtual reality as a rehearsal tool may reduce actors' injuries and enable theatres to reduce their rehearsal period, allowing for more shows, more actor experience, and more profitability. Additionally, if VR is effective for training in theatre, it may also be effective for other less hands-on fields.

IX. Acknowledgements

Special thanks to the directors of *Sense and Sensibility* and *Women of Lockerbie* at Rollins College during the 2017 to 2018 academic year for the opportunity to conduct this research, to the casts of *Sense and Sensibility* and *Women of Lockerbie* for their time and willingness to use virtual reality and participate in weekly surveys, and to the technical director of the Annie Russell Theatre for allowing access to the show designs. Additional thanks to Associated Design & Construction, Inc. for hardware funding.

Sincerest gratitude to Eugenia Quintanilla from New College of Florida for guidance with analysis of and formulation of questions for longitudinal data, and to Amberley Clark for helping me refine my survey questions.

APPENDIX A
COMPLETE DATA TABLES

TABLE V
DIFFERENCES IN AVERAGES OF PERCEIVED CHANGE IN ABILITY FOR ALL DATA

	Treatment	Load-In	Improvement
Blocking	-0.250	0.361	0.611
	0.125	*0.250*	*0.125*
Lines & Performance	0.185	0.074	-0.111
	0.583	*-0.083*	*-0.667*
Characterization	0.259	-0.333	-0.593
	0.500	*0.083*	*-0.417*
Director Relationship	0.222	-0.167	-0.389
	0.625	*-0.063*	*-0.688*
Peer Relationships	-0.244	0.200	0.444
	0.250	*-0.050*	*-0.300*

**VR treatment group data above italicized control group data.*

TABLE VI
DIFFERENCES IN AVERAGES OF PERCEIVED CHANGE IN ABILITY FOR *Sense and Sensibility*

	Treatment	Load-In	Improvement
Blocking	-0.500	0.214	0.714
	0.000	*0.167*	*0.167*
Lines & Performance	0.133	-0.238	-0.371
	0.556	*-0.444*	*-1.000*
Characterization	0.067	-0.381	-0.667
	0.222	*-0.111*	*-0.333*
Director Relationship	0.250	0.036	-0.214
	0.583	*-0.083*	*-0.667*
Peer Relationships	-0.440	0.057	0.497
	0.200	*0.000*	*-0.200*

**VR treatment group data above italicized control group data.*

TABLE VII
DIFFERENCES IN AVERAGES OF PERCEIVED CHANGE IN ABILITY FOR *Women of Lockerbie*

	Treatment	Load-In	Improvement
Blocking	0.063	0.875	0.812
	0.500	*0.500*	*0.000*
Lines & Performance	0.250	1.167	0.917
	0.667	*1.000*	*0.333*
Characterization	0.500	-0.167	-0.667
	1.333	*0.667*	*-0.667*
Director Relationship	-0.125	0.750	0.875
	-0.250	*0.000*	*0.250*
Peer Relationships	0.000	0.700	0.700
	0.400	*-0.200*	*-0.600*

**VR treatment group data above italicized control group data.*

APPENDIX B
PERIODICAL SURVEY

7 pt. Likert Scale

1) Production Assessment
   - During rehearsal, I feel comfortable moving on stage in front of others.
   - I can easily visualize the set, even when I'm not on the stage.
   - I am confident in my performance of this role.
   - I am performing at a presentable level.
   - I am comfortable using my props in character.
   - I fear the production quality may be compromised by the performance of my peers.
   - I fear something may go critically wrong in each run of the show.
   - I feel supported by fellow actors.
   - I wish I got more feedback relating to blocking.
   - I could be doing better in blocking.
   - I wish I got more feedback relating to line delivery.
   - I could be doing better in line delivery.
   - I am off book.
   - I understand the subtext of my lines.
   - I know my character well enough to anticipate what they may hypothetically say.
   - I can socialize with others in the cast.
   - Other actors understand how I feel.
   - Members of the crew are willing to assist me in any way.
   - I am better able to understand what the set looks like based on tape outlines.
   - I have learned skills that I will apply to the rest of my career.
2) I receive a lot of notes relating to...
   - line delivery.
   - timing of lines.
   - fluidity of blocking.
   - accuracy of blocking.
   - timing of blocking.
   - subjects I don't understand.
   - character representation.
   - stage presence.
   - good performance technique.

References

[1] Z. Hewitt, "Production design artists debate hand versus computer drafting," 2017. http://variety.com/2017/artisans/production/production-design-artists-1202584709/ [Accessed: May 2, 2018].

[2] M. Honauer and E. Hornecker, "Challenges for creating and staging interactive costumes for the theatre stage," in *Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition*, C&C '15, (New York, NY, USA), pp. 13–22, ACM, 2015.

[3] Y. Horiuchi, T. Inoue, and K.-i. Okada, "Virtual stage linked with a physical miniature stage to support multiple users in planning theatrical productions," in *Proceedings of the 2012 ACM International Conference on Intelligent User Interfaces*, IUI '12, (New York, NY, USA), pp. 109–118, ACM, 2012.

[4] G. Reitmayr and D. Schmalstieg, "An open software architecture for virtual reality interaction," in *Proceedings of the ACM Symposium on Virtual Reality Software and Technology*, VRST '01, (New York, NY, USA), pp. 47–54, ACM, 2001.

[5] T. Ohshima, H. Ishihara, and R. Shibata, "Virtual isu: Locomotion interface for immersive vr gaming in seated position," in *Proceedings of the 2016 Virtual Reality International Conference*, VRIC '16, (New York, NY, USA), pp. 2:1–2:4, ACM, 2016.

[6] J. Jerald, J. Joseph J. LaViola, and R. Marks, "VR interactions," vol. '17, 2017.

[7] F. Pittarello, "Experimenting with playvr, a virtual reality experience for the world of theater," in *Proceedings of the 12th Biannual Conference on Italian SIGCHI Chapter*, CHItaly '17, (New York, NY, USA), pp. 16:1–16:10, ACM, 2017.

[8] Z.-W. Chen and F. Goulette, "Fast computation of soft tissue deformations for real-time medical training simulators: The heml method and open-source software," in *Proceedings of the 2016 Virtual Reality International Conference*, VRIC '16, (New York, NY, USA), pp. 1:1–1:2, ACM, 2016.

[9] E. A. Novak and D. Novak, *Staging Musical Theatre*. Betterway Books, 1996.

[10] D. Koutsonanos, K. Moustakas, D. Tzovaras, and M. G. Strintzis, "Interactive cloth editing and simulation in virtual reality applications for theater professionals," in *Proceedings of the 5th International Conference on Virtual Reality, Archaeology and Intelligent Cultural Heritage*, VAST'04, (Aire-la-Ville, Switzerland, Switzerland), pp. 37–46, Eurographics Association, 2004.

[11] HTC, "*Vive*," 2018. https://www.vive.com/us/ [Accessed: May 2, 2018].

[12] Oculus, "*Rift*," 2018. https://www.oculus.com/rift/ [Accessed: May 2, 2018].

[13] Google, "*Cardboard*," 2018. https://vr.google.com/cardboard/ [Accessed: May 2, 2018].

[14] Y. Huang, L. Churches, and B. Reilly, "A case study on virtual reality american football training," in *Proceedings of the 2015 Virtual Reality International Conference*, VRIC '15, (New York, NY, USA), pp. 6:1–6:5, ACM, 2015.

[15] Google, "*Daydream*," 2018. https://vr.google.com/daydream/ [Accessed: May 2, 2018].

[16] D. Laverde, "https://medium.com/@dariony/room-scale-vr-using-unity3d-da39919d1063," 2018. https://medium.com/@dariony/room-scale-vr-using-unity3d-da39919d1063 [Accessed: May 2, 2018].

[17] E. Van de Kerckhove, "HTC vive tutorial for unity," 2016. https://www.raywenderlich.com/149239/htc-vive-tutorial-unity [Accessed: May 2, 2018].

[18] Vectorworks, "Vectorworks student," 2018. http://www.vectorworks.net/education [Accessed: May 2, 2018].

[19] R. Walton, "Annie russell theatre," 2018. http://lib.rollins.edu/olin/Archives [Accessed: May 2, 2018].

[20] T. Firriolo, "Sensibility0672[digital photo]," 2018. A.R.T. Photograph Collection. Winter Park, FL.

[21] T. Firriolo, "Lockerbie393[digital photo]," 2018. A.R.T. Photograph Collection. Winter Park, FL.

[22] 123Test, "Spatial reasoning test," 2018. https://www.123test.com/spatial-reasoning-test/ [Accessed: May 2, 2018].

[23] Fibonicci, "Spatial reasoning test," 2018. https://www.fibonicci.com/spatial-reasoning/test/ [Accessed: May 2, 2018].