Abstract

Ballet and Modern dance are two very different styles with interconnected histories.

Ballet was originally founded in the fifteenth century and started to take form in France in the seventeenth century under the rule of King Louis XIV. Ballet emphasized technique as a means to achieve aesthetic perfection. Modern dance was a style that emerged in the early twentieth century as a rebellion against the strict criterion of ballet. The focus of Modern dance was on personal expression instead of the technical focus of Ballet. This thesis compares the styles of Ballet and Modern dance to one another based on a set of Laban notated scores. Laban notated scores are inputted digitally through LabanWriter, and then run through a series of programs in R to extract information regarding the overall make-up of the scores and the level of repetition of the dances. It is expected that this analysis will support the comparisons made between Ballet and Modern: that ballet will have more repetition and modern will have a more random make-up of symbols. This thesis combines the fields of statistics and dance, and the methods used can be applied to other styles of dance for further research.

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Introduction

Ballet and Modern are two very different styles of dance. Ballet is a traditional dance style that started in the fifteenth century (Cohen & Dance Perspectives Foundation, Genres of western theatrical dance, 1998). Ballet has rules that govern the movements that are allowed, how those movements are executed, and the way the dancers look. Aesthetic perfection is the goal that ballet strives to achieve which is why every movement has a rule to be followed. Modern, however, is a style that emerged in reaction to and as a rebellion against the strict structure of ballet during the early twentieth century (Cohen & Dance Perspectives Foundation, Genres, 1998). Modern dance is a more expressive dance style that emphasizes personal experience rather than achieving perfection. Modern dance does not have all of the rules that Ballet dance has because Modern dancers do not want to put restrictions on movement. Ballet and Modern are connected because Modern emerged from Ballet. The two different dance styles existed within the same culture but Modern was a reaction to the rules imposed on Ballet dancers. The interconnected history of the two styles is a reason why Ballet and Modern are often compared to one another. A dancer may compare the two styles by his or her personal experience, and a dance critic may compare the two styles through observation.

Resources that can be used when studying any style of dance are the different forms of dance notation. Labanotation is a well-established dance notation technique that notates the movement in a dance piece through the use of symbols being placed on a staff. Rudolf Laban created Labanotation in the late nineteenth century as a universal way to record movement (Cohen & Dance Perspectives Foundation, Labanotation, 1998). LabanWriter is a computer software developed by Ohio State University that allows for Laban notated scores to be digitally drawn and stored (Ohio State University Department of Dance). LabanWriter produces a

corresponding output file with information about the digital score. An example of Labanotation can be seen in Figure 1, and an example of a LabanWriter Output file can be seen in Figure 5.

I propose that the output files for the Laban notated scores can be used as a way to compare the two dance styles of Ballet and Modern dance. Using mathematics, computer science, statistics, and repetition analysis, comparisons can be made between ballet and modern in a new way using quantifiable and objective data, rather than subjective comparisons made through observation. My hypothesis is that through the analysis of the Laban notated scores it will be clear that ballet is more repetitive and requires more footwork, and modern has less repetition and less footwork.

This thesis will contribute to the field of mathematics by building a bridge between math and dance and incorporate the use of statistical analysis and computer programming in dance in a way that has not been done before. Contributions will also be made in the dance field by developing a way to compare dance based on the actual structure of the dance and not just on observations. This method of comparing different dance styles will give better understandings of the more prominent movements of the different styles and can be used for further analysis of dance movement. The development of a computer program that takes LabanWriter files and extracts information about the choreographic works from the Laban notated score opens up the ability for other dance researchers to perform their own analyses on dance from Laban notated scores. Using the Laban notated scores of different Ballet and Modern pieces, I will compare the Ballet works "Dance of the Little Swans" from *Swan Lake* and "Variation 6 – The Lilac Fairy" form *Sleeping Beauty* to the Modern works "Fire Dance," "Brahms/Waltz NO. 15," and "Post Meridian" through the use of repetition and statistical analysis.

Background

Ballet

  I. **History**

     Ballet emerged during the renaissance period of the fifteenth century as a result of the combination of all art forms as a means of entertainment. The original purpose of Ballet was to be performed in front of royal courts for the entertainment of the royalty. The goal of Ballet was to strive for aesthetic perfection in order to be worthy enough for the eyes of the royal viewers. In order to achieve perfection, performers danced with grace, elegance, and proper posture.

     During the seventeenth century, Ballet made its way to France where King Louis XIV took an interest in the dance style. King Louis XIV was a Ballet dancer himself and starred in many ballets throughout his life. He wore extravagant costumes with gold and jewels. Louis XIV also wore high heeled shoes to make himself appear taller and to give him longer lines throughout his body. His interest in Ballet made the dance style more prominent in French culture, and brought lavish costumes and the use of high heeled shoes to the art form. The high heeled shoes that Louis XIV wore developed into pointe shoes which are the shoes that female dancers wear to dance on the very top of their toes in order create that perfect line down the legs that do not break at the feet. During the reign of King Louis XIV Ballet transitioned out of the royal courts and into a concert dance form, or a dance that is performed on a stage for a general audience. When Ballet transitioned to a concert dance form the focus of Ballet

was no longer on the royal courts and the audience they were performing for, but instead the focus was on the skill and technique of the dancers themselves.

II.   **Substyles**

Ballet is classified into three different substyles: romantic, classical, and neoclassical. Romantic ballet is used to define ballet that occurred during the nineteenth century. This substyle explored interest in mythical and supernatural ideas. Romantic ballets had mysterious storylines and the movement quality was often very soft and weightless. The dancers often appeared to float across the stage in their long tool tutus.

In the twentieth century, classical ballet emerged. Classical ballet had a stronger emphasis on technique and the difficulty level that was required to execute the technique. During this substyle, storytelling through ballets were very important. Classical ballets all had strong storylines that most people know of today, for example the Nutcracker, Swan Lake, and Cinderella. A lot of the characteristics that define ballet today emerged during this substyle including the costuming, cast, and progression of the piece.

Neoclassical ballet started to emerge during the mid-twentieth century. This substyle was a reaction to the romanticism and strong story telling that came before it. Neoclassical ballets were often plotless and focused heavily on the advanced technique required.

III.   **Characteristics**

a. **Cast**

The cast, or group of dancers performing in a ballet, consist of a female and male soloist, and the corps de ballet which is the group of female dancers that accompany the female soloist on stage and help with the progression of the narrative. All dancers have years of training in order to properly execute the movements.

b. **Costume**

Female ballet dancers wear pointe shoes which are satin shoes with a wood box at the toe that allow for the dancers to dance all the way on top of their toes. Female dancers also wear leotards and tutus which are skirts made of a netting-like fabric. Tutus either fall down from the hips to the middle of the shin, or they are more structured and stiff and stick out like a circular platter from the dancer's hips. The Ballet dancers wear the tutus to emphasize the length and beauty of the legs and body, and to reveal the feet in order to showcase the pointe work of the feet. Female ballet dancers also wear their hair in a sleek bun at the back of their head. This is done to keep the hair out of the face and to emphasize the length and line of the neck.

Male dancers wear a tight-fitted, long-sleeved embellished top, tights, and flat ballet shoes instead of pointe shoes. The tops are more elaborate for the male soloist so he stands out on stage, and the tights

showcase the strong lower leg muscles the male dancers needed in order to execute the technique.

c. Dancers

The body type of the female dancers are short and thin dancers that were also very strong and graceful. Female Ballet dancers have to be short because going up on pointe adds significant height and the female dancers have to be shorter than the male dancers even while on pointe. The female dancers are very thin because thin bodies create long, clean lines.

The body type of the male dancers are tall and very strong dancers. The male dancers are props more than they are performers; the purpose of the male dancer was to showcase the beauty of the female dancers. Male dancers have to be taller than the females when they are on pointe and strong enough to lift them.

d. Movement

The strict vocabulary of movement is comprised of French terms as a result of ballet's beginnings in France. Choreographic ballet works are made up of different combinations of these terms. For example, a dancer may have the following phrase: glissade a la second, assemble, pirouette en de hors, pique arabesque, sous tenu. This series of well-defined movement would last about six seconds and travels to the side with a series of small jumps and turns. For a list of these definitions please refer to the American Ballet Theatre's Ballet Dictionary (American Ballet Theatre).

With a strict vocabulary of movement comes one correct way to execute the movement. Therefore, the technical component of ballet is very important: "technical dexterity, especially when it appeared effortless, was found attractive to audiences, so dancers were eager to develop it" (Cohen, Dance Perspectives Foundation, Genres of western Theatrical Dance, 1998). Ballet technique is very demanding and in order to properly execute a ballet piece, many years of training are required.

Modern

I.   History

Modern dance began in the early twentieth century with early founders Loie Fuller and Isadora Duncan. Founders Fuller and Duncan were both dancers that rejected technical training and focused more on movement. Fuller was a self-taught dancer as a child and in her career she made choreographic works that used voluminous silken skirts. She focused on how those silks moved in reaction to the body moving. Duncan believed that ballet technique was unnatural for the human body and focused her work on expressing the music rather than expressing the technique. The ideals and practices of Fuller and Duncan were the seeds of the Modern dance movement.

Modern emerged as a reaction to and rebellion against Ballet dance. Modern dancers were more interested in abandoning technique, movement vocabulary, and the ideals of beauty that came along with ballet. "The new generation rejected pictures of simple beauty and harmony in order to deal with the struggles and emotional turmoil of their own world. Freeing themselves from

generally accepted codes of behavior, they claimed the right to make personal statements" (Cohen, Dance Perspectives Foundation, Genres of western Theatrical Dance, 1998). Modern was about a personal expression and experience rather than beauty.

II.   Substyles

Modern dance is classified into three substyles known as early modern dance, modern dance, and post-modern dance. Early modern dance occurred during 1809-1920 and was a rebellion against Ballet. During this early period, the foundations of modern were established which include the use of no ballet technique, the disappearance of a formal cast of dancers, and dance as a means of expression rather than a formal concert dance. The dancers were self-taught, and the movement derived from their own bodies while being inspired by music, nature, and culture. There were no concert performances of early modern dance; but the goal was not to entertain but to show creativity and self-expression instead.

Modern dance occurred during 1930-1950 and this substyle was a more established style of dance. The founders of this substyle wanted the style to be seen as an art form and for it to be taken seriously in the art community. Some characteristics of Ballet started to come back including the narrative and entertainment factor. There was no use of a movement vocabulary or technique; the movement was about expression. The focus was more on the internal experience and not about the exterior aesthetic. Prominent figures during this substyle included Martha Graham, and Doris Humphrey.

Post-modern dance occurred during 1950-1970, and was the rebellion of modern dance in order to completely drop the ideals of Ballet. The emphasis was solely about movement for movement's sake and there was absolutely no narrative involved. Post-modern dance also emphasized the idea that anyone could be a dancer. Even though technique was dropped during the early modern and modern periods, the dancers were often still technically trained dancers that were just putting the focus on expression rather than their technique. In the post-modern period it did not matter if you had training or not, you could still be a dancer. Movement was broken down into its most raw form and any movement was considered dance, even small gestures like waving your hand, or walking around.

III. **Characteristics**

a. **Cast**

There is no formal cast in a Modern dance. An entire piece can be performed by one individual or by a group of one hundred. There is not one lead dancer in a Modern piece, every performer is seen as equal on the stage.

b. **Costume**

Modern dancer wear pedestrian style costumes. Instead of elaborate costumes and restrictive leotards and tutus, the dancers wear everyday clothing that is easy to move in. Costumes are not gender specific and every dancer could be wearing the same costume or every dancer could have a different costume one. Dancer are barefoot and do not wear the pointe shoes or the flat Ballet shoes.

c. Dancers

Unlike Ballet, every person was considered a dancer in Modern dance. It does not take a certain body type, or any amount of training to be a Modern dancer.

d. Movement

Every movement is seen as dance in Modern dance. Instead of only being able to move based on a set dictionary of movements the body is free to move how it wants. A simple wave of the hand is considered movement in Modern dance which can be executed by any person. There were not more rules in Modern dance, everything is left up to the performer and choreographer to decide if it is 'dance.'

Comparison Between Ballet and Modern

There are many differences between Ballet and Modern dance. Modern dance is a reaction to Ballet and a rebellion against it. In Ballet, there is a set dictionary of movements, the dancers have to fit a specific body type, there are elaborate costumes and narratives, dancers exhibit an excellent level of technique, and the emphasis is to portray beauty and perfection. In Modern dance, there is no dictionary of movements because every movement is seen as dance, anyone can be a dancer, dancers wear pedestrian style costumes and are barefoot, and the emphasis is on personal experience and expression rather than technique and perfection. The different characteristics of Ballet and Modern are opposite by design because Modern wanted to be in contrast with Ballet.

These differences are made through personal experiences and through the observance of the two styles. My goal is to find a different way to compare the styles using data rather than

observation and experience. The results of my analysis should support the existing differences between the styles.

Labanotation

    I.   **History**

          Labanotation began in the late nineteenth-century by Rudolf Laban. This dance notation is based on Laban Movement Analysis in which movement is analyzed and broken down. In 1928 Laban first published Kinetography Laban, the notation system for notating movement that later became Labanotation (Wilke, Calvert, Ryman, & Fox, 2005). Laban realized "that a universally applicable system was needed" for the notation of dance and "he explored the idea of placing movement indications on a cross representing the body" (Cohen, Dance Perspectives Foundation, Labanotation, 1998). Labanotation was further developed into what it is today: staffs with symbols representing the different movements that occur in a dance according to time and space. In 1940 the Dance Notation Bureau was formed to further standardize and regulate dance notation (Wilke et al., 2005). Labanotation still exists and is used in the professional dance community. After many years of schooling one can become a Laban Notator and professionally notate different choreographic works and aid in the recreation of pieces from their Laban notated scores.

    II.   **Purpose**

          The purpose of Labanotation is to record and store choreographic works for long term use. Labanotation allows for a universal way to notate all styles of

dance, and for the creation of a permanent record of a piece. When pieces can be permanently stored, revival of dance works is also possible. Pieces can be accurately recreated no matter how long ago it was choreographed and last performed. Because of the extensive training required to read and write Labanotation it is not often used in the general dance community and is used more in the professional dance community. The invention of video recording allows the general community to store and recreate pieces through video instead of relying on memory or Labanotation. However, Labanotation provides a universal way to record and notate movement, a physical and observed form, in a new medium that is lasting (Cohen, Dance Perspectives Foundation, Labanotation, 1998).

III. Laban Notated Scores

Laban notated scores are composed of staffs that contain measures which contain beats. The staffs are read from left to right and bottom to top. The measures and beats represent units of time as the piece progresses; a measure is denoted as a horizontal bar that spans the width of the staff, and beats are small dash marks between each measure (See Figure 1 for an example). Figure 1 is a Labanotation staff with two measures, each with three beats. Below the double line is the starting position of the dancer and as the staff is read up the different symbols explain how and which body part is moving. The staffs are divided up into twelve total columns. Each column represents the body part that is moving (See Figure 2).
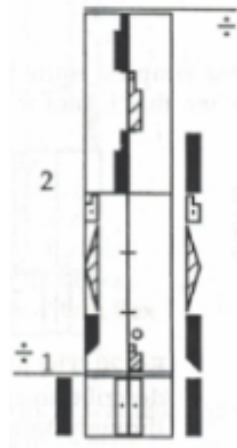
Figure 1. Laban notated score example (Topaz, Blum, & Segall, 1996).

Figure 2. Laban notated staff column body part assignment (Topaz et al.,1996).

Symbols seen in Figure 1 are placed on the staffs in their respective

columns to denote how each body part is supposed to move. Different symbols

represent the different types of movement that occur. The most basic and common

symbol in Labanotation is the direction symbol. This symbol starts out as a

rectangle in its most basic form (See Figure 3 "In place"). The different

alterations made to the symbol indicate different directions (See Figure 3). The

rectangle can also be shaded differently which identifies the level at which the movement is done (See Figure 4). The shape of the direction symbols shows which way the body part is moving, and the shading of the symbol shows at what level that body part is moving.
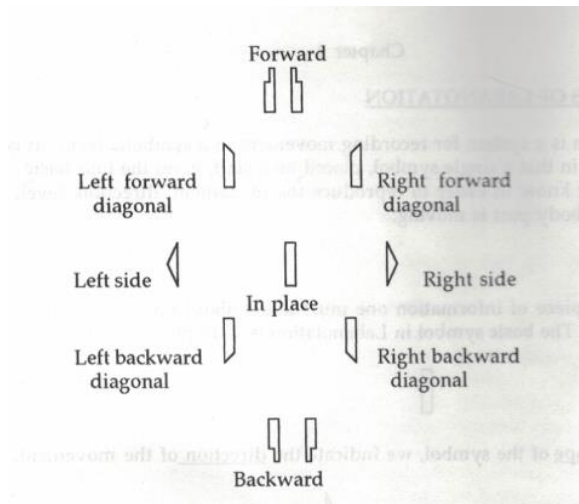
Figure 3. Direction symbols in Labanotation (Topaz et al., 1996).
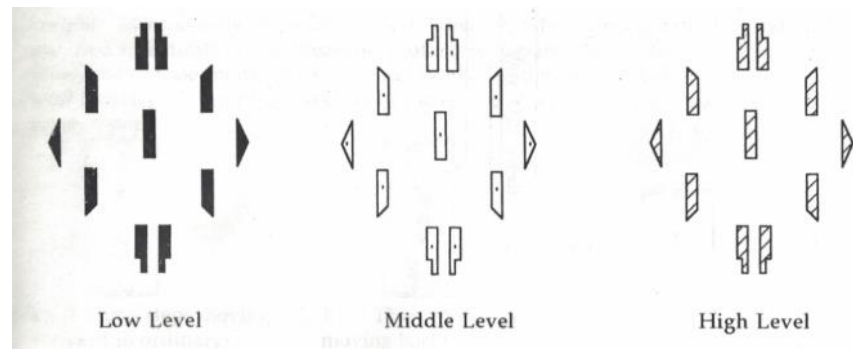
Figure 4. Shading levels of direction symbols in Labanotation (Topaz et al., 1996).

The lengths of the symbols correspond to length of the movement. The symbols represent the movement that happens after the movement before it to represent a continuous movement pattern (Topaz, Blum, & Segall, 1996). Other

symbols are used as well to indicate in front, in back, rotated, etc. These symbols get more complex and were not included in the analysis for this thesis. For more readings on Labanotation specifics please refer to *Elementary Labanotation: A study guide* (Topaz et al., 1996).

LabanWriter

I. **History**

LabanWriter is a computer program that was developed by the Department of Dance at Ohio State University in 1990. The LabanWriter project was directed by Lucy Venable and programmed by David Ralley (Wilke et al., 2005). This program was designed to allow for the creation and storing of Laban Notated dance scores in an electronic fashion. Before this software was created, all dance scores were written by hand. This program allows for the user to create scores using technology which improved the accuracy of the scores which in turn improved the ability for recreation of works.

II. **Purpose**

LabanWriter was designed to improve the process of notating dance scores. According to the Dance Department at Ohio State it "is a software program that permits dance to be copied, edited and stored on a computer. It utilizes the symbols for Labanotation… to record dance on paper" (Ohio State University Department of Dance). This software is used by both professional dance notators and students learning Labanotation.

LabanWriter is used to create scores from scratch, edit scores, and for further application of Labanotation and dance choreography. Files can be saved as

a LabanWriter file that can be edited, or as an image file that has a picture of the score that was created. Also, the document can be saved as a text file that produces an output file full of rows of numbers that store raw data regarding the image created in the LabanWriter file. See Figure 5 for an example of a LabanWriter output file in comparison to the Labanotation score.
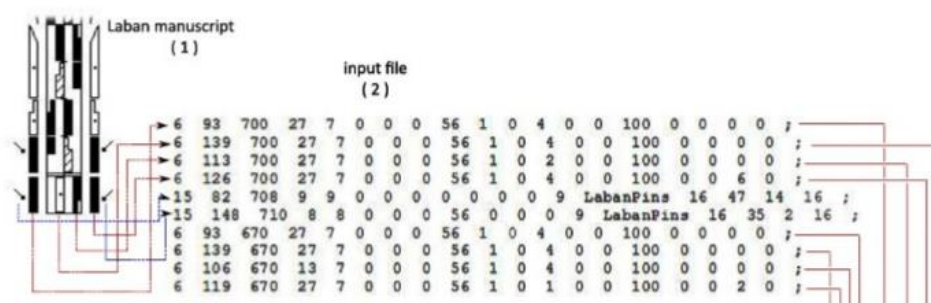
Figure 5. Section of LabanWriter output file (Ioan, Valcin, & Trausan-Matu, 2012).

III. How to use LabanWriter

LabanWriter is a unique computer software that is used specifically to input Laban notated scores into a computer to obtain an image of the score and/or the score's corresponding output file. It is composed of a blank screen in which one builds their Laban notated score. To begin drawing the Laban notated score one must first create the staffs. From the main menu staffs can be created by the user indicating how many staffs, measures, and beats per measure are needed.

After the staffs are created, the user can place the symbols on the screen. The symbol menu has submenus that contain the different symbols. The different submenus are related to different types of symbols (pins versus directions, etc.).

Those submenus have images of the different symbols and those symbols are selected by clicking on them with the mouse and then clicking a location on the staff. Manipulations can be made to the symbols once they are on the staff. They can be stretched, enlarged, reduced, filled with different level indicators, etc. These manipulations can all be made from the main menu. Symbols can also be dragged around the screen if they need to be relocated.

Once the user has completed placing all of the necessary symbols on to the screen they can then save the file in different forms: LabanWriter file (.lw), PDF (.pdf), image file (.png), or text file (.txt). Saving as a LabanWriter file allows the user to go back in to the LabanWriter software and make changes to the score. Saving as a PDF or image file creates an image of the score that was created. Saving as a text file produces an output file full of numbers that store information regarding the symbols on the score.

Literature Review

Since dance is a physical art form, most analysis of dance movement has been done through observation. Dance critics write about and analyze dances based on what they see. Even dancers are taught movement from watching someone else. Dance is recorded, however, through different methods of dance notation. The most well-known form of dance notation is Labanotation which is a way to notate dance movement based on Laban Movement Analysis. It was devised by Rudolf von Laban and is a universal way to notate movement so it is not restricted to a certain style of dance. Labanotation also allows for not only the storing of choreographic works but also the ability to recreate them (Gómez, 2015).

Some researchers have used their own methods of notation to analyze dance. In her paper "Method and Theory in Analyzing Dance Structure with an Analysis of Tongan Dance," Kaeppler used different combinations of letters and numbers to notate the different body positions in Tongan Dance. Kaeppler used these positons as kinemes, or the smallest gestures in movement, and analyzed the kinemes in a similar manner that phonemes, the smallest units of sound, are analyzed in language (Kaeppler, 1972). While Kaeppler developed her own way of notating dance from scratch, others developed a notation from dance that is derived from Labanotation. In "From Dance Notation to Conceptual Models: A Multilayer Approach," Labanotation was converted from symbols into descriptive words through multiple layers. This new descriptive notation was used to understand the movements occurring in the dance (El Raheb & Ioannidis, 2014). Some studies took that analysis from dance notation and applied it to further research. The LabanDancer project was developed from using LabanWriter to input Laban notated dance scores into a computer. LabanDancer takes the digital Laban notated dance score and creates a 3D video image of that score being executed (Wilke et al., 2005). Dance notation has been critical in analyzing dance and applying that analysis to further research and development.

One study in particular used Labanotation to classify different dance styles (Ioan, Valcin, & Trausan-Matu, 2012). This study quantified choreographic data in a way that could be analyzed and was a huge leap in the field of dance movement analysis. The study conducted by Ioan, Velcin, and Trausan-Matu used choreographic data tagging to tag Laban notated dance scores and analyze the structure of the piece in order to determine the style of dance for any given piece (2012). Ioan et al. used LabanWriter to input Laban notated scores into a computer and then retrieved the output file that was tagged. The output file is composed of lines of

numbers where each line represents an individual symbol from the Laban notated score. In the study by Ioan et al., the LabanWriter output files were tagged as general dance concepts (weight, sweep, shift, etc.) comparable to parts-of-speech tagging in language analysis. They used the tagged files to develop an algorithm that classified dances as different styles (Ioan et al., 2012). This study extracted measurable data from Laban notated scores in order to analyze and differentiate two styles of dance.

Methodology

Laban Notated Scores

I.   **Determination of Initial Data**

The initial data used in this research were Laban notated scores of dance pieces in the styles of ballet and modern. I first had to determine which specific dance pieces within each style I wanted to use. The pieces I chose are representative of their respective styles. Also, the pieces needed be able to be compared to one another so they had to have similar qualities such as length and number of dancers.

I determined that I needed two to three scores from each style that were one to five minutes in length and performed as solos or in unison. Creating restrictions on my initial data allowed me to make comparisons within the styles while keeping the amount of data manageable. Also, pieces performed as solos or in unison had less variables to take into consideration since information regarding stage positioning and partner work are not needed. With fewer variables, the comparisons between the styles were more direct.

When selecting the Ballet scores, I wanted scores in the classical ballet style, and that were well known to the general population. I focused on the classical sub-style of ballet since Modern was a reaction to classical ballet. Well known pieces were more representative of the style because their lasting power into today's time makes them important in the Ballet style. I made a list of different pieces that I potentially wanted to use which were: *Swan Lake*, *Sleeping Beauty*, *Copellia*, *Les Sylphide*, *Giselle*, *Serenade* or *Apollo.* This was my starting point since I did not know exactly what I would have access to.

For the Modern pieces, I determined I wanted to have some samples from a variety of the sub-styles of Modern (early modern, modern, and post-modern). Modern dance that is practiced today has elements from all three sub-styles therefore in order to make generalized statements about Modern dance I did not want to single one sub-style out. I looked at choreographers instead of pieces for modern. This was due to the fact that in Ballet, while choreographers are important, the specific works are more prominent since they are redone over time. In Modern, since there were more means for record keeping we have more information on the choreographers and their individual contributions to the style so they are more prominent. The list of potential Modern dance choreographers was as follows: Louie Fuller, Isadora Duncan, Martha Graham, Paul Taylor, and Merce Cunningham.

II.   **Obtaining Scores**

Once I had compiled a list of potential scores I needed to find a means to obtain these scores. My mentor, Deena Schmidt, had a contact at Ohio State

University that she recalled had access to Laban notated scores: Amy Schmidt, professor of dance notation at Ohio State University. I contacted her through email and discussed what my thesis was about and what I planned on researching. I gave her my lists of pieces and choreographers as well as the other specificities I needed and asked her if she could give me scores that met any of those conditions.

I was given the following Laban notated Ballet scores: "Variation 6 – The Lilac Fairy" from *Sleeping Beauty* originally choreographed by Marius Petipa, and "Dance of the Little Swans" from *Swan Lake* originally choreographed by Julius Reisinger. "Variation 6 – The Lilac Fairy" is a solo performed by a female dancer that is approximately a minute and a half in length. "Dance of the Little Swans" is a quartet performed by four dancers dancing side-by-side in unison and is approximately two minutes long.

I was given the following Laban notated Modern scores: "Fire Dance" by Loie Fuller, "Brahms/Waltz NO. 15" by Isadora Duncan, and "Post Meridian" by Paul Taylor. "Fire Dance" is a solo that is approximately five minutes in length and is from the early modern sub-style. "Brahms/Waltz NO. 15" is a solo approximately one and half minutes in length from the early modern dance sub-style. "Post Meridian" is a solo that is approximately one minute in length and is from the post-modern sub-style.

Due to publishing restrictions I cannot share any images or any output files of the scores I received. To see the scores that I used, one can contact Amy Schmidt at Ohio State University to obtain their own copy. See Figures 6-7 for partial examples of a Laban notated Ballet and Modern scores.
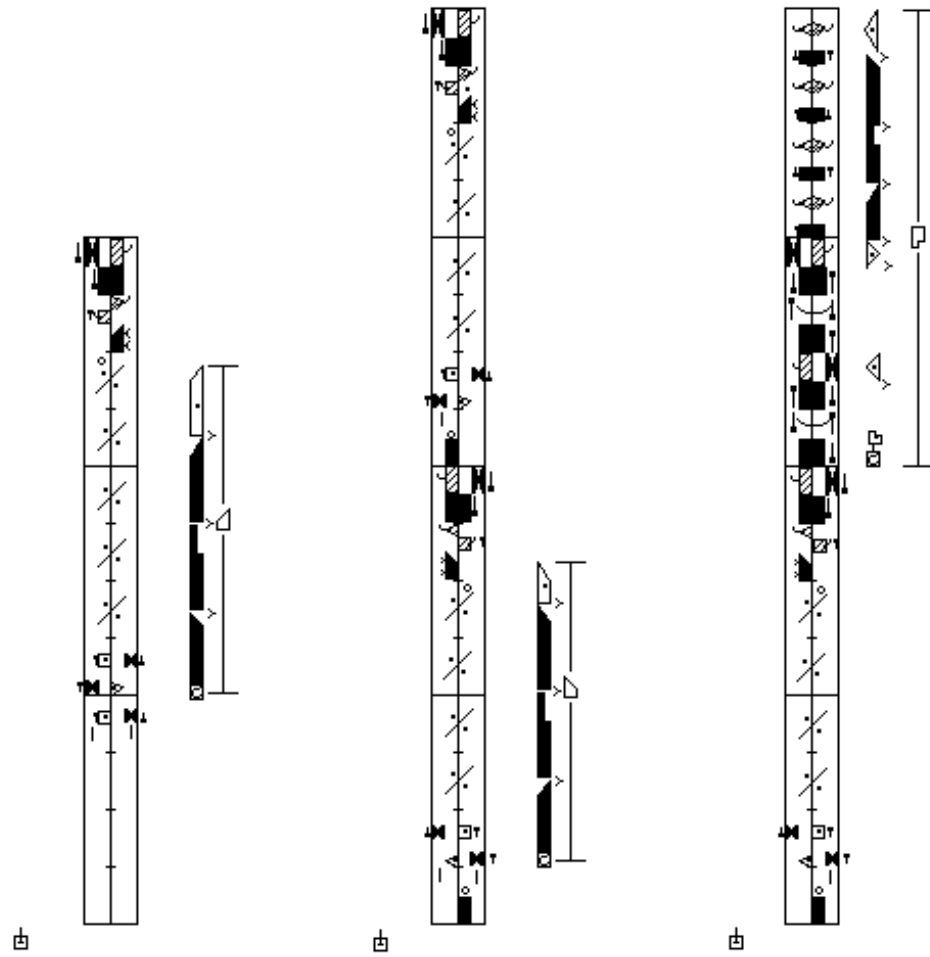
Figure 6. LabanWriter version of a partial Labanotation score of "Dance of the Little Swans."
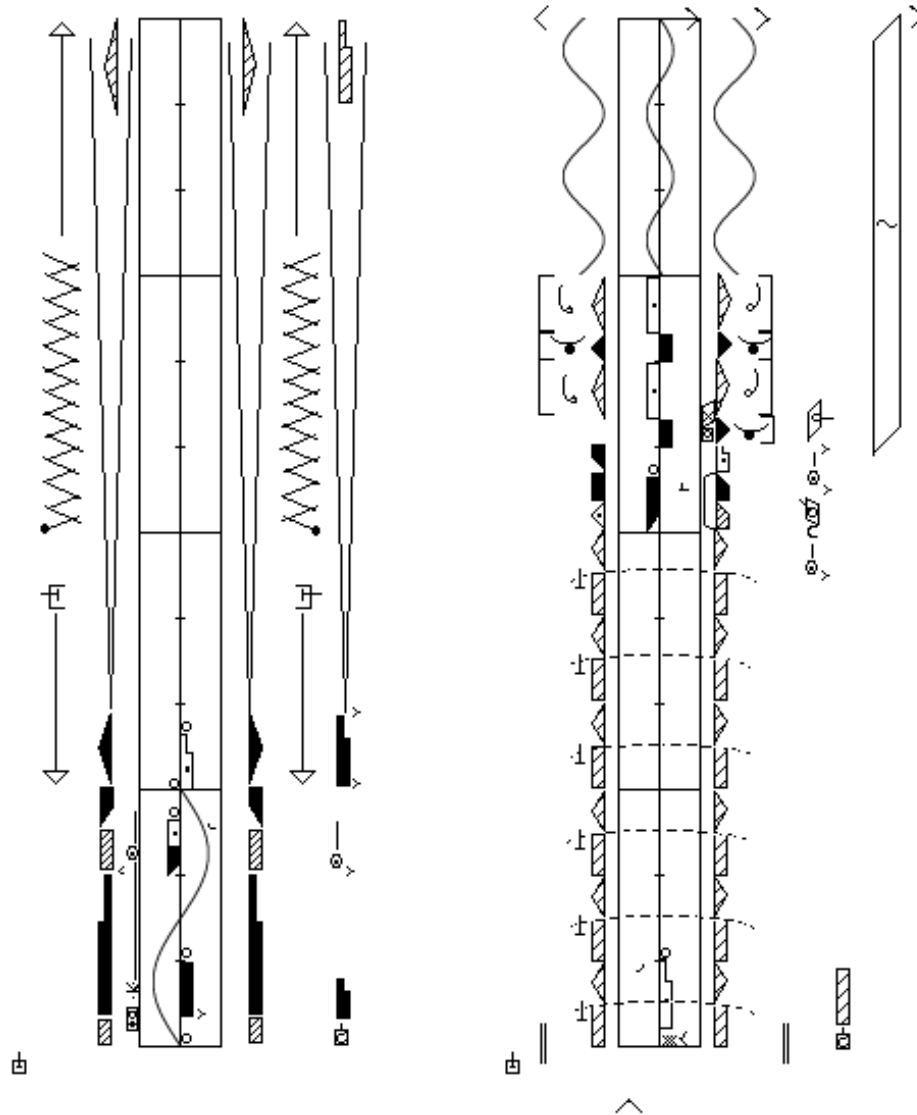
Figure 7. LabanWriter version of a partial Labanotation score of "Fire Dance."

III.   Reading and Understanding Laban Notated Scores

Before I began my data processing and analysis I first needed to be able to understand and interpret the Laban notated scores. Each column is called a staff, the sections or rows in each column are called measures, and the sub-sections in each measure are called beats. The symbols in the scores are read from bottom to top within each staff and the staffs are read from left to right. Each symbol represents a different type of movement and where the symbol is located on the staff determines the particular body part being moved. From left to right the columns that were used in my analysis represent left arm, left body, left leg, left support, right support, right leg, right body, and right arm. A string of symbols in the right most column would represent the right arm moving. Each symbol describes the movement that occurs after the movement that came before it. Symbols can occur in multiple columns at the same time to accurately represent the multiple parts of the body that are moving at the same time in a piece. For visual aid, refer to Figures 1-4.

LabanWriter

I.   Access to LabanWriter

LabanWriter was one of the most important components of my research as it was the software needed for the preprocessing phase. This software was only available for Mac computers and since I did not own a Mac computer myself I used my University's resources. The University of Nevada, Reno has a Mac computer lab in the library. To get the software downloaded onto the computers I needed to go through the person that oversaw the Mac computer lab, Kyle

Weerheim. I met him in person and discussed my request to have LabanWriter downloaded onto the computers in the lab. He reviewed the software and he downloaded LabanWriter onto all of the computers in the lab.

II.   **Preprocessing Stage**

The preprocessing stage of my research was where I input all five of the Laban notated scores into LabanWriter. I was given PDFs of the Laban notated scores which I printed out. I manually input each score into LabanWriter following the printed out PDF version of the score.

I researched how to use LabanWriter before I began inputting scores. I started each file with creating the staffs, and the scores that had more than four staffs had to be created on two separate LabanWriter files because the files could only be at most four staffs wide. I then placed each symbol onto the staff one at a time. It was difficult locating the symbol from all of the different submenus, but the more frequent a symbol type was the more familiar with where it was located I became. This process was slow to start but as I spent more time using the software it became much easier to use.

The order in which I created the LabanWriter files had no significance, I just completed one at a time. The order in which I placed the symbols was somewhat random. I mainly followed along with the way the scores are read, left to right and bottom to top, but I did not follow this strictly. If multiple of the same symbol were in a general area then I would place them all at the same time. Also, if there were repeating patterns of groupings of symbols I would copy and paste those groupings of symbols. I was able to do this quite often on both of the ballet

scores. This supported my original hypothesis that I would see more patterns in the ballet style. Each file was saved as both a LabanWriter File and PDF so that I had an image, could revisit the files if need be, and obtain the output files.

LabanWriter Output Files

I.   **Obtaining Output Files**

In Ioan et al's paper they used LabanWriter output files as a step in their data processing. I knew that the files were composed of rows and columns of numbers due to the descriptions and figures of the output files in Ioan et al's paper. However, it was never explained how to obtain these output files. I was able to reach out to my contact, Amy Schmidt, who informed me that these output files could be obtained by opening up the LabanWriter File with a different program such as a text editor, word, or excel.

I opened each of my files (nine in total due to four of the scores needing two files each) with text editors and obtained the corresponding output files. Just as mentioned by Ioan et al, they were rows and columns of numbers. Each row had a space between different numbers indicating a column break, and a semi colon at the end indicating a new row would begin. To better view these output files I reopened them with excel and used these files for the remainder of my research.

II.   **Determining the Meaning of the Output Files**

Having the output files was not enough, it was critical to understand what they meant and what the numbers corresponded to in order to complete the research. No key currently exists to decipher the output files, so I had to create a

key myself. To determine what the rows of numbers meant I had to go back into the text files and change individual numbers in the file to see how it affected the score in order to gain insight on what the numbers meant. I randomly selected a file to work with, Loie Fuller's Fire Dance. I started with one row and started changing one number at a time. Each time I changed a number I recorded the change in number and the change in the file. The changes made within one row of numbers altered one particular symbol; the symbol would change location on the page, change size, shading, etc. I continued testing different rows and columns until I felt comfortable that my findings were accurate. I also tested other scores to make sure it was the same across each file.

III.   LabanWriter Output File Key

I was able to successfully establish a key for the meanings of the output files. This key decoded the meanings behind the different rows and columns. From this key I was able to understand my data and analyze it properly during the processing stage. The first column indicates the row or column number on the file, and the columns that follow explain what that part of the output file means and represents.

Row/Col#	Meaning	Number	Number's Meaning	
Rows	Individaul symbols	Each row represents an individual symbol on the score		
		The order is not significant, the rows are in the order that the symbols were placed on the score		
Row with Col1:2-28	Staff information	Number of rows		
Col1	The type of symbol	1	Number of measures in that staff	
		1	The border around the page	
	The submenu that the symbol came from	2	The base information regarding one staff	
		6	Movement symbol	
		28	End of one staff	
Col2	Horizontal position of the symbol	Low	Farther left	Indicates the left most postion of the symbol,
		High	Farther right	must add width to receive the right most position.
Col3	Vertical position of the symbol	Low	Higher on the staff	Indicates top of symbol, must add length to
		High	Lower on the staff	receive the starting postion of that symbol
Col4	Length of symbol			
Col5	Width of symbol			
Col9	Staff identifier	Will correspond with the number in Col9 in the staff information	Belongs to that staff	
Col10	Alterations made to '6' symbols	1	No alterations	
		2	Symbol was shrunken down	
		other	Not a '6'	
Col12	Level/shading of the '6' symbols	1	high/lined shading	
		2	middle/dot in center	
		3	no specified level/blank	
		4	low/dark filled in	
		other	Not a '6'	
Col18	Shape/direction of the '6' symbols	0	Neutral	
		1	Left forward	
		2	Right forward	
		3	Right forward diagonal	
		4	Right	
		5	Right backward diagonal	
		6	Right backward	
		7	Left backward	
		8	Left backward diagonal	
		9	Left	
		10	Left forward diagonal	

Table 1. Key to understanding LabanWriter output files.

Processing Stage

      Once the output files were interpreted, I established a way to use the files for analysis. In the processing stage I took the .CSV output files, input them into R, extracted information from the files, and then developed ways to analyze the data. I used the statistical software, R, to analyze the data since Dr. Schmidt, Dr. Hurtado, and I were familiar with the software. R is available for free to download and I already had it installed on my computer. All of the R code was written in collaboration between Dr. Schmidt, Dr. Hurtado, and myself.

I.   **Input the Output File into R**

      The files were first input into R and stored in a format that I could then use. I created my own function called read.laban that took in any LabanWriter output file in a .CSV format and output a matrix with each row sorted in order in reference to time, and additional columns storing useful information including time, symbol categories and symbols ranks.

      The function reads in the .CSV file and removes any semicolons and any header information in the file. Next, the function removes all of the rows that provide information about the staffs and stores them in another matrix. The symbols are then categorized by the staff they are on. Time is assigned to each symbol next in order to sort the rows in a significant way rather than the order they were placed. From the assigned times the symbols are then ranked based on horizontal position in order to linearize the entire score. Examples of the code used can be seen in Appendix R code.

a. **Creating a Time Vector**

Since the LabanWriter output file sorts the symbols in the order the symbols were placed by the user, the output file has no meaning to the overall sequences of movements that occur in the piece; the output file relates only to the LabanWriter file and not the piece itself. By assigning times to the symbols the data is sorted in a more meaningful way that accurately represents the series of movements that occurred during the piece.

I used the information from column nine and three from each symbol to assign a respective time to each symbol using a linear transformation. The transformation divides the length of the staff from the number of measures and multiplies that value to the difference between the bottom of the staff and the vertical position of the symbol. This gives each measure the length of one, and assigns each symbol a number between zero and one based off of how far away from the bottom of the measure the symbol is located. The measures were combined by adding up the assigned times according to their location on the staffs. Then, the rows were all sorted based on their assigned time which put the rows in a more meaningful order.

b. **Symbol Assignment**

The read.laban function assigns the symbols to categories of unique symbols and body parts. In order to assign the symbols to body parts the width of the staff had to be divided by the width of each column in the staff. The distance of the symbol to the center of the staff determined which column and which body part the symbol belonged to on the score.

c. **Discretize Time**

In order to have more meaningful information about the symbols in relation to time I discretized time. Discretizing the time converted the time into counts that a dance would actually be in. Instead of the time being continuous, I made the time into eights, sixteenths, and thirty-seconds. Discretizing the time consisted of multiplying the time by eight, sixteen, or thirty two, rounding to a whole number, and then dividing by the eight, sixteen, or thirty two respectively. Not only did this convert time into something more meaningful in terms of dance, but it also fixed any slight errors that were made when creating the LabanWriter files, such as symbols being off by a pixel or two. Discretizing time grouped symbols together as either happening at the same time or not which made the symbols easier to analyze and compare.

d. **Concatenate Multiple Files**

Since most of the Laban notated scores were made up of two LabanWriter files I combined them into one piece. I input the files using read.laban, then combined the outputted matrices together. I also added the times from the second file to the ending of the first file. Eventually read.laban will be able to take in multiple LabanWriter files and concatenate them together, but for now this was done as separate code.

II. **Analysis**

a. **Summary Statistics**

The first type of analysis I conducted was to gather summary statistics on each staff. The summary statistics conducted found the number of different

symbol types per staff and total number of symbols per staff. Then, I found the average number of symbols per measure, the proportion of arm, leg and support symbols in the piece, and the average length of the direction symbols.

b. **Repetition Analysis**

I created a repetition analysis function that takes a section of the piece and compares that section to the rest of the piece. Depending on the metric used, the function returns a value that measures the level of repetition and stores the value in a matrix. The matrix is used to obtain results regarding the repetitiveness of the piece compared to other pieces.

First, the function takes in a score and information regarding time, length of the window, length of the step between window comparisons, and with metric that will be used. The metrics are what the window is comparing to the rest of the piece and are as follows: difference in the number of symbols, difference in the number of direction symbols, difference in the number of leg symbols, difference in the number of arm symbols, difference in the number of support symbols, difference in the number of body symbols, how many symbols have the same location on the staff, and how many symbols are identical.

The function was run with each score and each metric. The matrices were saved and stored for further analysis. I computed the mean, median, and mode of each matrix in order to obtain one final value that measured repetition so that repetitiveness could be compared between pieces.

Results

Summary Statistics

From the summary statistics analysis I was able to obtain the following table:

	AvgNumSym	TotArm	TotLeg	AvgSymLen	TotSupport	TotArmWeighted	TotLegWeighted	TotSupportWeighted	AvgSymLen6
Lilac	17.60656	225	124	16.517691	291	0.20949721	0.11545624	0.2709497	23.61969
Swans	27.92105	62	309	9.363808	438	0.05843544	0.29123468	0.4128181	10.73946
Fuller	18.05882	31	15	31.019544	31	0.10097720	0.04885993	0.1009772	30.07692
Taylor	247.00000	18	25	12.550607	48	0.07287449	0.10121457	0.1943320	17.73134
Duncan	16.00000	106	41	14.590116	189	0.15406977	0.05959302	0.2747093	19.31153

Table 2. Summary statistics results.

The columns in Table 2 represent the different statistics I found, and the rows represent the different pieces. Lilac is an abbreviation for "Variation 6 – The Lilac Fairy," Swans is an abbreviation for "Dance of the Little Swans," Fuller is an abbreviation for "Fire Dance," Taylor is an abbreviation for "Post Meridian," and Duncan is an abbreviation for "Brahms/Walts NO. 15." AvgNumSym represents the average number of symbols per measure; TotArm represents the total number of arm movements in the piece; TotLeg represents the total number of leg movements in the piece; AvgSymLen is the average length of each symbol; TotSupport is the total number of support symbols in the piece; TotArmWeighted is the average number of arm movements per measure; TotLegWeighted is the average number of leg movements per measure; TotSupportWeighted is the average number of support movements per measure; and AvgSymLen6 is the average length of the direction symbols.

The biggest findings from the summary statistics analysis is that in the ballet pieces, there is a higher proportion of leg and support symbols than there are in the modern pieces. This shows that Ballet uses both more floor foot work and more foot gestures in the air. This supports the

notion that Ballet emphasizes technique because foot work is very technical. Also, the use of pointe shoes in Ballet would result in more foot work choreography so that the pointe shoes get utilized and showcased. With Modern dancers being barefoot, there is no need to have that emphasis on the footwork.

Repetition Analysis

The repetition analysis resulted in matrices of very large sizes containing information about each window comparison (See Table 3 for a partial example of the output Matrix). Summary statistics were also found for each matrix and then standardized to establish a value that would measure the over repetitiveness of a piece based on the corresponding metric. Table 4 shows the findings of the repetition analysis.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20	V21	V22	V23	V24
1	0	1	2	2	2	2	2	1	1	4	5	8	8	8	8	6	6	3	2	1	0	1	1	0
2	NA	0	1	1	1	1	1	2	2	5	6	9	9	9	9	7	7	4	3	0	1	2	2	1
3	NA	NA	0	0	0	0	0	3	3	6	7	10	10	10	10	8	8	5	4	1	2	3	3	2
4	NA	NA	NA	0	0	0	0	3	3	6	7	10	10	10	10	8	8	5	4	1	2	3	3	2
5	NA	NA	NA	NA	0	0	0	3	3	6	7	10	10	10	10	8	8	5	4	1	2	3	3	2
6	NA	NA	NA	NA	NA	0	0	3	3	6	7	10	10	10	10	8	8	5	4	1	2	3	3	2
7	NA	NA	NA	NA	NA	NA	0	3	3	6	7	10	10	10	10	8	8	5	4	1	2	3	3	2
8	NA	NA	NA	NA	NA	NA	NA	0	0	3	4	7	7	7	7	5	5	2	1	2	1	0	0	1
9	NA	NA	NA	NA	NA	NA	NA	NA	0	3	4	7	7	7	7	5	5	2	1	2	1	0	0	1
10	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	1	4	4	4	4	2	2	1	2	5	4	3	3	4
11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	3	3	3	3	1	1	2	3	6	5	4	4	5
12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	0	0	0	2	2	5	6	9	8	7	7	8
13	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	0	0	2	2	5	6	9	8	7	7	8
14	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	0	2	2	5	6	9	8	7	7	8
15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	2	2	5	6	9	8	7	7	8
16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	0	3	4	7	6	5	5	6
17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	3	4	7	6	5	5	6
18	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	1	4	3	2	2	3
19	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	3	2	1	1	2
20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	1	2	2	1
21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	1	1	0
22	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	0	1
23	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	1
24	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0

Table 3. Partial repetition analysis matrix for "Dance of the Little Swans" using the metric: difference in the number of direction symbols.

	BalletIdentifier	num.of.symbols	num.of.6symbols	num.of.leg.symbols	num.of.arm.symbols	num.of.support.symbols	num.of.body.symbols	match.start.time	identical.symbols
Lilac	1	0.009349472	0.004945376	0.003482074	0.003069561	0.003147111	0.003015445	0.04444847	0.0003184598
Swans	1	0.031669955	0.016710302	0.009879566	0.003106217	0.013182024	0.004981203	0.08405181	0.0009933917
Fuller	0	0.046071464	0.016805370	0.005456894	0.007462095	0.008883995	0.008519536	0.11785808	0.0006938021
Taylor	0	0.097728295	0.042285200	0.013607737	0.004742626	0.040935673	0.002361673	1.01291990	0.2163076851
Duncan	0	0.016752589	0.007914868	0.002433328	0.003297290	0.004644483	0.001802793	0.03185542	0.0002434573

Table 4. Repetition analysis results.

In table 4, the columns represent the different metrics used, and the rows represent the different pieces. The value is the repetition factor of a piece given a particular metric.

Based off of these findings, there is no pattern in differentiating Ballet and Modern based off of how the number of each symbol type compares throughout the piece. The values were similar across all pieces, so some general comments about Ballet and Modern con be made in reference to what they have in common. Arm symbols have a more repetitive quality to them than leg, support and body symbols. The number of six symbols also have a more repetitive quality to them than the number of total symbols.

Logistic Regression

A logistic regression analysis was conducted on the findings to determine which metrics were best at discriminating ballet and modern pieces. A value of zero versus a value of one is modeled by a logistic regression to estimate a probability of an event occurring or not occurring. The graph of the logit function can be seen in Figure 8. This graph represent the correlation between two events and their respective zero or one probabilities.
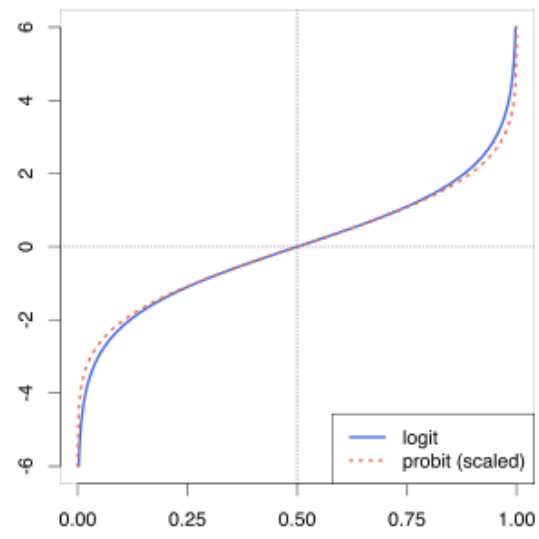
Figure 8. The graph of the Logit function.

Three different metrics were used in my logistic regression analysis: number of arm symbols per measure, number of leg symbols per measure, and number of support symbols per measure. These metrics were used based off of their variance inflation factors (See Figue 9). Since the variance inflation factors of the metrics are less than 5 or close to 5, the metrics are not collinear, or too dependent on one another which makes them better predictors. The results of the logistic regression analysis can be seen in Figures 10-11 and Table 5.

```
TotArmWeighted       TotLegWeighted TotSupportWeighted
     1.960189             6.033195           5.050060
```

Figure 9. Variance inflation factors of metrics.
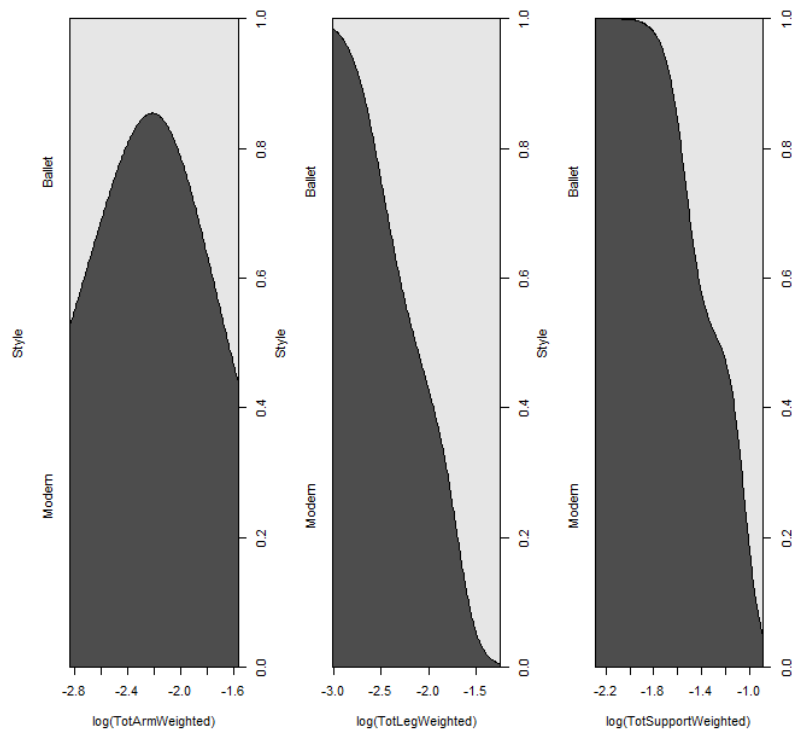
Figure 10. Logistic plot of metrics.

```
Coefficients:
                     Estimate Std. Error
(Intercept)           -72.15   207533.20
TotArmWeighted        399.70  1488485.77
TotLegWeighted        467.68  1686756.53
TotSupportWeighted   -151.87  1254413.53
```

Figure 11. Logistic regression model results.

Style	Predicted.Ballet
Ballet	1.000000e+00
Ballet	1.000000e+00
Modern	2.860871e-11
Modern	1.133750e-11
Modern	2.475533e-11

Table 5. Logistic regression style prediction.

Figure 10 shows the logistic plot of each metric. Since the average number of leg and support symbols plots are similar to the graph in Figure 8, those two metrics are good at discriminating Ballet and Modern pieces. The average number of leg symbols is not a strong discriminating metric but it is not weak either. Figure 11 displays the model that the logistic regression results in. The estimates are the coefficients for, or the values multiplied by, each metric. The errors are higher than one would want but it just means there is room for improvement in my model. Lastly, Table 4 shows that the model accurately predicted the Ballet and Modern pieces respectively, with Ballet assigned the value one and Modern assigned the value zero.

Conclusion

In conclusion, I found a very effective way to digitize dance in order to perform statistical analysis on different choreographic works. The contribution of my findings are that my methods can be used by other dance researchers to conduct further analysis on dance works and on different dance styles. Dance can now be analyzed using raw data from the notated scores of different dance pieces.

I was able to establish that Ballet pieces contain more foot work than Modern pieces which supports known differences between the two styles. I confirmed that leg and support symbols were good at discriminating Ballet and Modern dance in my logistic regression analysis. I also developed a model for predicting a dance as being either Ballet or Modern.

My small set of data made finding results a challenge. With a bigger data set I can establish more metrics for discriminating Ballet and Modern and I can test my prediction model on other works. The inputting of the dance scores into LabanWriter could have left room for

errors. Since this was my first time using LabanWriter I was not familiar with all of the symbols or the proper way to place them. The initial data of the output files may not accurately represent the pieces themselves which may be affecting my results.

In the future, I plan on continuing this work. First, more Ballet and Modern pieces will be collected to increase my data set. Then, I will develop more metrics for establishing repetition and discriminating Ballet versus Modern pieces. More logistic regression analysis will be run to generate more prediction models. With a larger data set I will then be able to test my prediction models and develop the best fit model for discriminating Ballet versus Modern pieces.

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Appendix

R Code

Read.Laban
Function for importing LabanWriter files and pre-processing them for analysis.

```
read.laban <- function(filename) {

#Open file, remove useless header info and chop ";" off of the end of each line
rawfile <- readChar(filename, file.info(filename)$size)
filecontent <- gsub(";", "", rawfile)
con = textConnection(filecontent)
labdat<-read.csv(con, header=F)
labdat
close(con)

head.index = which(labdat[,1]==1)[1]
#Remove useless header
labdat <- labdat[-(1:head.index),]

# Take staff info and store in separate matrix
head.index = tail(which(labdat[,1]==28),1)
staffstuff <- labdat[1:head.index,]
# Remove staff info from header and last row ("0 ;")
labdat <- labdat[-c(1:head.index),]
labdat <- labdat[-nrow(labdat),]

#Coerce first two columns to be numeric
options(warn=-1)
for(cindx in 1:2) { # if factors, convert to int and make non-ints "NA"
  if(is.factor(labdat[,cindx])) labdat[,cindx] <-
as.numeric(levels(labdat[,cindx]))[labdat[,cindx]];
  if(is.factor(staffstuff[,cindx])) staffstuff[,cindx] <-
as.numeric(levels(staffstuff[,cindx]))[staffstuff[,cindx]]; #as.integer(staffstuff[,1])
}
options(warn=0)
# above, we used the recommended conversion under "Warning" section of
factor() documentation. See ?factor

# Replicate staff ID (column 9) for each block
staff.id=-1
for(i in 1:nrow(staffstuff)){
  if(!is.na(staffstuff[i,9])) {
  if(staff.id!=staffstuff[i,9] & staffstuff[i,9]!=0) { #If col9 is != staffid, or 0, then
update ID
```

```
    staff.id = staffstuff[i,9]
  }
  if(staffstuff[i,9]==0) { staffstuff[i,9] <- staff.id} #if col9=0 then make col9=the
staffid
  }
}
# Remove "28" empty rows
staffstuff <- staffstuff[!is.na(staffstuff[,9]),]

# Double check that the order of staff info corresponds
# to the temporal order of the piece.


# get a list of staff IDs and other staff info (nmeausures, start/stop, etc)
staff <- data.frame(ID = unique(staffstuff[,9]), start=NA, stop=NA,
Nmeasures=NA, hstart=NA, hstop=NA, width=NA)


# start and end positions for each staff (via staffstuff)
for(i in 1:nrow(staff)) {
  tmpstaffinfo <- subset(staffstuff, staffstuff[,9]==staff$ID[i])
  # Here we need margin + staff length to get the pixel position for the bottom
  #start is col3+col4 of first measure, stop is col3 of last measure
  staff$start[i] = sum(tmpstaffinfo[2,3:4])
  staff$stop[i] = tail(tmpstaffinfo[,3],1)
  # Number of measuers is number of rows - 1
  staff$Nmeasures[i]= nrow(tmpstaffinfo)-1
  # horizontal starts and stops (start is col2, stop is col2+col5)
  staff$hstart[i] = tmpstaffinfo[2,2]
  staff$hstop[i] = sum(tmpstaffinfo[2,c(2,5)])
  #width (assuming all staffs same width)
  staff$width[i] = tmpstaffinfo[2,5]
}

staff$hmid = (staff$hstart+staff$hstop)/2

# Sort by horizontal position
staff <- staff[order(staff$hstart),]


#Fix some entries that don't have staff assignments
for(i in 1:nrow(labdat)) {
  if(! labdat[i,9] %in% staff$ID) {
    hpos = labdat[i,2]
    #assign to nearest staff based on midpoints (staff$hmid)
    dists = abs(hpos - staff$hmid)
```

```
    indx = which(dists == min(dists))
    if(length(indx)==1) { labdat[i,9] <- staff$ID[indx] }
    else { warning("Unassigned symbol equally close to 2 staffs!")}
  }
}


# Now create a staff.time column that converts positions to time (unit = 1
measure)
labdat$staff.time = NA
labdat$time = NA

#  Calculate staff times using our linear transformation
for(i in 1:nrow(labdat)) {
  j = which(labdat[i,9]==staff$ID)
  labdat$staff.time[i] <- staff$Nmeasures[j]/
                (staff$start[j]-staff$stop[j])*
                 (staff$start[j] - sum(labdat[i,3:4]))

  # Calculate time in units of measures from start of piece.
  labdat$time[i] <- labdat$staff.time[i] + ifelse(j>1,sum(staff$Nmeasures[1:(j-
1)]),0)

  #Calculate end times
  labdat$staff.endtime[i] <- staff$Nmeasures[j]/
    (staff$start[j]-staff$stop[j])*
    (staff$start[j] - sum(labdat[i,3]))

  labdat$endtime[i] <- labdat$staff.endtime[i] +
ifelse(j>1,sum(staff$Nmeasures[1:(j-1)]),0)

}

labdat <- subset(labdat, select = -staff.endtime)

#Create a category column for symbols above and below staff
labdat$category = NA

for(i in 1:nrow(labdat)) {
  if(labdat[i,5] < 0) { labdat$category[i] <- "Neg Width" }
  if(labdat[i,5] == 0) { labdat$category[i] <- "Zero Width" }
  if(labdat[i,4] < 0) { labdat$category[i] <- "Neg Height" }
  if(labdat[i,4] == 0) { labdat$category[i] <- "Zero Height" }
  if(labdat$staff.time[i] < 0 | labdat$staff.time[i] > staff$Nmeasures[1]) {
labdat$category[i] <- "Outside Staff"}
}
```

```
#Create a column that assigns symbols to body parts
labdat$body = NA

for(i in 1:nrow(labdat)){
  for(j in 1:nrow(staff)){
    if(labdat[i,9] == staff$ID[j]) {
      if(staff$hmid[j]-7 <= labdat[i,2] & labdat[i,2] < staff$hmid[j]){labdat$body[i]
= "Left Support"}
      else if(staff$hmid[j]+7 > labdat[i,2] & labdat[i,2] >=
staff$hmid[j]){labdat$body[i] = "Right Support"}
      else if(staff$hmid[j]-(7+82/12) <= labdat[i,2] & labdat[i,2] < staff$hmid[j]-
7){labdat$body[i] = "Left Leg"}
      else if(staff$hmid[j]+(7+82/12) > labdat[i,2] & labdat[i,2] >=
staff$hmid[j]+7){labdat$body[i] = "Right Leg"}
      else if(staff$hmid[j]-(7+2*82/12) <= labdat[i,2] & labdat[i,2] < staff$hmid[j]-
(7+82/12)){labdat$body[i] = "Left Body"}
      else if(staff$hmid[j]+(7+2*82/12) > labdat[i,2] & labdat[i,2] >=
staff$hmid[j]+(7+82/12)){labdat$body[i] = "Right Body"}
      else if(staff$hmid[j]-(7+3*82/12) <= labdat[i,2] & labdat[i,2] < staff$hmid[j]-
(7+2*82/12)){labdat$body[i] = "Left Arm"}
      else if(staff$hmid[j]+(7+3*82/12) > labdat[i,2] & labdat[i,2] >=
staff$hmid[j]+(7+2*82/12)){labdat$body[i] = "Right Arm"}
      else{labdat$body[i] = "Other"}
    }
  }

}



#Sort rows by time
labdat <- labdat[order(labdat$time),]


labdat$time8 = NA
labdat$time16 = NA
labdat$time32 = NA

#Discretize time
labdat$time8 <- round(labdat$time*8)/8
labdat$time16 <- round(labdat$time*16)/16
labdat$time32 <- round(labdat$time*32)/32

#Rank each time
labdat$rank = rank(labdat$time)
```

```r
labdat$rank8 = rank(labdat$time8)
labdat$rank16 = rank(labdat$time16)
labdat$rank32 = rank(labdat$time32)

#Fix symbols that share same rank

uniquerank <- sort(unique(labdat$rank))

for(j in 1:length(uniquerank)){
  if(nrow(labdat[labdat$rank == uniquerank[j],]) > 1){
    index = which(labdat$rank == uniquerank[j])
    index2 = index[order(labdat[index,2])]
    labdat[index,] = labdat[index2,]
    if(index[1] == 1){
      labdat$rank[index] = 1:length(index)
    }else{
      labdat$rank[index] = labdat$rank[index[1]-1] + 1:length(index)
    }
  }
}

labdat <- labdat[order(labdat$time),]

#Rank time8 left to right
uniquerank8 <- sort(unique(labdat$rank8))

for(j in 1:length(uniquerank8)){
  if(nrow(labdat[labdat$rank8 == uniquerank8[j],]) > 1){
    index = which(labdat$rank8 == uniquerank8[j])
    index2 = index[order(labdat[index,2])]
    labdat[index,] = labdat[index2,]
    if(index[1] == 1){
      labdat$rank8[index] = 1:length(index)
    }else{
      labdat$rank8[index] = labdat$rank8[index[1]-1] + 1:length(index)
    }
  }
}

labdat <- labdat[order(labdat$time),]

#Rank time16 left to right
uniquerank16 <- sort(unique(labdat$rank16))

for(j in 1:length(uniquerank16)){
  if(nrow(labdat[labdat$rank16 == uniquerank16[j],]) > 1){
```

```
    index = which(labdat$rank16 == uniquerank16[j])
    index2 = index[order(labdat[index,2])]
    labdat[index,] = labdat[index2,]
    if(index[1] == 1){
      labdat$rank16[index] = 1:length(index)
    }else{
      labdat$rank16[index] = labdat$rank16[index[1]-1] + 1:length(index)
    }
  }
}

labdat <- labdat[order(labdat$time),]


#Rank time32 left to right
uniquerank32 <- sort(unique(labdat$rank32))

for(j in 1:length(uniquerank32)){
  if(nrow(labdat[labdat$rank32 == uniquerank32[j],]) > 1){
    index = which(labdat$rank32 == uniquerank32[j])
    index2 = index[order(labdat[index,2])]
    labdat[index,] = labdat[index2,]
    if(index[1] == 1){
      labdat$rank32[index] = 1:length(index)
    }else{
      labdat$rank32[index] = labdat$rank32[index[1]-1] + 1:length(index)
    }
  }
}

return(labdat)

} # end function
```

Swans-merge
Reads in Lilac files and combines them

```
#source: read.laban

Swans1 <- read.laban("Swans1CSV.csv")
Swans2 <- read.laban("Swans2CSV.csv")

nMeasures = ceiling(max(Swans1$time))
Swans2$time = Swans2$time +nMeasures
Swans2$endtime = Swans2$endtime +nMeasures
```

```
#combine ranks
Swans2$rank = Swans2$rank + Swans1$rank[nrow(Swans1)]
Swans2$rank8 = Swans2$rank8 + Swans1$rank8[nrow(Swans1)]
Swans2$rank16 = Swans2$rank16 + Swans1$rank16[nrow(Swans1)]
Swans2$rank32 = Swans2$rank32 + Swans1$rank32[nrow(Swans1)]

Swans = rbind(Swans1, Swans2)
```

SwansSumStats
Computes the summary statistics for Swans

```
#source: read.laban, Swans-merge

#Number of symbols per measure
nM = ceiling(max(Swans$time))
measurestats <- data.frame(larm=rep(0,nM), lbody=0, lleg=0, lsupport=0,
rarm=0, rbody=0, rleg=0, rsupport=0, other=0, total=0)

for(i in 1:nrow(Swans)){
  msr = ceiling(Swans$time[i])

  if(msr == 0){msr<-1}

  if(is.na(Swans$body[i])){
    measurestats$other[msr] = measurestats$other[msr] + 1
  } else if(Swans$body[i] == "Left Arm"){
    measurestats$larm[msr] = measurestats$larm[msr] + 1
  } else if(Swans$body[i] == "Left Body"){
    measurestats$lbody[msr] = measurestats$lbody[msr] + 1
  } else if(Swans$body[i] == "Left Leg"){
    measurestats$lleg[msr] = measurestats$lleg[msr] + 1
  } else if(Swans$body[i] == "Left Support"){
    measurestats$lsupport[msr] = measurestats$lsupport[msr] + 1
  } else if(Swans$body[i] == "Right Arm"){
    measurestats$rarm[msr] = measurestats$rarm[msr] + 1
  } else if(Swans$body[i] == "Right Body"){
    measurestats$rbody[msr] = measurestats$rbody[msr] + 1
  } else if(Swans$body[i] == "Right Leg"){
    measurestats$rleg[msr] = measurestats$rleg[msr] + 1
  } else if(Swans$body[i] == "Right Support"){
    measurestats$rsupport[msr] = measurestats$rsupport[msr] + 1
  } else {
    measurestats$other[msr] = measurestats$other[msr] + 1
  }
```

```
}
for(i in 1:nrow(measurestats)){
  measurestats$total[i] <- sum(measurestats[i,1:9])
}

SwansInfo <- data.frame(AvgNumSym=0, TotArm=0, TotLeg=0,
AvgSymLen=0)

#Calulate average symbols per measure
SwansInfo$AvgNumSym = sum(measurestats$total)/nrow(measurestats)

#Calc total arm symbols vs leg symbols
SwansInfo$TotArm = sum(measurestats$larm, measurestats$rarm)
SwansInfo$TotLeg = sum(measurestats$lleg, measurestats$rleg)
SwansInfo$TotSupport = sum(measurestats$lsupport, measurestats$rsupport)

SwansInfo$TotArmWeighted = sum(measurestats$larm,
measurestats$rarm)/sum(measurestats$total)
SwansInfo$TotLegWeighted = sum(measurestats$lleg,
measurestats$rleg)/sum(measurestats$total)
SwansInfo$TotSupportWeighted = sum(measurestats$lsupport,
measurestats$rsupport)/sum(measurestats$total)

#Cal Average length of symbols
length = 0

for(i in 1:nrow(Swans)){
  length = length + Swans[i,4]
}

SwansInfo$AvgSymLen = length/nrow(Swans)

#Cal Average length of 6 symbols
length = 0
t = 0

for(i in 1:nrow(Swans)){
  if(Swans[i,1]==6){
    length = length + Swans[i,4]
    t=t+1
  }
}

SwansInfo$AvgSymLen6 = length/t
```

```
     #Frequencies of different symbol types
     SwansSymFrq <- table(Swans[,1])
```

d

Function that performs repetition analysis on given metric

```
     d <- function(i, j, data, time, length, dt, metric){

       blocki = data[time >= (i-1)*dt & time < ((i-1)*dt + length),]
       blockj = data[time >= (j-1)*dt & time < ((j-1)*dt + length),]

       if(metric == "num.of.symbols"){

         #differece between the two numbers of symbols
         n = abs(nrow(blocki) - nrow(blockj))
         if(nrow(blocki) + nrow(blockj) == 0){return(NA)}
         else{return(n)}

       }else if(metric == "num.of.6symbols"){

         a = sum(blocki[,1] == 6)
         b = sum(blockj[,1] == 6)
         n = abs(a-b)
         if(a+b == 0){return(NA)}
         else{return(n)}

       }else if(metric == "num.of.leg.symbols"){

         a = sum(blocki$body == "Left Leg" | blocki$body == "Right Leg")
         b = sum(blockj$body == "Left Leg" | blockj$body == "Right Leg")
         n = abs(a-b)
         if(a+b == 0){return(NA)}
         else{return(n)}

       }else if(metric == "num.of.arm.symbols"){

         a = sum(blocki$body == "Left Arm" | blocki$body == "Right Arm")
         b = sum(blockj$body == "Left Arm" | blockj$body == "Right Arm")
         n = abs(a-b)
         if(a+b == 0){return(NA)}
         else{return(n)}

       }else if(metric == "num.of.support.symbols"){

         a = sum(blocki$body == "Left Support" | blocki$body == "Right Support")
         b = sum(blockj$body == "Left Support" | blockj$body == "Right Support")
```

```
    n = abs(a-b)
    if(a+b == 0){return(NA)}
    else{return(n)}

  }else if(metric == "num.of.body.symbols"){

    a = sum(blocki$body == "Left Body" | blocki$body == "Right Body")
    b = sum(blockj$body == "Left Body" | blockj$body == "Right Body")
    n = abs(a-b)
    if(a+b == 0){return(NA)}
    else{return(n)}

  }else if(metric == "match.start.time"){

    tmpv = rep(NA, nrow(blocki))
    for(k in 1:nrow(blocki)){
      tmpv[k] = any(blocki[,1]==blockj[,1] & blocki$body == blockj$body &
round(blocki$time[k]/dt)*dt -i*dt == round(blockj&time/dt)*dt - j*dt)
    }

    return(sum(tmpv)/min(nrow(blocki), nrow(blockj)))

  }else if(metric == "identical.symbols"){
    tmpv = rep(NA, nrow(blocki))
    for(k in 1:nrow(blocki)){
      tmpv[k] = any(blocki[k,1] == blockj[,1] & blocki$body[k] == blockj$body &
blocki[k,4] == blockj[,4] & blocki[k,5] == blockj[,5] & blocki[k,12] ==
blockj[,12] & blocki[k,18] == blockj[,18] & round(blocki$time[k]/dt)*dt -i*dt ==
round(blockj&time/dt)*dt - j*dt)
    }

    return(sum(tmpv)/min(nrow(blocki), nrow(blockj)))

  }else if(metric == "identical.block"){

    if(blocki[,1] == blockj[,1] & blocki$body == blockj$body & blocki[,4] ==
blockj[,4] & blocki[,5] == blockj[,5] & blocki[,12] == blockj[,12] & blocki[,18]
== blockj[,18] & round(blocki$time/dt)*dt -i*dt == round(blockj&time/dt)*dt -
j*dt){
      return(1)
    }else{
      return(0)
    }

  }else{warning("Metric does not exist")}
}
```

SwansRepAnalysis
Function that performs repetition analysis on Swans

```
#source:d

#establish time unit of 16 and NxN matrix
time = 16
L = 1/2
M = ceiling(max(Swans$time))
N = M*time - L*time


metrics = c("num.of.symbols", "num.of.6symbols", "num.of.leg.symbols",
"num.of.arm.symbols", "num.of.support.symbols", "num.of.body.symbols",
"match.start.time", "identical.symbols", "identical.block")

if(FALSE) {
  for(metric in metrics){
    ## Reset A
    A = matrix(nrow = N, ncol = N, byrow = FALSE, dimnames = NULL)
    ## Fill in A
    for(i in 1:(N)){
      for(j in i:(N)){
        A[i,j] <- d(i, j, data = Swans, time = Swans$time16, length = 1/2, dt = 1/16,
metric = metric)
      }
    }
    save(A,file = paste("Swans.",metric,".RData",sep=""))
  }
}


#plot_ly(z = A, type = "heatmap")

#Load
load("Swans.num.of.symbols.RData")
Swans.num.of.symbols <- A

load("Swans.num.of.6symbols.RData")
Swans.num.of.6symbols <- A

load("Swans.num.of.leg.symbols.RData")
Swans.num.of.leg.symbols <- A

load("Swans.num.of.arm.symbols.RData")
Swans.num.of.arm.symbols <- A
```

```
load("Swans.num.of.support.symbols.RData")
Swans.num.of.support.symbols <- A

load("Swans.num.of.body.symbols.RData")
Swans.num.of.body.symbols <- A


SwansStat <- matrix(0, nrow=2, ncol=6)
rownames(SwansStat)<-c("mean", "median")
colnames(SwansStat)<-c("num.of.symbols", "num.of.6symbols",
"num.of.leg.symbols", "num.of.arm.symbols", "num.of.support.symbols",
"num.of.body.symbols")

SwansStat[1,1] = mean(Swans.num.of.symbols, na.rm=TRUE)
SwansStat[2,1] = median(Swans.num.of.symbols, na.rm=TRUE)

SwansStat[1,2] = mean(Swans.num.of.6symbols, na.rm=TRUE)
SwansStat[2,2] = median(Swans.num.of.6symbols, na.rm=TRUE)

SwansStat[1,3] = mean(Swans.num.of.leg.symbols, na.rm=TRUE)
SwansStat[2,3] = median(Swans.num.of.leg.symbols, na.rm=TRUE)

SwansStat[1,4] = mean(Swans.num.of.arm.symbols, na.rm=TRUE)
SwansStat[2,4] = median(Swans.num.of.arm.symbols, na.rm=TRUE)

SwansStat[1,5] = mean(Swans.num.of.support.symbols, na.rm=TRUE)
SwansStat[2,5] = median(Swans.num.of.support.symbols, na.rm=TRUE)

SwansStat[1,6] = mean(Swans.num.of.body.symbols, na.rm=TRUE)
SwansStat[2,6] = median(Swans.num.of.body.symbols, na.rm=TRUE)
```

BalletvsModerLog
Logistic regression analysis

```
# These don't work due to small sample size...
#confint(fit) # 95% CI for the coefficients -- see error.
#exp(coef(fit)) # exponentiated coefficients
#exp(confint(fit)) # 95% CI for exponentiated coefficients

# Here's predicted assignments (think of this as probability of)
predict(fit, type="response") # predicted values
mydat$Predicted.Ballet <- predict(fit, type="response")
mydat
car::vif(fit)
```

```
## These may or may not look nice, and may or may not illustrate
## which metrics correlate nicely with ballet vs modern:
x11()
par(mfrow=c(1,3))
cdplot(Style~log(TotArmWeighted),data=mydat); # effect
cdplot(Style~log(TotLegWeighted),data=mydat); # effect
cdplot(Style~log(TotSupportWeighted),data=mydat); # effect
```