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Visual Translation of Multi-Dimensionality: Comparisons In Physics And Dance

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VISUAL TRANSLATION OF MULTI-DIMENSIONALITY: COMPARISONS IN PHYSICS AND DANCE

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ABSTRACT

The fields of dance and physics both utilize tools for communication that translate movement into two-dimensional formats to share and process information in new ways. This research highlights issues surrounding this process, including: what is gained and lost in translation in both fields; the role of objectivity and subjectivity in dance and science; and what interdisciplinary research can potentially mean for advancing communication tools and shifting biases about how knowledge is valued. Both physics and dance register philosophical shifts in the twentieth century, related to the shift away from determinism and a Cartesian mind-body divide, and towards the rise of indeterminacy seen in quantum mechanics and dancemaking practices. This includes the popularization of improvisation as a choreographic method. I conceptualize modern communication tools in science and dance in terms of their relationship to time: predictive/descriptive (like scientific models and dance scores) or preservative (like apparatuses of instrumentation and notation systems). Choreographers who are using these communication tools for various purposes within their practice follow the historical examples of Merce Cunningham's improvisation strategies, Anne Teresa De Keersmaeker and Trisha Brown's scores, and William Forsythe's digital notation system, *Synchronous Objects for One Flat Thing Reproduced*. Through investigation in the studio and the creation of a performance that showcases translation of dimensionality, my theoretical and practical research demonstrate the value of multiple forms of communication and lenses through which to make and view dance.

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INTRODUCTION

Science and the arts have traditionally been viewed as disparate disciplines with fundamentally different sets of criteria for thought and knowledge production. However, as an increasing number of practitioners and theorists within each discipline start to research how these fields might be integrally connected, there is potential for increased understanding across and within them. A previously under-explored connection between science and art, specifically between physics and dance, is their relationship to dimensionality, in this case the translation of three-dimensional ideas about motion into a two-dimensional graphic depiction. Both disciplines are concerned with moving bodies in time and space, and the rules and patterns that govern their movement. Bodies interact and are affected by each other. Forces that act upon bodies govern their movement. Complex, interrelated systems are at play in both physics and dance but are extremely difficult to convey through a singular mode of communication. So how does each discipline attempt to express these forces and systems? How do the techniques of each discipline's methods for creating visual models inform the other?

Visual representations are a secondary mode of operation of both physics and dance. While the primary focus of both disciplines may be bodies in motion, both utilize static visual principles to convey this information. Scores, notation, and visual design elements of performance have played a role in establishing connections between choreographic work and the principles of physics. In dance, knowledge is often transmitted from body to body in three-dimensional space and in real-time without going through the process of translating it to the page. However, when dancemakers consider creating some sort of object of translational knowledge for their work to be documented, it becomes very difficult to condense an art form that deals with time and space into a static, visual form. Sandie Waters and Andrew Gibbons, for example, write about dance notation as a form of a design language, comparing it to notation and design systems used in computer science, physics, and chemistry (57).

Some of the choreographers whose work is influenced by scientific thought and who are modeling dance through written and visual material are: Merce Cunningham, William Forsythe, and Anne Teresa de Keesmaeker. Each of these artists has a unique relationship to changing audience visual perspectives through manipulating time and space in radical ways. Each has also used systems of scores and notation in their work, systems that I propose are influenced by modern scientific thought. Each of these artists, and myself as a choreographer, deployed these methods during the mid-twentieth century to the early twenty-first century. Therefore, in what follows, I contextualize their experimentations within this historical framework—specifically seeking to illuminate how the scientific knowledge available at this time affects their modes of thinking—in order to provide an artistic and historical context for my own choreographic thesis work.

As part of this research, I have applied the lens of dimensionality and visual translation to my artistic practice. One way this was incorporated in the rehearsal process was through my use of paper and visual records of the movement. This included creating a new notation system that generated and recorded fixed body positions, which will be explained in more detail later. Dimensionality was also incorporated into the performance work itself. Lighting and projection were used to either flatten or add dimension to the dancers' bodies. The movement vocabulary I worked in was very shape-based, designed to complement the visual design concepts.

Choreographic language and visual design worked in tandem to create an arc throughout the sections, which developed from flatness to a sense of fullness in space.

My research explores the intersection of physics and dance in the realm of visual representation. I aim to contextualize my own work within a historical framework, and evolving tradition, of blending science and dance knowledge. This framework is grounded in: the understanding of modern physical thought in comparison to classical physics; scientific modeling and apparatuses in comparison to dance writing and recording practices; and an analysis of choreographers working with these scientific concepts. These artists produce systems of knowledge within dance that have much to offer in the realm of physics. I propose that this type of interdisciplinary research provides new means to think about methods and values of different communication systems, ultimately calling into question the hierarchy of academic disciplines in the process of knowledge production.

CLASSICAL TO QUANTUM

I have chosen to contextualize my research and creative practice within a field of U.S. and European choreographers making work in the mid to late twentieth century, focusing on how their visual devices and theoretical lenses can be viewed in terms of scientific influence. To do so, I sought to understand the scientific historical framework in which their work emerged. Physics and chemistry have undergone major paradigm shifts over the last century with the development of quantum mechanics, which has radically changed how scientists conceptualize matter and energy at the deepest and most fundamental levels.

Early concepts in physics were based on the idea of forces acting upon matter. As explained in Charap's "Chance and Certainty: The Weird World of Quantum Mechanics," Isaac Newton's ideas of gravity and other forces were consistent with a deterministic worldview (2002, 43-51). If the initial conditions can be determined, equations can be used to calculate the exact motion of the particle or mass. For example, Newton's First Law of Motion states that an object in uniform motion will remain in motion unless acted on by an outside force. Equations were developed with the variables of mass, acceleration, speed, and force to predict outcomes like the trajectory of an object in a parabolic arch or the amount of force required to lift an object. The precision and predictability of Newtonian physics produced the sense that scientific study could control the natural world. This was related to the Cartesian mind-body divide in that human thought and the material world were seen as completely separate entities.

This type of reasoning appeared in choreography around the same time, in terms of setting structured (deterministic) work which was focused on the forces acting on the body. Nineteenth and early twentieth-century choreographers dealt with concepts from Newtonian physics like gravity, momentum, and force. For example, the famous "fall and recovery" technique of Doris Humphrey's early twentieth-century modern dance was based on the body's relationship to weight, specifically resisting versus succumbing to gravitational pull. Ballet during this period sought to combat Newtonian forces, defying gravity and momentum by making the dancer appear weightless and floating, especially after the development of the pointe shoe in the 1830s.

This sort of deterministic classical thinking also relates to predictability and reproducibility. Most ballet and early modern concert dances were strictly choreographed for the entirety of the work; positions of the body, spatial arrangement on stage, and relationship to the music were all carefully planned and executed to create a total work that was fixed and reproducible. Dances were also created by the male "genius" choreographer and then taught and performed by the female dancers whose only role was to execute the movement. These roles point to the gendered implications of the Cartesian mind/body divide in dance—men are associated with the mind and women with the dumb matter of executing bodies. Improvisation, for the most part, was not a part of concert performances. Thinking and planning choreography was considered separate from the actual action of performing.

Quantum mechanics complicates this kind of certainty with its basis in probability and uncertainty. Scientists in the early twentieth century began to realize that there were significant discrepancies between the laws of classical physics and the observed data for atomic and subatomic interactions. Although the classical physics equations continued to closely match the observable phenomena on the scale of the visible, the core principles of movement on a subatomic level are much less concrete. The basic principle is that on a subatomic level, energy does not exist in a continuum. Instead, it is transferred in discrete amounts, called "quanta." This means that particles exist in different energy levels and must absorb or release specific amounts of energy to change states. The equations that were created to account for this reality are not able to be solved completely for systems as complex as atoms. Therefore, along with the discovery of quantization came new ideas about uncertainty and probability. Instead of being discrete particles, subatomic particles were envisioned as waves with indeterminate exact locations in space. Equations to describe their motion were based on mathematical probability, rather than certainty.

This type of thinking de-stabilized the mind-body divide associated with Cartesian and Newtonian views in favor of a more integrated, yet complicated, way of thinking. Since quantum mechanics takes into account the potentially infinite number of interactions occurring at the subatomic level, systems could not merely be seen as consisting of separate, discrete parts, but rather as an interrelated whole. The concept of duality, like the wave-particle duality of electrons, made way for theories that blurred the binaries of thought and movement. Rather than the thinking mind and the doing body, the shift in philosophy allows for the idea of a thinking, intelligent body.

The effects of a philosophical shift toward thinking in terms of indeterminacy can be seen in a variety of innovations in postmodern and contemporary dance work. One example is the use of scores or improvisation. According to the Heisenberg uncertainty principle, exact movement of particles cannot be predicted. It is only ever possible to know either the exact position or momentum of a particle, but not both. With a dance score, only some movement can actually be predicted. For example, a score could dictate where the dancers move in space according to predetermined floor patterns, but not how they will get there. Or, it might dictate that dancers only move using straight lines in their limbs but not set any rules for how they interact with each other. Scholarly studies of improvisation in dance studies promote understanding this kind of decision making on the part of dancers as forms of embodied thinking. The dancer is not planning out each movement in the score but is using quick decision making and instinctive awareness of their bodies during the improvisation.

Contemporary dance works often contain elements of improvisation in their choreographic process and even in their final stages. For example, William Forsythe has created multiple versions of his instructional tool *Improvisation Technologies* that instruct dancers on how to think about spatial constructions within their improvisation. For example, one exercise instructs dancers to improvise with the idea of "parallel shears", made with the arms or legs, and find movements that can transform and relocate the parallel lines. The use of improvisation as a choreographic tool is an example of an embodied translation of the philosophical principle of uncertainty. With enough information about the initial conditions provided, the choreographer can let the experiment run its course onstage and see how the rules translate to movement. As with electrons, you can predict some information about what will occur based on the given or known information, but the end result will be different every time given the level of indeterminacy.

Looking at artistic work from the latter half of the twentieth century, the influence of quantum mechanics on choreographic thought is evident. Merce Cunningham is the choreographer whose work is most often studied in connection with scientific principles, specifically quantum mechanics. Many dance studies scholars, from Emily Coates to Gay Morris to Susan Manning, have written about Cunningham's aesthetic in terms of objectivism and de-personalization. However, I suggest that his work can also be analyzed in terms of quantum phenomena, specifically of Heisenberg's uncertainty principle, in the ways that he used chance methods and sought to manipulate audience perspectives through new ways of using time and space. In contrast to proscenium conventions, his dances do not have a specific front, rather they decentralize the stage space to allow for moments of interest to pop up and disappear at random. Clocks, dice, or games could determine when each movement would occur onstage, rather than accompanying a specific timing in the music or predetermined place in the choreography. Cunningham is considered one of the major innovators in terms of re-organizing perceptions of time and space in dance. Rather than choreographing with a strict relationship of movement to music, Cunningham wanted the movement to speak for itself, holding an equal, but unrelated, position to the music. Joyce Morgenroth writes:

> Like Einstein's thought experiments, Cunningham's dances have an almost mathematical premise: they address the very foundations for organizing movement in time and space. They push us to look at dance with fewer preconceptions, to wonder about how we perceive space and how multiple timeframes can coexist, to understand how anything can follow anything else, to realize that our comfortable beliefs in how the universe works may have to be upset. (Morgenroth 33)

In this way, although Cunningham's work does not directly deal with scientific principles, it is deeply influenced by them, particularly in the ways it registers and performs the historical shift from deterministic models to emphasizing principles of uncertainty.

It is important to note that I am not claiming that shifts in one discipline caused a direct effect in the other, but rather that these major paradigm shifts were emblematic of a greater shift in thinking across disciplines during this time. Artists were not necessarily studying quantum mechanics in the studio, and scientists were not participating in danced improvisations in the laboratory, but the breakdown of the assumptions of stable objectivity and the philosophy of an integrated whole permeated both science and dance. Having established an understanding of these paradigmatic shifts in these disciplines since the mid-twentieth century, the next question is: What does study across and between these disciplines do for advancing knowledge in each?

STAKES OF INTERDISCIPLINARY RESEARCH

Studying physics and dance in relation to each other has important implications in each field, as well as for the status of knowledge production more broadly. This interdisciplinary research practice, which is the premise of my thesis, destabilizes the long-standing tradition in academic knowledge of the hierarchy which values scientific disciplines over the arts. Recognizing that knowledge produced in the performing arts can offer previously unrecognized insights for scientific disciplines is aligned with a contemporary, feminist way of viewing the conditions of knowledge production. This opening of the interdisciplinary field of feminist science studies is also a result of the larger paradigm shifts I have outlined previously: the masculinist assumption of objectivity on the part of the researcher is complicated by feminist scholarly critiques that recognize indeterminacy in the implication of the researcher on the phenomena being studied (Barad 816). Studying the overlap in ways of thinking and processing information across these fields, rather than perpetuating a binary, hierarchical paradigm—right brain versus left brain, or science versus the arts—opens up space in research fields regarding what types of knowledge are valued. In my thesis, I intentionally explore *through* the overlap of research within these disciplines, proposing that their intersection opens opportunities for understanding the various communication systems and tools used in each field in new ways.

On a personal level, as a woman and an artist who holds a degree in chemistry, a traditionally male-dominated field, I approach my artistic work with different perceptual and organizational abilities, capacities that I would not have without that education. My chemistry education taught me how to carefully observe and record data, analyze and use complex systems, and recognize beauty in simplicity and order. When I discuss notation systems later, I will illustrate this with an example of using elements of vector diagrams in a notation system that I created for rehearsal. I completed both my undergraduate education and my graduate dance degree in liberal arts settings, where interdisciplinary thinking is built into the educational model. This approach has promoted creativity and innovation beyond traditional disciplinary divisions.

This type of interdisciplinary research also challenges ideas of subjectivity and objectivity within scientific and artistic discourses. Science is generally considered to be based on objective, hard facts, but this is never completely true. Science is still conducted by people, who inherently have their own biases and subjective interpretations. In addition, there are principles of quantum mechanics, according to Heisenberg, which state that merely observing a phenomenon precludes the ability to be objective. "Observation", through vision or instrumentation, involves light interacting with the thing being studied. Since light has its own energetic properties, observation, on a subatomic level, changes the material being observed. Therefore, by carrying out scientific studies with various instruments and apparatuses, the subjective experience of the viewer is already at play. In contrast, art is often considered to be subjective, based on the individual interpretations of the artist and the response of the person interacting with it. However, as I will discuss in the course of this research, objective analytical tools can be useful in communicating and recording dance. My intention is to continue to complicate these ideas of subjectivity and objectivity through my research on translational communication methods in physics and dance.

Objectivity and abstraction are also racialized constructs. The artists that are referenced in my research examples are white, and they therefore are afforded certain privileges of abstraction and perceived objectivism that artists of color are typically not in artistic and scholarly discourse. Since being white, in both the dance world and society at large, usually means that one is seen as "neutral" and are not already prescribed cultural significance, choreographic work done by white artists tends to have the privilege of being viewed as objective or "purely" movement based. Artists like Merce Cunningham, Trisha Brown, and William Forsythe are all studied as innovators within their styles for stripping away narrative constructs and other elements of theatricality in favor of featuring the abstracted body. While studying their work has proved useful to my project, in terms of its relationship to scientific disciplines and studying the use of scores and notations in dance history, I recognize that there is privilege embedded in the scholarly discourse available on these artists due to their whiteness. I also recognize that my own whiteness affords me similar privileges around abstraction in my artistic construction.

TRANSLATING DIMENSIONALITY

"Matter is composed almost entirely of empty space. How can this be true?" This was the first question posed to me in my introductory chemistry class in the eighth grade. It was designed as an impossibility, meant to make the students grapple with the discrepancy between what they could observe with their eyes and what they were being told was true. It is very difficult, as a thirteen-year old, to see the heavy, solid textbook in front of you and believe what you are told: that the atoms that make it up are comprised of over 99.99% empty space. Further, my classmates and I were told that if an atom was the size of a football field, the solid nucleus in the middle would be the size of a pea. So, how does one begin to help a young student understand such a complicated idea?

We began with models. Each student chose an element and created a model of one atom of the element out of materials of our choosing. I made a model of a platinum atom. It had a Christmas ornament as the nucleus and sequins looped on thin wire to symbolize the electrons orbiting it. Although not even remotely close to the scale that exists in nature, it was a manageable, helpful way to visualize the size comparison between subatomic particles by seeing the amount of empty space in our rudimentary versions. Translating difficult concepts into a visual framework is a useful tool employed in many scientific disciplines for this reason.

Scientific modeling is the generation of a physical, conceptual, or mathematical representation of a real phenomenon that is difficult to observe directly. Models are both descriptive and predictive. Some attempt to visually represent an object or a phenomenon, such as the DNA double helix or the model of the atom, while others are created using known information to attempt to predict the function of a system, such as ocean currents or breeding projections. In my discussion, I focus on visual models, since both science and dance are concerned with bodies moving in space and time. With these types of models, scientists attempt to represent a complex idea in visual-spatial form, which offers a different way of understanding than things like equations or descriptions could provide.

An equivalent type of predictive or descriptive visual tool in dance is a score. Scores take many different forms in dance. They are most often used to enact a set of boundaries on movement. This can take the form of written or verbal instructions, game-like structures, chance methods, and drawings. As discussed earlier, scores are often used as a way to structure improvisation. For the purposes of this comparison, I am focusing on scores that have a visual component, most often on paper. These scores tend to propose rules around space and time that the performers then follow with varying degrees of choice. Like models, they may encapsulate different amounts of information about the system depending on the tools being used and the intention of the communication.

My inquiry into the intersection of physics and dance is focused on the visual-spatial methods used to translate three-dimensional ideas in time and space into two-dimensional communication tools. Communication tools in physics and chemistry, the sciences I am primarily concerned with, do this through visual models and apparatuses that produce static depictions of the state of a system. Communication tools in dance include scores—usually combinations of drawings, writing, and other directions to create rules for a performance scenario—and written dance notation systems, which record body position and effort qualities step by step. I have decided to break down dance and scientific communication tools into two categories with distinct temporal implications: tools for prediction/description and tools for recording/archiving. Scientific models and dance scores tend to be predictive; they use established information about a system to describe or predict the way the system will function. Dance notation and scientific apparatuses record the state of things or movement.

Having discussed how modeling and scores function as tools for describing and predicting movement systems, I now want to explore how related tools are used for recording and preserving those systems. Both scientists and dance scholars are interested in documenting details of a system using instrumentation and data collection or systems of writing and symbols. The term that I invoke to relate this work in both fields is apparatus. An apparatus is a set of materials or equipment designed for a particular use. For example, a balance is a tool used to measure the mass of a material. A broader definition can be expanded to include the functional processes by means of which a systematized activity is carried out (Merriam Webster).

I choose to use this term in my analysis in order to connect Karen Barad's philosophy of physics with André Lepecki's philosophy of dance. Barad argues that apparatuses are not just objective ways of recording phenomena but are subjectively designed to investigate particular phenomena. Lepecki argues that choreography is an apparatus that captures dance and relegates it to a fixed state. I propose that Lepecki's definition can also be extended to thinking of notation as an apparatus of capture. Thinking of these theories together enables one to think about the subjectivity in translation and recording processes. Both the instruments and the functional processes I will discuss share the function of recording specific types of information about the subject with the inherent subjectivity of the creator. The subjectivity inherent in the apparatus impacts the observed phenomenon, in the way that setting choreography and or notating a dance directs the viewer's perception in a specific way.

Instruments (apparatuses) used in physics and chemistry often involve looking at a system using a light source that interacts with the thing being studied and report data collected from that interaction. For example, a physical chemist would use an IR (Infrared) spectrometer to scan an aqueous solution of unknown compounds. The instrument then produces a spectrum, a kind of visual data recording of the scan such as the one in Figure 1, to determine what compounds are present based on the vibrational energies of the bonds. The apparatus is the machine itself that collects the data and creates a visual document of the information to be interpreted. Although, from an empirical, positivist stance it could seem that these instruments are merely recording the "natural" state of things, further philosophical analysis presents the argument that there is implicit subjectivity in designing and using apparatuses. Barad, a feminist quantum physicist and philosopher, theorizes how:

> Apparatuses are not inscription devices, scientific instruments set in place before the action happens, or machines that mediate the dialectic of resistance and accommodation. They are neither neutral probes of the natural world nor structures that deterministically impose some particular outcome ... rather apparatuses are dynamic re(configurings) of the world, specific agential practices/intra actions/performances through which exclusionary boundaries are enacted. (Barad 816)

Barad argues that scientific apparatuses are not merely built to record the full complexity of a system as it is, but they are designed to provide insight into some very specific phenomena.

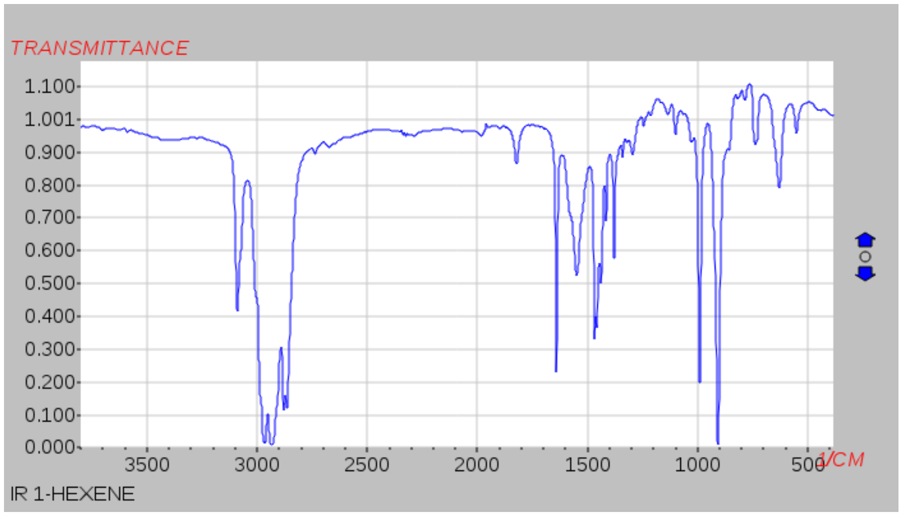

Figure 1. Example of an Infrared Spectrum

A similar point about subjectivity in the creation of apparatuses, and exclusionary boundaries created by those apparatuses, also exists in dance notation. In "Choreography as an Apparatus of Capture," Lepecki argues that choreography, at its core, is a tool of capturing movement. He writes, "To conceive choreography as an apparatus is to see it as a mechanism that simultaneously distributes and organizes dance's relationship to perception and signification" (Lepecki 120). The word choreography comes from the word "choreo," meaning dance, and "graphy," meaning writing. Thus choreography, as the writing of dance, suggests solidifying movement into a repeatable, learnable unit or pattern that can be analyzed. I wish to extend this definition to suggest that dance notation, too, is an apparatus of capture that reveals subjective preoccupations and exclusionary boundaries like Barad's apparatus.

For example, Feuillet notation from 1700 is a system that was used to record court dances and early ballet. In those dances, footwork and spatial patterning was the most important element, so the notation depicted the floor pattern of the steps. To learn the dance, one held a paper and quite literally followed the steps around the paper in different directions. This system focused on the feet, to the exclusion of other body parts, and spatial patterns, rather than embodied dynamics, revealing the subjective biases of its creator, who valued the social status associated with correctly and precisely performing the dances in the French court.

In 1928, Rudolph van Laban developed one of the most prominent forms of notation that is still in use today. Named "Labanotation" in his honor, this intricately detailed and comprehensive system records body position, facing, rhythm, dynamics, group arrangement, and other elements. It focuses on the tone and tension of the body moving through space, in a historical moment when choreography began to emphasize weight shifts and a different relationship of the body to gravity. This system revealed Laban's interest in the structural components of the body over any kind of association with rhythm or expression.

Each new notation system has attempted to solve a problem or improve upon earlier systems in order to make it more useful for a specific context. Despite their proclamations of objectivity and direct recordings of movement, each system also reflects the specific concerns of its creator(s) and thus the elements that are valued according to their subjective framework become the most legible in the notation system.

LOST IN TRANSLATION? THE ARGUMENT FOR DANCE ON PAPER

While visual models provide a compelling point of overlap between physics and dance, each field translates both predictive and recorded information into visual forms in distinct ways. Scientific models can make what is otherwise invisible, visible. In physics, visual forms such as models are often created to visualize something that is otherwise impossible to see with the naked eye. For example, a model of the atom helps people understand the basic three-dimensional arrangement of particles in space that are too small to be perceived through human visual senses. On the opposite end of the spectrum of scale, a model of our solar system situates our planet within the greater context of our galaxy and the interplanetary gravitational forces that govern orbits around the sun, making this information that can only partially be glimpsed with the human eye comprehensible as a totality. Scientists develop signs, symbols, and graphics to represent these concepts in a form that is recognizable and capable of literally being envisioned.

In dance "models" and apparatuses I discuss, the original data or form is already visible to the eye: moving bodies onstage. Models in dance make the invisible visible in a different way. Dances can be watched and perceived, or grasped with the naked eye, without additional visual context. The "invisible" that is made visible in scores and notation is the internal logic of the dance as determined by either the performers or the choreographer. These models provide insight into this internal knowledge of the dance's composition, which is often not legible to the audience.

The question might be asked: What is the purpose of communicating dances through language or visual mediums? There is a long history behind the stance that proclaims that the beauty of dance lies in its ephemerality, that the dance only exists in the moment it is performed by the dancers. Danielle Goldman outlines many of these arguments in her work on improvised dance *I Want to Be Ready,* citing scholars such as Mark Franko and André Lepecki who have proposed that attempting to preserve and record dance stifles the field of dance studies (Goldman 11). They argue that notation cannot capture the somatic physical experience of the dancer and that it relegates the dance to an unfeeling, analytical viewership. Even dancers and dance makers who relish the power of technology may be skeptical of its role in preserving dance over time.

The basis for the value in communicating dance through multiple methods, including written forms, is that there is always new information to be learned from translation into different forms. While certain aspects of the dance's creation or the underlying mechanisms that make it "work" may not be considered necessary to share with the audience, there is still much to be learned from processing and sharing that information. This information might help a choreographer recognize the unconscious patterns they have been making in their work, or it may be useful for a new dancer entering a given project to have a collection of rehearsal notes and footage to accompany a recording while they are learning the work. It also may make reconstructions of dance possible, such as the 1987 reconstruction of *Rite of Spring* by the Joffrey Ballet (Cook 1). The process of creating the recordings themselves is an exercise in recognizing what is fundamentally important to capture about a dance and how it might best be expressed.

The importance of translating information in ways other than written language is also shared in the scientific community. Catherine Chevalley writes about how quantum physicists, such as Bohr and Heisenberg, advocated for the importance of communication systems other than language to explain their research. She examines the way in which Bohr originally described concepts and "formal analogies" in his early papers and later switched to using the word "symbol" extensively after 1924 (Chevalley 241). The concrete systems of language and intuitive interpretations of classical physics would need to be re-conceptualized with more abstract ideas that were not so easily imagined. Bohr also declared that language, in the traditional sense, was unable to capture the ideas of quantum mechanics, and that in order to interpret these new ways of thinking, one would need to broaden their ideas about scientific communication. This invocation of symbols as a method of communication over language, as with notation and score systems as methods of translating dance, is consistent with many art forms.

Robert Root-Bernstein also argues for the importance of non-linguistic communication systems and philosophies in scientific fields:

> Creative scientists tell us that the languages we use to communicate objective results of science—mathematics and words, in the main—are simply inadequate for performing creative scientific thinking or for giving people insight into how this thinking occurs ... Only imagine, then, the possibilities if the tools of imagination—pattern recognition, pattern forming, analogizing, abstracting, kinaesthetic feelings, modelling, a "feeling for the organisms" and ways to synthesize these—what I call the "tools of thinking"—were directly communicable! (Root-Bernstein 1996, 72)

He argues that science should embrace the non-traditional methods of communication from artistic practice, specifically referencing kinesthetic knowledge, in order to broaden the scope of the type of information scientists can convey. This is an example of the potential for interdisciplinary research to broaden the possibilities of understanding and communication. Dancers are uniquely familiar with enacting multiple forms of knowledge in their practice. For example, linking kinaesthetic knowledge from years of physical training, spatial awareness of pattern forming within a group, and analytical knowledge of music structures are all simultaneously required to learn and execute a dance. While advocating that incorporating this multiplicity of approaches into scientific fields could emphasize the creative nature of the sciences, he does include the caveat that, as with all communication tools, certain elements will necessarily be left out.

Concern about the mistranslation of ideas through models or other visual formats is shared by dance scholars as well. Critics of dance notation often argue that attempting to translate movement to the page inherently does a disservice to the complexity of the art form. Laurence Louppe writes:

> It will be said that the notation of dance does treason to its emotion and to the urgency of a present moment, to a real transferal of energy; it will be said that what comes about in danced movement—what is "torn" out there, far more than simply manifested—cannot be translated, cannot be brought back, is linked to pure emotional and physical actualization, which no sign can restore, which no sign has even the right to inscribe as a definitive event in the annals of human time. (Louppe 20)

Any system has benefits and flaws. In creating a system that translates one element well, another is likely overlooked or unrepresented. In the following sections I investigate the methods of dimensional translations in physics and dance, exploring what the potential outcomes of these tools are in terms of gains and losses of information.

Another element of perceived "loss" in dance notation is the ability for the dance to morph. Lepecki writes, "Dance, once it falls prey to the powerful apparatus of capture called 'choreography', loses many of its possibilities of becoming" (122). His comment reflects the thoughts of other contributors to the special issue of *TDR* in which his essay is published. This would suggest that improvisation is the only form in which dance can retain its ability to transform and not "fall prey" to the rigidity of capture. Part of Danielle Goldman's project involves questioning this notion of improvisation as freedom from the constraints of choreography. She cites Lepecki's previous scholarship—on dance's ephemerality and the inability of dance notation systems, like Labanotation, to capture the complexities of improvised dance—as evidence of a tendency to dismiss improvisation as merely freeform movement, unworthy of analysis. Goldman intervenes by arguing that without some elements of recording, she would have no way to do her study, writing, "I also acknowledge the political significance of documentation and the frequent necessity and evidentiary potential of ephemera" (12). Documentation can be a process that legitimizes dancing in some contexts by allowing it to become part of recorded history. Beyond creating a static artifact of an absent performance, recording creates another type of artifact that can exist in relation to the original work or independently. Dances that are notated and documented in some way have an ability to continue to be studied, performed, and inspire new research. In this way, the ability for continued study and performance could be considered a different kind of "morphing." Perhaps instead of losing an ability to become, it is gaining an ability to become something new.

CHOREOGRAPHERS WORKING WITH SCORES AND NOTATION

To illustrate how dancemakers use these translational structures in various ways, I will discuss two examples from contemporary choreographers. Anne Teresa De Keersmaeker's *Drumming* (1998) relies on the creation of a floor pattern based on mathematical principles of the Fibonacci sequence (De Keersmaker and Cvejic 26). This pattern determines the pathways of the dancers and where they will align with each other in space. Although the pattern is presented alongside the work as a graphic made from tape laid on the floor, it is not immediately recognizable to the audience watching the work how this graphic frame is affecting the movement of the dancers. Scores and notes that accompany her work, created by dramaturg Bojana Cvejic, help reveal how de Keersmaeker constructed the overarching pattern of her composition and how the dancers execute specific movements across those given pathways. These visual, two-dimensional tools used in dance bring additional information to the surface of the audience's attention that cannot be gleaned from watching the dance alone.

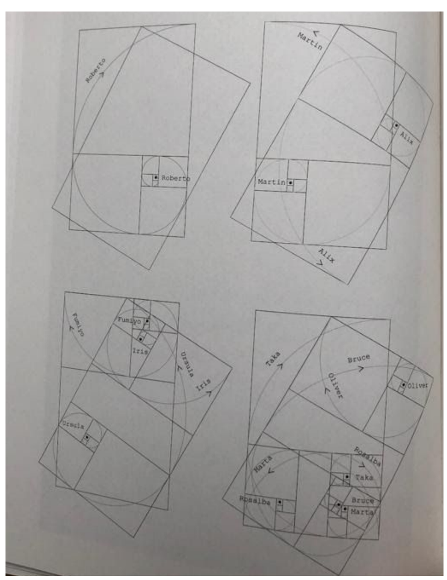

Figure 2. Score for Anne Teresa De Keersmaeker's *Drumming* (1998)

In 2009 William Forsythe, in collaboration with the Advanced Computing Center for the Arts and Design at Ohio State University, explored the possibilities of combining scientific and choreographic notation through the interdisciplinary work S*ynchronous Objects for One Flat Thing Reproduced*. Forsythe's *One Flat Thing Reproduced* first premiered as a stage piece in 2000 and was turned into a film in 2005. The film was set in a large warehouse featuring twelve dancers and twelve identical tables. Dancers enter and exit the space, sliding on and between tables, crouching underneath them, and partnering each other according to a complex system of cues. The *Synchronous Objects* interactive online program notated and mapped various elements of *One Flat Thing Reproduced* by analyzing dancer pathways, movement vocabulary, interactions, and more.

Data scientists collected information about the location and movement pathways of each dancer at every second throughout the piece. Each of these notations could then be added as layers, called "objects" for the purposes of the project, that are played on top of the filmed dance. One example is the Alignment Annotations, which mark instances of related pathways in bodies of multiple dancers. For example, if a dancer swipes their arm in a semi-circle, a red arc will appear drawn in the video footage tracing their path, while another dancer simultaneously creates this arc with their leg colored in blue. This allows the viewer to recognize patterns and moments of synchronicity in the sea of movement. Through *Synchronous Objects* scientists and dancers collaboratively reimagined the various possibilities and uses of visual data collected from dance.

A common critique of dance notation is that it does not take into account the personal experience of the dancer. The *Synchronous Objects* team combatted this by personally interviewing the dancers about when and how they gave and received cues throughout the piece, as well as where they were aware of alignments in the choreography. This information was collected as a data bank that serves as the basis for some of the "objects," including Cue Notations. This "object" makes visible the deeply personal knowledge of the dancers regarding where they take their movement cues from, something that would be impossible to know as an audience member watching the piece on its own.

As discussed previously, there is a concern among dance scholars that recording dance on paper misconstrues the truth of the dance. Rather than focusing on what notation and scores cannot accomplish, Norah Zuniga Shaw, a data scientist with a background in choreography and one of the collaborators on the project, provides perspective on how this perceived loss of information can be reframed in a research context, writing, "As in many forms of inquiry, quantification requires a reductive process that necessarily obscures certain aspects of knowledge (the dancers' intentions, performance quality, and kinesthetic awareness) in order to reveal others (in this case, choreographic structure)" (Synchronous Objects website, Intro:The Data). While some information may be lost in translation, such as performative intention, emotion, and other elements that make dance as a live performance art so special, new information about patterns and timing can emerge. *Synchronous Objects* is one of the most robust digital notations ever created for dance and completely reimagines the possibilities of using modern technology to gain new insight into the creative collaborative process between dancers and choreographers.

SCORES AND NOTATION IN THE REHEARSAL PROCESS

My performance work aims to explore the connection between choreographic and scientific modeling (specifically in quantum mechanics) through studies in dimensionality and visual design. Using a combination of lighting, projection, movement vocabulary, and video, I created scores and material for the dancers that highlighted bodies and silhouettes in varying forms. The work, entitled *(re)con(figure)*, does not attempt to portray specific scientific concepts, but instead uses various principles of physics and design such as symmetry, scaling images, and reflection as starting points for examining the intersection of the disciplines. I intentionally used scores and notations as both part of my rehearsal process and conceptual base for the arc of my piece.

I incorporated written scores into my artistic process to generate movement. The scores I created also recorded the floor patterns of the dancers and helped me to strategically separate their locations in space at any given time. This was especially helpful in the section that was lit by a projector, which created shadows of the dancers. Scores allowed me to mark certain moments where I wanted things to be aligned, while allowing for flexibility in the transitions between those moments. Each dancer had a specific pathway that kept them within the beam of light, while also leading to crossings and overlaps with other dancers' pathways. The movement vocabulary was also its own score. I directed the movement to be flat, angular, and involve multiple quick shifts of direction.

I found scores to be a particularly useful tool as I tried to navigate my role as both dancer and choreographer in the work. As a choreographer, scores allowed me to see the larger picture of the movement on stage and lay a framework for a section without strictly choreographing each step. As a dancer, they gave me the performative freedom to keep exploring within the limitations during each iteration. Similarly to how models can be a condensed representation of movement in time and space, scores can be a representation of a whole piece of choreography.

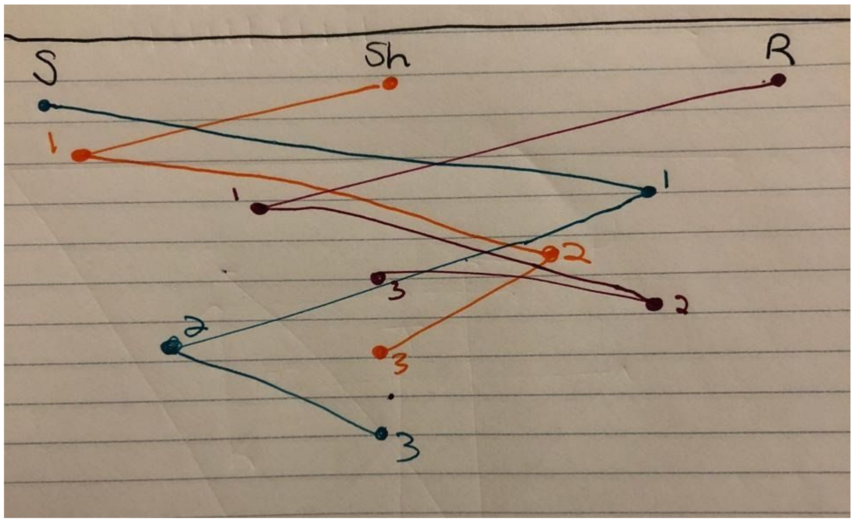

Figure 3. Score for (re)con(figure)

I propose that one potential consequence of this interdisciplinary research in regards to creating systems of recording is that one communication system can solve problems proposed by another. One example of this is the need to draw or write in three dimensions on a two-dimensional surface when creating dance scores and notations. I navigated this issue in my performance work when creating and recording static body positions that serve as the basis for movement material.

The body positions are based on a spatial system that is a cube divided into 27 points. There are nine points that make up a square at the ground level, waist level, and overhead level. Other dance artists have used this cube system for different purposes. Rudolph

Laban used the cube and other volumetric geometry to ascribe shape to movement (Brooks 1). Trisha Brown created movements that touched each individual point and then created a score to put these movements together when creating her 1975 solo *Locus* (Sulzman 118). I incorporated it by asking each of the dancers to create a set of gestures, each of which needed to simultaneously touch three points of the cube. As part of my rehearsal process, I created a system that could record these gestures and help other dancers in the work learn them. The system broke each layer of the cube apart. These layers were written on the page from an aerial view, with symbols for body parts and direction marking the placement of limbs on each level. The aerial orientation presented the challenge of the z-axis, movement in and out of the page, and I looked to other systems of recording that I was familiar with to answer this challenge.

In order to account for the spatial conceptions of the cube system, my notation system incorporates constructs from vector diagrams in physics. Vector diagrams are a tool used for modeling all of the forces acting on an object in order to calculate something unknown about its potential movement or energy change. For example, a box sitting on the ground has a relationship both to gravity and the force of the floor pushing up in the opposite direction. The same box sitting on a ramp has a different relationship to gravity, in addition to the friction between the surfaces. These forces are usually indicated with arrows pointing in the direction of the force. To indicate that a force is going in the z plane into the page, the ⊗ symbol is used. For a force going in the z plane out of the page, the ◉ symbol is used. I chose to incorporate that system of direction marking in the notation system I created to indicate vertical direction in the body. Having this knowledge of modeling systems in one discipline allowed me to create a more robust and legible system in the other.

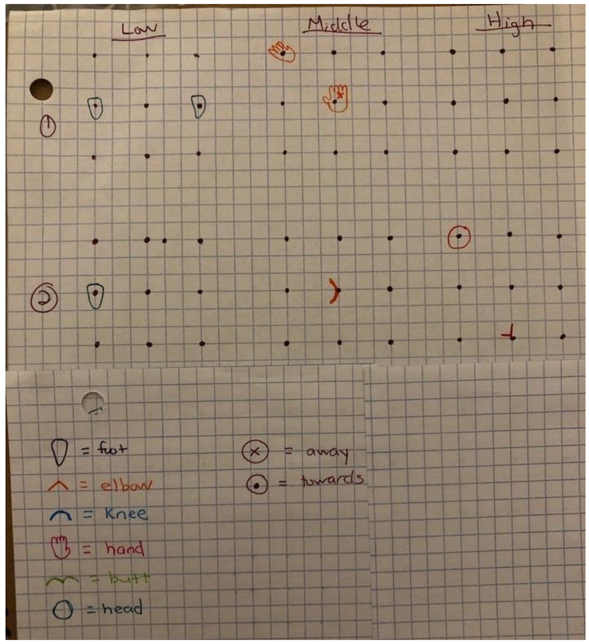

Figure 3. Example of notation built with 27-point cube system

Creating this system was a useful way to generate and record movement. I explained this system to my dancers and asked them to record movements that had previously been made using the new system. They also used it in the reverse direction, first creating notations using this system and then translating it into new movement. It was simple, easy to learn, and gave the dancers a new understanding of the movement material. Recording the positions in a view other than frontal also provided me with a new concept of space in the work. While the audience typically views dance only from the front, and this is the case in my performance as well, dancing is a multi-dimensional experience that requires knowledge of every plane. Especially with the lighting and projection effects I used (which I will explain in more detail in the next section), thinking about what the body looks like from multiple angles was an important consideration in structuring the shaping of the body throughout the piece.

PERFORMANCE WORK: (re)con(figure)

Disclaimer and Context

Due to the COVID-19 crisis, Sarah Lawrence College was required to move classes online starting in the middle of March 2020. The live MFA Thesis performance that was scheduled for the beginning of April was not able to happen as planned. Instead, the thesis candidates created digital projects that transform the work that was created for the stage. The writing collected here, unless otherwise specified, describes the original work as it was intended to be performed live. When discussing the work as it exists in its new digital format, I will explicitly differentiate the descriptions.

Lighting as a Performative Tool of Dimensionality

A main goal of my performance work for this thesis project was to incorporate the ideas of modeling, scores, apparatuses, and notation into a live performance that still honored the movement aesthetics that I enjoy working in. I chose to tackle this task through the use of a variety of lighting and video design elements in the work, which present distinct studies in dimensionality in different sections of the piece. I created the overall concepts for the design, and the lighting designer, Kenia Rosete, contributed with design and execution of the stage lights. The tools and designs we used attempted to create an arc of flatness to multidimensionality across the trajectory of the piece and guide the audience's vision in particular ways.

The piece opens on a black stage with a single dancer on stage who is obscured to the audience. All that is visible is the green glow tape shapes that wrap around parts of her limbs.

The audience can see movement, but they can't really distinguish the bodies or what parts are moving. Two more dancers join one at a time onstage, and eventually the pace of the movement picks up as they repeatedly switch spots in a tight clump, while they execute quick, sharp positions. As the dancers spread out in space, they do movements that create arcs of their limbs, like arm circles and fouetté arabesques. This quick, sweeping motion leaves a path of light in the audience's eyes, which can only see the trace of light from the bodies. In this way, the light traces are acting as a way of recording the movement, where only certain elements are retained based on the construction of where the glow material is placed. Over the course of a minute, low blue lights come on and the white, tight-fitting costumes of the dancers, which cover their entire bodies, start to glow, as if under ultraviolet light. The audience begins to get a picture of whole bodies, but still cannot see faces. The overall impression of this section is the conception of the dancers as moving objects, not yet fully visible or three dimensional.

From there, the next section of the work is lit by a projector and incorporates elements of both scores and notations. The projector is placed on the floor at the front and center of the stage space. The light is projected onto the back wall of the stage and falls onto the dancers, creating sharp silhouettes of the dancers when they stand in its beam. Silhouettes are used as an aesthetic device that transforms three-dimensional bodies into two-dimensional graphic design. The section starts with a black and white grid, and primary-colored dots appear at the corners of the squares one at a time. A dancer does a movement that casts a shadow, and the dot appears in the spot where a part of the body like a foot or a hand meets the corner. The first few times this happens, the timing is aligned so that the shadow hits the spot and the dot appears instantly. As the section progresses, this interaction becomes more random because the movement becomes part of an improvised score. Sometimes the dancers will pause in time with a dot, other times dots will appear in open spaces. My intention with this construction is that the audience is left to decipher the patterns of what is functioning as a recording and what is a chance encounter.

The collection of dots then regroups and assembles into three large red, yellow, and blue rectangles, signaling a transition into the next part of the projection section. The colored blocks slide and rotate as the dancers perform in front of them. Sometimes the dancers move in time with the shapes or in ways that mirror them. For example, the rectangles come together and overlap vertically in the center as the dancers line up behind each other directly in front of them. As each block rotates 90 degrees and flies upwards in a canon, the dancers tilt into a side arabesque and complete their own canon of movement. In contrast to the first section, the light from the projector is bright enough in this section to illuminate the full body. However, there is still a sense of flattening that comes from having front light as the only source. Throughout the section with the projector, there is also the tension between the full three-dimensional movement in space of the actual bodies and the two-dimensional moving images of the silhouettes on the flat wall created in tandem with it. In this way, multiple constructions of dimensionality are presented simultaneously.

*The following section describes the lighting design that was intended to accompany this section, but was not brought to fruition before classes transitioned online due to the 2020 COVID-19 outbreak.

As the dancing evolves from being more flat shape-oriented to more three-dimensional, the stage becomes brighter and is illuminated from multiple angles. Transferring the shapes from one surface to another angle is another method of exploring three-dimensionality, as it creates a very different lighting effect on the illuminated bodies. As the projector fades out, a red and a blue rectangle appear on the floor of the stage, mimicking the colored rectangles from the previous section. The bright color palette is carried throughout the design.

Finally, the lights fade back into darkness as the dancers repeat the opening cluster with different movement. The audience sees the dancers lit only by the traces of the tape again, but this time has much more information about the bodies and movement before the lights are taken away. Lighting design, therefore, functions in the piece as an apparatus of directing the audience's vision. Although this argument could be made for any lighting design choice, the unusual, highly specific constructions that I used in the piece played with visibility versus invisibility and flatness versus volume in strategic ways. The video design and lighting functioned also to produce a visual recording of the movement as a form of notation in real time. These elements were integral to the research process as well as to the final product.

Other Elements of Performance Work

The elements of my performance work that I have discussed thus far have mainly been about the structure of the piece and the theoretical lenses that I applied when creating it. To provide a fuller picture of the piece, I will now elaborate more on the content itself. This includes the movement vocabulary, music, and driving factors behind putting everything together. My goal was to craft a dance that took the concepts I was interested in and incorporate them into a cohesive piece that highlighted the skills of my dancers and my broader interests as a choreographer. The following sections will address how I attempted to achieve that goal and my influences in arriving there.

Since I work with projection, most of the movement material was designed for creating maximum visual impact. I have an interest in creating symmetry and identical forms both between the dancers and between the dancers and their shadows. A way to accomplish this is through geometric, sometimes static, body positions with an emphasis on distil expansion. This aesthetic was partially informed by how I like to move in my own practice, and partially based on the choreographers whose work I researched for this project. A common thread between the artists whose work I previously discussed is the aesthetic of the movement itself. Cunningham and Forsythe both incorporate elements of ballet into their work. Ballet as a dance form is based in the creation of a picturesque experience for the audience, focusing on elegant shapes and lines. These choreographers do not necessarily incorporate the same aesthetics from ballet, but both take the principles of clean, sharp, readable body positions as a method of organizing their movement. My choreographic work also utilizes this aesthetic. In the dark or through a shadow, small movements of individual body parts or the spine are not as legible. Movement that used the expansion of the limbs and frequent holding of positions created the strongest visual landscape.

The overarching structure of the piece moves through a progression in the movement vocabulary from very sharp, angular movements with static limbs, to movements with broken limbs and a fluid spine. The first movement, seen in the glow tape and then more visible as stage lights slowly turn on, is based on rigid geometric poses that then travel through space in sweeping and turning motions. In the middle of the piece, there is a movement phrase that is done as a solo, then repeated as a duet and a trio. During this section, the movement begins to shift into allowing more mobility in the spine, switching from swinging leg gestures to melting side bends and circling ribs. It is most visible in a movement where the dancers' feet are apart in a wide stance. Their arms reach out straight in front of their bodies, one higher than the other, followed by a body roll from the head down and then in reverse, from the pelvis up. It is a curve stuck between two lines. This spinal motion is carried through to the final section and is expanded to the limbs, starting with one dancer's solo movements involving waves that flow through her whole body punctured by quick stops. The final movement is a spatial reprise of the beginning cluster, but this time with a significant increase in mobility of each limb. This evolution is meant to mirror the lighting design that demonstrates the journey from flatness to multi-dimensionality.

For the soundscape, I wanted the music that accompanied the piece to set the tone of an abstract, narrative-free world that existed in some kind of blank space. I worked with a student composer, Kat Carlsen, to create original music for the piece. When we met at the beginning of the year, I gave Kat a general overview of what I was looking for and different ideas about tone and overall composition. I wanted electronic, fairly minimal music, that reflected ideas of dimension and arc through time. She created the music in several sections, each with a slightly different mood and melody. As I went through the rehearsal process, I met with her to discuss the length of each section and the major transition points that I wanted to line up with the movement. Having music created specifically for my work complemented the visual design and provided another sensory component that highlighted the arc of the work across sections.

New Video Work

The new video project focuses on four of the sections of the original work: positions created using the 27-point notation system, the grid projection, the color block projection design, and material that accumulated from a solo to a trio.

As previously discussed, the dancers and I used the 27 -point cube system to create four positions that each touched at least three points on the cube at any time. These positions were the basis for the first section of the live work, which was originally performed in the dark with only the traces of the glow tape visible. Rather than obscuring the creation of this movement, I decided for the digital work to make the creation more explicit and expose the system used for its creation. I decided to incorporate a picture of the handwritten score as the first image, which shows each "level" of the cube split apart into its component nine dots and the direction of the body parts touching the point on that level. I then used Microsoft Paint 3D to create a three-dimensional digital rendering of the cube system to show how it translates from paper to an object that can move in space. Using my own positions as a reference point, I created digital sketches of an abstract body-like figure inside the cube to illustrate how the body aligns within that framework. I shot a video of myself rotating in the positions that matched the video of the digital figure rotating to illustrate how the two correlated. My goal with this section was to intentionally reveal more of the inner workings of the creative process and to show multiple forms of notating and recording this material.

The internal logic of the piece is also revealed through additional documents of rehearsal scores. For one section, the score is incorporated as an inset to accompany the section of the dance which is dictated by that score. This allows the audience to see a concrete example of how scores were used to determine spatial locations of the dancers in the piece.

Inspired by the *Synchronous Objects* notations, I was very interested in creating live traces of the movement pathways. One way this was accomplished in the live work was with the glow-in-the-dark section where the audience could only see the path left by the limbs. For the new work, I was able to take this a step further in post-production and draw on the videos themselves to illustrate the shapes of the pathways created by the phrase presented in the section as a solo, duet, and trio. The live work also included a section where a grid was projected onto the wall and colored dots would appear when the dancers' silhouettes touched specific points. The video includes footage of this as performed on stage, but also recreates it using Zoom video conferencing software with the projection design as a virtual background. This showcased spatial orientation by comparing the effect of the grid being cast onto the dancers from the front and creating a shadow, versus the unsettling paradox of being both in front of and behind the grid as a virtual background where the dancers reached for the dots.

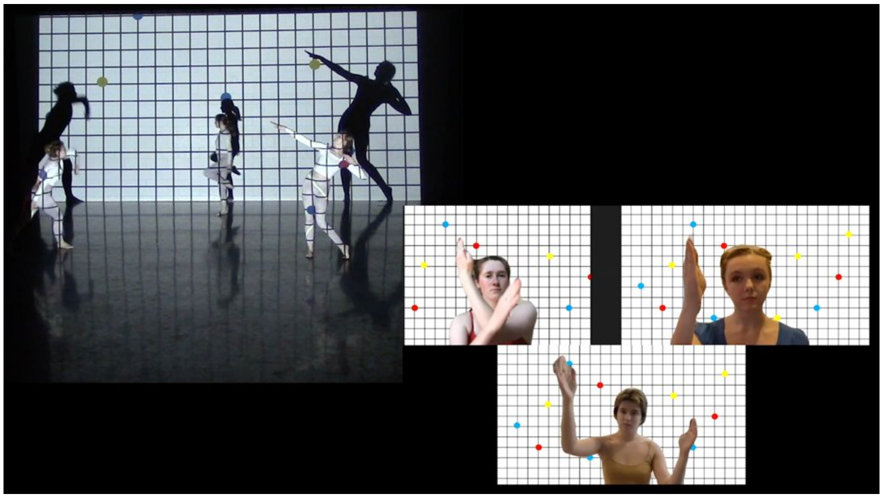

Figure 5. Grid design in projection and Zoom form

CONCLUSIONS AND FUTURE RESEARCH

As a dance artist, creator, and future educator, I believe there is value in continually expanding knowledge about dance communication and learning. Since scientific modes of thinking are so ingrained in my own world perspective, I feel it is important for me to productively use this interest to continue learning about the intersections of science and dance. This research, both in the studio and in my writing, has provided me with more insight into the stakes of interdisciplinary research for my own creative practices, as well as for the field of dance at large. Being engaged in these ideas of translation, multi-dimensionality, preservation, and objectivity has informed the way I make choices and talk about my creative work. It has also inspired future research questions regarding how communication systems are established and utilized.

One takeaway from this project is that every field of study requires structure and systems in order to communicate. Dance knowledge is transferred in countless ways, from mentorship, to oral history, to formal academic structures, to gaining embodied knowledge, to writing. Each of these relies on certain communication tools like a shared language or formal shared social constructs in some way. The visual communications that my research has discussed can also be part of this toolbox of communication methods, each with its own requirements for shared understanding. With any kind of communication and learning, the possibility of multiple or simultaneous ways of communicating have the potential to reinforce the information in different ways. To build on this research, I would be interested in examining the implications of using a wide variety of types of scores and notations in an educational context to investigate the potential impact on learning dance.

My research has mainly focused on the methods of translating dance information in these cross-dimensional tools, but leaves many additional questions to be explored about the purpose and potential implications of doing so. A question that I would pursue in further research is: who is doing/is able to do notation, and who is reading /is able to read it? Historical forms of notation are not widely known and studied, and therefore very few people can create new records or read the historical ones. So, if it is valuable for the field of dance notation to continue evolving, as I have argued here, who will be the ones creating and using the systems? What types of dances should or will they notate? These questions lead into much more complicated issues of access to technology, education, training, and more. They also lead to questions about the value of non-linguistic or symbolic communication methods being legible across cultures and languages. One of the beauties of scientific and mathematical research is the ability to share and preserve data across cultural barriers since there are systems in place that are taught across cultures as secondary language. I believe that the possibilities of creating systems in dance that had that same power would have a significant impact on cross cultural dance education.

Finally, this interdisciplinary work blurs boundaries between subjectivity and objectivity, especially in regards to which of these dimensions are typically associated with science versus the arts. Science does not deal with all objective facts and data collection. As Karen Barad and others theorize, the interactions that are studied in a scientific context will always have some sort of subjective element due to the fundamental nature of both how the collection occurs and the scientists involved in the process. In the same vein, dance creation, viewership, and study are not all subjective. There are systems like scores and other communication tools that choreographers have been using for decades to track and organize their work. As technology becomes more advanced, the potential for data to be extracted and studied from dance, as with the *Synchronous Objects* project, continues to grow exponentially. Recognizing that the arts and science are not in opposition to each other, but rather operate with many shared principles, is important for dismantling the privileging of scientific disciplines over the arts in formal knowledge structures.

BIBLIOGRAPHY

Barad, Karen. "Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter." *Signs: Journal of Women in Culture and Society*, vol. 28, no. 3, 2003, pp. 802-31.

Brooks, Lynn Matluck. "Harmony in Space: A Perspective on the Work of Rudolf Laban." *Journal of Aesthetic Education*, vol. 27, no. 2, 1993, pp. 29–41. *JSTOR*, www.jstor.org/stable/3333410. Accessed 3 Mar. 2020.

Brunning, Andy. "The History of the Atom: Theories and Models." Compound Interest, 13 Oct. 2016, www.compoundchem.com/2016/10/13/atomicmodels/.

Charap, John M. *Explaining the Universe : The New Age of Physics*. Princeton University Press, 2002. Pp. 43-63.

Charap, John M. *Chance and Certainty: The Weird World of Quantum Mechanics*. Princeton University Press, 2002, pp. 1-22.

Coates, Emily, and Sarah Demers. *Physics and Dance*. Yale University Press, 2019.

Cook, Greg. "A Reconstruction of 'The Rite of Spring' As The Infamous Ballet Turns 100." WBUR The Artery, 15 Mar. 2013, www.wbur.org/artery/2013/03/15/rite-of-spring.

Dolling, Lisa M. *Hypatia*, vol. 24, no. 1, 2009, pp. 212–218. *JSTOR*, www.jstor.org/stable/20618137. Accessed 3 Mar. 2020.

Gable, Kevin P. "Infrared Spectroscopy: Identifying Functional Groups." Oregon State University, 15 Dec. 2019, sites.science.oregonstate.edu/~gablek/CH335/Chapter10/IR.htm.

Goldman, Danielle. *I Want to Be Ready : Improvised Dance As a Practice of Freedom*. University of Michigan Press, 2010.

Hediger, Irène, and Jill Scott. *Artists-in-Labs: Recomposing Art and Science*. De Gruyter, 2016.

Heelan, Patrick A. *Quantum Mechanics and Objectivity: A Study of the Physical Philosophy of Werner Heisenberg*. Springer Netherlands, 1965, pp. 3-22.

Louppe, Laurence, editor. *Traces of Dance: Drawings and Notations of Choreographers*. Distributed Art Pub Inc., 1994, pp. 9-33.

Lepecki, André. "Choreography as Apparatus of Capture." *TDR (1988-)*, vol. 51, no. 2, 2007, pp. 119–123. *JSTOR*, www.jstor.org/stable/4492763. Accessed 3 Mar. 2020.

Manning, Susan. *Modern Dance, Negro Dance: Race in Motion*. University of Minnesota Press, 2004, pp. 179-221.

Massumi, Brian. "The Autonomy of Affect." *Cultural Critique*, vol. 31, 1995, pp. 83-109.

Morgenroth, Joyce. "Physics in Performance: Three Choreographic Adaptations." *Dance Chronicle*, vol. 33, no. 3, 2010, pp. 353–387., www.jstor.org/stable/29777210.

Morris, Gay. *A Game for Dancers : Performing Modernism in the Postwar Years 1945-1960*. Wesleyan University Press, 2006, pp. 166-204.

Sulzman, Mona. "Choice/Form in Trisha Brown's 'Locus': A View from inside the Cube." *Dance Chronicle*, vol. 2, no. 2, 1978, pp. 117–130. *JSTOR*, www.jstor.org/stable/1567474. Accessed 3 Mar. 2020.

Tauber, Alfred I. *The Elusive Synthesis: Aesthetics and Science*. Springer Netherlands, 1996.

Trembeck, Iro. "The Written Language of Dance or Preserving Dance on Paper." SubStance, vol. 10, no. 33, 1981, pp. 66-83. JSTOR.

Waters, Sandie H., and Andrew S. Gibbons. "Design Languages, Notation Systems, and Instructional Technology: A Case Study." *Educational Technology Research and Development*, vol. 52, no. 2, 2004, pp. 57-68. *JSTOR*.