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UNIVERSITY OF CALIFORNA, SAN DIEGO SAN DIEGO STATE UNIVERSITY

Reciprocal Engagement Between a Scientist and Visual Displays

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy

in

Mathematics and Science Education

by

Michelle Maria Nolasco

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University of California, San Diego

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The Dissertation of Michelle Maria Nolasco is approved, and it is acceptable in quality	
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	Co-Chair
	Co-Chair

University of California, San Diego San Diego State University 2012

DEDICATION

I dedicate this dissertation to my late game dog, Sega.

He was sixteen years old and held on until five weeks before my defense.

He was my best friend.

Now Atari gets more attention, but I still keep Sega's bowl filled with fresh water.



Sega 1995-2012

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VITA

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ABSTRACT OF THE DISSERTATION

Reciprocal Engagement Between a Scientist and Visual Displays

by

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Doctor of Philosophy in Mathematics and Science Education

University of California, San Diego, 2012 San Diego State University, 2012

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In this study the focus of investigation was the reciprocal engagement between a professional scientist and the visual displays with which he interacted. Visual displays are considered inextricable from everyday scientific endeavors and their interpretation requires a "back-and-forthness" between the viewers and the objects being viewed.

The query that drove this study was: How does a scientist engage with visual displays during the explanation of his understanding of extremely small biological objects? The conceptual framework was based in embodiment where the scientist's

talk, gesture, and body position were observed and microanalyzed. The data consisted of open-ended interviews that positioned the scientist to interact with visual displays when he explained the structure and function of different sub-cellular features.

Upon microanalyzing the scientist's talk, gesture, and body position during his interactions with two different visual displays, four themes were uncovered: *Naming*, *Layering*, *Categorizing*, and *Scaling*.

Naming occurred when the scientist added markings to a pre-existing, hand-drawn visual display. The markings had meaning as stand-alone label and iconic symbols. Also, the markings transformed the pre-existing visual display, which resulted in its function as a new visual object.

Layering occurred when the scientist gestured over images so that his gestures aligned with one or more of the image's features, but did not touch the actual visual display.

Categorizing occurred when the scientist used contrasting categories, e.g. straight vs. not straight, to explain his understanding about different characteristics that the small biological objects held.

Scaling occurred when the scientist used gesture to resize an image's features so that they fit his bodily scale.

Three main points were drawn from this study. First, the scientist employed a variety of embodied strategies—coordinated talk, gesture, and body position—when he explained the structure and function of extremely small objects. Second, three descriptive areas appear to influence the scientist's interactions: the small biological

objects' features, the interview context, and the interview space. Finally, the interaction of the scientist's body with the visual displays created a unique engagement that allowed the scientist to share his understanding about extremely small biological objects.

CHAPTER 1: INTRODUCTION

1.1 Chapter Introduction

In this study the focus of investigation was a professional research biologist and his reciprocal engagement with visual displays of phenomena that he encountered during his everyday work. The phenomena, which were muscle cell substructures of extremely small size, required electron microscopy in order to generate images that could be perceived by unaided vision. During the scientist's interpretations of the micrographs, he engaged with the visual displays in various manners. Specifically, in this study, explanation, interaction, and engagement were investigated as expressions of understanding of the not readily visible phenomena depicted by the visual displays. In light of these topics, the inquiry that drove this study concerned facets of embodiment. It was the descriptions of these interpretations that elucidated the embodied ways—talk, gesture, and body position—through which the scientist shared his understanding about the phenomena depicted by the visual displays.

1.2 Visual Displays

Visual displays are effective vehicles to present multiple relationships and processes, capture conjectures and impressions, display data, and organize complex information. In the case presented in this document, scientific phenomena that could not be observed or experienced directly due to their extreme size or function were presented by the visual data created by the scientist. The phenomena that were depicted by the visual displays were muscle cell components: sarcomere units and myosin molecules. Their original images were generated through electron

microscopy (Figure 1.1). The details of visual displays' formats, methods of creation, and their limits of acceptable interpretations are factors that influence how different types of scientific visualizations function in a given situation.

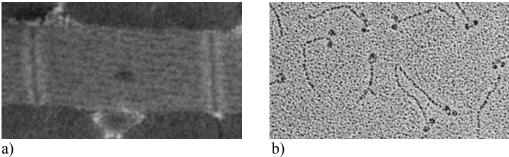


Figure 1.1: Electron micrographs of nanometer-level structures from muscle cells. a) A single sarcomere. b)

Multiple myosin molecules.

Experience between scientist and visual displays change over time. Initially, visual displays creations tend to be well-ordered events that are based on established protocols. In contrast, once the visual displays are ready to be analyzed, their interpretations are messy processes that include reciprocal negotiation between the scientist and the visual display. Interpretation is most effective when a visual display's modality, such as a graph, diagram, or three-dimensional object, matches the type of information that will be displayed. Often the phenomena and the visual displays are not perfectly matched. In these cases where the scientist is distanced from the visual display, which is itself disjointed from the phenomena that it displays, use of embodied interaction and engagement can be a solution.

1.3 Reciprocality and Visual Displays

In the realm of interpreting visual displays, explanation, interaction, and engagement all involve reciprocality between viewers and the visual displays. In

scientific practice, interpretations are sense-making events that occur when scientists take meaning from and assign meaning to phenomena depicted by visual displays. Scientists extract meaning from visual displays when the displays are, typically, encountered through the sense of sight. The new information about the phenomena depicted by the visual displays is incorporated with prior knowledge and experience related to the subject. Scientists then ascribe the newly synthesized understandings to the visual displays.

Explanation is the act of sharing understandings about phenomena that were developed during interpretation; it is a secondary meaning-making act. Although explanation is secondary, it can assist with problem solving and further develop the explaining scientists' understandings of the phenomena. The scientist-visual display reciprocality remains even when the third party, the one being explained to, is involved.

Interactions result when the scientists' abilities to manipulate and explore information is linked to changes in the associated visual displays' outcome. For instance, rotating a digital image could affect how the viewer understands it in the context of its usage. The display systems must offer choices, whether the phenomena depiction display systems are precise technological interfaces or simple sketching materials. Also important to the definition is that intent is present behind the scientists' interactions.

Engagement requires the ability to take action in terms of changing, constructing, viewing, or responding, for instance. As used in this document,

engagement has the added features that it involves personal states of connection and motivation with the issue, primarily the phenomena depicted by the display. When scientists are engaged with a visual display, they care about how their actions may affect their interpretation, understanding, or nature of the visual display.

1.4 Statement of the Problem

The problem addressed in this study centers on the relationship among scientists as viewers, visual displays, and phenomena as depicted by the visual displays. Even though the viewer-visual display interaction is a basic part of interpreting visual data, inquiries from this perspective are not fully explored in formal published arenas. Instead, visual display-related studies tend toward other types of research questions and study populations. A common type of study compared different visual display formats like graphs, diagrams, and photographs, to observe the effect on student learning (e.g., Keller, Gerjets, Scheiter, & Garsoffky, 2004; Korakakis, Pavlatou, Palyvos, & Spyrellis, 2009; Nathan & Kim, 2007). A frequently used format included co-operative, co-constructed meaning making around visual displays (Botzer & Yerushalmy, 2008; Heiser, Tversky, & Silverman, 2004; Schwartz, 1995; van Amelsvoort, Andriessen, & Kanselaar, 2007). Other studies investigated professionals' interactions with visual displays when presented as expert-novice comparisons (Jucks, Bromme, & Runde, 2007; Kozma & Russell, 1997; Lowe, 1995). Also, there are many published works that positioned visual displays along socio-cultural orientations of situated scientific practice (Burri & Dumit, 2008; Knorr-Cetina & Amann, 1990; Lynch, 1985a, 1998). In contrast, this study did not investigate student performance,

expert-novice comparisons, or use a socio-cultural conceptual framework. Instead, the visual display itself acted as the point of departure from which this study was born.

The founding inquiry of this study concerned how a scientist would explain visual displays that showed limited information about the actual phenomena depicted by the display. The strategy of this line of investigation was to add to the existing work that was based in scientific visual displays and their interpretation by professionals (O'Halloran, 2009; Trickett, Trafton, Saner, & Schunn, 2007, related). The phenomena depicted by the visual displays, the media upon which the phenomena were made visible, and the objects visible on the media, were all considered in the initial rounds of the investigation's development. The relationships considered between the scientist and the visual displays were explanation, interaction, and engagement. The final format of the investigation was structured to look into how embodiment, in the forms of talk, gesture, and body position, supported the scientist's interpretation of, and interaction and engagement with, visual displays and the phenomena depicted in the visual displays.

1.5 Research Question

The question addressed in this study was:

How does a scientist engage with visual displays when he explains his understandings of extremely small biological objects?

This exploratory study was organized to observe patterns in the professional scientist's interactions with visual displays in order to build knowledge about how he

structured his understanding about small biological objects. This aim was to describe what the scientist does in order to look at a visual display and *see* the phenomenon beyond it.

Traditionally, especially in some learning situations, there is the equivalent of a window-like barrier between viewers and visual displays. Viewers can experience the visual displays purely with their sense of vision, but the viewer remains in a realm external to the visual display where no reciprocal engagement can occur. The phenomena depicted by the visual displays are distanced and unavailable. Directing this research question to so-called non-traditional events presented an opportunity to rethink alternate reciprocal engagements.

Through the analysis of the scientist's talk, gesture, and bodily action, patterns of embodiment emerged. The patterns described the scientist's non-traditional engagement with the visual display. That is, through talk, gesture, and bodily position, the phenomena depicted by the visual display became indistinct from the scientist, existed in his personal space, and was available for reciprocal engagement.

1.6 Chapter Summary

The subject of this study was a professional scientist who interacted with visual displays of extremely small biological objects. These types of biological objects present challenges to understanding in that they are too small to easily perceive. In the process of making them visible the lost information must be accounted for when the visual displays are interpreted. To uncover patterns related to that interest, this study's

data analysis looked at how speech, gesture, and body position worked together to allow for scientist-visual display interactions in the form of patterns of engagement.

Visual displays, and the need to interpret them, saturate the practice of science. Although there is this widespread practical use, there appeared to be few studies in which a scientific visual displays played the central role in an environment that involved interpretation by a single professional scientist when he explained his understanding of the scientific phenomena displayed. This investigation contributed to that body of work.

CHAPTER 2: LITERATURE REVIEW

2.1 Chapter Introduction

This literature review presents three studies that act as the cornerstones of the chapter. The highlighted studies will portray landscapes comprised of viewers' relationships with scientific visual displays. The related relationships of engagement, interaction, and interpretation, are based in embodiment and will complement this investigation's query about explanations of visual displays of not readily visible objects.

Viewer's interact with visual displays sit rather passively in a way that "divorces knowledge and action" (K. Mayer, 2011, p. 30). It is suggested in some literature that a viewer's engagement with visual displays through embodied action overcomes any border that may exist. And, that engagement relates to their understanding of the phenomena at hand. One group of researchers who was of this opinion was. They looked at a scientist whose talk, embodied gesture, and bodily interaction with a graph resulted in his figurative travel through the visual display to experience the depicted phenomenon. The importance of embodied actions in engaging with phenomena was also stressed by Alač (2008). She described a scientist whose embodied semiotic interactions led to the creation of virtual objects at the interface of gesture and a digitally generated image. Finally, Roth and Lawless (2002) analyzed a teacher's integrated embodied resources with respect to a visual display within the framework of the environment. They found that there was an association

between the type of information communicated and the position of her body with respect to the locations of the visual display and the audience.

Taken together, this review will survey literature that addresses the engagement with, interpretation of, and interaction with scientific visual displays and how embodiment related to these avenues are related to understanding through talk, gesture, and bodily action.

2.2 Liminal Worlds

2.2.1 Introduction

In their seminal study, Ochs et al. (1994) argued that professional physicists, and the scientific phenomena that they studied, did not remain distinguished from each other but commingled when the scientists took part in visual display directed, collaborative, interpretive activities. Similar arguments have been put forth by investigators who looked at various situations, such as mathematical graphing by elementary school students' (Nemirovsky, Tierney, & Wright, 1998), spontaneous mapmaking by informally conversing adults (Barber, 2005), sketching by interactive design graduate students (Arvola & Artman, 2007), and electron density map analysis by protein crystallographers (Myers, 2008). The physicists in the Ochs et al. (1994) study worked together to interpret graphs that represented their scientific phenomena of interest, condensed matter physics. In addition to the scientists' joint activities, the authors attended to the scientists' personification of the scientific processes behind the displays. Ochs et al. integrated their observations of these dynamic constituents, including gesture and language, and claimed that the scientists' actions led to

"interpretive journeys" (p. 151) across visual displays. The authors argued that travel across visual display thresholds allowed the scientists and the scientific phenomena under study to shape and share a "liminal world" (p. 152), a symbolic destination where the "scientists-as-subject and constructed-scientific-world-as-object" (p. 152) conflated.

2.2.2 Scientists and Visual Displays

Ochs et al. (1994) observed that their scientists' most prevalent work-inprogress with visual displays incorporated multidimensional engagements. Through active engagement the scientists decreased the figurative distance between themselves and their phenomenon under study (Barker, 2009). To this end, some of the actions that the authors addressed as part of the scientists' engagement were mutation, construction, and characterization. In regard to the concept of mutation, Ochs et al. disagreed with the idea that visual displays seemed to be "immutable inscriptions" (p. 158). The authors witnessed visual displays' actual mutability when the scientists deconstructed, reconstructed, and modified a published graph during one of their group meetings. The scientists related to the graph as a flexible and editable participant in their collaborative event and idea development processes (Gooding, 2005). In addition to mutation, Ochs et al. observed that, during a visual display's construction or reconstruction process, scientists created visual display features in a particular sequence: outer boundaries and then internal details. In the case of the scientists' graph, the x- and y-axes comprised the outer boundaries. The scientists' subsequent annotations were within the external boundaries and consisted of lines and marks that modified and partitioned the internal space. Ochs et al. remarked that once scientists constructed visual displays, they characterized their descriptions of the displays in terms of feature classes or "visual aspects" such as shapes, areas, colors, locations, and two-dimensionality (de Vries, 2006; Ochs et al., 1994, p. 159; Scholl, 2001). These visible properties are readily detectable and relatively independent of viewing position (Biederman, 1985), so they are conducive to shared observation in a collaborative setting. Ochs et al. described mutation, construction, and characterization, multidimensional activities that led to the scientists' collaboratively created engagement with visual displays.

2.2.3 Gesture and Language

In addition to engagements with their visual displays, each other, and the objects around them, Ochs et al. (1994) included gesture and language as contributors to what they termed, "multimodal, distributed discursive," activities (p. 153). For example, during a specific group meeting interaction, the principle scientist instructed a student scientist to place his finger at a particular location on a graph. When the student scientist followed the instructions, the he executed his own gesture and the principle scientist's gesture in proxy. The gesture established a shared visual and theoretical reference point that brought a mutual focus to the principle scientists' language that followed (Baron-Cohen, 1995; Clark & Marshall, 1981; Heiser et al., 2004). The principle scientist then suggested, "You're going to say I'm in the paramagnetic state" (p. 152). He defined his participation as a dimensionless point on the graph. Second, by using the word, "in," he placed his dimensionless self within the

invisible scientific entity represented by the graph. The principle scientist's statement also brought both scientists into a personal relationship with the paramagnetic state, the scientific phenomenon beyond the visual display. The scientists' visual perception of the graph, the principle scientist's verbal instructions to the student scientist, the student scientist's physical connection to the graph, and the principle scientist's embodied journey into the paramagnetic state, all contributed to this collaborative event.

2.2.4 Related Perspectives

The crucial concept in the work of Ochs et al. (1994) asserts the idea of liminal worlds, a metaphorical space where scientists come to know scientific phenomena as instantiations in graphical form. Along a continuum of views that consider interactions with and interpretations of scientific visual displays, those of Ochs et al. seem to be at one extreme. At the other extreme is a conventional view held by many researchers and theorists that discretized scientists, visual displays, and the physical processes that those displays represented (MacEachren, 1992; MacEachren & Kraak, 1997; Mathewson, 2005; R. E. Mayer, 1989; Palmer, 1977, and others). Investigators whose perspectives speak to the Ochs, et al. liminal world concept often work with its general principles and amend its details based on their own work. In a version of the liminal world concept, Goodwin (1995) specifically introduced meaning making. He proposed that when observers cross the "open gateway[s]" that are visual displays, "new frameworks of meaning" become accessible through engagement in the world beyond the display (Goodwin, 1995, p. 259). Rosenfeld (1980) contemplated the actual act of

displaying, the equivalent to the graph's role in an interaction and interpretation event. He considered that the notion of display has to do with "the unconcealment of things" rather than mere representation. Similarly, Lynch (1985b) held the perspective that "graphic devices disclose" scientific phenomena (p. 43). This view seems to be a kernel within the idea that displays function as a portals that facilitate what Ochs et al. (1994) term, "interpretive journeys" (p. 151). Allchin (1999) concurred with the idea of visual displays as gateways to the objects behind them. He termed such visual images, "vicarious selectors," because they are indirect means that allow scientists to detect phenomena that are otherwise difficult to perceive (p. S289). In addition to the concept of vicarious selectors, Allchin (1999) impressed that engaging in the world of the phenomenon is a learned activity. Myers (2012) proposed a variation of the assertions made by Ochs et al. (1994). She observed dance performances where Ph.D.level science students physically interpreted their subjects of study through wholebody movement. She proposed that the human body could act as the modality of visual display through which phenomena can travel. And that such events can result in the scientists' understandings of the phenomena becoming conflated with the phenomena itself in the physical world. Overall, the literature suggests that those who sympathize with the liminal worlds concept find it flexible enough to incorporate their own observations while still upholding the idea that visual displays act as reciprocally directed thresholds through which indistinct borders result from scientist-phenomena engagement.

2.2.5 Summary

Ochs et al. (1994) described how scientists' interpretations, which employed visual display markings, language, and gesture, were linked by visual displays and resulted in indistinct borders between scientist and phenomena in a liminal world. Through collaborative actions with other scientists, the principle scientist embodied a theoretical position on the physical visual representation and journeyed through graphic space to symbolically experience a scientifically interpreted phenomenon.

The scientists' resources through which they came to engage the scientific phenomena were the visual display, language, and gesture. The visual display interactions were mutation, construction, and characterization. Mutation described the act of altering a pre-existing graphic that, for instance, was from a published journal. Construction occurred when meaningful markings created a new visual display or added to an existing visual display. Characterization allowed the use of descriptive concepts, such as color and shape, to bring attention to specific features of a visible display. In addition to the scientist's interactions with the visual displays, his language and gesture were intricately woven into the engagement development process. As multimodal, distributed discursive activities, language and gesture contributed to situate the scientist within the conditions of the collaborative event.

Altogether, Ochs et al. (1994) presented several indications when they constructed their case that scientist, as subject, conflated with scientific process, as object, during group settings where scientists interacted with visual displays. This established the authors' major claim that scientists navigate interpretive journeys that

traverse visual displays where the scientists can then symbolically experience scientific processes in a liminal world.

2.3 Digital Images and Gestural Interaction

2.3.1 Introduction

Alač (2008) held that scientists' bodily interactions with computer-displayed images facilitated "seeing in the digital realm" (p. 483). She noted that seeing was a process that concerned intersections and borders. For instance, within the study of visual displays, contrasts between physical and virtual realms, and two- and threedimensions, are ongoing points of interest. Alač investigated what occurred at the intersection of embodied actions, computer-displayed digital images, and scientists' practical image analysis. She observed collaborating neuroscientists while they interpreted digital brain scan images during their everyday practice. Interactions with images are inextricable from everyday scientific endeavors (Burri & Dumit, 2008; Roth, 2001). Alač also attended to what she called, "multimodal semiotic modalities" (p. 485). That is, she analyzed the scientists' body position, gaze, language, gesture, as well as their physical manipulations with the computer and the resultant alterations of the digital images. She asserted that through these coordinated actions phenomena were made perceivable. From this, Alač argued that during scientists' everyday practice of interpreting visual displays the engagement that occurs at the junction of gesture and digitally-displayed images results in dynamical phenomenal objects (p. 483).

2.3.2 Scientists, Digital Displays, and Gesture

Alač claimed that interactions between the neuroscientists and digitally generated images were practical activities in routine laboratory investigations. In her ethnographic study she observed collaborative efforts between two scientists from different laboratories. Each scientist was interested in interpreting digital visual images of brain scans that were generated through functional Magnetic Resonance Imaging (fMRI). This journal article described the two scientists as they worked in one of the laboratories that developed custom fMRI image analysis software. This was the lab of the central scientist. Her activities included embodied communication with the other scientist in addition to engagement with the computer displayed image as the visible form of the digital data.

Working with digital displays is a critical part of the fMRI process.

Digitization transforms functional activity of the objects under study, living brains, into brain scan images visible on computer monitors. This technological action organizes the invisible numerical data into specialized visual displays. The scientists understood that the unedited fMRI digital images had errors, such as the discrepancy between the structural and functional representations, due to standard image processing. The scientists accepted these images as starting points from which their practical analyses proceeded (e.g., Allchin, 1999).

Alač (2008) asserted that when a scientist's gestures interacted with a visual display it opened the possibility for encounters with visually unperceivable objects.

Gooding (2004) also described that one of a visual display's important features was its ability to explore possibilities and negotiate meanings. In the case of Alač's

neuroscientists, she posed that the act of gesturing created additional engagements with the image that depicted the digital phenomena through producing *dynamical phenomenal objects* in local, three-dimensional space (p. 483). Streeck (2008) made a complementary statement about images and gestures, "as we see *them*, we see something *in them*" (p. 286). In the instance of Alač's scientist's gestures, they demonstrated an image anomaly on the computer when she formed her hands into the shape of a sphere. Then, she shifted her hands in opposite directions to impart movement to the phenomenal object, which she created in physical space. In this way, the space between the two scientists was organized into an area of meaningful action through tightly coordinated gesture, talk, and interaction with the computer.

2.3.3 Related Perspectives

Alač (2008) propsed a key point that digital brain scans made the invisible visible. But, a sensorily perceivable image alone does not provide the conditions for meaning making or problem solving, which are part of scientific practice. In order to work with the image in an informative way, a process of *seeing* must be employed. In the practical setting of this study, seeing involved the intersection of manual manipulation of the physical instruments, practice with the software, and experience recognizing image details in order to solve problems. In the neuroscientists' collaborative session, a goal was for the central scientist to introduce the process of seeing the brain function, as digitally displayed, to the other scientist. Barber (2005) supported Alač's suggestion that seeing is a situated process through her concept of "preferential seeing" (p. 194). What Barber calls "preferential seeing" describes how

the practice of interacting with images, including using the tools that support the process, organize the phenomena in the immediate setting. With respect to Alač's position, Barber (2005) and Leonelli (2009) expressed that interaction with the world to creating shared meaning is intertwined with everyday practical activity.

Alač (2008) described that working with digital images is not a passive activity but involves multimodal engagement that brings "seeing into the digital realm" (p. 483). In contrast to this view, and at first glance, it might appear that digitization would limit a scientist's engagement with a phenomenon. This is the view held by de Chadarevian and Hopwood (2004), who asserted that when creators have less control over the visualizations produced, as with images generated directly from an instrument, the result is an increased conceptual and cognitive distance between the viewer and the images' contents and meanings. Roth and Lawless (2002) held that visual displays of more abstract subjects created "distance from lived experience" (p. 7). In contrast, the view of Maturana (1991) puts forth that no matter how abstract a phenomena may seem, or how different the domain in which it exists, it still can be related to the domain in which it is scientifically explained.

2.3.4 Summary

A central claim made by Alač (2008) was that fMRI scientists actively called upon bodily action when they engaged with images during their everyday laboratory practices of meaning making and problem solving. As an act of problem solving, she called the coordination of embodied action with the computer, "articulation of visibility" (p. 493). Technological processes make invisible numerical data visible in

that translated dimensionless virtual data into a computer displayed visible image that allowed for interaction. Similarly, the central scientist's gestures interfaced with the visible image and recreated it as an object to which she assigned motion and dimension. This led Alač to conclude that when gestures acted to visually enhance imagistic displays, encounters with visually unperceivable objects occurred.

2.4 Inscriptions and Positioning

Roth and Lawless (2002) investigated understanding communication in classroom settings when different types of visual displays, which they called inscriptions were integrated into the lessons. They investigated three different lecture-style environments where speakers' presentations incorporated inscriptions. Their directive did not include measuring learning outcomes. In the process of analysis, Roth and Lawless considered gesture, body orientation, and spatial positioning as resources. The authors synthesized the various findings and proposed that meaning-making phenomena required more than merely the speakers' gesture and talk, but it also depended on the speakers' body orientation and the types of resources available. The authors claimed that the resources, which included gesture, body orientation, and physical location in space, situated speakers' talk in a way that allowed for listeners' meaning making.

2.4.1 Inscriptions and Orientation

Roth and Lawless (2002) had the goal of understanding situations in which speakers lectured to audiences in the presence of inscriptions. They looked at three

different environments where the inscriptions that depicted the scientific subjects were situated differently. One case had to do with the dimensionality of the inscription and one case involved the content of the inscription.

In the first case there were three options. In the first case the phenomena depicted by the inscription was in three dimensions, in the second case the phenomena depicted by the inscription was in two dimensions, and in the third case the phenomena was not accompanied by an inscription. The authors observed a situation where the inscription was a map of an aerial photograph. The inscription form was a two-dimensional map, but the inscription depicted a three-dimensional vista. In this situation the speaker's gesture referred to the two-dimensional information and the speaker's talk referred to the three-dimensional information. This situation was termed a "lamination" of talk and gesture (p. 14). Roth and Lawless (2002) compared this idea to the concept of a "liminal world" by Ochs et al. (1994).

The second case concerned the relationship between the inscription, the speaker, and the audience. Roth and Lawless (2002) defined the spaces that described the speakers' position in the environment with respect to the type of orientation. When instructors' talk and gesture were about inscriptions present in the classroom then they positioned their bodies toward that inscription. The area defined by this positioning is termed local space; it is the space anchored between the speaker's body and the inscription. If the talk was about a feature not on the inscription then they positioned their body toward the audience, or toward narrative space. This can also be considered

interactional space, which is made up of the action hemisphere of the speaker and the attention hemisphere of the listener.

2.4.2 Related Perspectives

Roth and Lawless recognized difficulties with students' understanding lectures (Roth, 1994; Roth & Bowen, 1998, 1999; Roth, McGinn, Woszczyna, & Boutonne, 1999), scientific visual displays (Roth, McGinn, & Bowen, 1998), and mathematical representational formats such as graphs and charts (Roth & Bowen, 1999; Roth & Tobin, 1997). The authors suggested that part of the issue stems from inscriptions in lectures that have a large amount of detail. In these cases the speakers need to call on more resources, talk, gesture, body position, and body orientation, to communicate the necessary information. Roth and Lawless (2002) include motivation, a facet of engagement, in their description about the relationship of interactions with inscriptions. The authors claim that when motivated speakers' gestures point out features of inscriptions, motivated viewers' gaze are motivated to search for those features.

Roth and Lawless (2002) considered gesture, particularly deictic and iconic gestures, as the predominant resource type. Gesture can augment or substitute for information that is insufficiently expressed by speech or visual displays (Becvar, Hollan, & Hutchins, 2005; Hegarty, Mayer, Kriz, & Keehner, 2005). Gesture in educational contexts is a recently growing field (Roth, 2001) and deictic and iconic gestures, in combination with language, are appropriate for describing inscriptions in this environment. Space is an important factor when considering gesture as a resource. Gestures are more likely to occur during speech when the topic concerns spatial

information (Hadar & Krauss, 1999; Lavergne & Kimura, 1987), like scientific displays.

2.4.3 Summary

Roth and Lawless (2002) asserted that studies should not be restricted to speech and gesture, but should include bodily action and physical environment as well. This belief translated into their primary goal: to elucidate processes that occurred in active lecturer-inscription-listener environments. The authors' approach differed from popular study formats about visual displays in learning situations in that they looked at lecturers rather than students. Their investigation ultimately concluded that speakers' gestures, bodily actions, and orientation, in addition to their physical arrangement with respect to the inscription and listeners, greatly influenced their language use.

2.5 Chapter Summary

Various studies looked at the topic of interactions with visual displays and concluded that viewers engaged with visual displays and the scientific phenomenon that they depicted though multimodal engagement, that is, through gesture, talk, body position, and interaction with the environment. Ochs et al. (1994) looked at physicists who interacted with a large hand-drawn graph during a group meeting. Through talk and gestures, the lead scientist put himself in the role of a condensed matter physics concept in his efforts to explain to a junior scientist. The authors claimed that through these actions the scientist traversed the visual display and shared a liminal world that bordered physical existence and the phenomenal world. Alač (2008) studied neurobiologists who interpreted visual displays of fMRI data. The digital data were

translated, through software, to visual images on the computer screen, and the visual images on the computer screen were translated, through gesture, to phenomenal objects in physical space. The author observed that embodied interactions, including gesture, talk, and body position, were essential to making a brain function visible. Roth and Lawless (2002) were interested in classroom situations where instructors interacted with visual displays, which the authors called inscriptions. Their study asserted that there was a need to move beyond the study of speech and gesture because both environmental structures and body position are also key to understanding communication.

From an education perspective, in a similar way to Alač (2008), the use of technological artifacts, such as computers, can enable learning that calls upon embodied actions, perceptions, and reactions to the technological artifact (Botzer & Yerushalmy, 2008). When students have the opportunity to interpret and interact with visual displays they can develop a reciprocal engagement with the phenomena depicted by the display. Airey and Linder (2009) describe this point as the student and the instructor taking the "meaning for granted" in that they have "become fluent in the discourse of the discipline" (p. 37).

CHAPTER 3: METHODS

3.1 Chapter Introduction

In this study, the broad aim was to describe a scientist's actions during an activity that is pervasive in scientific practice: interpreting visual displays of scientific information. The goal was to explore the ways that the scientist's expressed his understandings of the structure and function of the extremely small biological objects that he studied. From the literature, as presented in Chapter 2, and from observations made during the pilot study, interactions in these situations call upon highly involved embodiment, therefore, embodied cognition was chosen as the theoretical framework. Briefly, embodied cognition holds that cognitive processes are deeply rooted in the body's interactions with the world (M. Wilson, 2002). Embodied cognition was a suitable framework because the study topic included the scientist's interpretive cognitive acts, his bodily expressions, and his interactions with visual displays as objects in his physical and cultural world. These factors guided the methods design which included: video recording interviews that incorporated visual displays, intricately examining the scientist's speech and bodily movements, and creatively analyzing the data to uncover themes. The result was a series of conceptualized connections and patterns that created a "textural expression" (Latham, 2009, p. 54) of the scientist's understanding that shed light on the research question: How does a scientist engage with visual displays to explain his understanding of extremely small biological objects?

3.2 Research Design and Execution

This exploratory and descriptive case study used as its subject a professional scientist when he explained phenomena depicted by visual displays. The Ph.D. scientist was from a university research laboratory that studied the phenomena of muscle structure. The visual displays were the sum of two parts: the visual object, which was the visually depicted phenomena, and the display, which was the presentation media. In one case the visual object was a sarcomere that was presented as a hand-drawn cartoon on a whiteboard. In the other case the visual object was a collection of myosin molecules that was presented as a micrograph as a projected image.

The data that was ultimately analyzed was from open-ended interviews where the scientist was presented with one of the visual displays and a simple prompt. The video recorded interview data reduction followed a series of steps that resulted in very short clips where each had an "amazing" aspect about it. For each clip narrative descriptions (Chapter 4: Introduction to the Data) and gesture analyses (Appendices B through H) were completed. The combination of data analysis types went through stages of grouping and regrouping by comparing and contrasting their characteristics until a set of unifying themes was found.

3.2.1 Study Design

This study took on a case study format. A case study approach was chosen because the research question involved complex instances where an extensive description and analysis of those instances would be able to situate a comprehensive understanding, both holistically and contextually (Feagin, Orum, & Sjoberg, 1991). A

case study research design was appropriate since the research question was of the "how" type, there was not control over the behavior of the subject, and there was interest in the contextual conditions (Yin, 2003). Further, the context-dependent knowledge that comes with a case study can be a "force of example" versus the predictive knowledge that comes with some study types that can produce formal generalizations (Flyvbjerg, 2006, p. 228).

The research question was linked to previous hypotheses, as described in Chapter 2: Literature Review, about embodied actions and engagement and virtual object creation during interactions with visual displays. The subject selection followed a purposeful sampling strategy (Maxwell, 2009) where the professional scientist was deliberately selected due to his area of expertise, which heavily relied on interacting with images.

Initially, this case study was microethnographically inspired. The microethnographic design format was chosen since the original research questions inquired about how scientists deal with interpretation obstacles during their everyday work with visual data. The original research questions were:

1. How do scientists develop structural and functional projections about the three-dimensional dynamic characteristics of minute biological objects from their corresponding 2-dimensional static visualizations? 2. What interpretational activities and informational compensations do scientists use when making sense of inherently uncertain two-dimensional static visualizations?

Given these research questions, the methods needed to include observations of scientists in situations where such activities would happen. Based on these factors, the study strategy included observation of everyday work and data collection over an eight-week period. The plan was to address the research questions from an embodied cognition standpoint. The video recorded data would allow analysis of embodiment while all data types collected would help to establish context.

3.2.2 Preparatory Phase

3.2.2.1 Location, Laboratory, and Human Subject Selection

The study components that were most germane were physical location, logistic accessibility, image type and scientific subject of interest, and scientist and laboratory cooperation. The location was the biology department of a large public university in the western United States. Public research organizations were found to be more cooperative than private institutions or companies. Once the greater location was chosen an appropriate laboratory, which studied muscle diseases at the genetic level, was identified. Straightforward arrangements allowed for open access to its laboratory rooms, imaging facilities, personal offices, as well as small and large meetings. In addition, the principal investigator (PI), several of the laboratory scientists, and the imaging facilities director agreed to personal interviews. During the first interview with the PI, he suggested two individuals who would be appropriate subjects for the

study. They each had multiple projects that they worked on, but the PI suggested that I inquire about their joint project because it heavily relied on visual displays.

Data were collected for both scientist, but data for only one of them was analyzed and presented in this dissertation. The one scientist whose interviews were analyzed will be referred to as "the scientist." The scientist has a Ph.D. in Physiology and Biophysics and held the position, "Adjunct Faculty, Biology Department." At the time of data collection he had seven years of post-degree experience in field, and five years of experience in this particular laboratory. If asked about his profession by a non-scientist he replied that he was a "muscle biologist." He worked on several projects at each of the different research institutions where he held appointments.

3.2.2.2 Laboratory Research Interests

The research laboratory that was observed was interested in investigating the molecular, cellular, and organismal functions of the muscle protein, myosin and myosin related structures. Defects in myosin and other contractile proteins are widely studied and high profile research topics because they can result in very serious skeletal and cardiac muscle diseases in humans. One of the most serious skeletal myopathies is muscular dystrophy. Some of the cardiomyopathies are ischemic cardiomyopathy, restrictive cardiomyopathy, and hypertrophic cardiomyopathy. The ischemic type of cardiomyopathy is commonly known as congestive heart failure due to coronary artery disease. Restrictive cardiomyopathy is a stiffness of the heart that interferes with proper blood flow. These patients are typically candidates for heart transplants. Finally, hypertrophic cardiomyopathy in a seemingly healthy young person can present with

the acute onset symptoms of sudden collapse and possible death. The seriousness of the diseases caused by myosin defects lends a certain amount of prestige to the laboratory, urgency to publish, and necessity for highly accurate and thorough research. These factors set the scientific context for this study.

3.2.2.3 Visual Displays

Visual displays of data are special forms of information that scientists encounter as part of their daily practice (Burri & Dumit, 2008); in this study, the scientist interpreted two different visual displays of myosin related data. Although the term *visual display* is used somewhat loosely in this document, a visual display is actually comprised of multiple components: the phenomena that exists beyond the visual display and the visual objects as they appear on a display medium, which allow the phenomena to exist in visual display format. So, the phenomena are information that can only be seen when depicted as visual objects presented on an appropriate medium. Examples of phenomena are numerical data, physical structures, and conceptual relationships. Some readily recognized visual object forms are images, graphs, and diagrams. Visual display mediums include paper, computer displays, and whiteboards. Because a visual display must have both a visual object and an appropriate presenting medium to exist, the terms are used interchangeably unless their separation is critical to the context.

Two different visual displays were used in this study; the scientist generated both of them. One visual display was a cartoon, an oversimplified diagram, that was displayed on a whiteboard and the other visual display was a micrograph, which was

displayed as a projected image onto a screen. For the first visual display, the scientist created a hand-drawn sarcomere on a whiteboard (Figure 3.1). A sarcomere is a muscle fiber subunit and is the individual unit of contraction. During the beginning of his explanation he drew the cartoon as he talked. The cartoon was based on generally accepted knowledge about sarcomere structure and the electron micrographs that the laboratory generates independently (Figure 3.2).

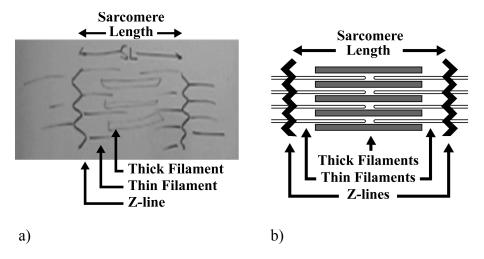


Figure 3.1: Basic sarcomere anatomy. a) The scientist's mid-study interview cartoon. b) Generic sarcomere graphic.

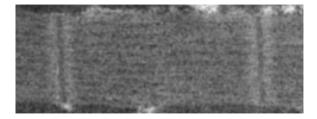


Figure 3.2: Electron micrograph of sarcomere from *D. melanogaster* indirect flight muscle.

The second visual display was a micrograph that the scientist created from a sample of myosin molecules (Figure 3.3). Myosin molecules are proteins found within

substructures of sarcomeres. The visual displays and the information that they display will be explained and contextualized in Chapter 4: Introduction to the Data.

The imaging technique that was central to this study was electron microscopy.

Electron microscopy is similar to standard light microscopy except, essentially, a

beam of electrons is used to form an image instead of a beam of light. The type of

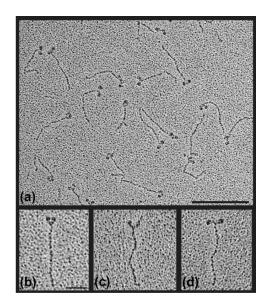


Figure 3.3: Micrograph visual display. (a) Random field of myosin molecules. (b), (c), and (d) Individual myosin molecules.

electron microscopy that is relevant to this study was transmission electron microscopy (TEM). TEM uses a wide beam of electrons that *goes through* a thinly sliced, stained specimen to form an image. As a comparison, the way the TEM works is reminiscent of the classic slide projector. A wide beam of light goes through the slide and an image is projected on the other side. The preparation of a scientific sample for EM imaging requires a staining step because during imaging the stained

areas either absorb or scatter the beam of electrons. Both of these actions result in a dark area in the image. Areas that do not have stain do not inhibit the electrons and appear light. It is the ratio of transmitted and scattered electrons that forms the images and sets the contrast of the visual data generated from the TEM. The resolution of the EM lab's TEM is in the range of 0.2 nm.

Focusing on visual data for this study site and circumstance helped to answer the ultimate research questions in several ways. First, EM images are the scientific artifacts central to the research questions of both this study and that of the participating scientists. These visual displays act as intermediaries that connect the scientist's understanding to his shared expression of his understanding. Electron micrograph images are mediating tools that visually display information about minute objects so that scientists can make sense about the structure and function of their protein. So, scientists come to better understand the particularities of their extremely small biological objects through interpreting EM images as visual data.

3.2.2.4 Pilot Study

After laboratory selection and project identification, a pilot study was performed. The pilot study lasted nine months and it included attending the laboratory's two-hour weekly meeting. The purposes of observing these meetings were to: become familiar with the science and ongoing projects of the laboratory; make note of the different forms of communication between and among the lab members; and allow the laboratory members to become comfortable with my presence. The meetings, which were held in a small conference room, were composed of a two-

part structure. First, two laboratory members presented current literature in the field and second, two different laboratory members presented their original research.

Another goal of the pilot work was to develop a familiarity with the university's core microscopy facility (EM lab). The EM lab maintains an electron microscope (EM) and is in a different building than the main laboratory space. The participant scientists perform most of their specimen preparation and fixing in the main lab, and use the EM lab for the last sample preparation steps and the EM imaging. After imaging, the resulting visual data can be analyzed at any location on the department's computer network.

3.2.3 Data Collection Phase

In order to address the original research questions, several types of data were collected, they included: journal articles, conference posters, single-observer field notes and video recordings of naturalistic observations, video recordings of scientists' meetings and personal interviews, computer-animations, presentation files, and protocols documents. For the two scientists, a variety of the naturalistic observations, one of their meetings, and all of the six personal interviews were video recorded. The goals that drove the selection of these data sources were several. For reasons described previously, the principles of this study followed a microethnographic design. That is, in order to answer the research questions, very close analyses of the scientists' actions during their daily practice was performed. To that end, the type of data collected would have needed to provide information at an acute level of detail. Since the data types collected all included characteristics of language, gesture, and artifact,

the information they provided could be analyzed to the most useful level of specificity. Of all of the data collected in the microethnographic study design that addressed the original research questions, two video-recorded personal interviews with one of the scientists was retained as the data corpus for the analysis described in this document.

Video is able to record more information than field notes taken by an individual and can be replayed for multiple viewings. Today's digital technology makes feasible the use of multiple recording devices during a given event resulting in visual access to the action from multiple perspectives. Additional benefits of video recorded data are the ability to capture gesture through time as well as the ability to capture gesture coordinated with spoken language. Recorded movement and sound provides a richness of data that is not capable with still images or field notes.

The video-recorded personal interviews with the scientist were held at three points in the 8-week study: at the beginning, near the middle, and at the end. The interviews were held in the conference room in which the laboratory members met for their weekly meeting. Each interview was open-ended and used a simple prompt. Two cameras were used to record each interview so that body movements could be captured from different angles to acquire more details about how gestures and bodily position occurred in space. The information from the interviews helped to uncover the scientist's conceptions of the small biological objects.

In the beginning and mid-study interviews the scientist had the opportunity to create drawings. Drawing can aid in the scientists' own comprehension and help them

to better communicate ideas (Botzer & Yerushalmy, 2008; Flores, 2005; Kavakli & Gero, 2001; Ochs et al., 1994). In the last interview the scientist interacted with a photographic-type image and did not have the opportunity to create drawings. This limitation encouraged gesture and physical interaction with the visual display.

For the beginning interview, the scientist was presented with paper printout of a simple myosin molecule diagram that appeared in one of the laboratory's published articles (Figure 3.4). The prompt was, "Tell me about the [S2/LMM] hinge region." The scientist was also was given colored marking pens with which he could annotate the diagram or create any other markings he wished. The scientist did not create any markings. Further, he did not pick up a pen, point at the diagram, or pantomime the structure or motion of the molecule. The scientist did not engage with the visual display so this interview was not included in the data that was analyzed.

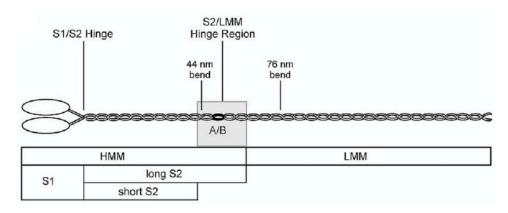


Figure 3.4: Myosin molecule diagram used as prompt for the interview that took place at the beginning of the study.

Since in the initial interview the scientist did not interact with the pre-made visual display provided, for the mid-study interview the scientist was asked to create his own visual display and was presented with a blank whiteboard and pens of various

colors. By giving him a blank canvas he was forced to create markings. The prompt was, "Tell me about sarcomere structure and function." During the process of his explanation he drew the sarcomere cartoon shown in Figure 1a. Sections of this midstudy interview, when the scientist engaged with the visual display, were used in the final analysis (see Chapter 4).

In the final interview, the scientist was presented with a pre-made micrograph image that was projected onto a wall-size screen. The image was a micrograph layout that appeared in one of the laboratory's journal articles (Figure 3.3). The prompt was, "Tell me about how you would analyze this data?" Since the scientist did not have the option of creating any markings on the visual display, he was forced to physically interact with it using various types of gesture and descriptive language. He also created gestures that, aside from the micrograph projection, enhanced his engagement with the projection. Sections of this final interview were used in the final analysis (see Chapter 4).

3.2.4 Data Analysis Phase

This data analysis will describe only the information used in the final analysis, the scientist's mid-study and final interviews. First, each interview was roughly transcribed in its entirety. Then, episodes where the scientist interacted with the visual displays were isolated from within the full interview. Detailed descriptions of the episodes were drafted to function as maps of events that facilitated viewing the data corpus through a comprehensive and holistic scope. Then, the episodes were annotated and further deconstructed into clips where each clip expressed a single idea and was

found to show something particularly enlightening. From the mid-study interview, four clips were selected (M1-M4). From the final interview, three clips were selected (F1-F3).

To address the goal of creating themes across the data in light of the continually evolving research question, each clip was analyzed through a detailed gesture study (Appendices B through H) and framed within the context of its respective episode. The gesture studies of the video clips were in-depth data analyses at the second-by-second and frame-by-frame level in order to "take advantage of the availability of film and videotape to record real behavior in ordinary contexts and slow it down for repeated viewings, for a careful consideration of structure" (Leeds-Hurwitz, 2005, p. 341). To formulate the themes, the clip analysis process followed linear and iterative patterns, but also had moments of arbitrary jumps and changes in direction or conception. There was ongoing clip distribution into groups, and then redistribution into new groups. The analysis was convergent and divergent to the extent that a large number of themes and theme groupings developed and dissolved. The research question evolution was also ambiguously directed. The result of the methodologically variable analysis process was four themes: Naming, Layering, Categorizing, and Scaling (Chapters 5 through 8; Appendix A).

3.2.5 Summary

The format of this exploratory and descriptive investigation was that of a case study where there was one human subject, a professional scientist, who took part in one central activity, the interpretation of visual displays. Given the exploratory nature

of the study and the subject of interest, interview data was apt to address the research question. Although the research question was evolving during the majority of the investigation, a case study research design was appropriate because the ultimate research question was in a "how" format: How does a scientist engage with visual displays to explain his understanding of extremely small biological objects?

The preliminary work for the study included identifying a cooperative research site and participants who regularly worked with visual displays. The laboratory identified used electron micrographs to study muscle cell substructures and proteins. Prior to the beginning of the study, in order to develop a working knowledge of the science and establish rapport with the laboratory members, the laboratory's weekly meeting was attended for approximately nine months. In addition, tutorial sessions were arranged with the coordinator of the central microscope facility to observe the standard techniques of sample preparation and imaging using electron microscopes.

Data collection lasted eight weeks and was of a microethnographic format. The data collection included nine different types of data for two scientists; however, only one type of data for one scientist was analyzed in this study. That one type of data was interview data for second and third of three interviews that took place. In the second interview the scientist had the opportunity to create an original drawing of a sarcomere. In the third interview the scientist was presented with a pre-existing micrograph of myosin molecules. In both interviews, the scientist had the opportunity to engage with the visual displays through language and bodily action.

For the data analysis, the interview data were initially transcribed and data reduction was comprised of several steps. From each entire interview, episodes where the scientist interacted with the visual display were extracted. From each episode, clips that maintained a single idea and showed an interesting interaction were selected. For each clip a gesture analysis was performed that tracked the details of the scientist's gesture and coordinated language. Also, a narrative that described the clip holistically was completed. In order to create themes, the video data, narrative description, and gesture analysis were analyzed using a mixture of linear, iterative, and circuitous approaches.

This case study followed a scientist when he interacted with different images during his explanation about the structure and function of extremely small biological objects. Of interest was the scientist's language and bodily actions during his engagement with the phenomena as depicted by the visual displays. The microanalysis of video clips with particularly rich demonstrations of signifying key terms, gesture, and other embodied action facilitated the generation of themes that addressed this study's research question.

3.3 Theoretical Framework

The theoretical framework that guided this study was embodied cognition. A central tenet of an embodied viewpoint is that cognition is shaped by the affordances and limitations of having a body such as ours in a particular contextual environment.

The scientist's interpretation of the visual object required him to use language, gesture, and body position to seamlessly engage with the environment while demonstrating his

understanding of the phenomena depicted by the visual display. As a conceptual framework, this perspective of embodied cognition was selected because it could guide explanations, extend existing knowledge, and allow for broad opportunities to explore observations of the professional scientist as he interpreted visual displays.

The embodied perspective emphasizes the sensory and motor capabilities of the body as it functions in the environment and looks to an experience-based model to describe human cognition (Nuñéz, Edwards, & Matos, 1999; Varela, Thompson, & Rosch, 1991). More specifically, embodied cognition can be viewed "as a physicallyembodied phenomenon, realized via a process of codetermination between the organism and the medium in which it exists" (Nuñéz et al., 1999, p. 48). As such, in order to gain insight into human cognition, biological structure must be considered in terms of its relation to multiple elements of its surroundings. Some of these elements include, physical encounters, cultural and social space, and various communication modalities (Hutchins, 2001; Roth, 2001; Varela et al., 1991). Furthermore, communication is viewed as enmeshed with cognition (Roth, 2001). According to embodied cognition, language use (Borghi & Cimatti, 2010; Richardson, 2003), especially metaphor (Nuñéz et al., 1999; R. A. Wilson & Foglia, 2011), gesture (Hostetter & Alibali, 2008; Roth, 2001), and mediation through representation and tool use (Botzer & Yerushalmy, 2008; Goodwin, 1994; Kozma, 2003) all contribute to the activity of cognition.

As a theoretical framework, embodied cognition aligns with the goals and research questions of this study. The embodied actions that the data capture and

analysis focused upon were gesture, speech, and body position in the context of the scientist's interaction with the visual display and his explanation of the small biological object. These are all avenues that will be treated as being enmeshed with cognition (Goodwin, 1994; Kozma, 2003; Roth & Bowen, 2001). Specifically, embodied cognition fits in the way that it approaches perception and cognition as an organic system rather than a series of inputs and outputs. This framework guided this study and its analysis in that the mind and body are inextricably linked (M. Wilson, 2002).

3.4 Chapter Summary

The research question concerned the connection among the scientist's acts of interpretation and his understandings about the extremely small biological objects as phenomena that are too small for direct interaction. The research approach was a case study where an electron microscopist explained the structure and function of sarcomeres as he drew on a whiteboard, and myosin molecules as were projected onto a wall-size screen. The data were interviews where the scientist interacted with these visual displays. Analysis of the interviews was guided by embodied cognition that puts forth that cognition is inseparable from the physical body and the affordances the body maintains within the world. Consequently, the framework supported the analysis, which looked at the language, gesture, and body position when the scientist engaged with the visual display.

CHAPTER 4: INTRODUCTION TO THE DATA

4.1 Chapter Primer

This chapter serves as an interlude between the Methods chapter (Chapter 3) and the Data Analysis chapters (Chapters 5, 6, 7, and 8). This Introduction to the Data chapter will independently describe seven video clips. Initially each clip secured equal potential for further analysis. Once in-depth analyses and preliminary comparisons were conducted, four themes emerged: Naming, Layering, Categorizing, and Scaling. Each theme will be analyzed in the following four chapters.

4.2 Chapter Introduction

4.2.1 The Interviews

During this eight-week study, the scientist participated in three interviews: the initial interview, the mid-study interview, and the final interview. All video recorded interviews took place in a small conference room occupied by the scientist and the interviewer. These surroundings established a high comfort level for the scientist since his laboratory's weekly meetings shared this venue. During each interview, openended prompts allowed the scientist to respond freely, in manner and detail. In each of the interviews, the interviewer offered the interviewee different visual display types to prompt visually based responses. Based on their applicability to the research question, the mid-study and final interviews will comprise this chapter's clip descriptions.

4.2.2 Advanced Data Reduction

For each entire mid-study and final study interview two selection levels, episode and clip, determined the final video material included in the data analysis.

From each of the two interview videos, the first selection level isolated a particular episode. Episode choice depended on how the scientist engaged with the sarcomere or micrograph visual display during his explanation. In the two selected episodes, the scientist extensively interacted with the visual display and verbally narrated a complete story. From each of the two episodes, the second selection level extracted several shorter clips. Episode selection and clip selection shared the same basic criteria: high scientist-visual display engagement and complete idea verbal narratives. The mid-study interview led to four clips and the final interview yielded three clips.

4.2.3 Persistent and Fleeting Objects

In the mid-study and final interviews, the scientist interacted with both persistent, visual objects and fleeting virtual objects. Persistent visual displays, termed visual objects, possessed visually informative qualities that existed for some amount of time. For example, in the mid-study interview, the white board diagram illustrated a visual object. The cartoon and micrograph's visual persistence allowed contemplation over time and centrally accessible information. Visual objects' persistence contrasted with virtual objects' fleetness. In this data analysis, gestures exemplified virtual objects. Gesture visibility depended on the moment in time and the viewer's position in relation to the gesturer. Both object types, persistent visible and fleeting virtual, played important roles in this data analysis.

4.2.4 Introduction Summary

This chapter will describe seven clips, those generated from the scientist's mid-study interview and final interview. The mid-study interview yielded four clips and the final interview produced three clips. Engagement between the scientist and a visual display determined clip selection. Concomitantly, clip choice required a complete-thought verbalized history. In each clip, both persistent visible objects and fleeting virtual objects played significant roles. These clips' descriptions, in light of their selection process and their content descriptions, moved the data analysis to a more detailed discussion of the question: How does a scientist engage with visual displays to explain his understanding of extremely small biological objects?

4.3 Mid-study Interview

In the mid-study interview, the sarcomere acted as the extremely small biological object of interest. Sarcomeres are the individual contractile units in muscle fibers.

The visual display medium available to the scientist included a white board and the appropriate pens. With these tools the scientist created a simple artistic rendition, or *cartoon*, of different sarcomere structural features (Figure 4.1a). The generic sarcomere diagram (Figure 4.1b) is based on the scientist's cartoon. The light horizontal bars are thin filaments, the grey horizontal rectangles are thick filaments, the vertical zigzag lines are Z-lines, and sarcomere length is defined as the distance from one Z-line to the consecutive Z-line. During this episode, the scientist described ideal sarcomere structure characteristics and non-ideal sarcomere consequences.

The entire mid-study interview lasted 11:22 (min:sec) and the episode spanned from 00:42 to 05:37. The episode yielded four video clips. Each clip, independently, represented a specific idea from within the episode. The four mid-study clips were coded M1, M2, M3, and M4 respectively. In Clip M1, the scientist initiated his sarcomere description. In Clip M2, he further explained his drawing's thick filament structures. Next, in Clip M3, the scientist explained the desired sarcomere length characteristics. And finally, in Clip M4, he described the consequence of ill-structured sarcomeres.

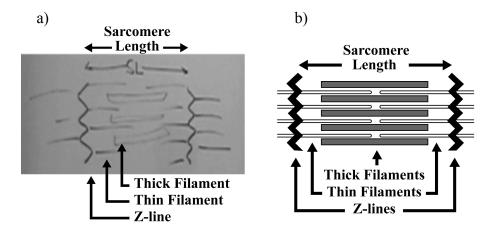


Figure 4.1: Basic sarcomere anatomy. a) The scientist's mid-study interview cartoon. b) Generic sarcomere graphic. For both a) and b) the labels were added for clarity.

4.3.1 Clip M1

Clip M1 contained eight seconds of video. The segment covered 01:16 to 01:24 from within the original 11:22 interview. In this clip, the scientist started his sarcomere structure and function description. The transcript below is his complete,

spoken language. The data analysis also included an entire coordinated picture, language, gesture, and interpretation analysis (Appendix B).

The Scientist: "Your sarcomere is, of course, your individual contractile unit.

The sarcomere length that we measure is the distance from one Z-line to one Z-line."

The visual display changed from the clip's beginning (Figure 4.2a), to its end (Figure 4.2b). Before this point in the interview, the scientist defined each structure as he drew it (Figure 4.1a). During Clip M1, he added, " \leftarrow SL \rightarrow ," above his pre-existing drawing. He neither created nor deleted any other markings.

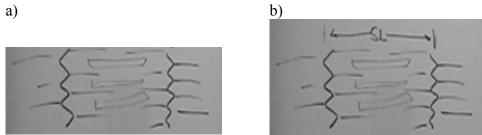


Figure 4.2: Cartoon visual display at the mid-study's start a) and end b). Image b): Final Clip M1 visual display. This visual display remained in this form for the remainder of the mid-study clips.



Figure 4.3: Body position and motion when he drew the "S."

During most of the clip, the scientist faced the white board. Before he spoke at the clip's beginning, the scientist held a pen to the top left point of a, yet to be drawn, "S." When the scientist said, "Your sarcomere is," he drew the, "S," above the preexisting diagram's center (Figure 4.3). Taken together, the scientist's, "S," drawing and this phrase's subject, "sarcomere," introduced the following events in the clip.

During the transition, between drawing the, "S," and the, "L," the scientist interjected the language, "of course." The scientist wrote, "SL," and said, "of course," but did not directly proceed to the acronym's meaning: sarcomere length. It was not until later in this clip, at the point where he drew the second of two arrows, that he defined the acronym, "SL," sarcomere length. Instead, he linked the drawn, "SL," to his verbalized, "individual contractile unit." His language, "individual contractile unit," presented the topic, "contraction." The static cartoon did not accurately illustrate the verb, "to contract." Also, the scientist did not perform any contraction-like gestures to enhance the static cartoon. Taken together, the scientist created an undefined linguistic abbreviation and verbalized an action, but he defined neither by visual display nor gesture.

At the four-second mark of the eight-second clip, the scientist defined the acronym, "SL." When he drew the left-facing arrow to the left side of the, "SL," he verbalized, "sarcomere length." Throughout the interview, he continuously defined the cartoon as a, "sarcomere." He linked the abbreviation, "S," with the word, "sarcomere," and the cartoon visual display. In a similar way that the cartoon represented a sarcomere, the scientist linked the abbreviation, "L, with the word, "length," and the oppositely directed arrows.

After the scientist finished drawing the final, left-facing arrow he used the word, "distance," to specify the length in question and the physical relation to the cartoon. When he made this utterance, he dropped his writing hand. Next, he verbally defined sarcomere length, "from one Z-line to one Z-line." Once again, he described the visual display structures through language alone. He dropped his writing hand and, momentarily, turned away from the white board. The clip ended with the scientist in this position.

Throughout the clip, the scientist used different modality combinations to describe a small biological structure, namely, the sarcomere. The modalities included a static visual display, whole-word verbalizations, drawn abbreviations, and drawn symbols. The scientist performed no gesture during this clip, so pure bodily movements played no part in this description. Of the parts included in this description, he first introduced the abbreviation, "SL," but did not present the associated whole-word equivalent. Next, he verbalized the word, "contractile," but did not interact with the board. When he drew the symbols, arrows that symbolized sarcomere length, it coordinated with his spoken words, "length," and, "distance." The scientist's last phrase was only accompanied by a verbal description, "Z-line to Z-line."

4.3.2 Clip M2

Clip M2 contained 11 seconds of video for analysis. The segment spanned from 02:03 to 02:14 within the original 11:22 interview. In clip M2 the scientist extensively interacted with the modified sarcomere diagram from clip M1. The following describes how he explained a sarcomere substructure to the interviewer. The

clip transcript below is the scientist's complete, spoken language. The data analysis also included an entire coordinated picture, language, gesture, and interpretation analysis (Appendix C).

The Scientist: "Thick filaments are always relatively equal in size. And you have a very structured, crystalline-like, uniform distribution of each of these individual contractile units."

During this clip the scientist engaged with the Clip M1 cartoon as it appeared at that clip's end (Figure 4.2b). In Clip M2 he neither created nor removed any other markings.

In the beginning section of the clip, the scientist faced the white board. He pointed his pen to the uppermost, rectangular, thick filament's top left corner. He proceeded to virtually trace thick filament segments. That is, he held his pen away from the board and followed the physically written lines. As he made these motions he expressed his initial language, "Thick filaments are always relatively equal." In this phrase the scientist contradicted his absolute, "always," with the qualified, "relatively."

The scientist expressed the first sentence's last word, "size." When he said, "size," he dropped his gesturing hand. With his gesturing hand he capped his pen and made his tool unusable. As it appeared here, the word, "size," did not specify height, length, depth, weight, or any other specific measurement unit. In contrast, in Clip M1, when the scientist specifically stated the term, "length," he created a visual display that indicated the length's direction.

The scientist's began his next idea with the phrase, "And you have." Then he said, "structured, crystalline-like, [and] uniform," to describe the sarcomere distribution in muscle fibers. When he said, "structured," he turned away from the board. He paused between, "structured," and, "crystalline-like," and created a hand shape. As he formed the hand shape, he moved his hands up toward his face and slightly changed each hand to a new shape. In the new hand shape each hand had the thumb and little finger extended while the three middle fingers curled in toward their respective palms (Figure 4.4).

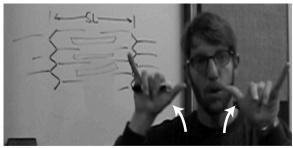


Figure 4.4: Body position, hand movement, and hand shape with outstretched thumbs and little fingers.

The scientist kept his hands in the same shapes as in Figure 4.4, and then made a series of small arcs away from the midline of his body (Figure 4.5). After building this virtual string of sarcomeres he turned his body so that it faced toward the white board.

In the last part of the clip the scientist said, "each of these individual contractile units." When he verbalized these words he gesturally enhanced the Z-lines already drawn on white board. He moved his hands into slightly different shapes. He outstretched his fingers and directed his fingertips toward the white board. With his

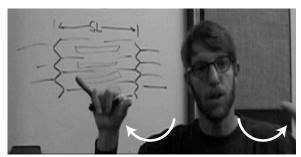


Figure 4.5: Body position and hand movement in arcs away from his body's midline.

hands in these shapes, the scientist repeatedly and virtually enhanced the Z-lines. As stated previously, he also gesturally built a series of side-by-side units. He emphatically repeated the related movements. Finally, when he said the last word of the clip, "units," the scientist dropped his hands from their locations over the Z-lines and turned away from the board.

Overall, in this clip, the scientist introduced sarcomere structure and substructure regularity. His language expressed that thick filaments were equal in size. He repeatedly gestured over the cartoon's Z-line features. The scientist's gestures referred to his current explanation in addition to the pre-existing diagram.

4.3.3 Clip M3

Clip M3 contained 13 seconds of video for analysis. The segment extended from 02:53 to 03:06 of the original 11:22 interview. In Clip M3 the scientist described the desired sarcomere length characteristics. He extensively interacted with the Clip M1 end diagram. His gesture overlaid some of the cartoon's more prominent features. The clip transcript, below, is the scientist's complete, spoken language. The data analysis also included an entire coordinated picture, language, gesture, and interpretation analysis (Appendix D).

The Scientist: "You want to make sure sarcomere lengths are of a consistent size and that, of course, each sarcomere and each half-sarcomere are roughly the same size."

The visual display in this clip is the same one that resulted from Clip M1 (Figure 4.2b). Before this point in the interview, the scientist specifically defined each structure (Figure 4.1b). In Clip M3 no other markings were created or removed.

In this third of four clips, the scientist continued his explanation about sarcomere structure and function. He focused on sarcomere length. At the clip's beginning, he faced away from the board. He lifted his hands, with fingers extended, in front of his chest. After he began his explanation, he turned back toward the white board and said, "make." During the beat when the scientist said, "length," he performed his next major gesture. He took his hands and outstretched fingers and, emphatically, placed them over, and in line with, the cartoon's Z-lines (Figure 4.6). He used this hand shape as he emphatically motioned toward the board. Throughout the entire interview the scientist repeatedly created this gesture to indicate sarcomere length.

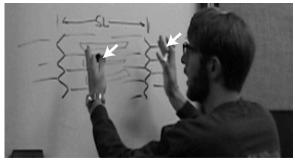


Figure 4.6: Position that emphasized the cartoon's Z-lines

The scientist continued his explanation with his gaze and body toward the white board. From this body position, he located his arms approximately shoulder distance apart, so that they aligned with the visible display's Z-lines. Then, he kept his hand shapes and moved them in progressive, distinctive, horizontal steps to the outside of either Z-line. When his gesture concluded, the scientist's hand shape remained, but his hand positions extended from his body's midline. When he created the horizontal step series through repeated gesture, each movement corresponded to one syllable in his language. Specifically, the syllables were, "-sist-," "-tent," and "size." His language paused. During the pause, he reversed his movements and executed the horizontal series in progressive, distinct steps, back toward the visible cartoon's Z-line features. With the last gesture step the scientist returned his hand position so that it aligned with the cartoon's Z-lines.

With these set of gestures, the scientist maintained the original hand shape that overlaid the cartoon's Z-lines. He started from the cartoon's single sarcomere and then created a series by adding units to either side of the sarcomere template. In this case, he varied his hand shape location when he fashioned a sarcomere series. He used the standard sarcomere length hand shape but built the series in a unidirectional, side-by-side direction. The scientist built the first unit series from right to left, then he repeated the motion, overlaid the first series, and build the second unit series from left to right (Figure 4.7).

After the scientist explained the information about full sarcomeres, he changed his description to information about half-sarcomeres. Initially, he exhibited the single

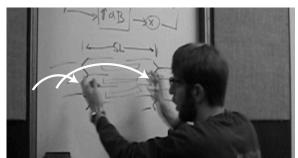


Figure 4.7: Hand shapes suggesting a left-to-right series of horizontal units.

sarcomere hand shape, the hand shape associated with the cartoon's visible features. During the scientist's verbal reference to half-sarcomeres, his gestures created a virtual object that deviated from the cartoon's visible features. He pointed out a rectangle where the top, bottom, and left side overlaid visible cartoon features. When the scientist created the rectangle's fourth side, it perpendicularly crossed all features organized across the sarcomere's center and he said, "and each half-sarcomere."

To summarize, the scientist established a gesture that indicated a structural feature: sarcomere length. The scientist used the same gesture to create inner-to-outer and side-by-side sarcomere unit series. And, he repeated the gesture's use when he showed sarcomere unit series horizontal organization. He described another sarcomere feature, the half-sarcomere. The half-sarcomere's gesture was based on visible cartoon features in addition to an implied, non-visible sarcomere definition.

4.3.4 Clip M4

Clip M4 contained 10 seconds of video for analysis. The segment's time span covered from 05:04 to 05:14 of the original 11:22 interview. In this clip, the scientist explained the conditions and consequences that led to malformed sarcomeres. Before

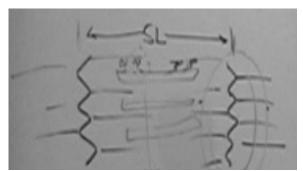


Figure 4.8: Clip M4 visual display. Many of the markings are not pertinent to the discussion here. The pertinent markings are shown in Figure 4.2b.

this point in the interview he slightly modified the diagram (Figure 4.8). However, the only pertinent structures are those previously drawn (Figure 4.2b). During clip M4 no other inscriptions were created or removed.

The clip transcript, below, is the scientist's complete, spoken language. The data analysis also included an entire coordinated picture, language, gesture, and interpretation analysis (Appendix E).

The Scientist: "If the sarcomere doesn't form properly and is not regulated in this nice distinct, coherent manner, you can activate all kinds of crap."

First, the scientist established the situation's conditional nature. He pointed toward the visual display's general direction, said, "If the sarcomere," and turned to face the white board. The clip began with his body perpendicular to the white board but, when compared with other clips, the scientist spent extended time with his body positioned away from the board.

The scientist first said, "If the sarcomere doesn't form properly." After this phrase he interacted with the cartoon on the white board and positioned each hand so that it aligned with a cartoon's Z-line. As his language progressed, he arranged a

virtual, horizontally aligned, sarcomeres series. To complete the sarcomere series, his hand shapes and motions mirrored those from other clips. Specifically, these movements were similar to those used in Clip M2 (Appendix C, Lines 15, 16, and 17) and Clip M3 (Appendix D, Lines 4 and 8). His hand shape and movements that aligned with the cartoon's Z-lines remained consistent. The scientist performed one aberrant gesture; he slightly curved his hand trajectory during one stroke of Z-line tracing (Figure 4.9)

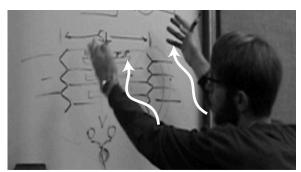


Figure 4.9: Curved hand motion indicating malformed Z-lines

The scientist laid out the sarcomere series around the cartoon's central diagrammed sarcomere, distinguished by consecutive Z-lines. In previous clips, he repeatedly noted that sarcomere Z-line features determined and defined both structure and function. He used his marker to tap on the board at the diagram's right Z-line's bottom-most point. He tapped five times in the same location with distinct regularity. The taps were hard enough to be audible. The rhythmic beats corresponded to his language, "act-ti-vate-all-kinds." When the scientist said, "kinds," his gaze turned away from the board and remained in that position until the end of the clip. When he said the next word, "of," he used the same tapping motion but pointed his pen toward

the center of the sarcomere cartoon. His pen did not come into contact with the board but hovered above a spot that had no corresponding drawn visual detail.

Here, there was a pause in the scientist's language. During the pause he looped his pen in counter-clockwise circles with his right hand. He crafted the over-the-board circles in a general location central to the sarcomere cartoon. During this language pause, his five virtual circles diminished in diameter. Finally, the scientist resolved this situation when he expressed the word, "crap."

Altogether, Clip M4 revolved around sarcomere organization. The scientist presented characteristics of desirable and undesirable structures. When he described desirable sarcomere qualities he made clear word and gesture choices. When he spoke of undesirable sarcomere organization his language and gestures were muddled.

4.4 Final Study Interview

The scientist's final study interview was the third of three interviews performed during the study. His interaction with a visual display during a biological structure explanation determined the overall episode selection. Through experimental protocol he created a four-panel, black and white, myosin molecule micrograph (Figure 4.10).

Panel (a), the largest panel, showed a field of approximately 20 molecules. Panels (b), (c), and (d) were equal in size to each other but smaller than panel (a). Each of the three smaller panels contained a single myosin molecule. The micrograph image projected onto a screen served as the visual prompt for all of the final interview clips, Clips F1, F2, and F3. The scientist did not have the ability to create or remove

any part of the projected visual display. He used his hands, rather than some kind of pointing tool, to emphasize certain micrograph features. He explained some of the qualitative information required to calculate myosin tail length.

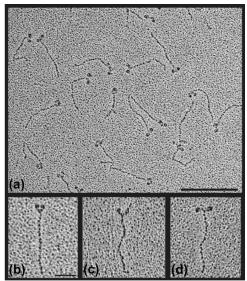


Figure 4.10: Micrograph visual display. (a) Random field of myosin molecules. (b), (c), and (d) Individual myosin molecules.

During the final interview the scientist stood to the left of the projected image so that his left shoulder was closest to the screen and his right shoulder was closest to the camera. So, if he faced the screen, the camera diagonally faced his right side as he



Figure 4.11: General body position with respect to the projected micrograph during the final interview.

stood between the camera and the screen (Figure 4.11).

As described, myosin structure contained two main subunits, a tail and a head (Figure 4.12). When scientists introduced mutations in a particular tail region, the myosin tail length changed. Myosin tail length related to its three-dimensional, dynamic bending ability. Since the micrograph only displayed two-dimensional, static structure, the visual display limited the scientist's interaction. The scientist suspended direct engagement with the visual display when he discussed molecular motion.

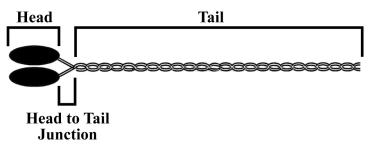


Figure 4.12: Myosin molecule anatomy.

The entire final study interview lasted 47:37 (min:sec). From this, the extracted episode was from 11:49 to14:44. The episode yielded three video clips. The episode clip choices specifically represented the episode's overall narrative and each clip represented a complete idea. Three Clips, F1, F2, and F3, provided data for further analysis. In Clip F1, the scientist pointed out the micrograph's panels (a), (b), (c), and (d). In Clip F2, the scientist pointed out a myosin molecule's tail beginning and end regions. Next, in Clip F3, the scientist indicated either bent or straight molecule tails. In total, these three Clips, F1, F2, and F3, illustrated how the scientist explained biological structures via a pre-existing and immutable visual display.

4.4.1 Clip F1

Clip F1 contained 18 seconds of video for analysis. The segment covered 12:06 to 12:24 of the original 47:37 minute interview. In this clip, the scientist introduced the visual display's organization and the featured molecules. The scientist pointed to specific regions of the myosin molecules in panels (b), (c), and (d). Then, he made a general gesture across panel (a). The clip transcript, below, is the scientist's complete, spoken language. The data analysis also included an entire coordinated picture, language, gesture, and interpretation analysis (Appendix F). Note: The S2/LMM hinge region is the particular amino acid region that the laboratory scientists mutate in order to look at tail length and flexibility. Its position was approximately one-third from the head-to-tail junction to the end of the tail.

The Scientist: "This S2/LMM hinge, which is located in this region of the molecules, here and here. Um, this is an overview picture of a wild type myosin, uh, population just kind of showing the field view of what our preps look like."

The scientist first pointed out the hinge region in panels (b), (c), and (d) (Figure 4.14). The hinge region resided approximately one-third down from the head-to-tail junction toward the tail's end. The scientist roughly indicated the span on each molecule that defined the hinge region. He adopted his right hand, with its right outstretched index finger, to accomplish this task (Figure 4.13).

Panels (b), (c), and (d) each displayed one myosin molecule. Each molecule was oriented with its head region at the top of the panel and its tail extended vertically from each head. The scientist's words, "here, here, and here," corresponded with his gestures toward the molecules in panels (c), (b), and (d), respectively. That is, during

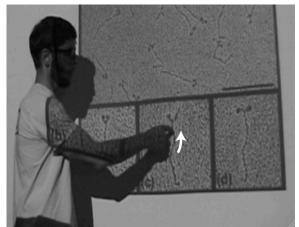


Figure 4.13: The scientist pointing to the hinge region of the myosin molecule in panel (c).

this language, he indicated each single panel's molecule hinge areas with an up and down motion. His motions covered a range on the tail of the molecules. The scientist did not specify an exact location on the molecules.

Next, the scientist raised his left hand, with all of his fingers outstretched, to panel (a). With this action he explained, "this is an overview picture." Panel (a) had roughly 20, variously oriented, individual, myosin molecules. This contrasted with the previous panels that had one molecule per panel. During these actions the scientist' right hand was down by his side. His hands remained in these positions until he



Figure 4.14: The scientist sweeping his left hand to the right across panel (a).

completed the word "of." He moved his left hand from its static position over panel (a), added a sweeping motion from its original position to the right, and then back to the left (Figure 4.14). His language during this motion was, "wild type myosin, uh." The scientist's left hand shape remained the same during his arm motions.

The scientist finished his sentence when he said, "population." As he said this word he changed the shape of his left hand, from his previous outstretched fingers, to a fist. Next, as he expressed the transitional type words, "just kind of," he brought his hands together at his waist. During this entire segment, the scientist's gaze remained at the screen with his body slightly faced away from the screen and toward the camera.

In the clip's next segment, the scientist swept both of his hands across a large span of panel (a). He made this motion when he expressed, "showing." During the next part of the sentence, he swept his left hand over panel (a), from its original position, to the right and then back to the left. The scientist made this gesture in a coordinated fashion with his words, "field view." This motion duplicated his gesture from earlier in the clip when he said, "wild type myosin, uh." Next, he continued speaking as he made smaller and more general sweeping motions with his left hand.

This segment of the clip concluded when the scientist said "like." As he expressed this language he changed his hand shape from one with extended fingers to that of a loose fist. This hand shape replicated the earlier fist form from when the scientist said, "population."

Overall, the visual prompt in this clip, Clip F1, contrasted microscope images of differently presented, individual myosin molecules. The scientist contrasted a

multiple molecule presentation to individual molecule presentations. He first used panels (b), (c), and (d) when he pointed out the hinge region's general range. Next, he interacted with panel (a), the panel that displayed multiple molecules. He used his hands to create sweeping gestures across that panel. The movement emphasized an extended image area that included many individual molecules. This was in contrast to panels (b), (c), and (d), that had smaller image areas and displayed only one molecule per panel. Finally, the scientist specifically said that his laboratory's experimental preparations produced visual displays that looked like the field view in panel (a).

4.4.2 Clip F2

Clip F2 contained 25 seconds of video for analysis. The segment spanned 12:39 to 14:04 from within the original 47:37 minute interview. In this clip, the scientist emphasized the physical locations that determined rod length. The clip transcript, below, is his complete, spoken language. The data analysis also included an entire coordinated picture, language, gesture, and interpretation analysis (Appendix G).

The Scientist: "Um, so then what I was doing with this was measuring the length of the rod. So you can clearly see where it stops and, for those of us who study them, you can clearly see where it starts. So then you just linearize, skeletonize this length along, along the length of the rod from the head-to-tail junction to the C-terminus."

In Clip F2 the scientist began his explanation with the verbalization, "Um, so then." After these words, he paused and performed a brief sweep over panel (b) with his left hand. With his left hand he made a smaller sweep toward panel (c) and then

back again to panel (b). He coincidentally verbalized, "what I was doing with this." His language and the sweeping motions introduced the explanation that followed. The scientist's explanation described how he measured tail length through precise tail stop and start point determination.

The scientist's next stated, "measuring." He changed his hand shape from one with softly extended fingers to one with a pointing index finger. This language and gesture pivoted the scientist from his general introduction to his specific explanation. The explanation showed how he determined myosin molecule tail stop and start points when he measured tail lengths. To initiate his explanation's following part, the scientist prepared his hand locations and shapes during his next phrase, "the length of the." Then, his explanation traced specific locations on the panel (b) myosin molecule. By the time he said, "the rod," he settled his right hand into a pointing configuration and precisely placed it at the distal end of the molecule's tail. With his right hand in the same position, he spoke, "and." The scientist s this word when he carefully placed left index finger at the panel (b) myosin molecule's proximal end.

The scientist shared information about expert scientists and their special knowledge. From the location where he pointed, the proximal end of the molecule's tail, he quickly motioned his entire left hand away from the screen in a tossing motion. The scientist simultaneously executed the tossing gesture and the verbalization, "us who." The complete phrase was, "for those of us who study them." The, "us," referred to professional scientists who specialized in myosin molecule structure analysis, and the, "them," were the actual myosin molecules.

After specifying the experts who typically do this work, the scientist explained the actual measurement process. He described a method where he employed a standard measuring software program to put consecutive line of segments down a length of the tail so that they followed the small bends in the coiled-coil structure. He referred to this action as, "linearize," and, "skeletonize." At the same time that he said these descriptive words, he used the tip of his little finger to slowly trace down the length of the tail in a proximal to distal direction (Figure 4.15). Midway during his trace down the myosin tail the scientist said, "this length." He verbalized, "length," when his little finger gesture arrived at the myosin tail's far end. Once he finished slowly tracing the tail, he used his index finger and quickly traced the tail. He used his index finger to point, first, to the tail's beginning or, "head to tail junction," and, second, to the tail's end or, "C-terminus." All together, the scientist's gestures became even more abbreviated as he described his tail length measurement method.

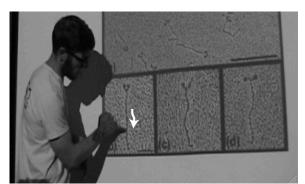


Figure 4.15: The scientist pointed out how tail length is measured.

During this clip, the scientist explained the tail length measurement procedure. First, he broadly gestured over the entire myosin molecule. Next, he explained the molecular structure and measurement protocol in more detail. His explanation took on

an hourglass type of structure. That is, he went from general information, to specific information, then back to general information. The scientist broadly indicated the molecule's image and then he pointed out the head and the tail. Following this, he first slowly traced the tail length, then quickly traced the tail length, and finally pointed out the independent head and the tail positions.

4.4.3 Clip F3

Clip F3 contained 15 seconds of video for analysis. The segment extended from 14:21 to 14:36 of the original 47:37 minute interview. In this clip, the scientist emphasized myosin molecule tail's physical shape as either straight or bent (Figure 4.16). The clip transcript below is the scientist's complete, spoken language. The data analysis also included an entire coordinated picture, language, gesture, and interpretation analysis (Appendix H).

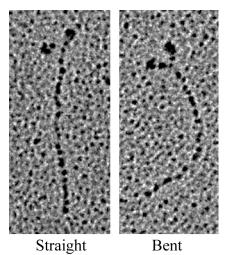


Figure 4.16: Examples of a straight myosin tail and a bent myosin tail isolated from the Figure 4.10, panel (a).

The Scientist: "And so, these [panels (b), (c), and (d)] are the sorts of orientations that I typically go for when I measure because there's a lot less bending

and torsion that's taking place which can, potentially, influence the length if you stretch or bend a molecule."

First, the scientist casually pointed to panels (b), (c), and (d) to show the myosin molecule orientations that he liked to measure. Each image had a somewhat extended tail with no apparent bends or kinks. The scientist used the phrase, "go for," when he referenced his molecule selection process. At this explanation's end section, he stopped gesturing and dropped his hand.

Next, the scientist used panel (a) for examples of myosin molecules with non-straight tail orientations. With his index finger he pointed out four different molecules. For three of the four molecules he traced their tail lengths with his index finger (Figure 4.17). For one of the four molecules he pointed to the molecule's head-to-tail junction. He mentioned the bent tail molecular level physical properties, "bending and torsion." The scientist dropped his hands at the transition between this part of his explanation and the beginning of the last part of his explanation.

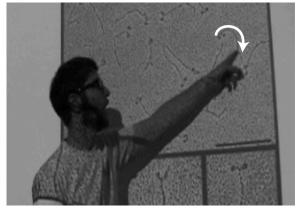


Figure 4.17: The scientist tracing a myosin molecule with a bent tail.

During the last part of the scientist's explanation he used language and gesture only, he did not reference the projected image. The scientist concluded his point when his hands defined a three-dimensional structure in space. The scientist gestured and deformed the virtual structure that he just created. With this action he said, "stretch and bend the molecule." As before, the scientist dropped his hands and turned away from the board when he concluded this explanation's section.

In this clip, the prompt asked the scientist to explain how he selected molecule tails to measure for his data analysis. He explained the process via three examples. The first example indicated three myosin molecules isolated in three micrograph panels. Each molecule exhibited a relatively straight tail. He noted that he preferred these orientations for tail length measurement. In the second example, the scientist pointed out particular molecules from the mysoin molecule field. His language and gestures described non-straight tails in contrast to straight tails. The last part of the clip showed how the scientist gestured and created a three-dimensional virtual object from a two-dimensional visual display. He deformed the virtual object through his hand shape and movement.

4.5 Chapter Summary

This chapter presented data from two interviews. The mid-study interview occurred approximately halfway through the eight-week study period and the final interview took place at the end of the study period. The scientist and the interviewer, this study's investigator, participated in the interviews. A different visual display played a part of each interview's prompt.

The interview data reduction criteria depended on the scientist's concurrent visual display engagement and complete idea narration. These criteria were applied to the full interview to partially reduce it to one episode per interview. The episode-level data used the same criteria to reduce it to the final clip-level data. The final data reduction generated the seven clips described in this chapter.

The interview that occurred midway through the two-month data collection period, the mid-study interview, yielded four clips, M1, M2, M3, and M4. A cartoon sarcomere served as the visual display for all mid-study interview clips; the scientist drew the cartoon sarcomere earlier in the interview (Figure 4.2a). In these clips, the scientist described proper sarcomere structure when he engaged with the visual display in both visual and virtual manners. During Clip M1, he added visual objects to the cartoon display to result in a new version of the cartoon (Figure 4.2b). During Clips M2, M3, and M4, the scientist left the visual display intact. He neither created nor destroyed any features. Instead, he referenced the visual display when he laid virtual objects over the existing sarcomere cartoon. In addition, he sometimes created virtual objects in space, not directly aligned with the sarcomere cartoon.

The final interview occurred at the data collection's end and generated three clips, F1, F2, and F3. These clips centered on a projected micrograph visual display (Figure 4.10). The micrograph showed myosin molecules with various tail shapes, both straight and bent (Figure 4.16). The final interview clips also revolved around myosin molecule's straight and non-straight tail characteristics. In Clip F1, the scientist pointed out two different tail shape layouts. First, straight-tailed molecules

resided, one molecule per panel, in three panels. Second, various shape-tailed molecules had multiple molecules in a single panel. In Clip F2, the scientist specifically indicated his tail length measurement procedure when he carefully traced down a straight-tailed molecule's the length. In Clip F3, the scientist specifically compared the single molecule per panel straight tail quality with the multiple molecules per panel non-straight tail qualities. Also in Clip F3, the scientist translated a static, two-dimensional bent molecule into one that had volume and motion.

Altogether, the video data review produced seven clips, four from the midstudy interview and three from the final interview. The previously applied data reduction criteria led up to this chapter's detailed clip description and provided information suitable for further analysis. The analysis developed in light of the question at hand: How do scientists engage with visual displays to explain their understanding of extremely small biological objects?

4.6 Data Analysis Chapters

As a prelude to the following four Data Analysis chapters, this chapter considered seven video clips via their detailed descriptions. In-depth comparisons led to four central themes: Naming, Layering, Categorizing, and Scaling. The themes arose through three complementary analytical factors: this chapter's descriptions, the Appendix B through H gesture studies, and the original video data. In the next four Data Analysis chapters, these clips will be presented by the themes that emerged from their analysis. Many conceivable events could have occurred when the scientist engaged with each visual display that he encountered during his interviews. Below is a

brief introduction to one potential way that the data analyses led to the organization into particular themes.

Chapter 5: Naming

In Clip M1, the clip that exemplified *Naming*, the scientist engaged with the cartoon sarcomere when he created a persistent visual object. The scientist drew persistent visual objects, markings that left visible evidence even after their original execution, on the white board. The scientist added these drawing to the pre-existing cartoon sarcomere. The scientist's Naming added markings that had stand-alone meanings as symbols. His Naming marks also expanded the pre-existing cartoon's meaning through their relative location to the cartoon's features. Naming through creating symbols with a potentially dual meaning with respect to the pre-existing cartoon showed the scientist's understanding about sarcomere length.

Chapter 6: Layering

In Chapter 6, the scientist exemplified *Layering* when he engaged with visual displays of small biological objects. In Clips M3 and F1 the visual displays were the cartoon and the micrograph, respectively. Layering occurred when the scientist gestured to create virtual objects. Virtual objects were fleeting in that they left no visible evidence, they could only seen at the time of execution. Layering occurred when the scientist gestured over visual display features and generated virtual objects. Layering also occurred when he gestured away from visual display features and created virtual objects. Layering emphasized the scientist's understanding about sarcomere organization and myosin molecule visual presentation.

Chapter 7: Categorizing

Categorizing occurred when the scientist interacted with visual displays in order to differentiate data. Clip M4 and its cartoon, and Clip F3 and its micrograph, exemplified Categorizing. Categorizing resulted from descriptive moments that fueled key contrasts between data characteristics. Order versus lack of order acted as the single Categorizing base for the two analyzed characteristics. The two analyzed characteristics included sarcomere assembly and myosin tail shape. So, the analysis approached sarcomere assembly as properly formed or not properly formed, and myosin tail shape as straight or not straight. The Categorizing approach led to a two-tiered patterned visual display interaction.

Chapter 8: Scaling

In Chapter 8, Clips M2 and F3, illustrated *Scaling*. Clip M2 involved the cartoon visual display and Clip F3 involved the micrograph visual display. With Scaling, the scientist changed visible objects with certain characteristics to virtual objects with different characteristics. Scaling occurred when the scientist virtually, "lifted off," visible display features and scaled them to a size that fit his bodily dimensions. As a result, the scientist created a type of universal language that shared his understanding about small biological objects.

CHAPTER 5: NAMING

5.1 Chapter Introduction

This chapter will describe a paradigm entitled *Naming*. In Naming, the scientist's pen-to-whiteboard contact resulted in markings that were added to a pre-existing cartoon (Figure 5.1). The newly drawn markings held certain meanings as individual symbols. One part was a letter-based symbol and the other part was a graphic symbol. When take together, the unified mark's meaning changed, especially when its location was considered relative to the pre-existing cartoon. Likewise, the meaning of the pre-existing cartoon changed with the addition of the littera-graphical mark; it became a different object. During Naming, the addition of an inscribed mark changed not only the visual appearance of the cartoon but its functional meaning as well.

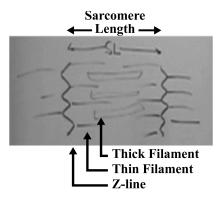


Figure 5.1: Sarcomere cartoon with labels. Pre-existing cartoon's features: Vertical zig-zag lines represented Z-lines. Horizontal boxes represented thick filaments.

Horizontal lines represented thin filaments.

5.2 Clip M1: Naming

5.2.1 Clip M1 Introduction

The Naming event described in this chapter occurred in Clip M1, which was described in Chapter 4. During the clip, the scientist added two markings above the initial cartoon (Figure 5.2). First, he wrote the initials, "SL," when he defined sarcomere length. Based on this Naming event, he assigned a second symbol that indicated a one-sarcomere span, oppositely directed arrows. He aimed to create markings that would bring attention to the cartoon's specific qualities and features. In order to accomplish this, the scientist interacted with the whiteboard in a direct and physical manner.



Figure 5.2: The "←SL→ mark above the pre-existing cartoon. Sarcomere length was abbreviated "SL," and the oppositely directed arrows indicated the span between adjacent Z-lines.

5.2.2 Clip M1 Data Analysis

Clip M1 was the first of four clips extracted from the mid-study interview. The interview video was edited to yield this clip, which was then described in detail in Chapter 4. The video clip was first sub-sectioned by the scientist's gesture, and then the corresponding language was added (Appendix B). In this analysis, as shown below, Clip M1 was first sub-sectioned by the scientist's language, and then the corresponding gesture was added. All dialogue clips in this document used the following notation conventions as described in Noble, Nemirovsky, Dimattia, and Wright (2004, p. 128):

(...) indicates omitted talk or gesture;

() indicates audible but uninterpretable speech;

[gesture] indicates gestures or other actions that occurred along with the transcribed talk;

[words] includes clarifying text that gives the referent for a pronoun, the person addressed, or talk or actions by another person that occur at the same time as the transcribed speech;

words Indicate words spoken with emphasis;

The Scientist: "Your sarcomere is, of course, your individual contractile unit.

The sarcomere length that we measure (...)"

5.2.2.1 Clip M1 language and gesture notation

1. Your sarcomere is,

[Began drawing the "S." Its horizontal position was roughly midway between the two Z-lines. Its vertical position was above the entire pre-existing sarcomere diagram.]

2. of course

[Finished drawing the "S."]

3. your individual

[Drew the "L" to the right of the "S."]

4. contractile

[Drew the right-facing arrow's horizontal line. The line was oriented to the right of the "L."]

5. unit

[Drew the right facing arrowhead.]

6. The sarcomere length

[Drew the left-facing arrow's horizontal line. The line was oriented to the left of the "S."]

7. that we

[Drew the lower diagonal line of the left-facing arrow.]

8. measure

[Drew the upper diagonal line of the left-facing arrow.]

5.2.2.2 Clip M1 language and gesture analysis

The language and gesture analysis follows a multi-part structure. First, the analysis repeats the line number and language based on the above notation. Then, for each line, the language analysis precedes the gesture analysis. Each subsequent line repeats the same organization. Note that all gestures correspond to the creation of a marking.

1. "Your sarcomere is"

The scientist's initial word was the second-person possessive pronoun, "your." His language indicated that he addressed someone other than himself. In contrast, if he initiated the phrase with the singular subjective, "I," or the plural subjective, "we," then his explanation would have included himself and his experiences as an expert. This first word, "your," taken with the last word in the phrase, "is," played a contextual role with respect to the central word, "sarcomere." Due to its context, and the scientist's cartoon definition, it was likely that he would introduce more

information about sarcomeres later in the clip. Also, "sarcomere," was the only noun in the sentence and nouns are easier to interpret into a cartoon. Non-nouns like, "your," or, "is" are especially difficult to simply convey as iconic visual objects.

The scientist held an uncapped pen in his right hand. He positioned the pen in a manner conducive to writing (Figure 5.3). He located his hand above the entire sarcomere carton and midway between the existing Z-lines. This placement indicated potential labeling. As it was situated, the pen acted as an extension of the scientist's bodily self to yield a functional tool. He used the pen tool when he added visible markings to the pre-existing cartoon to explain his knowledge about sarcomere structure.

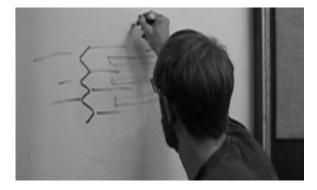


Figure 5.3: The scientist's initial position for cartoon creation.

2. "of course"

The scientist verbalized the phrase, "of course," a phrase that the he historically interjected during his verbal communications. Among the many possible reasons that could explain this observation, two came to the forefront. First, since he maintained intimate knowledge about his explanation's content then, "of course," would be true for his statements in total. Second, the scientist used, "of course," to fill

pauses or indicate transitions. When analyzed from this perspective, the phrase is comparable to habitually interjected words such as, "um," and, "like." From these prospective reasons, neither, the first, the second, or both could be applicable.

The scientist drew the letter "S," a reference to the full sarcomere structure. In support, the only noun he verbalized in Line 1 was "sarcomere," a word with the initial letter "S." When the scientist drew the "S," he partially named the sarcomere length feature when he used the minimum letter-based symbol. Since the sarcomere comprised the pre-existing cartoon's crucial subject, the letter "S" was essential to the Naming interaction's visual expression.

3. "your individual"

The scientist repeated the second-person possessive pronoun that he uttered in Line 1, "your." Twice he used the same language and each time it led to a similar analytic effect: he excluded himself from active participation in his explanation. The second word in this phrase was, "individual," a term that he used when he referred to sarcomeres. Sarcomeres' Z-lines were the boundaries that defined each sarcomere as an individual, countable unit. Alternatively, "individual," referenced a subject not yet introduced.

The scientist added markings to the existing cartoon during his verbal expression. He created the letter "L" next to the letter "S," which was described in Lines 1 and 2. There was one clear difference between the "S" in Lines 1 and 2 and the "L" in this line. In Lines 1 and 2, when the scientist drew an "S" and said "sarcomere," he meaningfully connected the symbolic and spoken linguistic forms.

However, in this line, the scientist drew an "L," but did not link it to any separate language or gesture.

4. "contractile"

This language shed some light on the word, "individual," spoken in Line 3. When the scientist said, "contractile," he immediately imparted action to the sarcomere. Before this, his

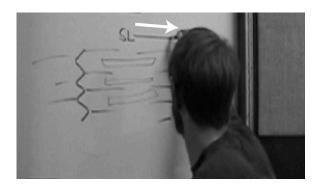


Figure 5.4: Left to right horizontal line. The scientist drew a horizontal line, from left to right, to the right side of the, "SL."

explanation allocated neither function nor animation to the static cartoon.

When the scientist said, "contractile," he drew a horizontal line from the right side of the "L" toward the right Z-line (Figure 5.4). His coordinated language and movement direction predicted that sarcomere contraction would move along the newly constructed line.

5. "unit."

In Line 5, the scientist spoke only one word: "unit." This language completed the first full sentence in the clip and communicated a complete picture about a

sarcomere characteristic. The scientist chose the term, "unit," which delivered the same sense as the word, "individual," that he spoke in Line 3.

When the scientist spoke the word, "unit," he drew a right-facing arrowhead on the right end of the horizontal line drawn in Line 4. The arrowhead's tip indicated one end of a span. In the actual experiments, the span designated a microscopic, physical distance. In the cartoon, the arrow designated the sarcomere's right half since it spanned from the approximate center to the sarcomere's right border.

6. "The sarcomere length"

The scientist clarified that the "SL," which he drew during this clip's first sentence, indicated, "sarcomere length."

The scientist drew a horizontal line from the left of the "S" toward the left so that the line's end stopped over the left Z-line. This line mirrored the horizontal line already drawn to the right of the "L." If the data analysis trend continued, the newly drawn line would create a symbol that indicated the other sarcomere half-length.

7. "that we"

The scientist said, "we," a pronoun that included himself. When compared with previous pronoun usage, "we" had to include the scientist and at least one other entity. The other entity could have been one or more specific instances of bodily scientists. For example, it might have included the scientists in his lab or outside collaborators. As an alternative, the other entity could have been less defined but still associated with sarcomere research, for instance, the muscle research community.

The scientist's gesture resulted in a small marking added to the cartoon. He added the left-facing arrowhead's, top, diagonal line. The small feature built upon the symmetry initiated by the previously created lines. The visual object created to the left of the "S" was one small line away from symmetrical, oppositely directed, horizontal arrows (Figure 5.2).

8. "measure"

The last word that the scientist said when he created his cartoon was, "measure." The language brought together the previous lines' subjects about sarcomeres: their length and their individuation.

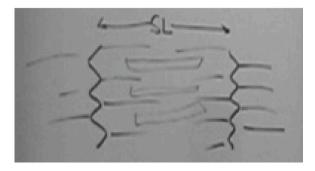


Figure 5.5: Final cartoon. Final cartoon at the end of Clip M1.

The scientist created a minimal marking: a diagonal line that made up the left-facing arrow's bottom half. The final Naming through drawing occurrence corresponded to the scientist's final intended explanation about sarcomere length. That is, the requirement for measuring sarcomere length was dependent on the span between the two arrows. The cartoon conveyed what was necessary and sufficient for the action described (Figure 5.5).

5.2.3 Clip M1 Summary

Clip M1 exemplified the scientist-named features when he created relationships between his understandings about sarcomeres and his interactions with visual objects. As the clip progressed, the scientist's Naming events coincided with his sarcomere structure explanation and visual object creation. The clip's witnessable Naming resulted in the creation of two visual object markings. One marking designated sarcomere length through the letter-based symbol, "SL." The other marking, the symbolic notation, " $\leftarrow \rightarrow$," indicated span. The two visual objects created a linguistic and symbolic visual duet. When united, the complex functioned as a single Naming mark for general sarcomere length. The highly generalizable mark described the sarcomere length feature for any given cartoon, photographic, actual, or virtual sarcomere. This is one way in which the mark continued to perpetuate as a meaningful symbol.

5.3 Chapter Summary

Clip M1 described Naming, an event that illuminated the scientist's reciprocal understanding-to-visual object engagement. From one perspective, the interaction created persistent visual objects related to the topic at hand, sarcomere length. The scientist linked sarcomere length to the letter-based symbol, "SL." He noted sarcomere length span with oppositely directed arrows to either side of the, "SL." As a single littera-graphical mark, the " \leftarrow SL \rightarrow " lacked a contextual referent. In this case, the missing referent was the sarcomere cartoon. Similarly, the pre-existing cartoon lacked labels to give visual meaning to the previous spoken language description. The mark

creation, and of equal importance, its spatial location in relation to the pre-existent cartoon, allowed the Naming event to occur.

CHAPTER 6: LAYERING

6.1 Chapter Introduction

This chapter will describe a particular descriptive class entitled *Layering*. With Layering, the scientist gestured in the space over visual features and, in the process, created virtual objects. Virtual objects' fleeting quality restricted observation to their moments of execution, while visible object features persistence allowed observation beyond their time of creation. During the scientist's Layering interaction, he created no persistent marks on either the cartoon or micrograph. The cartoon and micrograph's visual and implied features drove the scientist's virtual layering actions. This analysis

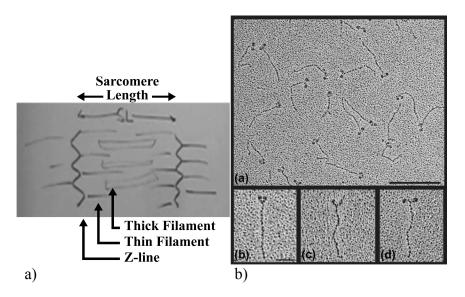


Figure 6.1: a) Sarcomere cartoon. b) Myosin micrograph. Left image: The sarcomere cartoon drawn by the scientist earlier in the interview. The labels were added for clarification in this document. Right image: An actual myosin micrograph generated by the scientist for data analysis, presentation, and publication. Panel (a), top, a field view of wild type molecules. Panels (b), (c), and (d), bottom, left to right, isolated myosin molecules with "straight tails."

investigated how the scientist engaged with the visual display in a manner that explained his understanding about small biological objects.

In Clip M3, Layering described how the scientist verbally and bodily expressed information about the cartoon sarcomere's organization. He principally based his utterances on the cartoon's visible features: sarcomere lengths as defined by Z-lines. Secondarily, he founded his explanations on an implied feature, the half-sarcomere. These two interactive conditions mimicked visual features and crafted implied features in a way that the scientist-cartoon interaction enhanced his explanation about sarcomere organization.

In Clip F1, during Layering over the micrograph, the scientist only interacted with panel (a) (Figure 6.1b, largest panel). Panel (a) showed, approximately, eighteen, randomly distributed, myosin molecules. The scientist interrelated with the micrograph when he swept his hand back-and-forth across the image. His motion figuratively spread out the molecules across the panel just as the molecules were literally distributed across the same area. After he spread out the molecules, he figuratively gathered them together when he formed his hand into a fist.

6.2 Clip M3: Layering

6.2.1 Clip M3 Introduction

In Clip M3, the third of four clips from the mid-study interview, the scientist explained the sarcomere lengths' desired characteristics. The scientist's physical interactions with the cartoon were all indirect in that he never touched, but always related his gesture, to the board. Instead, his movements resulted in Layering.

Layering resulted when he used his hands in order to reinforce and uncover the sarcomere cartoon's visible and implied features. The cartoon's pre-existing Z-lines were the visible features important to his gestures. In this clip, the scientist crafted two different features that were not visible in the cartoon: sarcomeres positioned to the visual sarcomere's sides, and a half-sarcomere positioned within the visual sarcomere itself.

6.2.2 Clip M3 Data Analysis

Clip M3 was originally sectioned by gesture. The resulting and entire gesture and language analysis of Clip M3 can be found in Appendix C. In Chapter 4, the clip was described in detail. As shown below, Clip M3 was first sub-sectioned by language and then the gestures were added and further described by the notation conventions, based on Noble et al. (2004), as described in Chapter 5.

Scientist: "You want to make sure that your sarcomere lengths are of a consistent size and that, of course, each sarcomere and each half-sarcomere...."

6.2.2.1 Clip M3 language and gesture notation

1. "You want to make sure

[Turned from facing the camera to facing the board. Positioned his hands to mimic that of the cartoon's two Z-lines.]

2. that your

[Raised hands so that they aligned over the cartoon's visible Z-lines.]

3. sarcomere lengths

[Said, "lengths," and emphatically motioned his hands over the cartoon's Z-lines.]

4. are of a

[Slightly relaxed hands.]

5. consistent size

[Moved hand shapes to trace over the visible Z-lines. He moved his hands to locations away from either side of the visible Z-lines and then back toward the visible Z-lines.]

6. and that

[Kept the same hand shape and their relative positions. Moved both hands to the right of the cartoon's right Z-line.]

7. of course

[Hand shape maintained but pause in movement.]

8. each sarcomere

[Maintained hand and arm shape and their relative positions. Moved them across the visible cartoon sarcomere from right to left and then back, from left to right.]

9. and each half-sarcomere"

[Used a pen to trace over a "half-sarcomere" made up of a rectangle where the only visible line corresponded to the cartoon's left Z-line.]

6.2.2.2 Clip M3 language and gesture analysis

The language and gesture analysis followed a multi-part structure. First, the analysis repeated the line number and language based on the notation above. Then, for each line, the language analysis preceded the gesture analysis. Each subsequent line repeated the same organization.

1. "You want to make sure"

The scientist started the entire clip with the personal pronoun, "you." His language expressed that he did not consider himself a subject in the explanation. Next, he said, "want to." These words were consistent with the language that he used with novices when trained them and recommended that they execute a particular action. Following the scientist's introductory words, he said, "make sure." These words transitioned the scientist's general set-up to a situation that required a certain amount of precision, attention to detail, or expertise.

When the scientist started to speak, he looked toward the camera. During his beginning words, he turned away from the camera and faced the white board. This change in bodily direction reflected his change in engagement objective. When he changed his body direction he began to change his hands (Figure 6.2) into their canonical Z-line form. Since the introduction to his explanation had yet to fully interact with the cartoon, his use of Layering had yet to fully develop. The scientist's personal subject knowledge, previous cartoon familiarity, and explanation details provided his communication foundation.

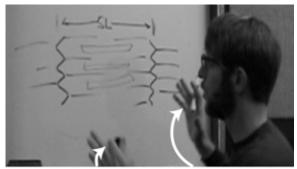


Figure 6.2: Forming Z-line hand shapes. The scientist turned toward the board as he, simultaneously, began to form his canonical Z-line hand shapes.

2. "that your"

As in Line 1 of Clip M1 in Chapter 5: Naming, the scientist used the pronoun, "your." That word choice addressed, in second-person form, the explanation process. When taken with the, "you," used in this clips first line, it verbally reinforced responsibility to someone other than himself.

In this line, the scientist faced the board and fully away from the camera. His hand shapes were much more defined than in Line 1 in that they were closer to the cartoon's Z-line angles. This first, complete, gesture clearly mimicked the cartoon's two Z-lines (Figure 6.3). The scientist's gesture imitated the Z-lines' shape but his body did not actually touch the board, even though he held a pen in his hand. So, the scientist's bodily position showed how he practiced Layering when he created a virtual gesture over the persistent Z-lines. The scientist practiced Layering that was bodily-based and aligned with the visible Z-line features on the cartoon.

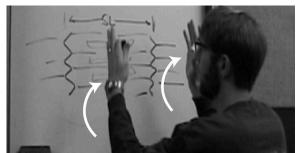


Figure 6.3: Hands over Z-lines. The scientist with his hands aligned with the cartoon sarcomere's Z-lines.

3. "sarcomere lengths"

The scientist introduced the central subject of the entire clip, "sarcomere lengths." At previous points in this interview he already defined sarcomere length, the distance between two Z-lines. By leaving out the definition of sarcomere length in this line, he avoided redundancy without compromising his explanation efficiency.

The scientist maintained his hand shape. He moved his hand's physical positions from one that was closer to his body to one that was very close to the board. His hands never touched the board. With respect to sarcomere length, he tightly coordinated his visual Layering motion with his verbal introduction. He emphatically moved his hands over the cartoon's Z-lines as he said, "lengths." His physical interaction resulted in Layering over the cartoon's Z-line features in that it indicated sarcomere length in its acknowledged definition. In the scientist's final gestural position, he directly aligned his hands over the cartoon's persistent Z-lines and, therefore, the cartoon directly instigated the Layering event.

4. "are of a"

The words, "are of a," prepared an assigned characteristic to, "sarcomere lengths." Up to this point in the interview, the scientist described sarcomere length as

a single unit or a series of units. He did not explain sarcomere structure or its details.

Also, since this phrase contained no subject, it functioned as a transition from "sarcomere lengths," to the subject in the following line.

The gestures were transitory in form. Pauses were important parts when transitions occurred. When the scientist said the word, "are," his body was paused. In addition to the pauses that took place during this line, he produced a slight gestural emphasis toward the board that aligned with the Z-lines. Specifically, his emphatic pulses coincided with the words, "of," and, "a." His action combinations showed similarity to those already executed. When he said the words, "of a," his previous hand shape partially relaxed and so did the Layering position that indicated sarcomere length. When the scientist's hand shape relaxed, it created a transition in his explanation.

5. "consistent size"

The scientist described an ideal sarcomere structure and organization characteristic. His language, "consistent," relayed information about the regularity of an already established feature, the sarcomere unit. In his previous language, he only mentioned "sarcomere length," as measurement size. Therefore, in this line, "size," indicated the distance from one Z-line to the subsequent Z-line, or "sarcomere length."

The scientist used the same hand shape as when he previously practiced Layering, over the visible Z-lines. In this case, his gesture maintained its previously defined meaning, sarcomere length. He sustained his hand shape as he moved them from their position over the visible Z-lines and horizontally away from each other. The

cartoon's features directed the Layering related to the scientist's original hand positions. The visible sarcomere formed a basis for the scientist's subsequent virtual sarcomere unit Layering. This gestural event did not solely determine sarcomere series organization. The cartoon showed partial sarcomere units to either side of the fully illustrated central unit (Figure 6.4). Also, at other times in the interview, the scientist created the same gesture to indicate that sarcomeres were found in a series of individual units.

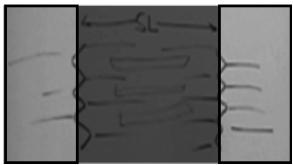


Figure 6.4: Partial sarcomeres. Light filaments, in lighter boxes, to either side of the central sarcomere.

6. "and that"

The scientist's words, "and that," added a characteristic to the established sarcomere description. He formerly mentioned the characteristics, "sarcomere length," and, "consistent size."

Previously, the scientist aligned his hands at his body's midline to indicate a sarcomere series' beginning. In this clip he repeated this approach. In this line, however, he crafted the sarcomere series from a location to the right of his body and to the right of the cartoon's Z-lines. To arrive at that position the he virtually picked up the visible, central, sarcomere unit and placed it to the right of that same visible

sarcomere. He performed that action when he said, "and." The word, "and," was appropriate because he virtually duplicated, or added, a sarcomere. He deposited the virtual sarcomere when he said, "that." When he said, "that," his emphatic gesture mirrored his straightforward explanation style. The pre-established hand shapes' and slightly modified location maintained the communicative consistency that he had established throughout the clip. The scientist's coincidental language and gesture rhythms foreshadowed similar coordinated events.

7. "of course"

The, "of course," in this line repeated of the, "of course," in Line 2 of Clip T21 in Chapter 5: Naming. Since the scientist repeated his language, it suggested similar reasons for the word choice. One possible reason he said, "of course," was because he had intimate knowledge of the subject matter and felt that all of the information he communicated was somewhat obvious. He also used, "of course," because, perhaps, he habitually interjected the verbal expression to fill pauses or indicate transitions. He could have used, "of course," as a combination of the two possible explanations. The scientist's gestures that accompanied his language reinforced the last proposed account.

The scientist maintained the hand shape that he used throughout the clip, the virtually Layering shape that mimicked Z-lines. He upheld his hands to the right of the cartoon's centrally drawn sarcomere. During this line, the scientist's limbs showed no motion. His verbal interjection acted as a pause that coincided with his pause in limb motion. Even though his limbs did not move, his head moved down when he said, "of,"

and up when he said, "course." This head motion continued the tempo-linked pattern that the scientist started in the previous line.

8. "each sarcomere"

With the expression, "each," the scientist considered sarcomeres as either individual units or a collective whole made up of a series of similar units. One similarity among the units in the collective lay in that each sarcomere had a consistent length measure. Also, the scientist referred to the sarcomere structure in its entirety rather than solely its length.

The scientist's hand shape built a series of sarcomeres when he gestured over the visibly drawn sarcomere. When he said, "each," he used Layering when he created sarcomere units when he gestured from right to left (Figure 6.5). When he spoke, "sarcomere," he used Layering when he created three virtual sarcomere units when he gestured from left to right. During this interaction with the cartoon the scientist maintained his hand shape when he overlaid the cartoon directly and when he used the cartoon's features to uncover virtual sarcomeres.

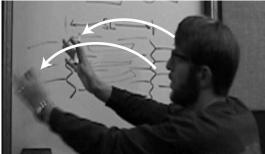


Figure 6.5: Layering virtual objects. Crafting virtual sarcomere, to the left side of his body, based on the visual sarcomere at his body's midline.

9. "and each half-sarcomere"

The scientist introduced the term, "half-sarcomere." He did not previously introduce this term any manner. However, by keeping the phrasing consistent with the language in Line 8, "each sarcomere," he implied a half-sarcomere definition.

However, the persistent cartoon's features could be split in half in either a sagittal or medial manner. Consequently, language analysis alone did not indicate the dissection direction.

The scientist changed his hand shape from that that mimicked Z-lines. His new body position had his right hand holding the uncapped pen in a position ready to write. He used Layering to designate half-sarcomere when he indicated a vertical line, over the board, at approximately the halfway point between the two Z-lines (Figure 6.5). This vertical line did not align with cartoon feature and resulted in more complex Layering. The more complex layering indicated an important measurement to his work, the, "half-sarcomere." The remainder of the scientist's gestures created virtual objects that reproduced features that already existed on the cartoon.

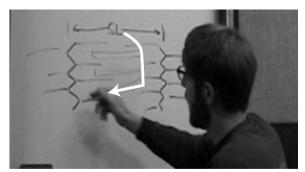


Figure 6.6: Half-sarcomere drawing path. The indicated path when he emphasized a half-sarcomere's shape relative to the visible sarcomere.

6.2.3 Clip M3 Summary

In Clip M3, the scientist practiced Layering when he aligned his gestures over the board in such a way that his body mimicked the cartoon's visual features. Even though his movements always related to the existing cartoon, they never resulted in persistent visible objects. He also created virtual objects when he positioned and moved his body so that its shape implied visual objects. Actual visual objects and their features, or lack of them, proved the foundation for the implied visual objects. In this clip, the scientist's Layering crafted fleeting virtual objects that directly and indirectly conveyed the meaning of the scientist's explanation about sarcomere sizes.

6.3 Clip F1: Layering

6.3.1 Clip F1 Introduction

From the final interview's first clip, Clip F1, the scientist's actions demonstrated Layering for the clip's last complete sentence. Therefore, from the total 18-second clip, this analysis covered the final 11 seconds. In this clip, the scientist interacted with the micrograph's panel (a) (Figure 6.6). The panel (a) area showed approximately eighteen, randomly distributed, wild type, myosin molecules. The scientist presented this panel in two ways. First, he waved his hand over panel (a) when he introduced the image as an unorganized, sample of individuals. Then, he increased the distance between his hand and the micrograph image when he further described the molecules as a collective of similar units. The verbal and gestural accompaniment to this explanation illustrated how the same visual display originated two different Layering types.

6.3.2. Clip F1 Data Analysis

Clip F1 was originally sectioned by gesture. The resulting and entire gesture and language analysis of Clip F1 can be found in Appendix E. In Chapter 4, the clip

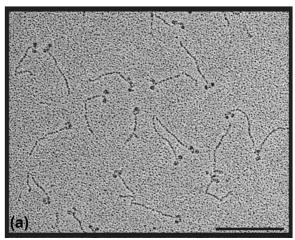


Figure 6.7: Wild type myosin molecules. Panel (a) of the scientist's micrograph that showed non-mutant myosin molecules. The scale bar, lower right, equaled 200 nm.

was described in detail. As shown below, Clip F1 was first sub-sectioned by language and then the gestures were added and further described by the notation conventions as described in Chapter 5 (Nobel, et al., 2004).

Scientist: "This is an overview picture of a wild type myosin, uh, population just kind of showing the field view of what our preps look like...."

The micrograph's, "field view," contains multiple molecules per panel, as with panel (a) (Figure 6.1b, top). Contrast panel a) with panels b), c), and d) (Figure 6.1, bottom) where there is only one molecule per panel.

6.3.2.1 Clip F1 language and gesture notation

1. "This is an

[Lifted left hand, with outstretched fingers, up to micrograph.]

2. overview picture of

[With the same hand shape, slightly moved his hand away from the micrograph.]

3. a wild type myosin

[Swiped hand across the panel, left to right and then left to right.]

4. uh, population

[Paused hand over the micrograph and then gathered fingers into a loose fist.]

5. just kind of

[Bent elbow so that a hand moved down by shoulder.]

6. showing the field view

[Put both arms up in front of the micrograph with the fingers of both hands outstretched, dropped right hand and made a small sweep with left hand from left to right and then right to left.]

7. of what our preps

[Made two hand small sweeps that bent from the wrist, each from left to right.]

8. look like."

[Dropped left arm to his side.]

6.3.2.2 Clip F1 language and gesture analysis

The language and gesture analysis followed a multi-part structure. First, the analysis repeated the line number and language based on the notation above. Then, for each line, the language analysis preceded the gesture analysis. Each subsequent line repeated the same organization.

1. "This is an"

The scientist started the entire sentence with the introductory phrase, "This is an." He used the indexical term, "This," which acknowledged that the micrograph provided the main interesting object in the immediate surroundings. Next he referred to the micrograph in the present tense when he used, "is." This word choice showed that he had an ongoing relationship with the image. He created the image, or analyzed its details, recently enough so that he still had a personal investment in it. The last word in this phrase, "an," foreshadowed the scientist's intention to describe the image as a single unit, rather than individual objects.

The scientist raised his left hand to a midpoint between the top and the bottom of panel (a) (Figure 6.7). His gesture toward panel (a) assigned his indexical language, "This," to a particular visual subject. When he raised his hand, he outstretched his fingers. With his outstretched finger span he attempted to cover the panel's visual span. This was the first Layering example in this clip. The scientist held his hand over the visual image and implied, that the darker, foreground units observed provided a collection of like-formed small units.



Figure 6.8: Lifting hand to panel (a). The scientist lifted his left hand to a point midway between the top and bottom of panel (a).

2. "overview picture of"

With the scientist's first word in this phrase, "overview," he described two points of view. He described the projected image at that moment in time, and the actual data image as witnessed during real-time analysis. However, the pure image, made up of random, grayscale pixels, did not convey the same information as the same image to one with a highly trained eye. Next, the scientist chose the simplified word, "picture," when he described the image. This greatly contrasted with the more specific description that he used in peer-reviewed journal articles. In one article he described the image as, "rotary-shadowed myosin molecules from wild-type...Drosophila IFM," where IFM stood for "indirect flight muscle" (Suggs, et al., 2007). The final word, "of," indicated that the previous words in the phrase described the subject that would come next.

The scientist maintained his hand height when he said "overview picture." Although his hand height stayed the same, his fingers flexed apart from one another as if to encompass more of the micrograph image. When he said, "of," he both looked down and slightly raised his hand away from the screen. These motions indicated a transition period in that he disengaged both his vision and his body from the micrograph.

3. "a wild type myosin"

These words introduced the panel's main subject, "myosin." The descriptive words, "wild type," enhanced the subject that followed. In contrast to the simple word choice in Line 2, in this line the scientist used the proper scientific term that meant

non-mutant, "wild type." Together, the whole phrase referred to the subject in the singular. A single item concurs with the singular form presented earlier when the scientist used the words, "an overview picture."

The scientist maintained his hand in its previous location except he swiped it across the image. He moved it from left to right (Figure 6.8) and then from right to left. The sweeping motion, along with the verbalizations in the singular, indicated that the molecules were all similar in someway. This is another Layering instance. The scientist motioned his hand over the micrograph and showed that each molecule, rather than a molecule's part, served as a visual display feature.



Figure 6.9: Left to right sweep. The scientist swept his hand across panel (a) in a left to right direction.

4. "uh, population"

With the hesitation utterance, "uh," the scientist tried to find an appropriate word to use that would encompass the entire panel (a) contents. He continued to choose words consistent with the descriptors he used in his publications, "population."

When he said, "population," he closed his hand into a loose fist (Figure 6.9). At this point his motion illustrated less Layering and more a symbolic gesture. His

gesture indicated that he was, "gathering up," the micrograph's randomly distributed features into a single group of similarly characterized molecules.



Figure 6.10: "Gathering up" molecules. The scientist went from an open hand sweeping motion to a partially closed fist.

5. "just kind of"

The scientist's words designated an indefinite description that applied to his future verbiage. Both, "just," and, "kind of," express uncertainty and qualify a statement. Also, these words could act like a hesitation as did, "uh," in Line 4.

The scientist bent his elbow and dropped his hand away from the board. This acted as a shift between his certain, descriptive, language and the following speech.

6. "showing the field view"

The scientist's language can be considered fairly straight forward. He used the word, "showing," a term that common to laypersons and muscle researchers. Also, in Line 2, he introduced the term, "overview,", a similar term to, "field view," so his language is fairly consistent.

The scientist raised both of his hands in contra-directional sweeping motions (Figure 6.8). Then, he dropped his right hand and repeated the single-hand sweeping

motion that he made in Line 3. As with the previous sweeping motion, this was a Layering event. The scientist interacted with the visual display and, generally, pointed to the molecules as implied features.

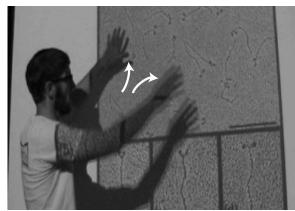


Figure 6.11: Oppositely sweeping arms. The scientist swept his arms in opposite directions when he said, "showing."

7. "of what our preps"

The scientist said the word, "our," in an inclusive manner because he shared the experimental protocols with others in the laboratory. He concluded the phrase with the word, "preps." This word that had multiple meanings. In the scientific world it is a commonly used abbreviation for preparation. It would not be used in formal situations. Scientific preparations could mean anything from mixing chemical solutions to recombining DNA. In this case the, "prep," was extracting myosin molecules from fruit fly muscles.

The scientist's hand position remained the same but he truncated his previous sweeping movements. He shortened his movements in that the execution originated from his wrist instead of his shoulder. During the course of this phrase he performed two back-and-forth sweeping motions, one-half sweep per syllable (Figure 6.10).



Figure 6.12: Small sweeping motion. Small sweeping motion with the wrist used as a fulcrum during the utterance, "prep."

8. "look like."

The word, "look," specifically brought in the vision modality to the interaction. This is in contrast to other modalities, such as touch or speech, through which information is acquired or delivered. Also, since "look," is a singular form, the scientist talked about each myosin molecule feature in panel (a) rather than the features as a whole. If he wanted to refer to the molecule features as a single unit, the phrase would be, "…looks like." With his expression, "like," he implied that the micrograph showed a version of the molecule's visual characteristics as imaged through several processing steps. He acknowledged that the two-dimensional image limited the information brought to light. In this case his words, "look like," could have referred to the two-dimensional image as it appeared in the projected micrograph, on a computer screen, or in real-time through the microscope. Each version would appear different.

The scientist slightly dropped his left hand from but it remained in front of the screen. He closed this hand into a loose fist as in Line 4. This action implied that

Layering occurred when he symbolically gathered the visual image's individual features, the myosin molecules.

6.3.3 Clip F1 Summary

The scientist approached panel (a) in two different ways where both methods exemplified Layering. First, he used a sweeping motion across the panel so that his hand overlaid large area of the micrograph. This out-sweeping gesture virtually, "scattered," the widely spaced molecules in panel (a). The Layering motion indicated the panel as a whole unit with each molecule as a single feature. Second, after he made the sweeping motions across the panel, he formed his hand into a fist, as if to gather the molecules together. This time the Layering gesture indicated each molecule as a whole unit with their individual structure as the variable feature.

6.4 Chapter Summary

Clips M3 and F1 illustrated a theme, Layering, that helped unfold information about a small biological objects when the scientist interacted with visual displays in cartoon and micrograph forms. When the scientist employed Layering, he executed his gestures without touching the board but by aligning them along the cartoon or micrograph's visible features. Layering also applied when his gestures did not align with the visual display's visible features but with one or more implied features. In the cartoon, the scientist's direct Layering occurred over a central, hand-drawn sarcomere. The cartoon's most frequent implied feature added sarcomeres that did not align with the central sarcomere. When compared with the cartoon, the scientist's micrograph-based Layering occurred in a different fashion. The direct Layering action happened

when he swept his hand over the entire panel (a) micrograph. This instance showed how he executed gestures without touching the board, but aligned his general movement to mimic one that would align with the micrograph's visible features. Per definition, the micrograph's implied Layering gesture did not align with the visual display features. The implied Layering gesture moved molecules from their visible locations across panel (a) to a virtual location within the scientist's fist. The clips that fell under Layering fit into the theme in different ways. The cartoon provided a path where gesture more clearly described the aligned features with the implied features. The micrograph's Layering was more circuitous in that the aligned Layering gesture reflected the distributed feature's visible area. In contrast, the implied Layering gesture deviated from the widespread visible area and indicated a local, virtual, "container."

CHAPTER 7: CATEGORIZING

7.1 Chapter Introduction

This chapter will present how the scientist's *Categorizing* posed certain sarcomere characteristics against each another and posed different myosin molecule characteristics against each another. When Categorizing the sarcomeres and myosin molecules, he shared key information about a contrasting element pair. The contrasting elements, order and lack thereof, proved a foundation when he engaged with the two visual display types. Clip M4 utilized a sarcomere cartoon and Clip F3 used a myosin molecule micrograph. Each clip had its own contrasting pair that overlaid the foundational, order versus lack of order, concept. The Clip M4 contrasting pair that overlaid the foundational concept described sarcomere organization.

Specifically, it pitted proper formation against not proper formation. In a similar fashion, the Clip F3 pair that overlaid the foundational concept countered myosin molecule shapes: straight tails against not straight tails. In this way, Categorizing yielded a two-tier pattern that presented the scientist's relationships with small biological objects through visual displays.

In Clip M4, the fourth of four mid-interview clips, Categorizing occurred when the scientist separated sarcomeres based on their contrasting qualities: properly formed or not properly formed. These characteristics were consistent with the terms well ordered or not well ordered. The cartoon showed a properly formed sarcomere (Figure 7.1), as did most of the scientist's supporting gestures. His gestures and language coordinated with each other to accentuate properly formed, or well-ordered,

sarcomeres. For the clip's majority, he directly addressed sarcomere order and indirectly referred to sarcomeres that lacked order. Later in the clip, the scientist's speech and gestures directly addressed sarcomeres that did not exhibit order.

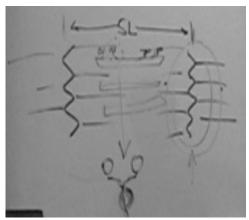


Figure 7.1: The scientist's final mid-interview cartoon sarcomere. See Figure 7.3 for pertinent structures and labels.

In Clip F3, the last of three clips extracted from the study's final interview, Categorizing led to myosin molecule tail shapes as the feature of interest. This micrograph displayed typical molecules with widely distributed tail shapes (Figure 7.2). The visual display presented straight or not straight myosin molecules, characteristics consistent with well ordered or not well ordered, respectively. In his actual research and throughout the clip, the scientist used only straight tails in his tail length measurement so he found the contrast between straight tails and not straight tails important.

In Clip F3 the scientist described myosin molecules that were not straight as bent. In actual experimental data, straight or not straight tails occurred randomly (Figure 7.2 (a)). The molecules in panels (b), (c), and (d) in Figure 7.2 were artificially isolated and rotated to like rotations. His tail shape stemmed from his need

to measure tail length and straighter tails yielded more consistent measurements. The scientist's subjective judgment assigned tail shape, not experimental protocol or computer-driven analysis.

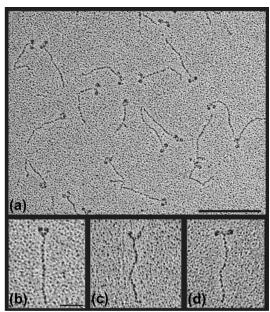


Figure 7.2: Micrograph visual display. (a) Random field of myosin molecules. (b), (c), and (d) Individual, straight-tailed myosin molecules.

For both of the clips, the visual displays were considered visual objects in that they persisted beyond their construction moment. The gestures in the clips are virtual objects due to their fleeting nature. For each of the Data Analysis sections in Clip M4 and Clip F3, the language and gesture notation preceded the language and gesture analysis. The language and gesture analysis was presented in the following format. First the line number and language, as oriented from the notation section, was repeated. Then, for each line, the language analysis was presented followed by the gesture analysis. The structure was repeated for each subsequent line.

7.2 Clip M4: Properly Formed Versus Not Properly Formed Sarcomeres

7.2.1 Clip M4 Introduction

In Clip M4, a cartoon sarcomere played the visual display role. The scientist drew the well-ordered, sarcomere cartoon over the course of his mid-study interview (Figure 7.1). The drawing's pertinent features are shown in Figure 7.3; the bold-face text and arrows were added for clarification.

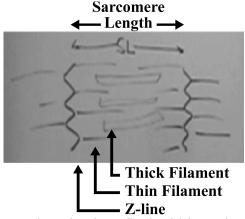


Figure 7.3: The scientist's final mid-interview cartoon sarcomere with external labels for clarification.

In Clip M4, the scientist contrasted different possible sarcomere structures. Specifically, he contrasted sarcomeres that formed properly with sarcomeres that did not form properly. The cartoon sarcomere showed a properly formed sarcomere, and the scientist's gesture's reinforced that quality. For most of the clip, his language coordinated with his gestures to accentuate the nature of properly structured sarcomeres. During this time, he referred to sarcomeres that were not well ordered only indirectly. Later in the clip, he used not scientifically proper speech and not well-ordered gestures when he directly described sarcomeres that did not formed properly.

7.2.2 Clip M4 Data Analysis

Clip M4 was the fourth of four Clips extracted from the mid-study interview. Chapter 4 described the clip in detail. In the original clip analysis, the gesture subsection process preceded the corresponding language introduction. The entire analysis can be found in Appendix D. In this analysis, as shown below, the clip was first subsectioned by language and then the corresponding gesture was added following the notation conventions as described in Chapter 5 (Noble et al., 2004).

Scientist: "If the sarcomere doesn't form properly and is not regulated in this nice distinct, coherent manner you can activate all kinds of crap."

7.2.2.1 Clip M4 language and gesture notation

1. If the sarcomere

[Body faced the audience; with pen in hand, he pointed to the general direction of the sarcomere cartoon.]

2. doesn't form properly

[Body faced the white board: aligned either hand with the respective Z-lines of the sarcomere cartoon.]

3. and is not regulated

[Moved his hands up in a curved motion but they were still aligned with the Z-lines; created a series of virtual sarcomeres to either side of the drawn sarcomere; faced the audience.]

4. in this nice, distinct, coherent manner

[Faced white board; motioned to create a series of virtual sarcomeres to either side of the drawn sarcomere.]

5. you can activate

[Tapped his pen at the bottom of the right Z-line.]

6. all kinds of

[Continued to tap his pen at the bottom of the right Z-line; turned toward audience; pointed to the general direction of the sarcomere cartoon.]

7 crap.

[Made a circling motion with the pen in hand before verbalizing "crap."]

7.2.2.2 Clip M4 language and gesture analysis

1. "If the sarcomere"

The first word that the scientist expressed in this clip was, "If." When he used this word the scientist prepared the scene as a hypothetical situation in an if-then format. His language, "the," described either a general unseen sarcomere or the particular sarcomere on the board. When he expressed, "sarcomere," it confirmed that a sarcomere was the central subject for both the hypothetical situation and the cartoon. The sarcomere began the unseen object-to-visual display alignment involved with his explanation. However, this alignment did not foreshadow the scientist's Categorizing that prevailed by the end of the clip: ordered versus not ordered.

The scientist held a pen as he pointed toward the top of the pre-existing cartoon. He did not point to any of the cartoon's particular features (Figure 7.4). As with his language, the scientist's gestures did not indicate that Categorizing played a role in his explanation.

2. "doesn't form properly"



Figure 7.4: The scientist's body position and movement when he said, "if the sarcomere."

In Line 1 the scientist expressed the sarcomere's key role in the explanation. In Line 2, he introduced the essential Categorizing characteristic: sarcomere formation. He explained that there were different ways that sarcomeres formed. He described one of the ways by the last words that he uttered in this phrase, "form properly." The first word in the phrase, "doesn't," indicated that improperly formed sarcomeres were also an option. So, the scientist's Categorizing brought forth the properly formed sarcomeres versus not properly formed sarcomeres theme.

The scientist aligned his hands over the cartoon's Z-lines and moved them in a vertical up and down motion (Figure 7.5). Throughout the interview, he used these gestures to mean properly formed sarcomeres. His motions were definite and did not indicate any suggestion about sarcomere structure that was not proper. Even though the language presented him with two options, the scientist executed a gesture that indicated properly formed sarcomeres thereby emphasizing their importance.

3. "and is not regulated"

The scientist introduced the term, "not regulated." In this case, "regulated," played the properly formed sarcomere role and, "not," acted as its negation. "Not,"



Figure 7.5: The scientist's body position and movement when he said, "doesn't form properly."

applied a negative condition grounded in the properly formed sarcomere category. The not properly formed sarcomere category is implied, not stated outright. This implication followed the format from Line 2 when the negation, "doesn't," suggested sarcomeres that were not formed properly. These two lines are happenings where Categorizing simultaneously displayed both order, in a direct fashion, and lack of order, in an indirect fashion.

The scientist's gestures supported the not ordered sarcomere option through his curved hand motion. During his gesture, the scientist slightly curved his hands in-and-out as he moved them from the bottom of the Z-lines toward the top of the Z-lines (Figure 7.6). The curved movement was different from either the cartoon's zig-zag Z-lines or the previously gestured straight line Z-lines, each which indicated proper sarcomere formation. The scientist's curved motion deviated from both the zigzag cartoon and the straight-line gesture and resulted an apt bodily expression that indicated sarcomere that lacked proper formation.

4. "in this nice, distinct, coherent manner"

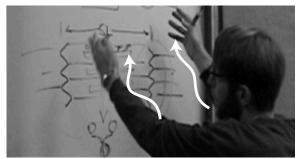


Figure 7.6: The scientist's hand movements when he said, "and is not regulated."

Language-wise the scientist effectively repeated words that clearly fell into the orderly category. The scientist specifically expressed three adjectives, "nice, distinct, [and] coherent," that had positive connotations and were consistent with properly formed sarcomeres. There was no verbal expression that indicated sarcomeres that were not properly formed.

The scientist's gestures mirrored the ordered sarcomere category described by his language. The scientist traced down the cartoon's Z-lines and then created virtual Z-lines to the outside of each pair in order to signify a series of consecutive, orderly sarcomeres (Figure 7.7). Effectively, his gestures reiterated the idea of regular structure by: the repetition of his up-and-down hand movements, the series with which he built them, and the tempo with which his movement coordinated with his language.

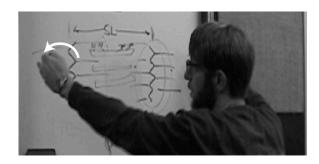


Figure 7.7: The scientist's body position and movement when he said, "in this nice, distinct, coherent manner."

Throughout the interview the scientist regularly used this set of gestures to indicate a series of properly formed sarcomeres.

5. "you can activate"

The scientist's perspective on, "activate," was a biological process that could result in a variety of outcomes, including ordered or not ordered structures. This being so, this line was analyzed as the, "then," clause that he established when he said, "If," in Line 1. The if-then language became, "If the sarcomere [presents certain qualities], then you can activate." Overall, the certain qualities presented were directly from the orderly sarcomere perspective. Not ordered sarcomeres were presented in indirect fashion.

The scientist tapped his pen several times at the bottom of the cartoon's right Z-line (Figure 7.8). He did not tap the board in any other instance during the interview. When he tapped, he brought attention to an important sarcomere feature without Categorizing it as either ordered or not ordered (Figures 7.5 and 7.6, respectively). However, the scientist made no association between Z-lines and activation. Consequently, the gesture described a neutral or transitory action.

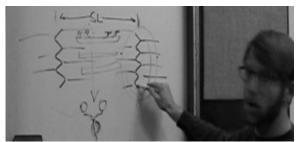


Figure 7.8: The scientist's body position when he said, "you can activate."

6. "all kinds of"

The scientist's words were ambiguous in terms of categories. His language did not lean toward properly formed sarcomeres or not properly sarcomeres. In fact, it appeared that the scientists Categorizing specifically opened his explanation to include both characteristic sides. This line, Line 6, synchronized with the message in Line 5, since neither had words that tended toward one or the other categories through direct or indirect language.

However, when compared with Line 5, in this line the scientist turned his gaze away from the board and assumed an open body position with respect to the board's plane. He made a slight arc with his left hand (Figure 7.9). The result signified how the scientist gesturally opened in addition to how he explanatorily opened the choice of categories.



Figure 7.9: The scientist's body position and movement when he said, "all kinds of."

7. "crap"

The slang word, "crap," was a generally derogatory term with, at least, two definitions that apply to this case. First, consider the word, "crap," to mean, "disorganized items." Most small biological objects, including sarcomeres, had a particular organization in space. Consequently, "crap," indicated an organizational absence that directly opposed the, "orderly," category. Second, "crap," to mean

something unspecific, indicated that the scientist dismissed sarcomeres that were not ordered as explanatorily unworthy. Furthermore, he decided on the word, "crap," to indicate that he wholly dismissed more detailed verbal descriptors. In contrast to the previous lines in this clip, the scientist previously described orderly sarcomeres with direct language like, "regulated," and, "activate."

Slightly before the scientist said, "crap," he pointed to a nonspecific, centrally located, position on the cartoon. He performed circular motions where the spiral's diameter increased with each rotation (Figure 7.10). When his language paused as he spiraled, he considered the choice of a precise, scientific word that described the situation. After approximately four rotations with his pen, he finally said, "crap." His gesture supported the linguistic interpretations established for, "crap." His circular gesture was in contrast with the linear gesture he previously used to indicate properly formed sarcomeres. In this way, the scientist's spiral gesture indicated spatially sarcomeres that were not properly formed.



Figure 7.10: The scientist's body position and movement when he said, "crap."

7.2.3 Clip M4 Summary

Clip M4 exemplified a case where properly formed sarcomeres maintained an ordered structural sense. This contrasted with sarcomeres that were not properly

formed. Properly formed sarcomeres indicated correct function, specifically, effective muscle contraction. The sarcomeres that were not properly formed displayed a lack of structural order. These sarcomeres' organization exhibited poor function, namely, ineffective muscle contraction. When Categorizing, he primarily talked about well-ordered sarcomeres in a direct manner whereas he talked about poorly ordered sarcomeres in an indirect manner. The scientist clarified that ordered sarcomeres functioned as a reference for not ordered ones through Categorizing contrasting characteristics when he engaged with the sarcomere cartoon.

The scientist used direct language when he talked about proper sarcomere structure. When he referred to sarcomere structure that was not proper, he had to negate the direct language he introduced. For example, in Line 2, he said, "doesn't form properly." Here, without, "doesn't," as a negating word, the phrase would conclusively indicate ordered sarcomeres. On the other hand, there were events when he made direct relations with not ordered sarcomere structure. In the last line, his language, "crap," directly related to not well ordered sarcomeres and contrasted with previous lines where his language directly related to ordered sarcomeres. In addition to his direct language about not properly formed sarcomeres, there were two distinct events when his gesture created virtual, not proper organization over the visual order on the board. The first was in Line 3 when his curved hand gesture directly contrasted with his linear hand gesture that indicated properly formed sarcomeres. The second event where the scientist's gestures directly reflected messiness was in the last line. The scientist's circular gestures indicated messiness and contrasted with how the

cartoon's Cartesian coordinate layout indicated orderliness. Through his Categorizing contrasting characteristics, the scientist shared sarcomeres' importance as small biological units.

7.3 Clip F3: Straight versus Not Straight

7.3.1 Clip F3 Introduction

In Clip F3, the scientist contrasted two different types of myosin tail shapes, straight tails against not straight tails (Figure 7.11). During this clip, he engaged with a micrograph visual display (Figure 7.12). The micrograph's upper panel, (a), showed approximately 18 variously shaped myosin molecules. The lower three panels, (b), (c), and (d), showed isolated molecules with "straight," tails. He stated that his data analysis procedure relied on straight-tailed myosin molecules. For the procedure, straighter tails generated more consistent tail length measurements and tail length related to the genetic variability his laboratory studied. After the scientist emphasized

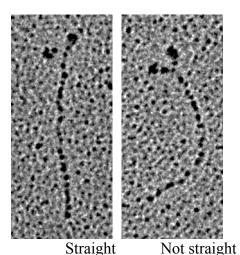


Figure 7.11: Myosin molecules with straight (left panel) or not straight (right panel) tails. These images were isolated from panel (a) of Figure 7.12.

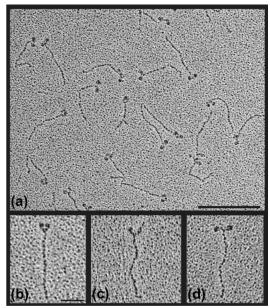


Figure 7.12: Micrograph visual display. Panel (a), random myosin molecule field. Panels (b), (c), and (d), individual, straight-tailed myosin molecules.

straight tails, he pointed out non-straight tail examples. Non-straight tails were not conducive to accurate tail length measurement. The scientist's Categorizing led to contrasting myosin tail patterns: straight versus not straight. These contrasting categories drove this clip's analysis.

7.3.2 Clip F3 Data Analysis.

7.3.2.1 Clip F3 language and gesture notation

Clip F3 was originally sectioned by gesture. The entire gesture and language analysis can be found in Appendix G. Chapter 4 described the clip in detail. Below, the sub-sectioned language had corresponding gestures descriptions added using the notation conventions as described in Chapter 5 (Noble et al., 2004).

The Scientist: "And so, these are the sorts of orientations that I typically go for when I measure because there's a lot less bending and, um, torsion that's taking place, which can, potentially, influence the length"

1. And so,

[Body faced the screen; he used the fingers of his left hand to point to panel (c) of the micrograph, the center image of a straight tailed myosin molecule.]

2. these are the sorts of orientations that I typically go for

[Pointed to the various panels that showed individual straight tailed myosin molecules.]

3. when I measure

[Continued to point to the various panels that showed individual straight tailed myosin molecules.]

4. because there's a lot less

[Dropped his left hand by his side.]

5. bending and, um, torsion that's taking place

[Lifted his left hand to several different bent tails in panel (a), the panel with the field view of many myosin molecules.]

6. which can, potentially,

[Continued point out several different bent tails in panel (a), the panel with the field view of many myosin molecules.]

7. influence the length....

[Dropped his hand to his side.]

7.3.2.2 Clip F3 language and gesture analysis

1. "And so,"

This initial language transitioned from the scientist's prior explanation this clip's beginning.

Although the scientist's Categorizing language did not reference either mysoin tail conformation, he pointed to one of the straight tail examples, the center example in panel (c) (Figure 7.13). Interestingly, that straight tail example was the least straight of the three isolated straight tail examples in panels (b), (c), and (d). Furthermore, the



Figure 7.13: The scientist's posture when he said, "And so."

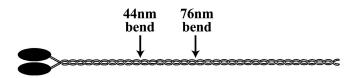


Figure 7.14: Myosin molecule with major tail bend locations at 44 nanometers and 76 nanometers from the head-to-tail junction.

scientist pointed to the least straight location, due to certain amino acid sequences, within that myosin tail (Figure 7.14). In this way, the scientist simultaneously

categorized straight and not straight characteristics for both the tail as a whole, and the tail as a modular series.

2. "these are the sorts of orientations that I typically go for"

The scientist's language indicated one of the two categories under examination: straight tails. The phrase part, "these are the sorts," indicated a positive reference to preferred tail shapes. When he used "orientation," he meant tail shape in general. Various orientation examples were vertical, horizontal, straight, or not straight. The scientist's words, "go for," specified straight tails since they generated more consistent tail length measurements.

The scientist gestured to each of the three of the single myosin panels at least once. He followed the pattern, (c), (b), (c), (d), (c), and (b). That is, starting from the center panel, he pointed to the left, center, right, center, and then left panel. Figure 7.15 shows his gesture from panel (c) to panel (d), or center to right. When the scientist distributed his pointing gestures among the various straight tail examples, he equalized their importance as a single category option within the straight tail category.



Figure 7.15: The scientist's motion when he said, "these are the sorts of orientations that I typically go for"

3. "when I measure"

The pronoun, "I," indicated that the scientist personally interacted with the micrograph when performed the measurements. This was in contrast to someone else measuring the tails or measurement via automation, for example.

The scientist continued his pointing action, described in Line 2, and pointed from the panel (b) molecule tail to the panel (c) molecule tail.

4. "because there's a lot less"

Since the scientist set up the preferred tail shape, straight, in the previous lines. He implied a non-straight tail shape when he used the comparative word, "less." He emphasized the difference between straight tails and not straight tails when he said, "a lot." With his experience in analyzing micrographs, he built a keen awareness so that he easily distinguished straight tails from a mixed tail shape population.

The scientist dropped his hand by his side when he spoke the words in this phrase (Figure 7.13). This act primed him for the next gesture set that he performed. In Lines 2 and 3, his gestures focused on straight tailed myosin molecules. In this line his language included the comparative word, "less." The combined Lines 2 and 3 straight tail gestures and the Line 4 non-straight tail language led to the scientist's next gesture set that emphasized non-straight tails.

5. "bending and, um, torsion that's taking place"

The scientist directly said words that meant less straight: bending and torsion.

In this analysis, bend described a two-dimensional curved or angular shape and torsion indicated a twist in three-dimensional space. The myosin tail was a very flexible

molecular domain and capable of many types of configurations, including various non-straight ones. Here, his words directly set the subject non-straight category. The scientist used, "taking," a verb in the present progressive tense. This word choice communicated that actual tails' malleable, configurations contrasted with the micrograph's tails' static image.

From within the variously shaped tails in the panel (a) field view, the scientist pointed to one of the non-straight tails. He used his left finger and traced the curved tail in order to emphasize its shape (Figure 7.16). He chose this particular tail because it was one of those that clearly showed a non-straight shape, in the form of a curve. Since bending was considered a two-dimensional motion, this curved tail provided a fitting choice when he interacted with the two-dimensional micrograph. In addition, the scientist interacted with the curved tail during this moment in a way that contrasted with his interaction with the straight tails at the beginning of the clip.

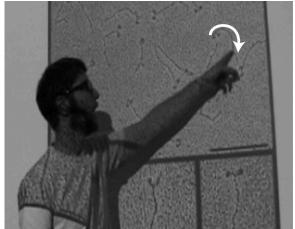


Figure 7.16: The scientist's body position and motion when he said, "bending and, um, torsion that's taking place."

6. "which can, potentially,"

The scientist's language still, as in Line 5, referred to non-straight myosin tails. His language, "potentially," suggested that these types of tails have an added ability, yet to be communicated.

The scientist pointed out additional non-straight tails from the field of myosin molecules in panel (a) (Figure 7.17). Since he selected several examples to trace, he indicated that bent tails were also an important tail shape. In practice, when he captured multi-molecule micrographs, the myosin tails had arbitrary conformations.

As a result, as shown in panel (a), the scientist had to cope with more possible bent tail occurrences than straight tail occurrences.

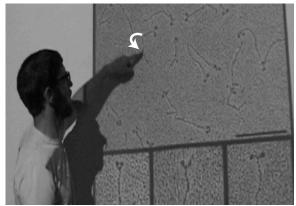


Figure 7.17: The scientist's body position and movement when he said, "which can, potentially."

7. "influence the length"

With respect to the undefined, "potentially," in the previous line, this line clarified that that particular word had to do with tail length measurement. Recall that the categories characteristics, straight or not straight, bookended the central subject, tail length.

The scientist did not perform any direct interactions with the micrograph.

Instead, dropped his arm to his side when he completed the phrase (Figure 7.18.). His head turned away from looking at a specific point on the board to looking in a more general direction.



Figure 7.18: The scientist's body position and movement when he said, "influence the length."

7.3.3 Clip F3 Summary

In Clip F3, the scientist's categorization center focused on myosin tail shape where the particular contrast, straight versus bent, overlaid the foundational contrast, order versus lack of order. To explain the difference between straight tails and non-straight, or bent, tails, he mainly relied on a particular type of visual display, the micrograph. He gesturally interacted with the micrograph when he pointed to straight tailed molecules. The straight tailed molecules were spatially prearranged to have one straight tail per panel. He also gesturally interacted with the micrograph when he pointed to non-straight tailed molecules. In contrast to his gestures that emphasized straight tails, the scientist spatially isolated one bent tail at a time. To do this, he carefully pointed out appropriately shaped tails from a panel that contained almost 20

variously shaped tails. So, the micrograph's pre-separated molecules had the straight tail characteristic in common. In contrast, the scientist actively separated molecules that had the non-straight tail characteristic in common.

7.4 Chapter Summary

Contrasting categorization proved this chapter's theme. Order versus lack of order founded the two secondary categorization sets. Clip M4 described the first secondary set, properly formed versus not properly formed sarcomeres. Clip F3 described the following secondary set, straight versus not straight myosin molecule tails. The scientist communicated key ideas when he emphasized each component's unique theme. For this chapter's analysis, the categories were screened over the scientist's interactions with different visual displays, a sarcomere cartoon in Clip M4, and a myosin molecule micrograph in Clip F3, in order to uncover happenings about how the scientist explained association with small biological molecules.

In Clip M4 the scientist's language demonstrated that he valued properly formed sarcomeres. Throughout the clip he used appropriate and accurate words for the communication at hand. For example, he used the words, "regulated," and, "activate," when he expressed orderly sarcomere characteristics. Conversely and later in the clip, he used a single, very imprecise, slang word, "crap." In the way that, "crap," was used it almost completely discarded any importance of sarcomeres that were not properly formed.

In Clip M4, another way that the scientist showed his preference for proper sarcomere formation was through his ordered gestures. Gestures that ran straight up

and down along Z-lines indicated properly formed sarcomeres. He executed this bodily movement over the cartoon's actual Z-lines to emphasize visible structures. He also used the same gestures to the cartoon's Z-lines to compose associated virtual structures. The high frequency with which he performed the properly formed sarcomere gesture throughout the entire T2 interview deemed ordered sarcomeres important. In contrast, the scientist's not properly formed sarcomere hand gestures occurred only in this clip and nowhere else in the T2 interview. The scientist used two gestures that indicated sarcomeres that were not properly formed. First, he performed a curved up and down motion along the cartoon's Z-lines. A curved is between the cartoon's straight line Z-lines and actual sarcomere's almost angular zigzag lines. Second, he performed a general spiraling action over the cartoon's area. This action corresponded to a more profound lack of order because it did not directly align with any of the cartoon's visible features and it did not correspond to any sarcomere shape or action. This inaccurate gesture that showed extreme non-proper sarcomere formation was coincident with the scientist's word, "crap," his moniker sarcomere formation that lacked order.

In Clip F3, the categories theme was myosin molecule tail shapes: straight tails versus not straight tails. His language, gesture, and body position emphasized the different categories.

The scientist showed Categorizing when he verbally expressed the term, "less," in a contrasting capacity. The context in which he used the word indicated that he meant that straight tails are "less" not straight, therefore, bent.

Gesturally, the scientist *pointed* to different straight tail examples in panels (b), (c), and (d), and verbally indicated their preferred status for measurement. The preisolation and larger display size did not require the scientist to perform detailed gesture to emphasize their straightness, language and visual inspection sufficed. After pointing out the straight tails, the scientist *traced* different non-straight tail examples in panel (a) and described reasons why they were unsuitable measurement targets. In this case, the molecules in panel (a) were of various tail shapes and were displayed as a smaller size. The scientist reinforced their not strait nature when he carefully traced the tails. He did not rely on his language or the micrograph's ability to adequately display the characteristic.

With respect to body position, the scientist's distinctively changed when he changed his explanation topic from straight tails to not straight tails. At one point during the clip he dropped his and he no longer interacted with the projected micrograph. At first, he interacted with the micrograph when he pointed at straight tails, then he dropped his arm to his side when he changed tail type explanation, then he interacted with the micrograph again when he pointed at not straight tails.

The scientist emphasized the distinction between straight tails and non-straight tails because tail length was important data that his experiment required and because determining tail length was the main purpose for the micrograph's generation.

The Categorizing approach led to a two-tiered patterned visual display interaction. Order versus lack of order acted as the single, contrasting Categorizing base for the two analyzed characteristics. Clip M4 had sarcomere formation, properly

formed or not properly formed, as its central idea. Clip F3 had myosin molecule tail shape, straight or not straight, as its major idea. The happenings within these clips showed that the scientist's explanatory style used dissimilarities, in the form of categories, when he described various small biological object formations.

CHAPTER 8: SCALING

8.1 Chapter Introduction

Scaling will be this chapter's theme. Scaling came about when the scientist changed the positions of virtual objects, scaled to bodily space, with their corresponding virtual object feature. That is, he either lowered a body scaled virtual object onto a visible object feature or he virtually lifted off a visual object feature and then scaled it to his physical bodily dimensions in actual space. In Scaling, the representations in space that the scientist created were not only limited by his physical body's capabilities, but they were also guided by the desire to maintain feature fidelity. When the scientist expressed information at bodily scale it helped him to overcome weaknesses in his interaction with the subject of the visual display. To alleviate this possibility, the scientist crafted visual display-based, bodily scale representations in order to better engage with the scientific object under study. Through Scaling, the scientist created a bodily-based language that shared his understanding about small biological objects

In the first of the two clips that will be presented in this chapter, Clip M2, Scaling described how the scientist interacted with the cartoon of the single sarcomere (Figure 8.1a). This example of Scaling was executed in the other possible direction, that is, the scientist *lowered* a virtual object onto the visible display's feature. He established a virtual object in space that showed the *in vivo* macro-organization of multiple sarcomeres. Then, he dropped that virtual object, created in accord with a comfortable body scale, onto the corresponding visual display feature.

In the second clip, Clip F3, the scientist worked with the micrograph that displayed myosin molecules (Figure 8.1b). In this case, the Scaling direction was from visual display to virtual object. Scaling happened when the scientist changed from interacting with features that were small on the physical visual display, myosin tails, to creating virtual representations of those features as determined by his body's natural scale.

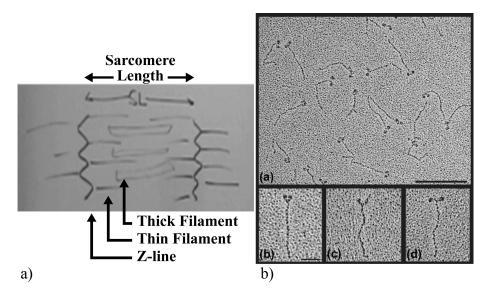


Figure 8.1: Sarcomere cartoon and myosin micrograph. Left image, a): The sarcomere cartoon drawn by the scientist earlier in the interview. The labels were added for clarification in this document. Right image, b): An actual myosin micrograph generated by the scientist for data analysis, presentation, and publication. Panel (a), top, a field view of wild type molecules. Panels (b), (c), and (d), bottom, left to right, isolated myosin molecules with "straight tails."

8.2 Clip M2: Scaling and the Sarcomere Cartoon

8.2.1 Clip M2 Introduction

In Clip M2, the scientist described sarcomere organization at the macro level, how multiple sarcomeres are arranged *in vivo*. The scientist used his body to create a virtual version of sarcomeres arranged as horizontally concatenated structures. The scientist's body assumed two positions that were defined by Scaling. First, his hand position designated the span of a single sarcomere, which defined sarcomere length. The scientist scaled the cartoon's actual drawn sarcomere length down to a span between his extended little finger and extended thumb. The second position defined by Scaling was the scientist's arm position that showed the span of a sarcomere series. He initiated the sarcomere series construction from his body's midline and continued it outward until his arms reached their fullest extent while still maintaining the sarcomere series' horizontal orientation.

8.2.2 Clip M2 Data Analysis

Clip M2 was the second of four clips from the mid-study interview. As with all of the clips, the data analysis included an in-depth study that originated from subsectioned gesture (Appendix C), a detailed narrative (Chapter 4), and an in-depth study that originated from sub-sectioned language (this chapter). From this clip, the scientist's language related to Scaling is below. The language analysis adopted the notation conventions specified in Noble et al. (2004) and was described in Chapter 5.

Scientist: "And you have a very structured, crystalline-like, uniform distribution of each of these individual contractile units."

8.2.2.1 Clip M2 language and gesture notation

1. And you have a

[Body turned away from the white board so that his shoulders were more than 45-degrees away from its plane; both hands down by his sides.]

2. very structured

[Beginning body position the same as in Line 1; head looked down. Ending body position away from the white board's plan; head looked forward; both hands raised to shoulder height with the right hand still grasping the writing pen.]

3. crystalline-like,

[Body and head position the same as in Line 2; both hands lifted to mouth level with thumbs and little fingers extended away from each other; hands maintained shapes as he moved them, in a small arc, from his midline to positions to either side of his body; hands maintained shape as he continued to move them, in several small pulses, away from his midline.]

4. uniform distribution

[Beginning body and head position, and hand shapes, the same as in Lines 2 and 3; hands moved back toward body midline in several small pulses. Ending body position the same as at the beginning, head turning toward the white board, hands dropped down by his sides.]

5. of each of these

[Body and head faced directly toward the white board; fingers of both hands extended and pressed together; arms moved up and then down the cartoon's Z-lines.]

6. individual

[Body and head position, and hand shape the same as in Line 6; arms moved back up the cartoon's Z-lines.]

7. contractile units.

[Beginning body and head position the same as in Lines 5 and 6; fingers relaxed slightly from previous shape; arms moved back down the cartoon's Z-lines. Ending body position had shoulders slightly turned away from white board with head looking over shoulder toward camera area; dropped both arms down out of field of view.]

8.2.2.2 Clip M2 language and gesture analysis

1. "And you have a"

The scientist introduced the section with the personal pronoun, "you," in a way that highlighted the upcoming scientific subject rather than himself. When he said, "have a," he referred to something with which one could develop familiarity. The explanation that immediately preceded this clip's sentence referred a sarcomere substructure, thick filaments, so the context pointed to an entity on the sarcomere level or smaller.

During this phrase the scientist held his body in a neutral position. His body and head positions faced the left side of the room, toward neither the white board nor the camera, and his hands were down and out of frame (Figure 8.2).

2. "very structured"

The scientist described the item as, "structured," which only assigned a quality, the adjective did not clarify its identity. Likewise, the adverb, "very," did not provide any clues to the object's identity.



Figure 8.2: The scientist's body position when he said, "And you have a."

After dropping his head momentarily, the scientist raised his head and turned his body completely away from the white board when he said, "very." Coming from his previous neutral position, this change in direction separated his connection to the cartoon and presented him with opportunity to explain his understanding using means other than direct engagement with the visual display. It was also a hint that the subject of his description was not a detail included on the cartoon. When he said, "structured," the scientist raised his relaxed hands from out of frame to approximately shoulder height (Figure 8.3). This was a ready position for his continued explanation.

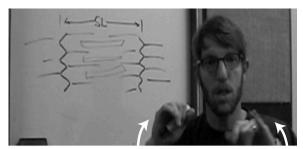


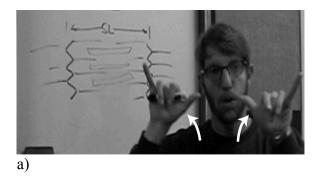
Figure 8.3: The scientist's body position and movement when he said, "structured."

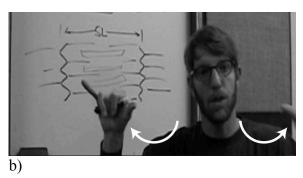
3. "crystalline-like"

In Line 3, the scientist continued to describe the unidentified subject of his explanation. He said, "crystalline-like." In science at the molecular-level, crystals are indicative of extremely pure and highly organized substances. "Crystalline-like," is consistent with the descriptive phrase in Line 2, "very structured," but it still did not identify the object in question. If the scientist did not hyphenate, "crystalline," with, "like," it would have narrowed the possibilities for the object's identity.

The scientist's gesture provided a clue to the subject of his description. First, by direct comparison, it was an object that was not a part of the cartoon's features. Second his body position and movement suggested that the object in question had two important features. He designated the first important feature by his hand shape (Figure 8.4a). His hand shape was deliberate, it was not a natural or default hand shape that one might assume when relaxed. In fact his hand shape was an instance of Scaling, although the object that his hands represented was still unknown. His thumbs and little fingers were nearly outstretched to their limit, especially if you consider that the scientist is holding a large diameter pen with the first three fingers of his right hand. The scientist stressed the feature's importance when he used both hands to mirror the hand shape and created the shapes before he initiated the second important gesture. For the scientist's second important gesture he made incremental movements from his body's midline to beyond its sides (Figure 8.4b and c). This was another instance of Scaling in that the scientist showed a horizontal line of units where his hand shapes needed to maintain their relative orientation to that horizontal trajectory. Had the

scientist fully extended his arms, he would have sacrificed the accuracy of the virtual object that he wanted to create. And so, this movement showed an example of context-





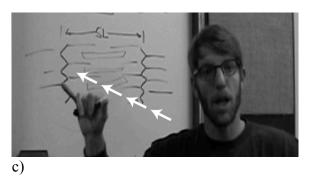


Figure 8.4: Scientist's body position and movement when he said, "crystalline-like." Image a), top, shows the hand shape created and maintained during Line 3. Image b). middle, shows the scientist's hands' initial arced movement when he said, "crys-." Image c), bottom, shows the scientist's hands' incremental movements when he said, "-talline-like."

limited Scaling that resulted in a distinctly organized virtual object that the scientist built from a sequence of like units.

4. "uniform distribution"

In Line 4, the phrase, "uniform distribution," reiterated the gestures that the scientist made during Line 3, "crystalline-like." "Uniform," and, "crystalline-like," had comparative meanings but the former was applicable to more situations than the latter. The word, "distribution," did not repeat the meaning of any previous statements, but it did match the scientist's gestures in Line 3.

Just as his word choice repeated his previous language, the scientist's movements echoed his previous gestures. The scientist maintained his hand shape and their incremental step movements, but he reversed their direction and brought them back to his midline. He went so far as to touch his thumbs together at the end of the gesture sequence (Figure 8.5). This action emphasized that his virtual object was a single series of units, not two series that he built on either side of his body. It was only after his thumbs met did he drop his hands and turn toward the white board.

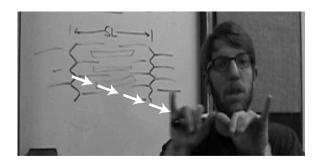


Figure 8.5: The scientist's position and movement when he said, "uniform distribution." He moved his hands in incremental steps from the sides of his body to his midline where his thumbs touched.

5. "of each of these"

The scientist continued to refer to the object as an individual unit. In this line he used the word, "each," and in Line 1 when he introduced the subject, he referred to it as, "a." In contrast, if the scientist's explanation was about multiple objects, he could have opted for a phrase like, "And you have many," instead of "And you have a," in Line 1, for example. Also, the scientist continued speaking during his transition from facing away from the white board to facing toward the white board. He did not end his sentence or use a conjunction to indicate that the discussion topic changed.

In contrast to his continued topic of explanation, the scientist turned his body toward the white board so that his torso and head faced it square-on. This position showed full engagement with the cartoon diagram. In combination with the drastic change in body position, when the scientist dropped his arms at the end of Line 4, it showed that he also released the virtual object that he created earlier. The scientist created mirrored shapes with his arms and hands. His fingers were extended and pressed together and his wrists were unbent so that his hands aligned with his forearms. He brought them up to accentuate the cartoon's Z-lines, the features that define a sarcomere unit (Figure 8.6a). He further accentuated the Z-lines when he brought his

This line expressed a mixed message. The language continued from the introductory segment where the scientist faced away from the board; he continued to refer to the object in the singular. However, his original gestures clearly showed an assemblage of multiple units whereas this motion indicated a single unit.





Figure 8.6: Scientist's position and movement when he said, "each of these." Image a), top, shows upward motion along the cartoon's Z-lines. Image b), bottom, shows downward motion along the cartoon's Z-lines.

6. "individual"

When the scientist expressed, "individual," he once again referred to the subject of the explanation in the singular. This instance, along with those in Lines 1 and 5, strengthened the likelihood that he referred to an entire object.

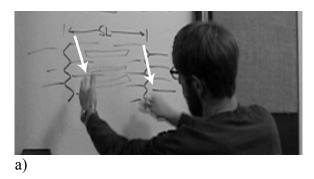


Figure 8.7: Scientist's position and movement when he said, "individual."

The scientist maintained his body position and raised his hands back along the cartoon sarcomere's Z-lines. This brought the number of passes over the Z-lines up to three (Figure 8.7).

7. "contractile units."

The final phrase indirectly clarified that the sentence actually had two subjects, each of which he referred to in the singular. When he faced the cartoon his language indicated a single sarcomere. Earlier in the mid-study interview the scientist defined the sarcomere as a functional contractile unit so, "contractile units," meant more than



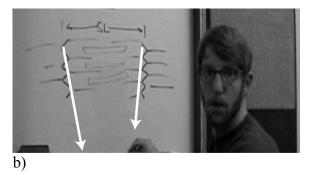


Figure 8.8: Scientist's position and movement when he said, "contractile units." Image a), top, shows his second repetition of moving his hands down the cartoon's Z-lines. Image b), bottom, shows when he puts the pen down and turns away from the cartoon at the conclusion of his sentence.

one sarcomere. The scientist's previous language when he faced the white board, "each of these individual," also concerned sarcomeres. Since the scientist discussed sarcomeres when he faced the whiteboard, and he did not use a verbal transition when his body transitioned to face the white board, then it is likely that his discussion topic also involved sarcomeres when he faced away from the white board.

The scientist's use of repetition continued when he moved his hands down the cartoon sarcomere's Z-lines for the second time (Figure 8.8a). That brought the total number of passes over the Z-lines to four. When the scientist finished thoroughly emphasizing the sarcomere unit, he dropped his hand and turned away from the board (Figure 8.8b). This action coincided with the end of the sentence, physically disengaged him from the cartoon, and showed that he completed his explanation.

8.2.3 Clip M2 Summary

The scientist used Scaling in two different ways during this clip. First, the scientist created scaled down virtual sarcomeres when he faced away from the white board. Each virtual sarcomere spanned between his extended thumb and little finger. The cartoon's visible sarcomere unit was just less than shoulder width. When the scientist faced away from the white board, he used his scaled down sarcomere units as building blocks for a larger object. Second, when the scientist built the larger object he scaled its maximum width to accommodate a limit that was comfortable with his body and maintain the virtual sarcomeres' side-by-side orientation. Had he extended his arms any further, his little finger would begin to arc down followed by the entire horizontal assembly.

During this clip the scientist assumed one of two body orientations. His initial body position faced away from the white board and his final body position faced toward the white board. When the scientist faced away from the board neither his language, nor his gesture, nor their combination expressed the object that he wanted to describe. When the scientist faced the white board, his gesture and language described a coherent story. His language described individual contractile units and his gestures emphasized the cartoon's features that defined individual contractile units. The scientist gave the gestures and language that he uttered, when he faced away from the white board, meaning when he faced toward the white board.

In Clip M2, the scientist used Scaling to help interpret his understanding about sarcomere units and how they are organized. However, when he created virtual objects before he established a visual display reference and used ambiguous language he compromised aspects of Scaling's benefits. Without a clear reference to the scientific object that inspired the virtual display, it would be a challenge for the explanation to lead to engagement with the scientific object under study.

8.3 Clip F3: Scaling and the Micrograph

8.3.1 Clip F3 Introduction

In this clip, Scaling occurred when the scientist translated the twodimensional, static visual display of a small myosin molecule into a three-dimensional, animated, bodily-scaled virtual object. The micrograph image displayed information about myosin molecules that both allowed and inhibited the scientist's progress. The scientist's interest laid in measuring tail region length where the measurement protocol depended on straight lines. However, tail amino acid sequence allowed for flexibility and, in turn, resulted in a variety of tail shapes on the micrograph. In addition to its flexibility, myosin tails had a significant three-dimensional volume. The two-dimensional, static micrograph image did not display myosin tail volume or action. In this clip, the scientist highlighted these issues when he interacted with the myosin tails from the micrograph via Scaling.

8.3.2 Clip F3 Data Analysis

Clip F3 was the third of three clips from the final interview. From this clip, the scientist's language related to Scaling is below. The language analysis adopted the notation conventions specified in Noble et al. (2004) and was described in Chapter 5.

Scientist: "Which can, potentially, influence the length if you stretch or bend a molecule."

8.3.2.1 Clip F3 language and gesture notation

1. Which can

[Body and turned toward project micrograph image; gaze looking up at left hand; with his left hand index finger extended, he pointed to and traced a myosin molecule with a curved tail.]

2. potentially influence

[Body turned slightly to side wall; gaze dropped to neutral; dropped his left arm by his side.]

3. the length

[Same general body and gaze position as in Line 2; both hands beginning to rise.]

4. if you

[Same general body and gaze position as in Line 2; both hands continued to rise.]

5. stretch or bend

[Same general body and gaze position as in Line 2; both hand shapes as if he was holding a pipe of an approximate diameter of 6 inches; moved his hands from palms toward each other to palms facing up with little fingers touching.]

6. a molecule.

[Body and gaze turned away from the micrograph projection; both hands dropped by his side.]

8.3.2.2 Clip F3 language and gesture analysis

1. "Which can"

The scientist's utterance, "which can," provided an introduction to a, yet to be explained, molecular ability of the tail. These words continued from his previous language that discussed the same subject, myosin molecule tail length, but did not apply to Scaling (Appendix H).

The scientist held his left hand up to a molecule in Panel (a) of the micrograph (Figure 8.9). He positioned his index finger at the head-to-tail junction of a myosin molecule with a curved tail. He traced the tail with his finger from the head-to-tail junction to the more prominent kink in the molecule, the one that corresponded to the

first skip residue. To increase the precision with which he indicated the molecule's tail shape the scientist bent his index finger and wrist in distinct ways. He sharply bent his index finger at its metacarpal-proximal phalange joint. This allowed him to use the very fingertip to trace to tail's shape rather than the less precise finger pad. Also, the scientist slightly bent his wrist up and at an angle so that his fingertip's movement was visible.



Figure 8.9: The scientist's body position and movement when he said, "Which can."

2. "potentially influence"

When the scientist said, "potentially," he reiterated the idea of the molecules' action capabilities, which he introduced in Line 1. When he voiced, "influence," he defined the action that the molecules could perform.

The scientist maintained his body and glance directions toward his index finger, which continued to trace the molecule with a bent tail. As his finger approached the end of the molecule's tail, the scientist's index finger and wrist bends relaxed so that his finger pad matched up with the very end of the molecule's tail (Figure 8.10a).

Once he finished emphasizing the bend in the molecule with his index finger, he

dropped his left arm by his side but remained looking in the general direction of the micrograph (Figure 8.10b).

3. "the length"

The scientist expressed the topic that his previous words led up to, "length." With this word he implied myosin tail length since that was his focus during the whole interview as demonstrated by his interaction with the micrograph, his language, and his gesture.



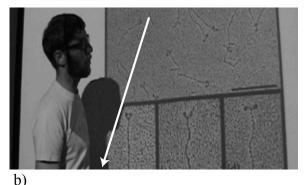


Figure 8.10: The scientist's body position and movement when he said, "potentially influence." In image a), when he said, "potentially," he traced along a curved molecule tail. In image b), when he said. "influence," he dropped his left hand out of frame.

The scientist did not make any appreciable motion but his language joined the previous gesture that pointed out bent tail shape.

4. "if you"

As in other clips, including Clip M2 in this chapter, the scientist used the personal pronoun, "you." When he used this word he provided those other than himself with the ability to influence the tail length, which was critical to his research on both the genetic and analysis levels.

The scientist lifted both hands from beside his body (Figure 8.11) with his arms bent at the elbows so that his hands were in front of his body at waist height. His fingers were outstretched and his palms faced down. He faced the general direction of the wall to the right of the projected micrograph. In Line 2, the scientist gesturally linked his hand shape to a fingertip-scale bent tail, and disconnected it from the visual display. In Line 3, he verbally transitioned to the subject of length. And, in this line the two are offered together to an undefined, "you."

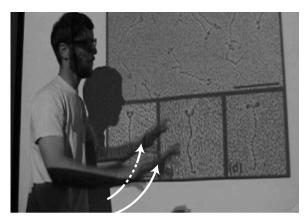


Figure 8.11: The scientist's body position and movement when he said, "if you." The dashed line indicates his left hand's movement that is obscured by his right hand.

5. "stretch or bend"

The scientist offered two specific ways that myosin tails were flexible. They could, "stretch," and they could, "bend." In the previous lines he only verbalized information related to stretching; he said "length." In the previous lines he only gestured to show information about bending; he did not correspond the subject with an utterance. Both words in this line were verbs, neither of which could be demonstrated by the static image. The scientist used the conjunction, "or," to indicate the independence of the two motions.

In this line, the scientist's hand shape showed that he created a cylindrical object, the basic shape that is most like the myosin tail. The scientist continued to increase the bend in his arms so that his hands were higher than waist level and wider than body width. When he said, "stretch," he rotated and shaped his hands so that they suggested that he held a cylindrical object of about six inches in diameter, parallel to the ground, and in front of his body. He pointed his thumbs up and his palms toward each other so that the space between his thumbs and index fingers faced away from his body (Figure 8.12a). The scientist's virtual cylinder grasping orientation, with the object held out from his body, indicated that he could hold the virtual cylinder's weight with his wrist strength. Since his hands were away from either side of his body, it suggested a stretching motion. So, with this first motion the scientist created a virtual object that he held and stretched without excessive effort. Next, when the scientist said, "bend," he kept the same hand shape but he brought his little fingers together so that they were touching (Figure 8.12b). He reduced the space between his hands in addition to rotating them so that his palms faced up. This gesture indicated

that the scientist held the cylindrical object by either end then brought the ends together in order to bend it. His hand orientation showed that the bend in the object curved above the scientist's hands and formed the shape of a lowercase, "n." If his object were real with real resistance, the scientist strongest body position to bend





Figure 8.12: The scientist's position and movement when he said, "stretch or bend." Image a) was when he said, "stretch." Image b) was when he said, "bend."

the cylinder would be with his hands together so that he could engage his oblique and abdominal muscles, that is, the position that the scientist actually assumed.

6. "a molecule."

The scientist said his main subject, molecules. However, he did not mention the part of the molecule that he was most interested in, the tail. Tail length as the topic

could be inferred because that was his explanation's subject. The scientist's previous language about tail characteristics mentioned their length and capabilities to stretch and bend.

The scientist used gesture to imply that his subject was more detailed than just molecules, that it was their tails in particular. His previous gestures showed tail characteristics that included bent tail images and stretching and bending tail action. When the scientist dropped his arms and looked away from the micrograph it showed that he finished with his explanation (Figure 8.13). His body position eliminated any direct engagement with the visual image.



Figure 8.13: The scientist's position and movement when he said, "a molecule." He dropped his arms to his sides and looked away from the projected micrograph.

8.3.3 Clip F3 Summary

The scientist engaged with the visual display when his explanation concentrated on certain myosin molecule tail characteristics. He specifically highlighted points that related to the qualities that affected his data collection. His overall interest was to determine tail length. Tail length data collection relied on the visual display to show myosin molecules with straight tails. In this final interview segment, the scientist shared his understanding about factors that led to bent tails.

These factors interfered with his immediate data analysis and his long-term experimental program.

The scientist verbally explained possibilities that could lead to tail length inconsistencies and visual displays with unacceptable tail shapes. To start his talk he mentioned that general circumstances could influence tail length. If the visual display showed tails with length anomalies, it could lead to inaccurate measurements and skewed results. However, tails that resulted from unintended influences were not distinguishable on visual displays. Through words and gesture, the scientist added a specific characteristic to his general characteristic of tail length influence vulnerability. He used coordinated verbiage and gesture to express that tails have the ability to stretch. The scientist also explained that certain unacceptable tail shapes could be captured on micrographs. First, he used his index finger tip to trace a bent tail as it appeared on the projected micrograph. His gesture overlaid onto this image showed the resultant shape but it did not explain what led to its form. At the end of the clip the scientist coordinated his language and gesture to show a tail's three-dimensional character and the action that led to undesirable tail shape.

In order to fully explain the characteristics and causes that resulted in tails with undesirable shapes, the scientist created a tail in space. When he released his direct engagement with the visual display he more accurately showed his understanding of the qualities that he wanted to explain. Specifically, he created a version of a tail that related to his own body, something that was three-dimensional and moved in three-

dimensional space. The scientist created a bodily scale object that exhibited characteristics that could not be explained by the visual display alone.

8.4 Chapter Summary

The relationship among the visual display, the information communicated, and the bodily interpretation of that information, synergistically acted as an effect of Scaling. In the cases presented here, the practiced physical range and use influenced Scaling's manifestation.

In the first case of Scaling, Clip M2, the scientist created sarcomeres that were defined by his hands and a series of sarcomeres that were defined by his arms. He created a virtual object through gestures that were already scaled to fit his body and worked within his physical comfort zone and limits. Then, he indicated one particular feature on the visible display that corresponded to one feature that he created in his virtual object. These motions started on a bodily scale and then finished on the scale of the cartoon visual display. In effect, the scientist transformed and *lowered* the virtual object that he created onto the visual display. Finally, in Clip F3, when the scientist established tail volume and motion, he interpreted the myosin molecules' qualities into bodily-based orientations. When the scientist created a virtual object before he referenced a visible object and then diminished the virtual object in order to lower it onto the visual display's feature it led to an unclear gesture narrative.

Another Scaling property is *lifting off* visual display features and then scaling them to bodily size. The scientist took this approach in Clip F3. He traced the small, index finger length myosin tail as it appeared on the projected micrograph. His

description of its undesirable nature was limited by the image's two-dimensional, static quality. Although, it was the data form that he used for his ultimate length measurements, it was not able to display the actions that led the variety of tail shapes in the resultant image. In order to show the action that led to the tail shape variety, the scientist lifted the tail off of the micrograph, scaled it up to body dimensions, and assigned it volume and movement. In this Scaling example, the scientist's explanation direction, visual display and then virtual object, facilitated interpretation.

In these two examples of Scaling, both created virtual objects that depended on bodily scale. However, the order that the scientist created the virtual object and highlighted the corresponding visual object differed. In one case, the virtual object was comprised of several smaller units and the visual object was a single larger unit. The scientist first created the virtual object at bodily scale, increased the size of a portion of it, and then lowered it to match the visual object. In the other case, the visual object was much smaller than the virtual object. The scientist first highlighted the visual object, lifted it off of the visual display, and then resized it to bodily scale. These examples show that Scaling can occur between visual and virtual objects in either direction, those objects can either be scaled up or scaled down in size. With these possible variations, Scaling is a type of universal language between the embodied virtual and visible worlds.

CHAPTER 9: DISCUSSION

9.1 Chapter Introduction

In this study the aim was to explore how a scientist who engaged with visual displays, a whiteboard with a hand-drawn diagram and a projection of a microscope-generated photograph, explained his understanding of extremely small biological objects, the unseeable phenomena in question. The results show that three main descriptive lines appear to influence the scientist's interactions: the small biological objects' features, the interview context, and the interview space. The features of the small biological objects were size and fluidity, both being properties of all biological entities. The *interview context* describes the circumstances under which an issue relates to a situation either outside of the interview or within the interview. The *interview space* is the physical environment in which the interview occurred. The item that connects the objects' features, interview context, and interview space is the scientist's actions. He incorporated gesture, language, and body position during his engagement with and explanations about the visual displays.

The findings from this study that relate the scientist's "embodied actions" to visual display interactions correspond with those from other studies that investigated similar situations. Some studies which claim that the observed interactions were intricately wound to some type of embodied action include Alač (2008), who watched a pair of scientists interpreting images that were displayed on a computer monitor; Barber (2005), who observed a tutor and a tutee when they created a hand-drawn map on paper; Botzer and Yerushalmy (2008), who investigated high school students as

they engaged in computer-mediated graph creation; and Ochs et al. (1994), who followed scientists that interacted with hand-drawn graphs on a whiteboard.

In addition to visual display interaction, the findings from this study suggest that the scientist called upon different embodied action modes to clarify or emphasize existing information, or to compensate for any lacking information (Chen & Herbst, 2007; Emmorey & Casey, 2001). The surrogate and enhancing natures of embodied actions likely stems from the abilities of visual displays to facilitate engagement with the objects of interest. This discussion presents that the scientist primarily engaged with the visual display through gesture, guided the explanation through language, and framed the combined visual display-gesture-language delivery through body position. Preferential reliance on a particular embodied action mode was proposed if it appeared sufficient, or significantly more efficient than any other single embodied action mode, for the explanation or interpretation.

In this chapter the results of this study will be presented and in the following order. First, a short review of the four themes is presented. Then, in the three sections that follow the three main descriptive lines found to influence the scientist's interactions with the visual display will be discussed: the small biological objects' features, the interview context, and the interview space. Each of these sections incorporates the type and scope of the appropriate embodied actions. Finally, the limitations of the findings are discussed.

9.2 Revisiting Themes

The data analysis included three complementary analytical factors: the clips' narrative descriptions in Chapter 4, the gesture studies in Appendices B through H, and the original video data. Four themes emerged from the analysis: *Naming, Layering*, *Categorizing*, and *Scaling*. Appendix A contains the consolidated, abbreviated details for the four themes.

Naming occurred when the scientist directly interacted with the visual display so that his pen left visible markings on the display medium, a whiteboard. The scientist-created mark imparted a particular meaning due to its relative location to the preexisting diagram. Similarly, the preexisting diagram assumed a new meaning when the scientist added the symbol to it.

The second theme, *Layering*, described the scientist's actions when his gestures created virtual objects in different spatial areas. He created objects that were either layered over existing visual display features, or in space away from the visual display.

With *Categorizing*, the scientist interacted with visual displays in order to differentiate data. Certain data were assigned into contrasting categories: ordered or not ordered. The scientist's explanatory style used dissimilarities, in the form of categories, when he described various small biological object formations.

Scaling occurred when the scientist interacted with visible display features and scaled them to a size fitting the dimensions of his bodily space. As a result, the scientist crafted bodily scale representations as a type of universal language, which linked visible and virtual objects.

These themes exhibited trends that allowed for classification; however, mutual exclusivity did not exist across them. They described examples of possible events that could have occurred when the scientist engaged with visual displays during his interviews.

9.3 Small Biological Objects

The findings suggest that the scientist's embodied interactions with the visual displays seemed to heavily rely on gesture. Gesture was most frequently highlighted were during the clips categorized in the Layering and Scaling themes. The preference for gesture within these themes seems to parallel the small biological objects essential characteristics of *size* and *fluidity*, possibly because these straightforward features easily translated into readily producible gestures that efficiently clarify the visual displays.

The extremely small biological objects' *in vivo* sizes are much smaller than can be physically experienced by unaided human senses and all biological objects contain smaller structures and are part of larger structures. The scientist's gestures seemed to allow him to relate to the small biological objects' absolute and relative sizes when he engaged with the visual display and the size ranking. In cases where audiences do not know an item's size, presenters preferentially incorporate gesture into their explanations (Holler & Stevens, 2007). To demonstrate, in Layering's Clip M3, not only did the scientist repeat gestures over the object's visual features that defined length (Figure 9.1a), he gestured to either side of (Figure 9.1b) and within (Figure 9.1c) the visual features of the object to showcase the structural hierarchy. The

scientist's gestures suggest a resolution to the discrepant size relationships among the genuine biological object, the visual object as displayed, and his physical body.

9.3.1 Size

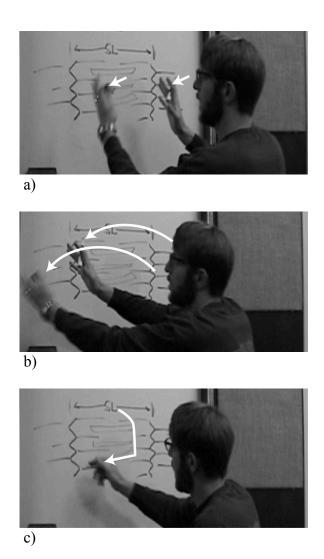


Figure 9.1: Gestures that attempted to align the size hierarchy of the genuine object and the visual display. Images a), b), and c) from Appendix D, Lines 8, 15, and 21, respectively.

The absolute and hierarchical size display seemed to challenge one of the limitations that this study's visual displays possessed, each visual display showed a

singe image size that needed to function for all versions of object size. In contrast, this limitation does not affect most computer-displayed images, which are able to zoom, pan, adjust intensity, and filter with real-time performance (Rosset, Spadola, & Ratib, 2004). During his experiment that generated the photograph, the scientist had the ability to perform such computer-based image manipulations. He lost those options once he captured the display into a still image with fixed-size objects, a required step to complete his data analysis and the remainder of the experiment. The data from Clip F3 (Chapter 8) show the how the scientist, because he could not zoom in on the image, greatly scaled down his gesture in order to engage with the visual display as he explained a measurement protocol. The scientist's



Figure 9.2: Tracing object's feature with index finger. From: Figure 8.10a.

gesture required the use of the tip of his index finger to trace the feature of interest (Figure 9.2). If the image would have been displayed on an interactive computer screen, the

scientist would have had the option to magnify the image and, therefore, not attended as strictly to the required gesture. Because these computer-based affordances were not available in this study, the findings show that the scientist used gesture as a

conduit between the characteristics of the actual object's size, the images sizes as displayed, and his own gestural interactions with that size.

9.3.2 Fluidity

The scientist's smooth or sharp gestures seem to play a role in emphasizing features that are structurally less variable or more variable, respectively. All biological objects have the property of variability; their defining structures are fluid, not exact like a line on a graph. When an object is displayed as a static visual image it cannot always convey which features are structurally flexible or constant. This can pose a problem to a viewer who may be interested in the biological object's fluidity.

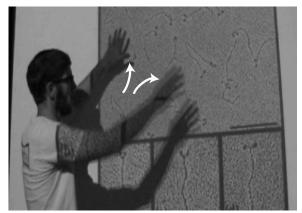
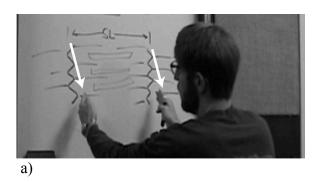


Figure 9.3: Curved motion of oppositely sweeping arms over the micrograph's panel (a). From: Figure 6.8.

The scientist employed smooth motion in conjunction with variable structures (Figure 9.3). The scientist faced the micrograph, lifted his hands in front of panel (a), and swept his arms away from each other in an arcing motion. This smooth, curved motion related the variable distribution of molecules across the panel's area. The gesture also enhanced the idea that the visual display showed many biological objects that were imaged in various orientations, and existed in various shapes. The results

linked the scientist's smooth gestures with the fluidity of the objects' various shapes and distribution.





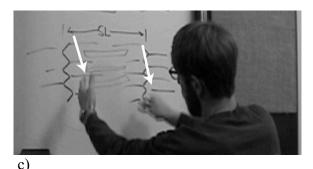


Figure 9.4: Images a), b), and c): Repetitive vertical movements along the diagram's defining features. From: Figures 8.6b, 8.7, and 8.8a.

In a gestural enhancement of a constant feature, the scientist held his hands over the diagram strict vertical boundaries and then repeated an up-and-down motion (Figure 9.4). It is possible that the precise, repeated gestures visually solidified the

features so that the scientist could use them to frame the variable features in his explanation.

9.3.3 Small Biological Objects Summary

In light of the extremely small biological objects characteristics, the findings suggest that the scientist's explanation of the visual displays necessitated the predominant use of gesture. The challenge of explaining small biological objects' characteristics were compounded by the visual displays' fixed images. The scientist seemed to preferentially use gesture to indicate the small biological objects' absolute and relative sizes. Also, the findings seem to indicate that the scientist accommodated the objects' displayed size when modifying his own gesture size. In addition, a potential for reliance on gesture was seen when the scientist, in describing the small object's fluid qualities, used curved gestures related to flexible structures and used repetitive, precise gestures related to more strict structures. The data suggest that the small biological objects qualities of size and fluidity relate to the scientist's apparent reliance on gesture during his engagement with visual displays.

9.4 Interview Context

The interview context describes how the interview circumstances relate to broader and narrower scopes of study. *Context beyond the interview* describes the interview's circumstances in a broader manner. From the data, it appears that the scientist preferentially relied on language in terms of the interview's one-way explanation format. *Context within the interview* described the interview's circumstances in a narrower manner. It described the use of the two visual display

types, diagrammatic and photographic. It seems that since each visual display type appears in three of the four themes, Naming, Layering, Categorizing, the embodied actions were similarly enacted across those same themes.

9.4.1 Context Beyond the Interview

The interview situation suggests that lecture-like one-way explanations rely on the scientist's language to share his understanding about the visual displays. This oral presentation approach is still very common in university education where students are often reduced to passive observers (Airey & Linder, 2009). However, a strength of lectures is that the speaker can specially organize the lecture to meet the needs of particular audiences (Bonwell, 1996). In this study, the scientist seemed to spotlight the study's instigating element, visual displays, when he organized the details and set the trajectory of his spoken explanations. This was shown by the lecture formats where he verbally repeated concepts throughout his explanation. Below, arrows indicate the topic progression for the mid-study interview. Repeated concepts that describe the small biological object are italicized.

Clip M1: Small biological object \rightarrow *individual contractile unit* \rightarrow small biological object's *length* \rightarrow definition of *length*

Clip M2: Object's substructure *consistent size* → uniform organization → *individual contractile unit*

Clip M3: Small biological object's *length* → substructure's *consistent size* → substructure's *consistent size*

Clip M4: Poor small biological object's formation → results from poor regulation → result is poor outcome

The narration dissection indicates that the scientist repeated three key concepts throughout the first three clips: individual contractile unit, length, and consistent size. Of these three concepts, contractile unit and consistent size appear to be more efficiently expressed through language than the concept of length. In the mid-study interview, the findings seem to indicate that the scientist's language use guided his explanation through a formatted narration that took on a traditional lecture-like strategy of repeating key points.

For the final interview, the scientist's explanation did not appear to rely on language as shown by the indexical references in his dissected speech. It seemed that the indexical references aligned with moments of gesture (Appendices F and H). In Clip F2 the scientist's narration did not include indexical references and showed repeated concepts as in the mid-study interview. Similarly, the language dissection results indicate that the scientist relied on language to guide his explanation.

Clip F1: Small biological object substructure → indexical reference → indexical reference

Clip F2: Measuring structure length → structure's beginning and end → procedure to measure structure length → structure's beginning and end

Clip F3: indexical → structure's desired orientation → structure's action

Teaching by spoken word is a context that extends beyond this interview. One
of the strategies to improve the effectiveness of lectures is to repeat key points. To do

this the orator needs to guide the lecture in an organized way so that concept repetition can occur, key points are specifically favored, and moments of repetition are optimal.

In the majority of the data clips, the scientist seemed to use language to this effect.

9.4.2 Context Within the Interviews

The unique contextual feature within the scientist's interviews concerned the two different visual display types with which he interacted, which is in contrast to most observational investigations that incorporate only one visual display type. The result is that this study may provide insights about interactions with visual displays that are likely different than other study formats. The first of the two visual displays was the mid-study interview's diagrammatic object that was hand-drawn on a whiteboard. The diagram on the whiteboard displayed the visual result of an in-themoment and intuitive creation from a thorough understanding acquired through extensive experience. The second of the two visual displays was the final interview's photographic object that was projected onto a wall-size screen. The projected photograph displayed the visual result of a lengthy and delicate procedure from an intentionally planned and executed experiment. Interestingly, three of the four themes, Layering, Categorizing, and Scaling, each contained two clips where one clip was from the mid-study interview and the other clip was from the final interview. Since each visual display type was cross-sorted into like themes, the clips suggest that the scientist's engagement style and origins likely lay in mutual embodied actions that stem from his explanation strategies that might share overlapping frameworks. Possible common frameworks situated within embodiment include those such as

object-based attention (Scholl, 2001), embodied interaction facilitated by the visual objects' orientation (Maniatis, 2008), and spatial interrelationships (Logothetis & Sheinberg, 1996; Vekiri, 2002). In this study, a proposition is put forth that the engagement style and origins lay in embodied interaction with a visual imagistic display.

9.4.3 Interview Context Summary

The interviews seem to have contextual placements that are both beyond and within the event as it occurred. For the context beyond the interview, the arrangement was similar to traditional lectures that are defined as teaching by the spoken word. The contextual situations seem to strongly relate to the scientist's verbal concept repetition and narrative progression. Each interview incorporated a different type of visual display. The visual displays showed different objects that used different imaging techniques and were presented on different media types. However, each theme, Categorizing, Layering, and Scaling, had one of each visual display type. This suggests that the visual displays have something in common from which the scientist called upon during his demonstrated understanding about the biological objects.

9.5 Interview Space

The interview space and the layout of the objects within it (Figure 9.5) determined how the scientist positioned his body. The findings suggest that the scientist used body position to establish a continuous system with two extremes. That is, one extreme drew attention to the scientist and away from the visual display, and the other extreme drew attention to the visual display and away from the scientist. On

either side, his body position appears to coincide with the way that he used language and gesture to fill in, clarify, or embellished a feature.

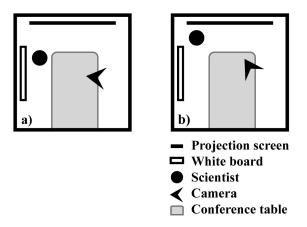


Figure 9.5: Interview space layout. Symbols are as noted. Camera arrow indicates location and direction. Diagram a): Mid-study interview; scientist seated in front of the whiteboard. Diagram b): Final interview; scientist standing in front of the projection screen.

His body position determined his personal active working space, which will be defined as the 90- to 180-degree arc with respect to the axis across the front of his shoulders (Figure 9.6). This description is based on the speaker-listener interaction work by Haviland (2000), where he puts forward that the hemisphere in front of the speaker is most important, and the investigations on speaker's body position by Roth and Lawless (2002), mentioned earlier.

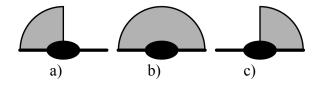


Figure 9.6: Body position active working space range. a) 90-degree front left. b) 180-degree front. c) 90-degree front right. Adapted from Roth and Lawless (2002).

On one side of the system his body position was turned away from the visual display (Figure 9.7a). He broadcasted his active working space to the area opposite to the visual display. This may have been a way to increase attention to his actions in open physical space, where he created and talked about virtual objects, and decrease attention that the visual display attracted. On the other side of the system the scientist's body position was turned toward the visual display (Figure 9.7b). He shared his active working space with the visual display and concealed it from open space. This could have been to redirect attention to the visual display where the scientist gesturally and verbally interacted with the visible object.

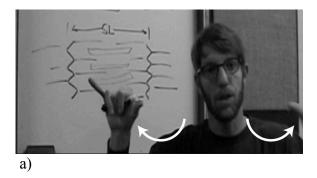




Figure 9.7: Active space body position change within a single clip. Image a) Roughly 150-degrees away from parallel to the visual display. From: Figure 8.4b. Image b) 180-degrees toward the same visual display. From: Figure 8.6a.

Although Figure 9.7 shows extreme positions with respect to the visual display, the findings suggest that partial rotation toward or away from the visual display can help the scientist's explanation cross zones and relate a virtual object to the corresponding visible object (Figure 9.8).

Interestingly, all of these body position changes were rotational with respect to the plane of the visual display. He did not translocate toward or away from a display's plane in order to create a virtual object that extended in a three-dimensional fashion from the visual object. Overall, it appears that when the scientist faced the board he shared his personal space with the visual display and often closed off his active working space in a way that that he could redirect attention to the visual display. When he faced away from the whiteboard he broadcasted his active working space as the active visual display and the location that should be focused upon.

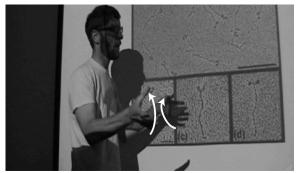


Figure 9.8: Ninety-degree body position from the visual display.

9.6 Limitations and Strengths

This case study is useful in its exploratory design in that its findings can support current viewpoints and promote new directions in the field of interactions with visual displays. This work has the ability to promote new ideas through various

reinterpretations of the data. Because of this, the interpretation presented here cannot be considered correct or incorrect.

The visual objects and visual display types were clear factors that brought both limitations and strengths to the study. There were two visual objects, the cartoon diagrammatic image and the micrograph photographic image. Having two different image types in one study could lend itself to comparison along the lines of other studies about visual qualities of images. Contrasts common to many of those studies are: two- versus three-dimensions, station versus animation, or diagram versus text. Unfortunately, in this study, the images did not display the same small biological object and so comparison across the interviews is difficult. Furthermore, the display media were different. The diagrammatic image was displayed on a whiteboard and the photographic image was displayed via light projection. In spite of these drawbacks, this study served as a preliminary step toward comparing different types of visual objects displayed by different types of visual media during their use for explanation.

All aspects of the study design, data collection, and data analysis were influenced by the investigator's prior knowledge as a professional molecular biologist. Her experience tinted the study, especially the data analysis. There is the strong possibility that her pre-existing knowledge may have ascribed meaning to benign happenings in the interview. Nevertheless, her hands-on scientific research experience provided great insight into the context of laboratory organization and function, the genetic strategies and protocols, and the experiment results and dissemination.

Both smaller and larger data corpora, depending on the unit of analysis, have their limitations and strengths. The ultimate video data analyzed in this study was small: 100 seconds. Arrival at this very select field of data required time-intensive data reduction procedures. A possible drawback of this small data pool was that the opportunities for broader generalizations were lost. On the other hand, extensive reduction allowed for greater data manageability and less convoluted data examination. In addition, the process of narrowing down vast amounts of information into a selective, small quantity of data went hand-in-hand with focusing the research question.

Developing coherent data interpretations was challenging due to the numerous explanatory options, partly due to the flexible conceptual framework guide. For example, a particular scientist interaction could have been interpreted as a unique act that happened to recur. In contrast, the scientist's interaction could have been interpreted as a repeated trend of action, or "ritual performance," that happened across similar contexts (Alač, 2008, p. 500). The variety of analysis options could be viewed as a shortcoming in that they led to somewhat random interpretations of the data. However, those same analysis options are strengths in that they show that the data are conducive to re-interpretation from different perspectives.

There was a considerable discrepancy between the study, as planned, and the study, as completed. Originally, the study was designed to investigate information-deficient scientific visual displays and scientist's compensations during their interpretations of them. The methodology was to borrow from ethnographic strategies.

The analysis plan was to make use of systematic content analysis to develop coding schemes in which the data were categorized. In contrast, in the study's final form, the visual display of scientific information was secondary. The range of ethnographic-influenced data was reduced to two interviews. The data analysis, after initial data reduction, was based on the idea of selecting interview clips that showed an "amazing" event. Then, the data were processed through unstructured iterative cycles in order to develop categories. Although the study as executed differed from the study as planned, the iterative analysis method was similar to several types of distinguished data analysis methods.

This study had a variety of limitations and strengths, which were based in its overall design details, analysis, and results interpretation. Interactions with the different visual displays could not be compared within this study design but comparison across image types is a field worth additional study. The study designer's background in science introduced field-specific biases but provided first-hand insight into the profession. The process of extreme data reduction paralleled the evolution of the well-focused research question. The study's proposed design greatly varied from the study in its final form but was realized as a specific approach to qualitative investigations. The different specific qualities in the study all contributed to the interpretation as discussed which, overtly and covertly, illustrated its limitations and strengths.

9.7 Chapter Summary

The results suggest that three facets influence the scientist's interactions with the visual display: the extremely small biological objects' features, the context beyond or within the interviews, and interview space. The small biological objects' features focused upon were *size* and *fluidity*. The *context beyond the interview* aligned the interviews' lecture-like format with the similarities in the linguistic strategies for teaching. *The context within the interview* demonstrated a comparison of two different visual objects, one diagrammatic image and one photographic image. Finally, The physical interview space related the scientist's body position and *active working space* to the visual display during his explanation.

Each of these interaction topics was viewed as amalgams of embodied action that included language, gesture, and body position. For each topic, if a particular embodied action mode seemed sufficient, or significantly more efficient, that any single other embodied action mode, then preferential reliance on that particular mode was proposed. The scientist's interpretations appeared to favor gesture for small biological object's feature, language for context beyond the interview, and body position in the physical environment space. No single embodied action mode seemed sufficient for context within the interview.

The main players in the interviews were the scientist, the visual display, the small biological object, and the interview space. The scientist connected to himself and the other three through his embodied actions: language, gesture, and body position. These connections both created and demonstrated the scientist's engagement,

explanation, interaction, and understanding about the subject of extremely small biological objects.

The study's results yielded context-relevant information that supported findings from studies in related contexts (Roth & Lawless, 2002, and others). Foremost, this is a strength of this case study because its primary aim was not to simplify what can not be simplified (Shields, 2007). Rather, the study approached the goal through a more holistic view of cognition, which encompassed expressing ideas as a collection of understandings in the broad sense (Airey & Linder, 2009; Hansen, 1990).

CHAPTER 10: CONCLUSION

10.1 Chapter Introduction

In this study the goal was to describe how a scientist used visual displays in conjunction with bodily action to share his understanding about scientific objects. The investigation was a detailed case study of a Ph.D. scientist whose everyday work included interacting with extremely small biological structures. The visual displays of these small biological structures provided the impetus for his descriptions during open-ended interviews. The first of the two visible displays was in the form of a hand-drawn cartoon and the depicted subject was a sarcomere. The second of the two visible displays was a micrograph and the depicted subjects were myosin molecules. Even though the scientist interacted with these different visual display types, analysis of his speech, gesture, and body position engagement showed similar themes. Each of the four themes developed, *Naming, Layering, Categorizing,* and *Scaling*, contained examples from both visual display type. From the data presented here, the conclusion can be drawn that certain patterns of embodiment are useful when engaging with a visual display when the goal is to explain the phenomena depicted by that display.

10.2 Response to the Research Question

The research question was: How does a scientist engage with visual displays when he explains his understanding of extremely small biological objects? The response founded in the analyzed data is that the scientist developed an embodied relationship with the phenomena depicted by the visual display and through his interpretation he participated in non-traditional engagement. Further, an assertion is

proposed that visual displays generated using these the types of phenomena, those that are not readily visible, can be seen to facilitate the non-traditional viewer-visual display engagements that are local, reciprocal, and borderless.

10.3 Future Work

Two issues that should be addressed with future research in order to strengthen the existing literature on visualizations have to do with the setting in which the study is performed and the interactions between the representation and its user. On the first point, there is a question about the generalizability of results from visualization studies executed in experimental settings versus the potential results from visualization studies that take place in contextually sensitive and authentically rich environments. The contrast between the information found when studies are set in contrived experimental conditions and the information found when studies are set in more naturalistic environments is an ongoing point of question in studies of human cognition and performance. On the second point, there remains a limited understanding of what characterizes scientists' interactions with visualizations during the process of interpretation. This deficiency is partially due to the wide variety of scientific visualization types and modalities and their particular roles in specific instances of scientific investigation. Since the study of cognitive tasks, like interpreting scientific visualizations, can be approached from a wide variety of perspectives, the generation of a diverse pool of results can suggest or support any models that may emerge.

10.4 Chapter Summary

A scientist's explanations of visual displays are a powerful means through which he can share his understandings and provide meanings to an otherwise random assemblage of lines and spaces. Uncovering patterns about how scientists interpret and explain visual displays can inform ways that interactions with visual displays can inform visual literacy, learners, and how action is based in knowledge, for educators.

APPENDIX A

Theme Summaries

Chapter 5: Naming

In *Naming*, the scientist engaged with the cartoon sarcomere when he drew persistent visual objects, markings that left visible evidence after their original execution. The markings had dual meanings, one as stand-alone symbols, and another as the part of the pre-existing cartoon that resulted in the cartoon's transformation into a new visual object.

Clip M1:

Scientist: "Your sarcomere is, of course, your individual contractile unit. The sarcomere length that we measure...."

Chapter 6: Layering

In *Layering*, the scientist gestured over visual objects so that they aligned with one or more features but did not touch the actual visual display. Layering also occurred when the scientist layered his movements over virtual objects in space away from the visual display.

Clip M3:

Scientist: "You want to make sure that your sarcomere lengths are of a consistent size and that, of course, each sarcomere and each half-sarcomere...."

Clip F1:

Scientist: "This is an overview picture of a wild type myosin, uh, population just kind of showing the field view of what our preps look like...."

Chapter 7: Categorizing

In *Categorizing*, the scientist used contrasting categories to explain his understanding about different characteristics that the small biological objects held. The default category was order, which was contrasted with lack of order. The scientist extended this categorization to properly formed versus not properly formed sarcomeres, and straight versus not straight tails.

Clip M4:

Scientist: "If the sarcomere doesn't form properly and is not regulated in this nice distinct, coherent manner you can activate all kinds of crap."

Clip F3:

The Scientist: "And so, these are the sorts of orientations that I typically go for when I measure because there's a lot less bending and, um, torsion that's taking place...."

Chapter 8: Scaling

When *Scaling*, the scientist resized a visible object's features to a corresponding virtual object that fit his bodily scale. Or, he built a virtual object at bodily scale then resized it to fit a visual object's corresponding feature.

Clip M2:

Scientist: "And you have a very structured, crystalline-like, uniform distribution of each of these individual contractile units."

Clip F3:

Scientist: "Which can, potentially, influence the length if you stretch or bend a molecule."

APPENDIX B

Clip M1 Gesture Analysis

[1:16-01:24] (8 sec)

This clip includes an instance of the scientist adding labels to the pre-existing cartoon.

For the duration of the clip the scientist is seated in front of a white board and the interviewer is seated across the table next to the camera. The white arrows indicate hand and arm movements.

Below is the pre-existing diagram that the scientist uses in this clip. The vertical zigzag lines symbolize Z-lines. The thin horizontal lines symbolize thin filaments. The horizontal rectangles symbolize thick filaments.

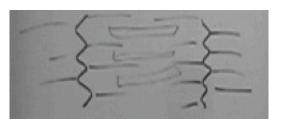


Figure B.1: Initial sarcomere cartoon.

Below is the transcript from the entire clip.

Scientist: Your sarcomere is, of course, your individual contractile unit. The sarcomere length that we measure is the distance from one Z-line to one Z-line.

Image	Time	Language	Image & Description
1	Point 00:00	(Beginning of clip)	The scientist looked at the white board that already had a diagram of a sarcomere including the Z-lines, and thick and thin filaments. The left bracket indicated the full sarcomere diagram. The scientist's arm was positioned to write above the pre-existing diagram. Inning of the next point he wanted to make for his explanation about
	sarcome	_	nning of the next point he wanted to make for his explanation about
2	verbalize to decide	ed just before whether to w	The scientist drew an "S" on the board above the existing diagram. The scientist faced the board. added for the scientist's explanation. The spoken word "sarcomere" was the scientist wrote the "S" symbol. This might have been because he had rite out the whole word or use some sort of abbreviation.
3			The scientist moved his pen from the end of the "S" stroke and placed it on the board in another location. The scientist faced the board. It this movement while he wrote his explanation. His use of "of course" ation of his confidence in the information that he was about to explain.

Figure B.2: Clip M1 gesture analysis.

Image	Time	Language	Image & Description
#	Point	56.	
4	00:01+	your indi <u>vid-</u>	The scientist wrote an "L" on the board. The scientist faced the board.
	This was	s the second s	ymbol the scientist wrote and it completed the abbreviation he used to
	stand for	r <u>s</u> arcomere <u>l</u> e	ength. This abbreviation was completed before he used the full term
			his could have been because once he decided on the written abbreviation
			abbreviation for "length" naturally followed. In this light, he continued without actually verbalizing the full word.
5	WILII IIIS	-ual	vidiout actuarry verbanizing the run word.
			The scientist moved his pen from the stopping point of the "L" to the
			starting point of the next stroke in the diagram. The scientist faced the
	The	maina no 111	board.
			we had the idea that since the "SL" symbol was already written that he at part of the diagram for his explanation.
6	00:02	contractile	The scientist wrote a horizontal line to the right of the "SL" that ended of the right Z-line above the existing diagram. The scientist faced the board.
	It was no		he horizontal line is connected to the concepts of "individual" or

Figure B.2: Clip M1 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point	Language	mage & Description
7	00:02+	unit	SI SI
			The scientist added a right facing arrow to the end of the horizontal line
	A 1.1'4'	6.41 :	he just drew. The scientist faced the board.
			symbol could have been a way of enhancing the existing "SL," a way to
	_		concept "individual contractile unit," or a way of introducing a new
8	concept.	(pause)	
0	00.04	(pause)	The scientist moved his hand from the finish point of the right facing arrow and placed his pen to the left side of the "SL." The scientist faced
			the board.
	enhance scientist	d the existing	"SL" or the right facing arrow. Or, it could have been a way to the already verbalized concept "individual contractile unit" or a way of
9	0:04+	sarcomere length that	The scientist wrote a horizontal line to the left of the "SL" and that ended above the left Z-line of the existing diagram. The scientist faced the board.
	The scie	ntist's verbali	ization could have suggested that the horizontal lines were related to the
			comere length.

Figure B.2: Clip M1 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
10	00:04++	we mea <u>sure</u>	The scientist drew a left facing arrow at the left end of the horizontal line just drawn. The scientist faced the board.
	The symn	netry of the a	rrows on either side of the "SL" suggested that the distance from arrow
	tip to arro diagram, arrow tip	w tip stood for the scientist in ended roughl	or an individual sarcomere's length. Also, when he drew the pre-existing indicated that the vertical zig-zag lines stood for Z-lines. Since each y above a Z-line, it could be that the scientist wanted to indicate that inship between sarcomere length and Z-lines.
11	00:05	is the	Tar
			From the end point of the left facing arrow the scientist dropped his hand out of frame as the arrow on the image indicated. The image was at a mid-point in the trajectory. The scientist faced the board. st's hand could have indicated that he wrote all that he intended to and is explanation could have been transmitted verbally.
12	00:06	from one Z-line	The scientist placed the cap back on the pen. His eye gaze shifted away from the white board and, roughly, to a point that was parallel to it.
			capping of the pen highly suggested that the scientist completed the is was trying to make. This was supported when the scientist moved his
		from the box	

Figure B.2: Clip M1 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
13			The scientist turned and looked at the interviewer. His hands moved out of frame as indicated by the arrow. In the day of the day o
		d of his expla	nation.
14	verbaliza understo	ation of his ex ood his point.	The scientist began to turn his head and eye gaze away from the interviewer and back toward the white board. is gaze away from the interviewer when he completed the last eplanation. This could mean that he thought that the interviewer This could have been due to a previously performed gesture by the
	interviev	ver, such as h	ead nodding.
15	The	(End of clip)	The scientist continued to turn his head so that it was fully facing the white board. The white box indicated the diagram completed to this point in the full interview.
			we looked back to review his latest addition to the diagram for its
	complet	eness or accur	racy.

Figure B.2: Clip M1 gesture analysis, continued.

APPENDIX C

Clip M2 Gesture Analysis

[02:03-02:14] (11 sec)

This clip includes a case of the scientist gestures denoting structures both within and beyond the cartoon.

For the duration of the clip the scientist is seated in front of a white board and the interviewer is seated across the table next to the camera. The white arrows indicate hand and arm movements.

Below is the pre-existing diagram that the scientist uses in this clip. The vertical zigzag lines symbolize Z-lines. The thin horizontal lines symbolize thin filaments. The horizontal rectangles symbolize thick filaments. The " \leftarrow SL \rightarrow " indicated sarcomere length and was added during Clip M1.

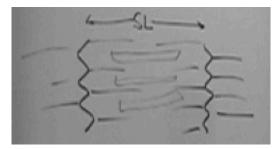


Figure C.1: Full sarcomere cartoon.

Below is the transcript from the entire clip.

Scientist: Thick filaments are always relatively equal in size. And you have a very structured, crystalline-like, uniform distribution of each of these individual contractile units.

Image	Time	Language	Image & Description
#	Point	Lunguage	image & Bescription
1	00:00	(Beginning of clip)	The scientist pointed to a location, the uppermost thick filament that was already drawn. The pen was not touching the white board. His
	mi :		right shoulder was toward the board. His gaze was toward the board.
			g gesture to the diagram feature could have been an indication that it was
2	00:00+	Thick	o the explanation to come.
2	00.00+	fila <u>ments</u>	ALAB -80
			With the tip of his pen the scientist traced, in the air and from left to
			right, the bottom line of the uppermost red box. His right shoulder was toward the board. His gaze was toward the board.
	When th	e scientist mo	ved his hand horizontally and in one stroke, he could have been using
		o simplify the	feature's box shape. Also, the movement coincided with his descriptive
3	00:01	are al <u>ways</u>	With the tip of his pen he traced, in the air and from right to left, the
			top line of the center box. His right shoulder and gaze were toward the board
	explanat	ion. Also, the	and movement could have indicated the importance of the feature to his repeated hand movement coordinated with the language suggested that
	ne was c	onfident abou	t the structure he was describing.

Figure C.2: Clip M2 gesture analysis.

Image	Time	Language	Image & Description
#	Point		
4	00:02	relatively equal	With the tip of his pen he traced, in the air and from left to right, diagonally across the lowest red box. His right shoulder and gaze were toward the board.
			ut, since he qualified his "always" with "relatively" it could indicate that
			his knowledge of the structure and of the uncertainty that rested within that
	knowled		NI WIS TO
5	00:02+	in <u>size.</u>	He moved his hand toward starting point of the thick filament tracing.
			His body was partially faced the board. His right shoulder was toward
			the board, his left shoulder moved slightly away from the board, his gaze was toward the board.
	part of h When he	is thought, o	s hand to the starting point, the scientist could have been finishing the first r he could have been trying to figure out how he could symbolize "size". body away from the board he could have been transitioning to the next part
6	00:03	And you	100 - 100
		have a	The scientist dropped his hand from the board and out of frame. His body rotated toward the interviewer. His gaze moved away from the
			whiteboard.
	The lang	guage here su	ggested that the previous phrase ending with "size" was the end of the
	scientist	's initial idea	a. The scientist's gestures also indicated this possibility. Along the same
	line, his	language and	d movement could have indicated a transition to the next idea.

Figure C.2: Clip M2 gesture analysis, continued.

Image	Time	Language	Image & Description	
#	Point	Dangaage	mage & Description	
7	00:03+	very	The scientist returned the cap to the pen. His body slightly rotated back toward the board. His gaze was down and approximately parallel to the board. ade the pen unusable by capping it, it further supported that the scientist's	
			st idea was complete.	
8	00:04	structured	TAB -XX	
			He turned his body and his gaze away from the board. At the same time, he raised both loosely fisted hands, with pen in right hand, in front of his	
	an aid in	the next par	shoulders. positioning could have indicated that he would not use the white board as t of his explanation. His hand movement could have been used to ture from which he might enhance through gesture and language.	
9	00:05	(pause)	TAB -XX	
			He continued to move his hands up toward his face .The new hand shape	
			of each hand had the thumb and little finger extended while the three	
			middle fingers were curled in toward their respective palms.	
	between	each thumb	re represented a sarcomere with the sarcomere length being the distance and small finger. When he lifted his hands up The scientist could have sh that sarcomeres were horizontally conjoined.	
	oven a ying to establish that sarcomeres were nonzontally conjuned.			

Figure C.2: Clip M2 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
10	00:06	crys	The sixting state of the state
			The scientist maintained the same hand shape when he moved his hands outward as if to draw the bottom half of a circle. He then made a small
			pushing motion. His left hand was partially out of frame. His body and
			gaze were toward the interviewer.
	By mov	ing his hands	out in a coordinated fashion the scientist could have been "drawing" the
			rcomeres. The pushing motion might have emphasized the change in
	location	from the firs	st placement of the sarcomere to the next and that they were forming a
		al string of u	nits.
11	00:06+	taline- like (pause)	With the same hand shape, the scientist moved his hands slightly away from each other and made the same pushing motion. This occurred four
			times as his hands moved away from each other and from his body.
	The scie	ntist's move	ment repetition could have further indicated extension of the horizontal
	string of	sarcomeres	already established. The accompanying language supported the concept
			tures are an ordered array of units. Since his last movement occurred
	during a	pause, it cou	ald have been the gestural equivalent of the phrase, "and so on."

Figure C.2: Clip M2 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		-
12	00:08	(pause) uniform <u>dis</u> trib	TAB -X8
			With the same hand shape, he repeated the pushing motion four times. At the emphasis point of each push his hands moved closer to each other.
	The dire		al could have emphasized the point that sarcomeres were regularly
13	00:08+	<u>u</u> tion	Tab -8
			The scientist dropped his hands and began to turn his body and gaze
			away from the interviewer and toward the board.
	By lowe	ring his hand	ds, he could have indicated that he was done setting up the concept of a
			ince his body turned toward the board in the middle of a word, he might
14	not have 00:09	of each	plaining his idea and that he would use the board in some fashion.
			As he continued to turn his body and gaze toward the white board, the
			scientist began to raise both of his arms toward the board. His hands and fingers were extended with all of his fingers touching each other. Each
			hand was roughly in line with the sarcomere length vertical lines from the pre-existing diagram.
	He used	the existing	diagram to aid his explanation. He used his two hands to represent the
	sarcome	re length wh	ere before he used his outstretched thumb and little finger to indicate his could have been an instance where he used different modalities to
		ze the same	

Figure C.2: Clip M2 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
15	00:09+	of these	Tab -x
			While maintaining the same hand shape and relative distance, he
			lowered his hands so that they were roughly in line with the bottom of
			the Z-lines. The scientist's body and gaze were both facing the white
		0.771	board.
			scientist tracing the boundaries of the sarcomere could have been
			thing motion that defined each sarcomere of the series. This could be a
1.6	•		t re-emphasized the established sarcomere structure.
16	00:10	indivi <u>dual</u>	TAB -X
			While maintaining the same hand shape and relative distance, the
			scientist raised his arms until his fingertips were again roughly aligned
	Dr. ro to	oing the 7 1	with the vertical lines associated with sarcomere length.
		acing the Z-11 basic unit.	nes the scientist further emphasized the importance that the sarcomere
	was tile	vasic uiii.	

Figure C.2: Clip M2 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
17	00:10+	contractile	TAB -XX
			The scientist lowered his hands so that they were roughly in line with
			the bottom of the sarcomere diagram. His left hand retained the same
			shape except his thumb was slightly distanced from his index finger.
	A i 1i	. 16 h	His right hand was in a loose fist and he still held his pen.
		re as a basic	acing the Z-lines the scientist further emphasized the importance of the
18	00:11	units.	TAR CONTRACTOR
10	00.11	(pause)	The scientist dropped his left hand out of frame and with his right hand put the pen in the white board shelf. He turned his body so it was almost perpendicular to the board and turned his gaze toward the interviewer.
	The activ	on of replacir	ng the pen to the holding tray could have indicated that he would no
			or as a pointer. When he lowered his hands and turned toward the
			ave indicated that he had finished expressing his idea and that he was
			back from the interviewer.
<u>-</u>	•	-	

Figure C.2: Clip M2 gesture analysis, continued.

APPENDIX D

Clip M3 Gesture Analysis

[02:53-03:06] (13 sec)

For the duration of the clip the scientist is seated in front of a white board and the interviewer is seated across the table next to the camera. The white arrows indicate hand and arm movements.

Below is the pre-existing diagram that the scientist uses in this clip. The vertical zigzag lines symbolize Z-lines. The thin horizontal lines symbolize thin filaments. The horizontal rectangles symbolize thick filaments. The " \leftarrow SL \rightarrow " indicated sarcomere length and was added during Clip M1.

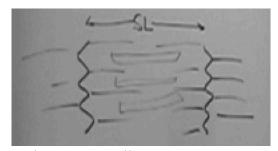


Figure D.1: Full sarcomere cartoon.

Below is the transcript from the entire clip.

Scientist: You want to make sure sarcomere lengths are of a consistent size and that, of course, each sarcomere and each half-sarcomere are roughly the same size.

Image	Time	Language	Image & Description
#	Point	Language	mage & Beschpion
1	00:00	(Beginning of clip)	The scientist's fingers were outstretched on his right hand and it was held up to his right side. He was looking toward the interviewer.
	It was no	ossible that the	e scientist faced the interviewer to get her attention before he began his
	explanat		s belonds the difference to get her attention before he began his
2	00:01	You want to make sure	As he turned his body toward the whiteboard he brought both hands up toward the board. His right hand fingers were extended and the pen rested between his index and middle fingers. The index finger and thumb of his left hand were wrapped around the pen cap, his other fingers were extended. His gaze was toward the board. used the word, "you," as a collective rather than the interviewer in
	particula		l scientific reference probably also applied when the scientist said,
3	"sure." 00:01+	that your sarcomere	The scientist maintained the same hand shapes and their relative positions. The scientist used a semi-circular motion and raised both hands up toward the top of his head. His gaze was toward the board.
	rather th lines. Th	an the intervients movement	st probably used, "your," to mean the scientific community in general ewer specifically. His hand movement aligned with the sides of the Z-could have served as an emphatic gesture to highlight specific features His body could have been square to the board because it replicated his
	perspect	ive when he a	nalyzed actual data.

Figure D.2: Clip M3 gesture analysis.

Image	Time	Language	Image & Description
4	Point 00:02	lengths ossible that the	the scientist maintained the same hand shapes and relative positions. He moved both hands down toward the board so that each hand was aligned with a Z-line in the pre-existing diagram. His gaze was toward the board. e scientist moved his hands closer to the Z-lines on the board to further
	-		tance from one Z-line to one Z-line defined sarcomere length.
5	00:02+	(pause)	The scientist maintained his hand heights and hand shapes but he changed their relative locations. He moved each hand away from the
			midline of his body. His gaze was toward the board.
			a length of conjoined individual units, the scientist's hand gestures could
6	00:03	are	the scientist brought both hands back toward the midline of his body.
			The left hand was held higher than the right hand. On the left hand the thumb and forefinger touched each other and the other three fingers were outstretched. The right hand was in a "C" hand shape. His gaze was toward the board.
	When th	l e scientist reti	urned his hands toward his body it could have been a transition
			n into his next point.

Figure D.2: Clip M3 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
7	00:03+	of a	The scientist raised both hands back toward his face. The palms of
			each hand faced each other and remained in the relative positions. The
			fingers on his left hand maintained the same shape and the fingers on
			the right hand were outstretched. His gaze was toward the board.
	gesture f	or his next po	ved both hands away from the board it could have been a preparation int. It could have been an exaggerated movement that would add extra lea he conveyed.
8	00:03+	consis-	The scientist maintained his hand shapes and his hands maintained their relative positions. He moved both hand toward the board so that they lined up with the Z-lines of the diagram. His gaze was toward the board.
		nning of the co	urned his hands to align with the Z-lines it could have been to establish urrent idea that he was explaining, the consistency of neighboring

Figure D.2: Clip M3 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
9	00:04	- <u>tent</u>	Tab &
			The scientist moved each hand away from its respective Z-line, away
			from the midline of his body. His left hand retained the same shape. His right hand was out of view. His gaze was toward the board.
	The scie	ntist's movem	ent repeated the gesture in line 5, but it continued further away from his
			could have been how the scientist indicated full sarcomeres on either
			drawn on the board.
10	00:04+	size	TAB -XX
			The scientist's left hand maintained its shape. He moved it in a semi- circular path so it was farther away from the midline of his body. His
			right hand was out of view. His gaze was toward the board.
	The scie	ntist repeated	the movement in line 9 but his hands moved even further away from his
			been how the scientist indicated the second set of sarcomeres on either
	side of tl	ne first set of s	sarcomeres.

Figure D.2: Clip M3 gesture analysis, continued.

	Time	Language	Image & Description
	Point	(pause)	The scientist's left hand maintained its shape. He moved it in a semi-circular path so it was closer to the midline of his body. The portion of his right hand that could be viewed had the fingers extended and the palm facing the left hand's palm. His gaze was toward the board.
			arned his hands back to his body it could have been a gesture that
			t sarcomeres were in line with one another.
	00:05+	(pause)	His hands retained their shape and relative locations. At the same time, he (1) slightly brought both hands up toward his face and away from the board then (2) returned his hands toward the board. His gaze was toward the board.
	omplete		ent could have shown that his explanation of consistent size was
13	00:06	<u>and</u>	The scientist's left hand maintained its shape as it moved in a semi-circular path toward the scientist's right side. His right hand moved and became hidden by his head. His gaze was toward the board.
		ntist's hand m is explanation	oved in a way that could have interpreted that he began to start the next.

Figure D2: Clip M3 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point	Language	mage & Description
14	00:06+	that of	The scientist's left hand maintained its shape as it made a small counter-clockwise loop up and back to the right. His right hand was out of view. His gaze was toward the board.
			and hand position suggested that he used them and established a full
			the right side of his body, where there was not a full sarcomere drawn
	on the di		
15	in space,	, to the left sid	The scientist's right hand retained its shape. His left hand was blurred. He moved his hands in unison and in a semi-circular path toward the left side of his body. His gaze was toward the board. and hand position suggested that he used his established a full sarcomere le of his body, where there was not a full sarcomere drawn on the
16	diagram. 00:07+	each	While maintaining the same hand shape the scientist slightly raised his right hand and then returned it to its original position. His gaze was toward the board.
	His gesti	ure likely re-e	mphasized the virtual sarcomere he just established.
	THS gest	ure likely le-e	imphasized the virtual salcomere he just established.

Figure D2: Clip M3 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point	Lunguage	image & Bescription
17	00:07+	sarcco	His right hand kept the same shape. The fingers of his left hand closed around on the pen cap. He moved both hands up and to the right so that each hand aligned with its respective diagramed Z-line. His gaze was toward the board.
	He could	have support	ted his point in two ways. First, the scientist began the utterance,
			phasize that the topic at hand concerned sarcomeres. Second, the
			nds back to the sarcomere on the drawn diagram to re-emphasize the
18	00:07+	mere mere	uctural definition.
			His right hand moved to behind his head, looped it up slightly up, and then moved slightly down. His gaze was toward the board.
			could have been to re-emphasize the virtual sarcomere previously
19	establish 00:08		t of the one drawn on the diagram.
19		(pause)	He moved both of his hands down and toward the midline of his body. His left hand changed to a loose fist. The fingers of his right hand moved to slightly grasp the pen he had been holding. His gaze was toward the board.
	I ne scie	ntist possibly	released his hand position as he prepared to convey his next point.

Figure D.2: Clip M3 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
20	The scie topic he		The scientist dropped his left hand out of frame. The scientist grasped the pen in his right hand in a writing position. He raised it to the "SL" written on the board. His gaze was toward the board. pointed to the "SL" written on the board to remind the interviewer of the explaining. Also, he may have moved his hand as he began his next
21	associate	ed words. This	The scientist moved his right hand down the right side of the three thick filament cartoons and then to the left across the lowest thick filament cartoon. His left hand was still out of frame. His gaze was toward the board. This gesture that indicated a half-sarcomere before he began to say the scould have been because he thought that he had already established sarcomeres and so the next point did not need a detailed explanation.

Figure D.2: Clip M3 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
22	00:09+	half	The scientist moved his right hand up to the top left corner of the uppermost thick filament cartoon and then dropped his hand down to
			the right end of the middle thick filament cartoon. His left hand was
			still out of frame. His gaze was toward the board.
	that he h sarcome	ad already est res, did not ne sely gestured	ve completed his gesture before he finished his point because he thought cablished both visual and virtual sarcomeres and so the next point, half-ed a detailed explanation. In support of this explanation, the scientist to indicate the location of a half-sarcomere even when there was not a diagrammed on the board.
23	00:09+	sarc	The scientist dropped his right hand out of frame and lifted his left
			hand into frame. His gaze was toward the board.
		_	ve completed his descriptive movement before he completed the
			ecause he thought that the concept was not complex enough that it
	warrante	d a thorough	explanation, especially in light of the detailed description he gave before.

Figure D.2: Clip M3 gesture analysis, continued.

_		T _	
Image	Time	Language	Image & Description
#	Point		
24	00:10	mere	He moved his right hand from behind his body to next to his chin. His fingers were in a loose fist. He continued to raise his left hand. It maintained the same hand shape. He turned his gaze from the
			whiteboard to his left.
	The scien	tist might hav	ve dropped his hands and removed his glance from the board as signs
	that he fin	ished his des	criptive gesture for the point that he continued to express.
25	body mov	ement, as we	The scientist maintained the location of his hands and returned his hand's shapes to that of the beginning of the clip. The right hand fingers were extended and the writing pen rested between his index and middle finger. The left hand's index finger and thumb grasped the pen cap. the scientist's gaze continued to rotate to his left. eared to have completed his gesture related to the board, his hand and all as the associated language, it could have been how he transitioned to on a personal level.
26	00:10++	are	His hands kept the same shape. He turned his palms away from each other so that they faced away from his body. The left hand was partially out of frame. He turned his gaze to the left until he faced away from the whiteboard.
	See fine 2	J.	

Figure D.2: Clip M3 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
27	00:11	roughly	Tab -x
			The scientist's right hand moved slightly up and to his right. The
			scientist's left hand followed a semi-circular path up and across his
			face. He moved his left hand away from his body's midline until it was
	W/141. 41.1.		slightly out of frame. The scientist continued to face the interviewer.
			cientist appeared to re-establish a virtual sarcomere unit. He may have sus explanations were sufficient and so he did not need to coordinate his
			diagrammatic reference.
28	00:11+	the same	diagrammatic reference.
			In unison, the scientist dropped both hands. The right hand retained its
			shape and the left hand dropped out of frame. The scientist continued
			to face the interviewer.
			ands did not move respective to each other, this could have been how the
29	00:12		language with his gesture.
27	00.12	same size.	The scientist kept his gaze toward the interviewer and slightly raised
			his chin.
	sarcome	re lengths wer	ovement mimicked his hand movement from when he explained that be the same size. Since he already established that movement to mean, been the standard gesture that he used for that meaning.

Figure D.2: Clip M3 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
30	00:12+	(end of clip)	The scientist continued to face the interviewer and dropped his chin. He slightly lowered his right hand.
	The scie	ntist dropped	his hands as a possible indication that he had finished his intended point.
			apported because his hand movement corresponded with a final head
	nodding	motion.	

Figure D.2: Clip M3 gesture analysis, continued.

APPENDIX E

Clip M4 Gesture Analysis

[05:04-05:14] (10 sec)

For the duration of the clip the scientist is seated in front of a white board and the interviewer is seated across the table next to the camera. The white arrows indicate hand and arm movements. His position varies from facing the board or facing the interviewer.

Below is the pre-existing diagram that the scientist uses in this clip. The vertical zigzag lines symbolize Z-lines. The thin horizontal lines symbolize thin filaments. The horizontal rectangles symbolize thick filaments. The " \leftarrow SL \rightarrow " indicated sarcomere length and was added during Clip M1.

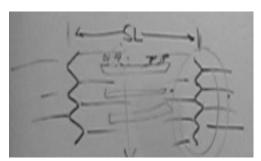


Figure E.1: Full sarcomere cartoon.

Below is the transcript from the entire clip.

Scientist: If the sarcomere doesn't form properly and is not regulated in this nice, distinct, coherent manner you can activate all kinds of crap.

Image	Time	T	Image & Description
Image #	Time Point	Language	Image & Description
1			The scientist lifted his right hand toward the white board. He held a pen in his right hand. His left hand was out of frame. A diagram was already on the white board. The scientist faced the interviewer. scientist faced the interviewer to get her attention before he began his
	explanation		
2	00:00+	If the sarcomere	The scientist continued to hold the pen and he maintained his hand shape. His left hand was out of frame. His gaze remained at the interviewer.
			re remained toward the interviewer when he began his verbal
			ot have been convinced that he had her attention.
3	Previous	doesn't	The scientist continued to hold the pen and he maintained his hand shape. His hand moved down slightly as he moved his gaze toward the board. His left hand is out of frame.
			e. The definition was based on the diagram on the white board. Since he
	already ga	ave meaning to	o the gestures, he could have decided that this abbreviated, one-hand
	gesture sa	tisfactorily co	nveyed what he meant.

Figure E.2: Clip M4 gesture analysis.

Image	Time	Language	Image & Description
#	Point	Lunguage	mage & Bescription
4	00:01	form	
			The scientist continued to hold the pen and he maintained his hand
			shape. His right hand moved up slightly. The scientist raised his left hand up and in unison with his right hand. The shape of his left hand
			could not be determined from this angle. The palms of his hands faced
			each other. His gaze remained toward the board.
	The scie	ntist changed	from the abbreviated one hand representation for sarcomere to the full,
			a sarcomere. He continued to use the diagram as a reference. He could
	have exp	oressly define	d the sarcomere to highlight that it was a key player in his explanation.
5	00:01+	<u>prop</u> erly	
			The scientist maintained his hand shapes and the relative position of his
			hands. With his hands and in unison he made a small looping motion
	The soie	ntist's motion	toward the board. His gaze remained toward the board. could have emphasized that the "proper" sarcomere structure was
			agram on the board and defined by his previous explanations.
6	00:02	and is not	Tab -8
			The scientist extended the fingers and thumb of his right hand. He held the pen in the valley between his thumb and forefinger. The scientist
			extended the last three fingers of his left hand. His index and thumb
			were touching. In a mirrored fashion, the scientist moved his hands in
			then out while he moved them up to just above his head.
	The curv	ve that his har	nds followed could have been in contrast to the straight trajectory (lines
	two and	four) that his	hands followed when he spoke about properly structured sarcomeres.

Figure E.2: Clip M4 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		·
7	00:02+	reg	
			The scientist's right hand retained the same shape. It appeared that the fingers on the left hand were making a fist. While he maintained his hand's relative position, the scientist dropped both hands to just above
			shoulder level. The scientist's gaze remained toward the board.
			here could have been to re-establish that the sarcomeres he talked about
			med ones, not the irregular ones referred to in the previous line (line six).
8	00:03	gul <u>ated</u>	A STATE OF THE STA
			The scientist moved both hands away from his body's midline and they
			followed a curved path. His right hand moved to a position that was
			obscured by his head. His left hand retained its shape. The scientist's gaze remained toward the board.
	A versio	n of this mot	ion was seen in earlier parts of this interview. As with that case, the
	scientist sarcome	's motion course. Since sarc	ald have established virtual sarcomeres to either side of the diagrammed comeres were found as a series of conjoined units, the scientist's motions such an arrangement.
9	00:04	in this	such dir direngement.
		nice	The scientist's right hand remained obscured by his head. The scientist's left hand retained its shape. The scientist kept his arms at
			approximately the same height and his left hand followed a path shaped
			like a small curve. The scientist's gaze remained toward the board.
			ed motion could have emphasized the regularity and linearity of
	sarcome	re series.	

Figure E.2: Clip M4 gesture analysis, continued.

Image	Time	Language	Image & Description			
#	Point	Language	inage & Description			
10	00:05	dis	The scientist's left hand retained its shape while it moved in a smaller (than line 9) curved trajectory away from the mid-line of his body. The scientist's right hand remained obscured by his head but his forearm moved in a way that suggested the right hand's movement mirrored that of the left hand. The scientist's gaze remained toward the board.			
	The scie	ntict reduced	the size and distance of each subsequent pair of mirrored sarcomeres			
			was limited by the constraints of his body's capacity to represent them.			
11	00:05+	tinct	TaB -8			
			The scientist's left hand retained the same hand shape. The path it followed was a slight "S" shape and moved away from the mid-line of the scientist's body. His hand also dropped to shoulder level. The			
	The sein	entist apuld be	scientist's gaze remained toward the board. eve dropped his arms because he reached the limit of his arm span rather			
			oleted his point.			
12	00:06	coherent	The scientist's left hand dropped out of frame. He began to lift his right hand so that it was visible. His right hand still held a pen. The			
	It is non	gible that the	scientist's gaze remained toward the board.			
			scientist dropped his arms and prepared his gestures for the next point			
<u> </u>	even though he had not finished the current explanation.					

Figure E.2: Clip M4 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point	_	
13	00:06+	man <u>ner</u>	The scientist's right hand held the pen in a writing position and the tip of the pen touched the white board. The tip was placed near the bottom of the right Z-line. The scientist's head moved away from the board as he leaned back in his chair. The scientist's gaze remained toward the
			board.
			could have indicated that he had already transitioned to the next point
1.1		completed th	e prior one.
14			The scientist used the pen in his right hand to rapidly tap four times on the board Each tap consisted of movements one and two on the image. Each tap landed at the same location (as in line 13) of the diagram. The scientist's gaze remained toward the board. of rapid pen tapping might have been a way he physically interpreted
	the idea o	f activation.	
15	00:07	vate	On the fifth tap the scientist started to change his glance from the white board to the interviewer. His left hand remained out of frame. His right hand retained its hand shape and position.
	It was pos	ssible that the	scientist adjusted his glance because he finished communicating the
			and he wanted to check that the interviewer followed his explanation.

Figure E.2: Clip M4 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
16	00:07+	all kinds of	With his right hand the scientist made a small counter-clockwise loop. At the end of the motion the pen tip no longer touched the board. The scientist's gaze continued to turn toward the interviewer. The scientist's left hand is still out of frame.
	The scie	ntist possibly	moved his hand over a non-specific area and lifted his hand from the
			ded both the structural information he explained and the functional
	informat	ion he explai	ned.
17			The scientist circled his right hand to the left. His left hand remained out of frame. His gaze remained at the interviewer. at since the scientist's continued and ill-defined motion coincided with his he had not decided how to complete his final point.
18			With his right hand the scientist traced a small counter-clockwise circle five times in rapid succession. Each circle was slightly smaller than the previous one. The scientist maintained his gaze when he leaned slightly toward the interviewer. noved in a more regular pattern while his language was still paused. The and in consecutive circles that decreased in diameter. This gesture could
			e scientist was narrowing in on the language he wanted to use to finish is
	last poin		

Figure E.2: Clip M4 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
19	word, 'general	'crap," that co lly, meant un	The scientist traced his final and smallest circle. His left hand was still out of frame. His gaze was still toward the interviewer but he leaned back to assume his original body position. This hand in his final and smallest circle when he chose the descriptive completed his idea. This was a non-scientific term that, connotatively and desirable. As such, it appeared that the scientist could not narrow in on a rm even after his language paused.

Figure E.2: Clip M4 gesture analysis, continued.

APPENDIX F

Clip F1 Gesture Analysis

[12:05-12:24] (19 sec)

In this clip the scientist points out panels (a), (b), (c), and (d) on the projected image of myosin molecules. He stood in front of the left side of the projected image. The interviewer sat in front of and just to the left of the image. The white and black arrows indicate the scientist's hand and arm movements.

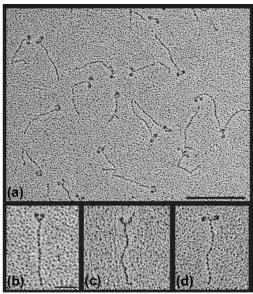


Figure F.1: The image used in Clip F1.

Below is the transcript from the entire clip.

Scientist: This S2/LMM hinge, which is located in this region of the molecules, here and here. This is an overview picture of a wild type myosin, ah, population just kind of showing the field view of what our preps look like.

Image	Time	Language	Image & Description
1			The scientist faced the projected image. His left arm is bent at the elbow and his hand is in a loose fist in front of his body. ave faced the image in order to bring attention to the details he was going
	to desc		
2	00:00	This <u>S2</u>	The scientist dropped his left hand by his side. He continued to look at
			the screen.
			we been preparing to explain a new topic to the interviewer and dropping
	his han	d could have a	cted as a transition gesture.
3	00:01	LMM hinge	The scientist raised his right hand toward panel (c) of the projected image. His right index finger was extended and pointed to the center of the myosin molecule's tail. The scientist's gaze remained toward the screen.
	With th	nis movement.	the scientist could have intended to bring the interviewers attention to the
	mid-se	ction of the my	yosin molecule's tail. He said "hinge" at the same time that he pointed to yosin tail so that region could have mapped to the hinge region.

Figure F.2: Clip F1 gesture analysis.

Image	Time	Language	Image & Description
4	myosir syllable	n molecule. He e he pronounc	The scientist traced his right index finger up the myosin molecule in panel (c) from approximately the middle of the tail to one-quarter of the way down the tail from the head-tail junction. The scientist's gaze remained toward the screen on could have indicated the general location of the hinge region on the ec continued this up and down motion in the same tail region. With each teed the region he indicated became smaller and smaller. (see lines 5-)This
			ne scientist mentally reviewed the scientifically detailed hinge region ed a more accurate area on the molecule.
5	00:02	is	The scientist moved his right index finger down a small portion of the myosin tail in panel (c). His gaze remained toward the screen.
	(See lii	ne 4)	
6	00:02	<u>lo-</u>	The scientist moved his right index finger up a small portion of the myosin tail in panel (c). His gaze remained toward the screen.
	(See lii	ne 4)	

Figure F.2: Clip F1 gesture analysis, continued.

Imaga	Time	Languaga	Imaga & Dagarintian
Image #	Point	Language	Image & Description
7	00:02	<u>-ca-</u>	
			The scientist moved his right index finger down a small portion of the
			myosin tail in panel (c). His gaze remained toward the screen.
	(See lin	l ne 4)	myosiii tan in paner (e). This gaze remained toward the sereen.
8	00:02	-red	
8	00.02	-ied	The scientist moved his right index finger up a small portion of the myosin tail in panel (c). His gaze remained toward the screen.
	(C 1:.	4)	myosin tail in panel (c). His gaze remained toward the screen.
9	(See lin	in	
7	00.02	<u> 111</u>	The scientist moved his right index finger down a small portion of the
			myosin tail in panel (c). His gaze remained toward the screen.
	(See lin	ne 4)	

Figure F.2: Clip F1 gesture analysis, continued.

Imaga	Time	Language	Image & Description	
Image #	Point	Language	mage & Description	
10	00:02		The scientist began to move his right index finger away from the myosin tail in panel (c). His gaze remained toward the screen.	
			or the molecule in panel (c).	
11	00:03	region	The scientist completed moving his index finger and it stopped midway	
			down the tail of the myosin molecule in panel (b). His gaze remained	
	The	4 1	toward the screen.	
			ge in index finger location was probably a cue to the interviewer that was not specifically language-based.	
12	00:03	of <u>the</u>	The scientist moved his right index finger up a small portion of the myosin tail in panel (b). His gaze remained toward the screen.	
			gestures, the scientist was probably showing a general indication of on maps to on myosin's tail. He repeated this up and down motion for a	
		tne ninge regi two cycles.	on maps to on myosin s tan. He repeated this up and down motion for a	
	27.00 27.00 27.000			

Figure F.2: Clip F1 gesture analysis, continued.

Image	Time Point	Language	Image & Description
13	00:03	mol-	the scientist moved his index finger down a down portion of the myosin tail in panel (b). His gaze remained toward the screen.
1.4	(See lin	<u> </u>	
14	00:03	<u>-e-</u>	The scientist moved his right index finger up a down portion of the myosin tail in panel (b). His gaze remained toward the screen.
	(See lii	l no 12)	myosin tan in paner (b). His gaze remained toward the screen.
15	00:04	- <u>cules</u> here	Using his right index finger, the scientist slightly traced down the myosin tail in panel (b) and then curved it away from the tail and to the right. His gaze remained toward the screen.
	least tw traced empha (b) area	vo ways. First before. Since size the locati	If that he could have been moving on to a new topic and or example in at the his gesture was more casual, he might have thought that he did not need to on of the hinge region more. Second, his hand moved away from the panel sted that the scientist was going to use a different part of the image for the

Figure F.2: Clip F1 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
16	00:04	(pause)	
			The scientist continued moving his right hand across the lower panels of
			the image until his right index finger pointed to a position on the myosin
			molecule, approximately one-fifth down from the head-tail junction, in
	The go	iontist's sostu	panel (d). His gaze remained toward the screen.
			re could have changed the interviewer's attention to the specific location cule in panel (d).
17	00:05	and	die in paner (d).
			The scientist moved his right hand, with its index finger extended, to approximately two-fifths down the tail from the head-tail junction. His gaze remained toward the screen.
			es in panels (c) and (b), the scientist indicated a general region in the tail
1.0		ntained the hi	nge region.
18	00:05	<u>here</u>	The scientist moved his right index finger up a down portion of the myosin tail in panel (b). His gaze remained toward the screen.
	(See lii	ne 18)	7 p (-), p
	(- , - , - , - , - , - , - , - , - , -	- /	

Figure F.2: Clip F1 gesture analysis, continued.

T	Time	T	Income & Description
Image #	Time Point	Language	Image & Description
19	00:05	(pause)	The scientist dropped his right arm to his side. His gaze remained toward the screen.
			on could have indicated that he was finished talking about that subject and
20	00:06	Um,	the next point he wanted to explain.
20	00.00	<u>Oili</u> ,	
			Both of the scientist's arms remained down and by his sides. He slightly
			turned his right shoulder away from the screen. His gaze remained toward the screen.
	The sci	l ientist's body	movement could have been an initiation to turn toward the interviewer.
			ine 21, the reason for the scientist's body movement was so that he would
			al position to use his left hand for the upcoming explanation.
21	00:07	This is an over <u>view</u>	The scientist moved his left arm from his side to a position in the left bottom section of panel (a). His fingers were all extended and his palm faced the screen. His gaze remained toward the screen.
			displayed in panel (a) were in a different configuration that in the other
	panels,	it is likely the	at the scientist was moving on to the next point in his explanation.

Figure F.2: Clip F1 gesture analysis, continued.

T	Tr'	т	T 0 D : (
Image #	Time Point	Language	Image & Description
22	00:11	of a wild	
		type	
			With his left hand, the scientist made a sweeping motion in a clockwise
			direction over the bottom left section of panel (a). His left hand fingers remained extended. His gaze remained toward the screen.
	It is lik	ely that his sy	veeping motion is to indicate the multiple myosin molecules in panel (a) in
			myosin molecules in the other panels. His gesture and language indicates
	that all	of the molecu	ales in the panel come from the same genetic background.
23	00:13	myosin, <u>ah</u>	With his left hand, the scientist swept his hand slightly up, then away from his body, then in an upward, curved, counter-clockwise direction. His left hand fingers remained extended. His gaze remained toward the screen.
	(See lin	ne 22)	
24	00:13	(pause)	The scientist kept his left arm and hand in their previous locations but changed his extended fingers into a fist. His gaze remained toward the
			screen.
	The sci	entist's move	ment could have been a moment where he decided what to explain next.

Figure F.2: Clip F1 gesture analysis, continued.

-	m:	-	V 0.D 1.1		
Image #	Time Point	Language	Image & Description		
25	00:14 The sci		He kept his left hand in a fist. He bent his left arm so that his fist was in front of his left shoulder. His gaze remained toward the screen. In could be interpreted as an intermediate moment. Since he did not drop		
			t is likely that his next point would also involve panel (a).		
26			The scientist opened his left hand fist so that all of his fingers were extended with his palm facing away from his body. He raised his right arm, hand, and fingers so they mirrored those positioned on his left side. His gaze remained toward the screen. scientist raised both hands to emphasize the generality of the molecules in ey were of a wild type genetic makeup.		
27	00:14 The sci	entist's motio	The scientist continued to raise his hands until his palms, still facing away from his body, were stacked on top of the other. The left hand was above the right. His gaze remained toward the screen. In could indicate a starting position for another sweep with his hands to		
			neity of the molecules in panel (a).		
	indicate the homogeneity of the molecules in patier (a).				

Figure F.2: Clip F1 gesture analysis, continued.

Image	Time	Language	Image & Description	
#	Point	Lunguage	mage & Beschpiton	
28	00:15	ing	With his arms, hands, and fingers in the same position, the scientist	
			swept his hands apart so they were about 16 inches away from each	
			other. His gaze remained toward the screen.	
			oing hand motions could be a way to indicate the homogeneity of the	
		les in panel (a	a).	
29	just per	rformed with	The scientist dropped his right arm to his side. He kept configuration of his left hand and fingers and swept them to the right in panel (a). His gaze remained toward the screen. ing movement with only his left hand could be to emphasize the motion he both hands. (See line 28)	
30	00:16	entist could h	The scientist kept his left arm lifted and his left fingers extended. He slightly moved his left hand, at the wrist, to the left. His gaze remained toward the screen. ave been diminishing his movements because he had already pointed out	
	the area of interest several times.			

Figure F.2: Clip F1 gesture analysis, continued.

Image	Time	Language	Image & Description	
31	Point 00:16	of what	He slightly changed his hand shape. All of his fingers were still extended but his thumb was slightly drawn toward the rest of his fingers so that his palm no longer faced the screen. His gaze remained toward the screen.	
	When	the scientist d	id not maintain his palm facing the screen, it could have indicated that he	
			more casual about pointing out the field of molecules in panel (a),	
32	00:17	our preps	ad already pointed them out several times.	
	(See lii	ne 30)	The scientist returned his hand to its original hand shape so that all of his fingers were extended and his palm faced the screen. He moved his hand up and slightly to the left. His gaze remained toward the screen.	
33	00:17	look <u>like</u>	The scientist began to lower his hand from its position in front of the screen. As he did that, he relaxed his fingers into a loose fist. His gaze remained toward the screen. have retracted his fingers and removed his hand from the screen because he	
	finished that part of his explanation.			

Figure F.2: Clip F1 gesture analysis, continued.

Image #	Time	Language	Image & Description
	Point	(D	
34			The scientist dropped his left arm to his side. His gaze remained toward the screen. cientist fully dropped his hand to his side because he finished that part of
		tely that the solanation.	cientist fully dropped his hand to his side because he finished that part of

Figure F.2: Clip F1 gesture analysis, continued.

APPENDIX G

Clip F2 Gesture Analysis

[12:39-13:04] (25 sec)

In this clip the scientist points out details of the myosin molecule in panels (b) and (c) of the myosin molecule micrograph.

For the duration of the clip there was a projected image of myosin molecules. The scientist stood in front of the left side of the projected image. The interviewer sat in front of and just to the left of the image. The white arrows indicated the scientist's hand and arm movements. Dashed lines indicated movements that were out of view.

Below is the image that the scientist pointed to during this clip.

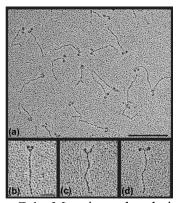


Figure G.1: Myosin molecule image.

Below is the transcript from the entire clip.

Scientist: Um, so then what I was doing with this was measuring the length of the rod, So, you can clearly see where it stops and, for those of us who study them, you can clearly see where it starts. So then you just linearize, skeletonize this length along, along the length of the rod from the head-to-tail junction to the C-terminus...

Image	Time	Language	Image & Description
#	Point	Language	mage & Description
1	00:00	(beginning)	The scientist gazed toward the screen. Both of his arms are down by his sides.
			ientist is facing the screen in order to explain something about the
2		ed image.	
2			The scientist raised his left hand and made his hand into an open "C" shape. The curve of the "C" was at the level of the myosin molecule head region in panel (b). The scientist's gaze remained toward the screen. ave moved his hand toward the myosin's head region in order to bring the
		ewer's attentio	
3	00:01	(pause)	The scientist's left hand shape remained the same. He moved his hand down the length of the myosin tail in panel (b). The scientist's gaze remained toward the screen. His right arm remained by his side.
			notion could have indicated that he intended to talk about the whole
	molect	ıle, not just the	head region.

Figure G.2: Clip F2 gesture analysis.

Image	Time	Language	Image & Description
#	Point		
4	00:01	what <u>I</u>	The scientist swept his left hand up to the general direction of the myosin head in panel (c). He opened his hand slightly so that all of his fingers were extended. The scientist's gaze remained toward the screen. His right arm remained by his side.
			have briefly motioned to the other molecule to indicate that they were
			for the purposes of this explanation.
5		was doing with this was	The scientist swept his left hand back down then up near the head portion of the myosin molecule in panel (b). He changed his hand shape to a loose fist. The scientist's gaze remained toward the screen. His right arm remained by his side. ave returned his hand to the original molecule so that he could use it as the ference.
6	00:02	measur	The scientist slightly raised his left index finger. The scientist's gaze remained toward the screen. His right arm remained by his side.
			exact location on the myosin tail, the scientist's motion could have
	indicat	ed the hinge r	egion or the head-tail junction.

Figure G.2: Clip F2 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
7	00:03	ing	He lowered his index finger to recreate his closed fist. The scientist's gaze remained toward the screen. His right arm remained by his side.
	(See lin		
8	00:03	<u>the</u>	
			The scientist brought both of his hands together in front of his body, just
			above waist level. The scientist's gaze remained toward the screen.
	changi	ng the origina	on could have been a transition movement where he could have been l left hand used for gesture to the right hand. Or, it could have been an e the use of both hands for his explanation.
9	00:04	length	The scientist separated his hands and positioned each into a pointing shape with the index fingers extended. His palms were facing each other. His right index finger is aligned with the end of the myosin tail in panel (b). His left hand is approximately one-third down the tail from the head-tail junction but not aligned with the projected image. The scientist's gaze remained toward the screen.
	The sc	ientist most li	kely is using his index fingers to convey they idea of length although the
			left and right index fingers do not relate to any defined length.

Figure G.2: Clip F2 gesture analysis, continued.

-		T -	
Image	Time	Language	Image & Description
10	Point 00:06	of the <u>rod</u>	The scientist kept his hand shape but rotated his hands so that the palms were facing the floor. His right index finger was aligned with the end of the tail of the molecule. His left hand was midway down the tail but not aligned with the projected image. His gaze remained toward the screen.
			ed his palms as a way to reinforce his point about measuring length.
11		So you can clearly see where it stops (pause)	The scientist's right hand remained in place. His left hand maintained approximately the same shape but he moved his index finger so that it aligned with the head-tail junction of the myosin in panel (b). The scientist's gaze remained toward the screen. ave repositioned his left hand to show a more specific indication of the
12	00:10	and, for those of <u>us</u>	The scientist's right hand maintained its shape and location. The scientist's left hand quickly rotated up at the wrist so that his hand was approximately parallel to the myosin molecule's tail. The scientist's gaze remained toward the screen.
			ement could have been an intermediate motion that occurred after he
	specific	cally pointed	out the length that he measured.

Figure G.2: Clip F2 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
13	00:10	who study them, you can clearly see where it starts.	The scientist's right hand maintained its shape and location. The
			scientist's left hand rotated down at the wrist so that its index finger
			returned to the molecule's head-tail junction. The scientist's gaze
		<u> </u>	remained toward the screen.
			his previous hand movement, the whole motion could have been a reset
1.4			general explanatory point of view to a more precise, expert point of view.
14	00:12	So then you	
			The scientist's right hand maintained its shape and it traced a path over the myosin's tail and stopped at the head-tail junction. The scientist's
			left hand dropped at the wrist from its previous location at the head-tail
			junction. The scientist's gaze remained toward the screen.
4 -	-		e tail length, he could have supported the length that he measured.
15	00:14	just, <u>um</u>	
			With his right hand, the scientist changed pointing to the head-tail junction with his index finger to pointing with it using his little finger. He continued to drop his left arm and hand. The scientist's gaze
	It is no	ggible that the	remained toward the screen.
			scientist wanted to make a more precise mapping of the myosin tail so he finger that could point out finer details.
L	change	a to a sinanci	migor that could point out this details.

Figure G.2: Clip F2 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point	Language	mage & Description
16	00:15	linearize,	The scientist maintained his right hand shape and carefully traced down the myosin's tail to about the one-third point. His left arm remained by his side. The scientist's gaze remained toward the screen.
	The sc	ientist's caref	ul tracing could have mirrored the caution with which he took when he
	did the	actual measur	rements.
17	(See lin		The scientist maintained his right hand shape and carefully traced down the myosin's tail to about the two-thirds point. His left arm remained by his side. The scientist's gaze remained toward the screen.
18	00:18	this <u>length</u>	The scientist maintained his right hand shape and completed his careful trace down the myosin tail. His left arm remained by his side. The scientist's gaze remained toward the screen.
	(See II	ne 16)	

Figure G.2: Clip F2 gesture analysis, continued.

т	T.	т .	T 0 D : (:
Image #	Time Point	Language	Image & Description
19	00:19	along,	The scientist tucked in his little finger so that his right hand was in a fist. He slightly moved his whole fist away from the projected image and toward his body. The scientist's gaze remained toward the screen. In could have indicated a change of topic in his explanation.
20	00:20	ah,	a could have indicated a change of topic in his explanation.
20			The scientist changed his right hand from a fist and extended his index finger. He moved his hand and arm so that his index finger aligned with the myosin's head-tail junction. The scientist's gaze remained toward the screen.
			e scientist's movement was to initiate an explanation repetition about tail
21	00:21	along the length of the rod	The scientist maintained his hand shape and traced down the molecule's tail from head-tail junction to just before the end of the tail. The scientist's gaze remained toward the screen.
		e aid not tract tail end sever	
			tail from head-tail junction to just before the end of the tail. The

Figure G.2: Clip F2 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
22	00:23	from the head-to-tail junction	
			The scientist retained the same hand shape. Rather than tracing the
			molecule's tail, he picked up his hand from the tail's end then replaced it
			at the head-tail junction. The scientist's gaze remained toward the
	ъ.	1 . 1 . 1	screen.
			and, rather than tracing the length of the tail from end to head-tail junction,
			ave been indicating that when doing the actual measurements he started at a then worked his way to the end of the tail.
23	00:25	to the <u>C-</u> terminus	The scientist retained the same hand shape. Rather than tracing the
			molecule's tail, he picked up his hand from the head-tail then replaced it
	The co	 	at the tail's end. The scientist's gaze remained toward the screen. ed just the points of the tail and the head-tail junction. This could have
			traced along the length of the tail several times and so he could have
			to point out only the start and stop points of his measurement.

Figure G.2: Clip F2 gesture analysis, continued.

APPENDIX H

Clip F3 Gesture Analysis

[14:21-14:36] (15 sec)

In this clip the scientist points out details of the myosin molecule in panels (b), (c), and (d) of the myosin micrograph.

For the duration of the clip there was a projected image of myosin molecules. The scientist stood in front of the left side of the projected image. The interviewer sat in front of and just to the left of the image; his general body and face angles were described. The white and black arrows indicated the scientist's hand and arm movements.

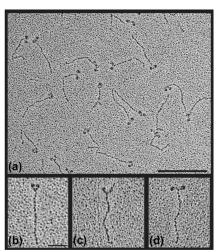


Figure H.1: Myosin molecule image.

Below is the transcript from the entire clip.

Scientist: And so, these are the sorts of orientations that I typically go for when I measure because there's a lot less bending and, um, torsion that's taking place which can, potentially, influence the length if you stretch or bend a molecule.

Image	Time	Language	Image & Description
#	Point	<i>a</i>	
1	00:00	(beginning)	
			The scientist's right hand across was at the front of his waist and under
			his left arm. His left hand was bent at the elbow and his forearm was
			directed away from his body and approximately parallel to the floor.
			The index and middle fingers of his left hand were extended and pointed
			to the myosin in panel (c). The other fingers were tucked in. He gazed
	TD1		toward the screen.
			ning posture could have been how he attracted the interviewers attention
			ale in panel (c).
2	00:00	And <u>so</u>	The scientist retained his body position except for the index and middle fingers on his left hand. He moved them together so that they were still extended but their sides touched one another. The scientist's gaze remained toward the screen.
	By bri	nging his finge	ers together the scientist could have been clarifying his pointing direction
			convergent line rather than two divergent lines of direction as in Line 1.

Figure H.2: Clip F3 gesture analysis.

Image	Time	Language	Image & Description
#	Point		
3	00:00	these	
			The scientist's right arm did not move. The scientist retracted his left
			index and middle fingers and changed his hand shape to a loose fist.
			Simultaneously, he moved his left hand toward his body so that his fist
			was aligned over the middle of the panel (b) myosin tail. The scientist's
	The go	iontist probabl	gaze remained toward the screen. y used this general motion, that is without the specific use of fingers, to
			osin in panel (b) was part of the group included when he used the term,
	"these.		osin in paner (b) was part of the group included when he used the term,
4	00:01	are the sorts	The scientist did not move his right arm. He maintained his left arm and hand shape but moved his left hand to the approximate middle of the myosin in panel (c). The scientist's gaze remained toward the screen.
			scientist's loose fist hand shape could have been his new alternative to based method of pointing.

Figure H.2: Clip F3 gesture analysis, continued.

Image #	Time Point	Language	Image & Description
5	00:02		The scientist did not move his right arm but his left arm moved away from his body so that his right hand was exposed. The scientist's body slightly rotated away from the screen. He maintained his left arm and hand shape and began to move it toward the myosin in panel (d). The scientist's gaze remained toward the screen. scientist is calling upon the rhythm of his language to enhance his
	panel (anation and needed to rotate his body in order to reach far enough toward as clear that that was the molecule to which he was referring. (See Lines 4
6	and 6) 00:02	tions ssible that the	The scientist's body position, in reference to the screen, did not change. He slightly dropped his right arm so that it was still bent at the elbow and the forearm was approximately 45 degrees from horizontal. The scientist's left arm remained extended and he extended his index and middle fingers. The scientist's gaze remained toward the screen. scientist extended his fingers as a way to more clearly indicate the
			erring to because it was out of direct reach.

Figure H.2: Clip F3 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
7	00:03	that I typically	The scientist fully dropped his right arm to his side. He moved his left hand, with its index finger extended, so that it aligned with the middle of the myosin tail in panel (c). The scientist's gaze remained toward the screen.
	Since	this is the third	d time that the scientist pointed out this molecule in this clip, it is likely
			e characteristic that is critical to his explanation.
8	00:03	go for	The scientist's right arm remained by his side. The scientist kept his left hand shape and aligned his index finger with the middle of the myosin tail in panel (b). The scientist's gaze remained toward the screen.
9	See lii 00:04	when I measure	The scientist's right arm remained by his side. The scientist kept his left hand shape and aligned his index finger with the bottom third of the myosin tail in panel (b). The scientist's gaze remained toward the screen.
			th time that the scientist pointed out this molecule in this clip, it is likely
	that it l	nas at least one	e characteristic that is critical to his explanation.

Figure H.2: Clip F3 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point	Dangaage	mage & Description
10	His mo		His right arm remained by his side. He dropped his left arm so it was also to his side. The scientist's gaze remained toward the screen. of verbalization could have indicated a transition of ideas in his
	explan		
11	00:06	because there's a lot less bending	
			His right arm remained by his side. He raised his left arm, with the index finger extended, and pointed at the head region of a myosin molecule in
	This n	l art of the expl	panel (a). The scientist's gaze remained toward the screen. anation appears to be about the types of molecules in panel (a), the field
			re of the same genetic background but in different physical conformations.
12	00:07	(pause)	
			The scientist's right arm remained down by his side. His left arm and hand remained in their position. The scientist traced the first two-thirds of the tail of the molecule that he pointed to in the previous image (line 11). The scientist's gaze remained toward the screen.
			bint out myosin molecules with tails that were not straight, he could have
			the different structures affected his data. The pause could have suggested change the topic he was explaining. He traced from the head of the
			change the topic he was explaining. He traced from the head of the molecule as its beginning.
		- ··· , <u>r</u>	,

Figure H.2: Clip F3 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
13	00:08	<u>and</u>	The scientist's right arm remained down by his side. The scientist lowered his left hand from the end of the molecule he had been pointing to. His left hand shape changed to a loose fist. The scientist's gaze
			remained toward the screen.
			e in hand shape could have been an intermediate posture that he used
			different molecules. His use of a conjunction, "and," suggests that he is
)	etween two d	ifferent molecules.
14	00:08	<u>um</u>	The scientist's right arm remained down by his side. The scientist lowered his left arm so that his elbow was bent and his left hand was at the height of his left shoulder. His hand shape remained the same. The scientist's gaze remained toward the screen.
			mporal space-filling utterance between the scientist's pointing to two
	differe	nt molecules.	(Also, see line 13)

Figure H.2: Clip F3 gesture analysis, continued.

Image #	Time Point	Language	Image & Description
15	00:08	torsion	E
			The scientist's right arm remained down by his side. The scientist moved his left hand in a small circular path and changed his hand to a pointing position with his index finger extended toward the head of a second molecule in panel (a). The scientist's gaze remained toward the screen.
	more p	recise with no nave been so tl	ave changed his hand shape from a loose fist to a pointing shape to be ting the position along the molecule. The scientist's circular hand motion hat he could start pointing out the molecule at its head region. He might
			oint when he was bringing his hand down from the previous molecule.
16	00:09	that's	The scientist's right arm remained down by his side. His left hand shape remained the same. His index finger pointed, briefly, to a location approximately three inches below and halfway down the tail of a third molecule in panel (a). The scientist's gaze remained toward the screen.
	he trace	ed what was o g the visible b	rew his finger down the straight part, the first two-thirds of the molecule, in the screen. However, his finger continued down the same trajectory, bend (at approximately the second skip residue) in the projected molecule race the tail as if it was not bent.

Figure H.2: Clip F3 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point	Lunguage	iniuge & Description
17	00:09	tak-	The scientist's right arm remained down by his side. His left hand shape remained the same. His index finger pointed toward the head of the third molecule (line 16) in panel (a). The scientist's gaze remained toward the screen.
	Unlike	the other mol	ecules he pointed out in panel (a), the scientist traced this straight
			head. This could have been because his previous tracing left his index
	finger closer to the tail of this next molecule rather than its head. Taken with line 16, the		
			onsecutive molecules that had either visible or invisible straight tails. This
		ntrast to the to	opic of his explanation about molecules with bent tails.
18	00:09	<u>-ing</u>	The scientist's right arm remained down by his side. His left hand shape remained the same and he pointed to, approximately, the same location
			as described in line 16. The scientist's gaze remained toward the screen.
	The sci	ientist's langu	age had a rhythm that synchronized with his movements. Perhaps this
			evement back to the location that he previously pointed out in line 16.

Figure H.2: Clip F3 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
19	00:10 He poi	which	His right arm stayed down by his side. His left hand shape stayed the same. His index finger indicated a point close to the head-tail junction of a fourth molecule in panel (a). His gaze remained toward the screen. ad of another bent molecule. Once again, pointing to the head of the
	molecu	ıle's head coul	d indicate that that is where he considers the molecule's beginning to be.
20			The scientist's right arm remained down by his side. His left hand shape remained the same. His index finger pointed to a bend near the first skip residue of the fourth molecule (line 19) in panel (a). The scientist's gaze remained toward the screen. Sule's curve, it is possible that he wanted to more clearly emphasize the particular molecule's tail. This could have been because he did not clearly
			e previous two molecules that he pointed to.
21	00:11	potentially	His right arm remained down by his side. His left hand shape remained the same. Still in panel (a), his index finger followed a small counterclockwise path to a point half-way between the bend (line 20) and the end of the fourth molecule's tail. His gaze remained toward the screen.
	(See lin	ne 21)	

Figure H.2: Clip F3 gesture analysis, continued.

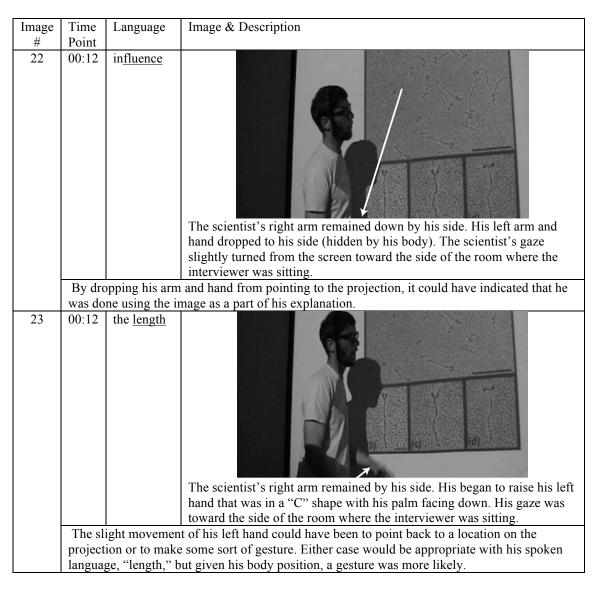


Figure H.2: Clip F3 gesture analysis, continued.

Image	Time	Language	Image & Description
24	Point 00:13	<u>if</u> you	
			At the same time, the scientist lifted his left and right arms in front of him so that they were at waist level. His hands shapes and movements were mirrored. Each hand was in an approximate "C" shape and he turned his hands in at the wrist so that each thumb faced toward the floor and each palm faced slightly away from his body. The scientist's gaze remained the same.
	hand sl	nape and motice, i.e. a myosii	his both hands and his gaze remained toward the side of the room. His on suggested that he was picking something up that was cylindrical and in tail. There was no gesture that suggested the existence of a myosin head
25	00:13	stretch	
			The scientist's arms were bent with his hands slightly above his elbows. He rotated his thumbs up so that his palms faced each other. His hands were in modified "C" shapes with his fingers slightly apart from one another. The scientist's hands were spaced about the width of his body. The scientist's gaze remained the same.
		eientist moved held increased	his hands away from one another so that the virtual cylindrical object/tail d in length.

Figure H.2: Clip F3 gesture analysis, continued.

Image	Time	Language	Image & Description
#	Point		
26	00:14	and <u>bend</u>	The cointist's arms remained in the companitions. His hand always
			The scientist's arms remained in the same positions. His hand shapes
			remained the same. He moved his hands so that his little fingers were touching at the midline of his body. The scientist's gaze remained the
			same.
	virtual		entist brought his hands together suggested that he previously held the ther end when he brought his hands together the resulting bend made a
27	00:15	the molecule (end)	The scientist dropped both arms to his sides. He turned to face the
			interviewer.
			ropped his hands it probably was an indication that he was done with that
			explanation. His turning to look at the interviewer supports this
	specula	ation.	

Figure H.2: Clip F3 gesture analysis, continued.

REFERENCES

- Airey, J., & Linder, C. (2009). A disciplinary discourse perspective on university science learning: Achieving fluency in a critical constellation of modes. *Journal of Research in Science Teaching*, 46(1), 27–49. doi: DOI: 10.1002/tea.20265
- Alač, M. (2008). Working with brain scans: Digital images and gestural interaction in fMRI laboratory. *Social Studies of Science*, *38*(4), 483-508.
- Allchin, D. (1999). Do we see through a social microscope?: Credibility as a vicarious selector. [Article]. *Philosophy of Science*, 66(3), S287-S298.
- Arvola, M., & Artman, H. (2007). Enactments in Interaction Design: How Designers Make Sketches Behave. *Artifact*, 1(2).
- Barber, A. I. (2005). Chaining Spaces. *Journal of Linguistic Anthropology*, 15(2), 194-217. doi: 10.1525/jlin.2005.15.2.194
- Barker, J. M. (2009). *The tactile eye : touch and the cinematic experience*. Berkeley: University of California Press.
- Baron-Cohen, S. (1995). The Eye Direction Detector (EDD), and the Shared Attention Mechanism (SAM): two cases of evolutionary psychology. In C.Moore & P.J.Dunham (Eds.), *Joint Attention: Its Origins and Role in Development* (pp. 41-59). Hillsdale, N.J. Lawrence Erlbaum Associates.
- Becvar, L. A., Hollan, J., & Hutchins, E. (2005). Hands as molecules: Representational gestures used for developing theory in a scientific laboratory. *Semiotica*, *156*(1-4), 89-112.
- Biederman, I. (1985). Human Image Understanding: Recent Research and a Theory. *Computer Vision, Graphics, and Image Processing, 32*, 29-73.
- Bonwell, C. C. (1996). Enhancing the lecture: Revitalizing a traditional format. *New Directions for Teaching and Learning, 1996*(67), 31-44. doi: 10.1002/tl.37219966706
- Borghi, A. M., & Cimatti, F. (2010). Embodied cognition and beyond: Acting and sensing the body. *Neuropsychologia*, 48(3), 763-773.
- Botzer, G., & Yerushalmy, M. (2008). Embodied semiotic activities and their role in the construction of mathematical meaning of motion graphs. *International Journal of Computers for Mathematical Learning*, 13(2), 111-134.

- Burri, R. V., & Dumit, J. (2008). Social Studies of Scientific Imaging and Visulization. In E. J. Hackett, O. Amsterdamska, M. Lynch & J. Wajcman (Eds.), *The Handbook of Science and Technology Studies* (Third ed., pp. 297-317). Cambridge, Massachusetts: MIT Press.
- Chen, C.-L., & Herbst, P. (2007). *The interplay among gestures, discourse and diagrams in students' geometrical reasoning.* Paper presented at the 29th Annual Conference of the North American Chapter of the International Group for the Psychology of Mathematics Education, Lake Tahoe, NV.
- Clark, H. H., & Marshall, C. R. (1981). Definite reference and mutual knowledge. In A. K. Joshi, B. Webber & I. Sag (Eds.), *Elements of discourse understanding* (pp. 10-63). Cambridge: Cambridge University Press.
- de Chadarevian, S., & Hopwood, N. (2004). *Models: the third dimension of science*. Stanford, Calif.: Stanford University Press.
- de Vries, E. (2006). Students' construction of external representations in design-based learning situations. *Learning and Instruction*, 16(3), 213-227.
- Emmorey, K., & Casey, S. (2001). Gesture, thought and spatial language. *Gesture*, I(1), 35-50. doi: 10.1075/gest.1.1.04emm
- Feagin, J. R., Orum, A. M., & Sjoberg, G. (1991). *A Case for the case study*. Chapel Hill: University of North Carolina Press.
- Flores, M. (2005). The Alchemy of Art: Transforming Student Art into Science Knowledge in the Chemistry Classroom. *Science Teacher*, 72(1), 48-49.
- Flyvbjerg, B. (2006). Five Misunderstandings About Case-Study Research. *Qualitative Inquiry, 12*(2), 219-245.
- Gooding, D. C. (2004). Cognition, Construction and Culture: Visual Theories in the Sciences. *Journal of Cognition & Culture*, 4(3/4), 551-593.
- Gooding, D. C. (2005). Seeing the Forest for the Trees: Visualization, Cognition, and Scientific Inference. In D. C. Gooding, M. E. Gorman, R. D. Tweney, D. C. Gooding & A. P. Kincannon (Eds.), *Scientific and technological thinking*. (pp. 173-217). Mahwah, NJ US: Lawrence Erlbaum Associates Publishers.
- Goodwin, C. (1994). Professional vision. American Anthropologist, 96(3), 606-633.
- Goodwin, C. (1995). Seeing in Depth. *Social Studies of Science*, *25*(2), 237-274. doi: 10.1177/030631295025002002

- Hadar, U., & Krauss, R. K. (1999). Iconic gestures: the grammatical categories of lexical affiliates. *Journal of Neurolinguistics*, *12*(1), 1-12. doi: 10.1016/s0911-6044(99)00001-9
- Hansen, Y. M. (1990). *A formative evaluation study: Development of a graphic handbook to promote visual thinking in adults.* (51), ProQuest Information & Learning, US. Retrieved from http://libproxy.sdsu.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=1991-51898-001&site=ehost-live
- Haviland, J. B. (2000). Pointing, gesture spaces, and mental maps *Window into thought and action* (pp. 13-46). Cambridge: Cambridge University Press.
- Hegarty, M., Mayer, S., Kriz, S., & Keehner, M. (2005). The Role of Gestures in Mental Animation. *Spatial Cognition & Computation*, 5(4), 333-356.
- Heiser, J., Tversky, B., & Silverman, M. (2004). Sketches for and from collaboration. In J. S. Gero, B. Tversky & T. Knight (Eds.), *Visual and spatial reasoning in design III* (pp. 69-78). Sydney: Key Centre for Design Research.
- Holler, J., & Stevens, R. (2007). The Effect of Common Ground on how Speakers use Gesture and Speech to Represent Size Information. *Journal of Language and Social Psychology*, 26(1), 4-27.
- Hostetter, A. B., & Alibali, M. W. (2008). Visible embodiment: Gestures as simulated action. *Psychonomic Bulletin & Review, 15*(3), 495-514.
- Hutchins, E. (2001). Distributed cognition. In N. J. Smelser & P. B. Baltes (Eds.), *International encyclopedia of the social & behavioral sciences* (pp. 2068-2072). Amsterdam; New York: Elsevier.
- Jucks, R., Bromme, R., & Runde, A. (2007). Explaining with Nonshared Illustrations: How They Constrain Explanations. *Learning and Instruction*, 17(2), 204-218.
- Kavakli, M., & Gero, J. S. (2001). Sketching as mental imagery processing. *Design Studies*, 22(4), 347-364.
- Keller, T., Gerjets, P., Scheiter, K., & Garsoffky, B. (2004). *Information visualizations* for supporting knowledge acquisition: The impact of dimensionality and color coding. Paper presented at the 26th Annual Meeting of the Cognitive Science Society, Chicago, IL.
- Knorr-Cetina, K., & Amann, K. (1990). Image Dissection in Natural Scientific Inquiry. *Science, Technology & Human Values, 15*(3), 259-283. doi: 10.1177/016224399001500301

- Korakakis, G., Pavlatou, E. A., Palyvos, J. A., & Spyrellis, N. (2009). 3D visualization types in multimedia applications for science learning: A case study for 8th grade students in Greece. *Computers & Education*, *52*(2), 390-401.
- Kozma, R. (2003). The material features of multiple representations and their cognitive and social affordances for science understanding. *Learning & Instruction*, 13(2), 205.
- Kozma, R., & Russell, J. (1997). Multimedia and understanding: Expert and novice responses to different representations of chemical phenomena. *Journal of Research in Science Teaching*, *34*, 949-968.
- Latham, K. F. (2009). *Numinous experiences with museum objects*. (Doctor of Philosophy), Emporia State University, Emporia, Kansas. (Publication No. AAT 3357980)
- Lavergne, J., & Kimura, D. (1987). Hand movement asymmetry during speech: No effect of speaking topic. *Neuropsychologia*, 25(4), 689-693. doi: 10.1016/0028-3932(87)90060-1
- Leeds-Hurwitz, W. (2005). Ethnography. In K. L. Fitch & R. E. Sanders (Eds.), Handbook of language and social interaction (pp. 327-353). Mahwah, N.J.: Lawrence Erlbaum Associates.
- Leonelli, S. (2009). Understanding in Biology: Nature of Biological Knowledge. In H. W. d. Regt, S. Leonelli & K. Eigner (Eds.), *Scientific Understanding: Philosophical Perspectives*. University of PittsburghPress: Pittsburgh.
- Logothetis, N. K., & Sheinberg, D. L. (1996). Visual object recognition *Annual Review of Neuroscience* (Vol. 19, pp. 577-621).
- Lowe, R. K. (1995). Selectivity in diagrams: Reading beyond the lines. *Educational Psychology: An International Journal of Experimental Educational Psychology, 14*(4), 467 491. Retrieved from http://libproxy.sdsu.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=9501244969&site=ehost-live
- Lynch, M. (1985a). Art and artifact in laboratory science: A study of shop work and shop talk in a research laboratory. London: Routledge and Kegan Paul.
- Lynch, M. (1985b). Discipline and the material form of images: An analysis of scientific visibility. *Social Studies of Science*, *15*(1), 37-66.

- Lynch, M. (1998). The production of scientific images: Vision and re-vision in the history, philosophy, and sociology of science. *Communication & Cognition*, 31(2-3), 213-228.
- MacEachren, A. (1992). Visualizing uncertain information. [skimmed]. *Cartographic Perspectives*, 10-19.
- MacEachren, A., & Kraak, M.-J. (1997). Exploratory cartographic visualization: Advancing the agenda. *Computers and Geosciences*, 23, 335-343.
- Maniatis, L. M. (2008). *The physical logic of visual perception*. (69), ProQuest Information & Learning, US. Retrieved from http://libproxy.sdsu.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2009-99020-472&site=ehost-live
- Mathewson, J. H. (2005). The visual core of science: Definition and applications to education. *International Journal of Science Education*, 27(5), 529-548.
- Maturana, H. R. (1991). Science and daily life: The ontology of scientific explanations. In F. Steier (Ed.), *Research and reflexivity* (pp. 30-52). Thousand Oaks, CA US: Sage Publications, Inc.
- Maxwell, J. A. (2009). Designing a qualitative study. In L. Bickman & D. J. Rog (Eds.), *The SAGE Handbook of Applied Social Research Methods* (2nd ed., pp. 214-253). Thousand Oaks, CA: Sage Publications.
- Mayer, K. (2011). Scientific images? How touching! 2011, 7(1).
- Mayer, R. E. (1989). Cognitive views of creativity: Creative teaching for creative learning. *Contemporary Educational Psychology*, 14(3), 203-211.
- Myers, N. A. (2008). Modeling proteins, making scientists: An ethnography of pedagogy and visual cultures in contemporary structural biology. *Dissertation Abstracts International Section A: Humanities and Social Sciences, 68*.
- Myers, N. A. (2012). Dance Your PhD: Embodied Animations, Body Experiments, and the Affective Entanglements of Life Science Research. *Body & Society,* 18(1), 151-189. doi: 10.1177/1357034x11430965
- Nathan, M. J., & Kim, S. (2007). Pattern generalization with graphs and words: A cross-sectional and longitudinal analysis of middle school students' representational fluency. . *Mathematical Thinking And Learning*, 9(3), 193-219.
- Nemirovsky, R., Tierney, C., & Wright, T. (1998). Body Motion and Graphing. *Cognition and Instruction*, *16*(2), 119-172.

- Noble, T., Nemirovsky, R., Dimattia, C., & Wright, T. (2004). Learning to See: Making Sense of the Mathematics of Change in Middle School. *International Journal of Computers for Mathematical Learning*, *9*(2), 109-167. doi: 10.1023/B:IJCO.0000040891.50250.7e
- Nuñéz, Rafael E., Edwards, L. D., & Matos, J. F. (1999). Embodied Cognition as Grounding for Situatedness and Context in Mathematics Education. *Educational Studies in Mathematics*, 39(1-3), 45-65.
- O'Halloran, K. L. (2009). Multimodal Analysis and Digital Technology. In A. Baldry & E. Montagna (Eds.), Interdisciplinary perspectives on multimodality: Theory and practice. Proceedings of the Third International Conference on Multimodality. Campobasso
- : Palladino. Retrieved from http://multimodal-analysis-lab.org/?page_id=217.
- Ochs, E., Jacoby, S., & Gonzales, P. (1994). Interpretive Journeys: How Physicists Talk and Travel through Graphic Space. *Configurations*, 2(1), 151-171. doi: DOI: 10.1353/con.1994.0003
- Palmer, S. E. (1977). Fundamental aspects of cognitive representation. Hillsdale, NJ: LEA.
- Richardson, D. C. (2003). *Embodied cognition: The psychological processes of a situated mind*. (Ph.D.), Cornell University, United States -- New York. Retrieved from http://libproxy.sdsu.edu/login?url=http://proquest.umi.com/pqdweb?did=76569 0371&Fmt=7&clientId=17862&RQT=309&VName=PQD
- Rosenfeld, L. W. (1980). The practical celebration of the epideictic. In E. E. White (Ed.), *Rhetoric in transition: studies in the nature and uses of rhetoric* (pp. 131-155). University Park: Pennsylvania State University Press.
- Rosset, A., Spadola, L., & Ratib, O. (2004). OsiriX: An Open-Source Software for Navigating in Multidimensional DICOM Images. *Journal of Digital Imaging*, 17(3), 205-216.
- Roth, W.-M. (1994). Thinking with Hands, Eyes, and Signs: MultiModal Science Talk in a Grade 6/7 Unit on Simple Machines. *Interactive Learning Environments*, 4(2), 170-187. doi: 10.1080/1049482940040204
- Roth, W.-M. (2001). Gestures: Their Role in Teaching and Learning. *Review of Educational Research*, 71(3), 365-392. doi: 10.3102/00346543071003365

- Roth, W.-M., & Bowen, G. M. (1998). Decalages in Talk and Gesture: Visual and Verbal Semiotics of Ecology Lectures. *Linguistics and Education*, 10(3), 335-358. doi: 10.1016/s0898-5898(99)00012-1
- Roth, W.-M., & Bowen, G. M. (1999). Complexities of graphical representations during ecology lectures: an analysis rooted in semiotics and hermeneutic phenomenology. *Learning and Instruction*, *9*(3), 235-255. doi: 10.1016/s0959-4752(98)00029-2
- Roth, W.-M., & Bowen, G. M. (2001). Professionals read graphs: A semiotic analysis. *Journal for Research in Mathematics Education*, 32(2), 159-194.
- Roth, W.-M., & Lawless, D. V. (2002). When up is down and down is up: Body orientation, proximity, and gestures as resources. *Language in Society, 31*(1), 1-28. doi: 10.1017/s004740450200101x
- Roth, W.-M., McGinn, M. K., & Bowen, G. M. (1998). How Prepared Are Preservice Teachers to Teach Scientific Inquiry? Levels of Performance in Scientific Representation Practices. *Journal of Science Teacher Education*, *9*(1), 25-48. doi: 10.1023/a:1009465505918
- Roth, W.-M., McGinn, M. K., Woszczyna, C., & Boutonne, S. (1999). Differential Participation During Science Conversations: The Interaction of Focal Artifacts, Social Configurations, and Physical Arrangements. *Journal of the Learning Sciences*, 8(3-4), 293-347. doi: 10.1080/10508406.1999.9672073
- Roth, W.-M., & Tobin, K. (1997). Cascades of inscriptions and the re presentation of nature: how numbers, tables, graphs, and money come to re present a rolling ball. *International Journal of Science Education*, *19*(9), 1075-1091. doi: 10.1080/0950069970190906
- Scholl, B. J. (2001). Objects and attention: The state of the art. *Cognition*, 80(1-2), 1-46
- Schwartz, D. L. (1995). The emergence of abstract representations in dyad problem solving. *Journal of the Learning Sciences*, *4*(3), 321-354.
- Shields, C. M. (2007). Can case studies achieve the "Gold Standard"? Or when methodology meets politics. Paper presented at the Annual Meetin of the American Educational Research Associationo, Chicago, Illinois.
- Streeck, J. (2008). Depicting by gesture. [Article]. Gesture, 8(3), 285-301.
- Trickett, S. B., Trafton, J. G., Saner, L., & Schunn, C. D. (2007). 'I don't know what's going on there': The use of spatial transformations to deal with and resolve

- uncertainty in complex visualizations. In M. C. Lovett & P. Shah (Eds.), *Thinking with data* (pp. 65-85). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.
- van Amelsvoort, M., Andriessen, J., & Kanselaar, G. (2007). Representational tools in computer-supported collaborative argumentation-based learning: How dyads work with constructed and inspected argumentative diagrams. *Journal of the Learning Sciences*, 16(4), 485-521.
- Varela, F. J., Thompson, E., & Rosch, E. (1991). *The embodied mind : cognitive science and human experience*. Cambridge, Mass.: MIT Press.
- Vekiri, I. (2002). What is the value of graphical displays in learning? *Educational Psychology Review*, 14(3), 261-312.
- Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review*, 9(4), 625-636.
- Wilson, R. A., & Foglia, L. (2011). Embodied Cognition. In E. N. Zalta (Ed.), *The Stanford Encyclopedia of Philosophy* (Fall 2011 ed.).
- Yin, R. K. (2003). *Case Study Research: Design and Methods*. Thousand Oaks, Calif.: Sage Publications.