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Studies to Inform a Visual Language for Authoring Interactive Exercise Prescriptions

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Communicating dynamic motion content, such as exercise, with a static medium, such as paper, is difficult. The technology exists for presenting 3D animated exercise content to patients; however, the tools for allowing exercise domain experts to effectively author the content do not exist. We conducted two formative studies with exercise science domain experts to discover the requirements for an exercise prescription authoring notation. Based on our findings, we implemented a prototype notation and performed a think-aloud study to understand its strengths and weaknesses. The results of our studies have implications for any software solution aimed at the authoring of physical activity content.

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Studies to Inform a Visual Language for Authoring Interactive Exercise Prescriptions

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Jonathan Dodge, Author

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Chapter 1 – Introduction

According to the Bureau of Labor Statistics, there were over 400,000 Physical Therapists and Fitness Workers employed in the U.S. in 2006 [1, 2]. Consumers of these services are not often experts in the exercise domain, and their inexperience can be potentially harmful if they perform exercises incorrectly, possibly aggravating an existing injury, or even causing a new one. However, it is important to note that the time of clinicians, such as physical therapists, athletic trainers, and personal trainers, can become quite expensive if the client desires supervision every single time they exercise. Although in cases of extreme injury, it may be advisable to seek full supervision, in many other cases, experts demonstrate exercises for the novices to perform *on their own*. To illustrate, clinician prescribed, home-based, individualized exercise programs have proven to be successful in reduction of fall risk in aging adults [3, 4].

Properly performing an exercise can be a difficult task, so various support mechanisms exist in order to help ensure that the client remembers how to properly perform the exercise. Paper handouts have been used by physical therapists to communicate exercise prescriptions for many years. Typically, these handouts feature pictures and descriptions of the exercises chosen by the clinician. Unfortunately, it can be very difficult to convey information about the dynamic performance of an exercise using a static medium.

Elsewhere in the fitness industry, exercise videos have long been a staple for the explanation of how to perform a particular exercise routine. Most video-based content is not intended to allow a clinician to customize the content to meet the specific needs of a particular client who may require specialized exercises or instruction. While animated sequences and videos may be more effective in showing the desired motion than static illustrations, they can only offer the specific videotaped point of view and the costs associated with producing videos or manually generated animations are relatively high. Fitness video games have some advantages over traditional video, such as user-selected exercises and camera views. However, as with videos, there is no expert supervision available in these products to ensure that a user is strong and healthy enough to perform certain exercises safely, which makes them poorly suited for use in rehabilitation.

Hence, there exists a need for tools that domain experts can use to efficiently develop interactive, individualized, and kinematically correct exercise regimens that may be accessed efficiently by their clients. Further, incorporating the ability to evaluate the client can provide invaluable information for the clinician. In this paper, we present a series of studies that we conducted to inform the design of an exercise authoring and viewing environment that uses motion capture data to convey 3D animated exercise motion to exercisers, as well as a prototype system for performing these tasks. The series of studies includes: **1)** Case Study (Single case, Holistic), **2)** Pencil and Paper Study, and **3)** Think-aloud Study.

Chapter 2 – Related Work and Background

Recently, several popular applications presenting exercise content have surfaced, namely *Wii Fit*™ (Nintendo of America, Inc., Redmond, WA) and *Yourself! Fitness*™ (responDESIGN, Inc., Portland, OR). Both of offer dynamic content with the benefit of user interactivity, allowing for user-selected exercises and camera views. These products do not provide mechanisms for clinicians to customize the exercise regimens for clients, making them poorly suited for use as in-home rehabilitation tools. However, a recent article in PT Magazine indicates that *Wii Sports*™ is being used in some clinics, with positive early results [5]. Most of the research on these systems focuses on how they can effectively present motion to the user, rather than providing the clinician with effective control of the content [6]. As such, our studies will focus on the needs of the clinician instead of the needs of the client.

Fitness video games contrast sharply with the existing content creation systems used by clinicians, which are mostly targeted toward the creation of static media. Existing systems make a much larger array of targeted exercises available to the clinician than are available in fitness games, but the content is much less interactive. Visual Health Information (VHI) is a fitness company that has been selling this type of content to fitness and health professionals since 1980. While VHI initially sold “consumable pads of tear-off information sheets,” in 1991 they began selling collections of cards, which could be composed and reproduced via a copy machine [7]. In 1999, the card collections became available in a digital format, allowing a clinician to use their software to compose exercises and print the results without requiring a copy machine. A recreation of such a card is shown in Figure 2.1. In some of the most recent versions, VHI has also added animations to their library; however, these animations are not interactive. Other software solutions, such as Tools RG^{TM} (Isokinetics, Inc., De Queen, AR), are available to fitness professionals, but most are intended for the construction of paper printouts. Note that we would like to provide 3D interactive media, but investigating existing tools for a similar task helped to inspire aspects of the prototype design.

Dance choreographers have been using Labanotation for many years to represent dance movement symbolically [8]. This notation is very low level and is designed for dance experts to record the movement in enough detail to be read

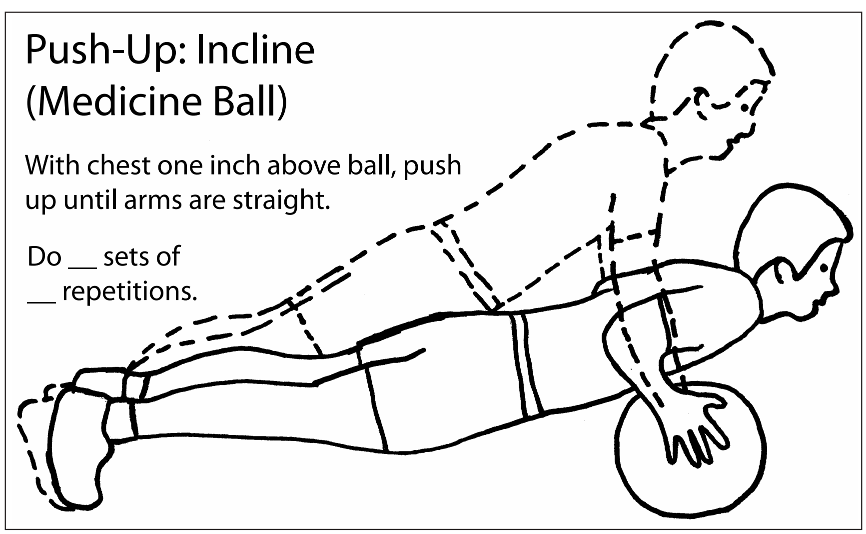


Figure 2.1: A recreation of an electronic “card” from VHI

and re-enacted by another expert, much like music notation. Calvert has done extensive work creating a software interface designed to support choreography, providing insight into the lessons learned during development in a 1993 paper [9]. Additionally, a recent publication by Hachimura and Nakamura has demonstrated that it is possible to extract dance notation from motion capture data, which may have implications for procedurally generating motion [10]. While a low-level motion description is not desirable for authoring exercise regimens that are compositions of already recorded motion capture sequences, they may have implications for editing a particular captured motion sequence.

The computer animation field of research has explored methods for generating motion for many years and the techniques generally fall into three categories: keyframe animation, physical simulation, and motion capture animation [11]. Keyframe animation requires a skilled animator and is therefore not appropriate for end-users, such as a clinician. Even in a system intended to allow novices to perform 3D agent programming, such as ALICE, an animator must prepare some predefined keyframe animations [12]. While this tool has been very successful in pedagogical situations, it is intended primarily as a means for teaching programming and is therefore not suited to our particular audience. Physical simulation is a preferred approach for animating passive objects, such as a kite, but is generally not used for human character motion. Motion capture is a technique that allows for recording movement and translating the movement onto a digital model and has long been used as a means of conveying human motion information in the film and video game industries.

Motion capture offers advantages over traditional video for communicating exercise because the camera can be moved by the user, and the character can be presented with various meshes and skins applied to it, allowing for customization. Additionally, when compared with traditional video, motion capture is not as sensitive to lighting conditions to produce a high quality of output. This technique is preferable for exercise prescription because the motion can be recorded from an expert performing exercises with correct form. A motion sequence for a particular exercise can then be used as a component in a library from which a clinician can compose a larger exercise regimen. Motion capture marker data can be obtained with great accuracy, as Windolf et al. report an accuracy of 63±5 micrometers on a Vicon-460 system (Vicon, Oxford, UK) [13]. It should be noted that motion capture is used in biomechanics, so the resolution and physical realism obtained via motion capture are appropriate for the presentation of exercise motion.

Further, clinicians have little programming experience and a large body of domain specific knowledge. The natural programming approach seeks to discover a user's natural tendencies in order to maintain a close mapping between the user's mental plan and the notation used to express the plan. Additionally, Myers notes that in natural programming, attention must be paid to the metaphor on which the language is based, as well as how abstraction, terminology, and other constructs, such as iteration, should be represented [14]. Thus, we designed the paper and pencil study to be similar in format to the studies conducted by Pane [15].

According to J.H. Wilmore, an exercise prescription "...is based on the individual's exercise capacity and includes a definition of the type, frequency, duration, and intensity of exercise" [16]. Type is a description of the kind of movement to be performed and frequency describes how often exercises sessions should occur. Duration represents how long the exercise should last, while intensity describes how much energy should be spent. From this description, it is possible to suggest a data structure to store a prescription, but this alone is not sufficient for an interactive application. It is necessary to discover how prescriptions are constructed, as well as how they are manipulated, and how they change over time. One important way that prescriptions may change over time is through "modifications" and "progressions," which are different ways of performing a similar exercise to challenge the client less or more, respectively.

Chapter 3 – Case Study

It can be difficult to design a study without some basic knowledge about the domain. Thus, we began by observing exercise science classes, using existing software designed to support clinicians, and participating in exercise science research projects. None of these tasks was aimed at determining the answers to any research questions, but rather building a knowledge base to allow for the asking of good questions later in the research, and thus were not documented. After this preparation, we chose to conduct a single case, holistic Case Study because they afford an opportunity to observe the tasks currently performed by the study population, without requiring excessive domain knowledge.

Prior to performing any observations, we held a preliminary meeting between the two researchers, the patient (*P*), and an athletic trainer (*T1*). During this time, we obtained proper consent documentation, discussed the planned observations, and scheduled the first observation. The data collected includes handwritten notes from three observations and an interview with *T1*, as well as paper documents used in the interaction. All three observations were made within two weeks of the first observation. No recording devices were employed during observation or interview. Our Case Study was aimed at answering the following research question:

> **What are the information needs of patients and clinicians during the exercise prescription process?**

3.1 Observations

Observation 1, Diagnosis The first observation was set in an athletic trainer's office. During the observation, *T1* evaluated *P* and determined a diagnosis. Then, *T1* provided a very high level explanation of the diagnosis and the prescription to *P*. After the observation was finished, the researchers performed a semi-structured interview of *T1*. Table 3.1 summarizes the individuals present for each observation.

Observation 2, Trainer Meeting During the second observation, *T1* met with a personal trainer under his employ (*T2*) in the same office to pass along the diagnosis, and proposed plan for treatment. After this meeting, *T2* assumed the responsibility for conveying the prescribed exercises to *P*.

Observation 3, Exercise Demonstration During the third observation, *T2* demonstrated the prescribed exercises to *P* in a gym setting. *P* was then given the opportunity to try them out with supervision and cueing. During this time, *T2* encouraged *P* to ask any questions that arose.

Table 3.1: Participants present during each Observation from the Case Study

#	Observation	Patient	Primary clinician	Secondary clinician
1	Diagnosis	*P*	*T1*	
2	Trainer Meeting		*T1*	*T2*
3	Exercise Demonstration	*P*		*T2*

3.2 Analysis

Upon conclusion of observations, we performed open coding on the data. Each of the two researchers who performed observation separately determined a set of categories that could be used to classify statements made and actions taken during the observations. Then, the researchers met and devised the final set of codes, which we used to perform selective coding on the data. Using the final code set and the selective coding, we began to devise hypotheses. No agreement calculations were performed on the data obtained during the Case Study. Refer to *Appendix A* for a listing of the codes, with descriptions.

3.3 Hypotheses

Our main discovery from the Case Study was that the core category in our data was **Communication**. In fact, at one point during Observation 3, *T2* commented:

> "...our entire job is based on communication.
> If they don't understand, there is no point."

Communication is extremely important because most of the time spent exercising is done in the absence of the trainer. Not only must the clinician communicate *what* to do, but *how* to do it in order to avoid injury and effect progress for the client. Note that in Observation 1, *T1* discovered some diagnostic information, then passed it along to *P* at a high level of abstraction. During Observation 2, *T1* gave the same information to *T2* in more detail. Finally, during Observation

3, *T2* provided great detail about each exercise to inform *P* about proper exercise performance. As *P* performed each exercise, *T2* gave near constant feedback to *P* in the form of repeated cues, as well as reasons why following the cues would prove beneficial. During each observation, various mechanisms were used to improve the quality of communication, such as providing time for questions, using forms to collect information, and clarifying technical details with an anatomical model. Note that much of the communication was intended to teach *P* about exercise, making it a form of expert to novice communication. However, expert to expert communication is an important concept that must also be considered because multiple clinicians may share the treatment of a single client, as was the case in our observations.

3.3.1 Use familiar concepts when demonstrating exercise

During Observation 1, *T1* used an anatomical model of a human knee to clarify to *P* the details of the diagnosis and treatment. The anatomical model allowed *T1* to point at something when jargon was inappropriate, as well as to teach a small number of technical terms that would prove helpful to *P*. Also in Observation 3, *T2* insisted that *P* write down the cues for each exercise after it was demonstrated. *T2* claimed that by having *P* write the cues it would not only eliminate problems that might arise from handwriting, but would also offer *P* the chance to rephrase the descriptions. Additionally, *T2* stated that writing might also help to reinforce the information in *P*'s mind.

There was a noticeable difference in the language used during Observation 2, where two experts discussed exercise, when compared with the language used during Observation 3, where an expert taught a novice. Expert to expert communication focused on groups of exercises, termed "protocols," rather than individual exercises or low level descriptions of an individual exercise. When an expert was communicating with a novice, protocol terminology was rarely used, instead providing very low level information on proper performance for individual exercises.

Since communication is so important to this interaction, a software system should have adequate help features to describe any terms or concepts used by the interface. In addition, if the system provides default descriptions of exercises, they should be at a fairly low level so that the client can understand them. This hypothesis is consistent with Nielsen and Molich's heuristic, "The system should speak the users' language," but is especially relevant since the expertise of the clinician and client differs so greatly [17].

3.3.2 Clinicians need to modify details of media

Paper handouts with pictures and descriptions of the exercises were notably absent from the artifacts used to communicate. When asked about this, *T1* indicated that the organization had purchased software to produce these handouts, but had stopped using it, stating:

> "...It doesn't allow me to modify anything. ...
> We started using it, but there were so many limitations that we stopped."

T1 indicated repeatedly that the diagrams and descriptions found in the software needed adjustment. To illustrate, *T1* showed an exercise that used a piece of equipment that, according to *T1*, was no longer on the market. Part of the need to modify media could be a result of changes to the recommended form of the exercises due to research in this field, but occasionally certain clients will require some special instructions.

A rival to this hypothesis is that clinicians only need to modify the parameters of the exercise, but this argument can be discarded because we have shown an example where the *type* or *form* of the motion needed to be changed. Another rival is that perhaps these details do not need to be *changed*, but rather just annotated for the client. Previously, we discussed the case of an exercise using equipment that is no longer available. In this example, annotation could not be used to make the content useful to the client, because the form of exercise must be changed. While these cases may be infrequent, other cases where adjustments are required were observed, such as in the use of protocols discussed in the next section.

Modification of descriptions allows the clinician to customize the content to meet the needs of a particular client. This can be beneficial because then the clinician is able to provide a consistent vocabulary for both office visits and home exercise. However, this places the burden of providing understandable descriptions of the exercise on the clinician, which may be time consuming.

3.3.3 Clinicians need to create reusable abstractions

During Observation 2, *T1* and *T2* spent their time discussing which "protocols" would be prescribed to *P*. In particular, *P* would be put on "modified lower extremity," "modified trunk," and "balance progression" protocols. Thus, clinicians create reusable abstractions, which loosely consist of a collection of exercises. On several occasions, the two clinicians discussed the removal of a particular exercise from the protocol for *P* due to risk factors. This implies that some protocols might not be appropriate for all people, and may need some adjustment, but presumably on a small scale.

It should be noted that *T2* is employed under *T1* and carries fewer certifications. This means that the clinicians might be using protocols for liability reasons, since *T2* carries less responsibility if restricted to enacting protocols created by *T1*. However, *T1* stressed the need for software to support the creation of protocols with great frequency, lending credibility to the hypothesis.

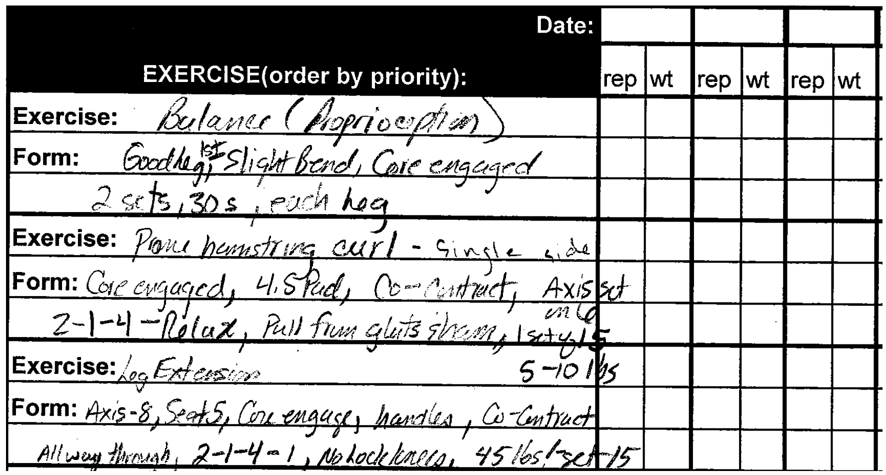
The creation of abstractions is an excellent way to avoid duplication of work, as well as promote reuse and manage complexity. A clinician may treat a number of people with the same injury, which can afford the opportunity for reuse. However, note that each person may have slightly different needs, so it should be possible to modify abstractions to be more individually tailored.

3.3.4 Clinicians need to monitor clients' risk factors and goals

During Observation 2, the first thing that *T1* communicated to *T2* was information about the "risk factors" of *P*, such as reconstructive surgery. Risk factors were among the information present on the document that *T1* and *T2* both referred to throughout the observation. After describing the results of the examination from Observation 1, *T1* began to identify the goals of the rehabilitation in terms of muscle groups to strengthen. To conclude the trainer meeting in Observation 2, *T1* mentioned to *T2* that *P*'s functional goal was "...to play basketball again." A potential rival explanation to this hypothesis is that risk factors and goals only need to be considered during the first visit, where the initial prescription is created. However, if a recurring client were to become injured again, the clinician should be made aware of it, which implies that risk factors need to be monitored over time. Similarly, once a goal is met, a new one should be created.

3.3.5 Clinicians need to change prescriptions over time

During Observation 3, *T2* presented each exercise with descriptions of how to make the exercise more challenging for *P*. For many exercises, challenge can be increased by simply performing more repetitions and sets, potentially with more weight. The "balance progression," however, was a notable exception in that the form of the exercise changed to make it still provide a challenge in the distant future. After Observation 3 was complete, *P* had a card with a list of the prescribed exercises, as well as cues for each exercise, shown in Figure 3.1. Note that the card contains cells



EXERCISE(order by priority): Date:	rep	wt	rep	wt	rep	wt
Exercise: Balance (Proprioception)						
Form: Good leg, 1st Slight Bend, Core engaged						
2 sets, 30 s, each leg						
Exercise: Prone hamstring curl - single side						
Form: Core engaged, 4.5 Pad, Co-contract, Axis set in 6						
2-1-4-Relax, Pull from glutes stream, 1 set 4 15						
Exercise: Leg Extension 5-10 lbs						
Form: Axis-8, Seat 5, Core engage, handles, Co-Contract						
All way through, 2-1-4-1, No lock knees, 45 lbs/set-15						

Figure 3.1: Portion of the card used to record exercise performance

to record the number of repetitions of each exercise and the date of performance. This information about the progress of the client could prove useful to a clinician trying to adjust a prescription for a recurring patient. Another application of the information logged on this card is to provide an indication to the client that they are actually getting stronger and healthier.

Clinicians who repeatedly see a large number of clients can benefit from a software system which helps them track their patients' information. Current systems for doing this are largely paper based, but it may prove helpful to have a software representation of a client's risk factors, goals, and current exercise prescription. As time passes, not only will the exercise prescription change, but the client's goals may change. Thus, having a history of the client's past exercise prescriptions, risk factors, and goals may help a clinician inform a new prescription. With this history, it might prove useful to log feedback from the user, since much of the cueing observed during Observation 3 was intended to elicit feedback from the patient.

3.4 Threats to Validity

Note that our Case Study attempts to assess the information needs of clinicians, which are not directly measurable because they are stored in clinicians' heads. Because of the need to use indirect methods of measurement, case studies usually take steps to help mitigate threats to validity. We used observations, interviews, and artifacts as multiple sources of evidence to provide extra reliability. In addition to this, we collected evidence following a case study protocol and stored it in a case study database.

The most major threat to construct validity was that in order to elicit *T1*'s participation, we had to provide specific background into the nature of our research and our ideas for potential software tools. During Observation 1, it was not infrequent for the topic at hand to drift into potential features for a software system, rather than a "normal" clinician-client interaction. Another threat to construct validity is that the observations had to be performed within set time periods, which made post-observation interviews a bit hurried at times.

Since our Case Study was exploratory in nature, we did not attempt to substantiate any causal relationships. Nonetheless we applied a grounded theory approach to the creation of hypotheses to help ensure that our inferences were based on solid evidence. In addition to this, we considered rival explanations in contrast to our hypotheses to help provide better internal validity [18].

Due to the fact that we followed a single case design, its external validity is inherently lower than if we had observed multiple cases. According to Yin, a researcher is most justified in using a single case design when the case is a *representative* one, but another justification can be that a case is *revelatory* or *unique*, among others [19]. To the best of our knowledge, no one has conducted a study like ours, so it could be described as revelatory. Also, our case is somewhat unique because observation opportunities were limited due to patient privacy rights.

Chapter 4 – Pencil and Paper Study

After performing the Case Study, we had answered some questions, but had generated many more. Based on our findings, we designed a lab study to further investigate the exercise prescription process, with an emphasis on the particular language and structure used by clinicians to communicate exercise prescriptions when the client is not present. To learn how domain experts use language to describe exercise, we chose to use a Pencil and Paper Study similar to that used by Pane to understand the language of novice programmers [15]. This approach is applicable for two reasons. First, while we consider our participants to be exercise domain experts, they are novices at directing a virtual character to perform an exercise regimen. Second, we hoped to learn more about the use of sketches and spatial organization used when describing an exercise regimen.

4.1 Population

We performed the study with 10 participants affiliated with the fitness or rehabilitation fields, with five participants of each gender. The participants included two physical therapists, two athletic trainers, three fitness instructors, two graduate students in sports medicine, and the owner of a fitness club. The participants were aged 36.7 ± 10.3 (Mean±SD), with 7.8 ± 6.9 years experience prescribing and

9.8 ± 7.8 years experience teaching exercise. Participants were labelled in chronological order, thus Participant A corresponds to the first participant outside the research team to respond to our questions.

4.2 Methods

All studies were performed in a quiet setting with two members of the research staff and one participant present. Most of the studies were conducted at Oregon State University, although one was conducted at a nearby hospital. No recording devices were used. Participants were given an overview of the process, then provided with an IRB informed consent form. After consent was granted, the participants were given 10 questions to work through. The questions were intended to discover more about the process that a clinician might carry out when creating an exercise prescription for a client, as well as how a prescription might be communicated to a client.

For the first four questions, the participant was asked to detail various aspects of devising a prescription and delivering it to a client. Then, the participant was introduced to a virtual character. Many of the remaining questions were framed in such a way as to have the participant "program" the character's behavior in demonstrating exercise. We felt that the use of an extra character with no sentience would make participants less inclined to write instructions without details which the participant would assume to be implicit in the responsibilities of a qualified trainer. A description of each question can be found in Table 4.1.

Table 4.1: Questions answered during the Pencil and Paper Study

#	**Question**
1	Devise a prescription based on a patient history
2	Describe when the client should exercise
3	Describe a specific exercise in detail
4	Describe the materials that a client would get
5	Describe the motion in a video clip (2 questions)
7	Describe when modifications/progressions should be used and how they are described
8	Describe how sensation cues should be conveyed
9	Describe when the client should cease an exercise
10	Provide further comments

Prior to gathering data from Participant *A*, we conducted several iterations of question generation and response within the research team to try to ensure that the questions were clear and would provide useful data. After preliminary analysis of responses from Participants *A*, *B*, and *C*, several edits were made to the study questions. These adjustments are documented in *Appendix C*, along with the coding results that are not presented in this chapter. In addition, a verbatim copy of the final questions is available in *Appendix B*, without space for responses.

4.3 Analysis

We analyzed the responses using an open coding approach. Since most questions were designed with a different goal in mind, we analyzed each question with an independent set of codes. Some questions had overlap in the code sets as a result of similarity between the two questions. For example, questions 5 and 6 were both intended to elicit a low level description of a motion. For each question, we developed a code set and two coders then independently coded a subset of the data. We used the Jaccard index to compute agreement since we allowed multiple codes to be assigned to an answer [20]. After iterating over the code set until reaching agreement of 88% or better on all coded questions, the code set was fixed and one researcher coded the rest of the data.

4.4 Results

Through the Pencil and Paper Study, we were able to determine how a prescription might be represented, as well as learn how they are created and manipulated. In addition, we learned some lessons about how a prescription should be communicated. We found the responses to the first question from the Pencil and Paper Study (Figure 4.1) to be particularly useful.

4.4.1 Prescription Organization

Many of the clinicians prefaced a prescription with important information. Half of our participants started a prescription with a list of goals and/or risk factors, as can be seen in Table 4.2. Presumably, this information was used by the participants to help guide them in choosing the specific exercises for the regimen. This discovery corroborates Hypothesis 4 from the Case Study: "Clinicians need to monitor clients risk factors and goals" (*Section 3.3.4*).

Please provide an exercise prescription for the person described below. Imagine the prescription as notes to yourself. Use as much space as you need. Feel free to give your prescription using words, diagrams, pictures, etc. - whatever works best for you. You may assume he is available to exercise 5 times a week for 45 minutes at each session.

> Bill Divine is 69 years of age and resides in his own home with his wife of 34 years. Bill would like to initiate an exercise program to reduce fall and fracture risk because he has been experiencing a steady decline in his balance abilities. He wears eyeglasses for reading only and has a hearing aid in his right ear. Because of his increasing balance problems he uses a single point cane on occasion when he is planning to be out for a good portion of the day. Bill reports no falls in the previous year, though he feels very unstable on uneven surfaces.

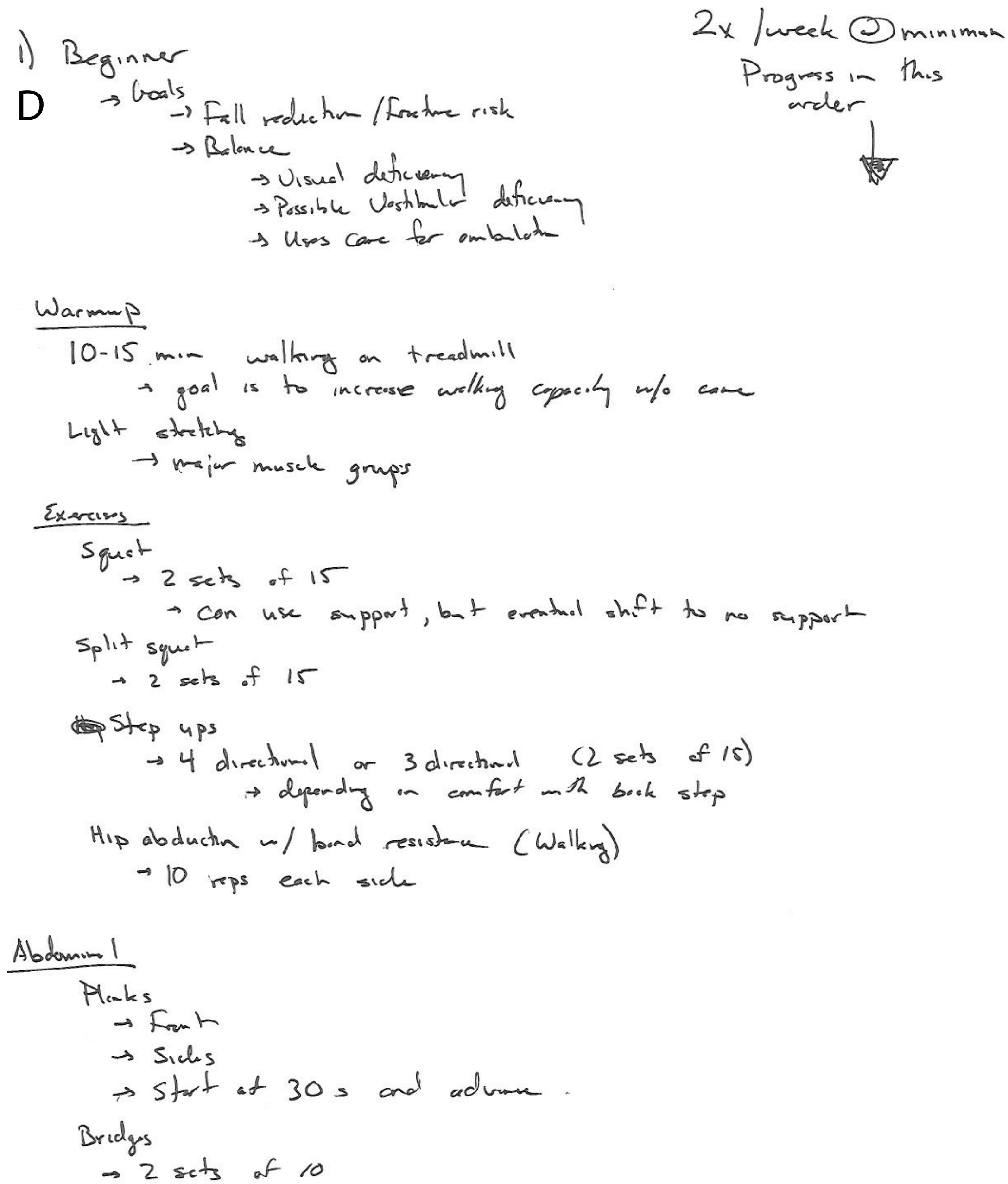
Figure 4.1: First question from the Pencil and Paper Study

There seem to be differences in the methodology used by clinicians to develop a prescription, including the ordering of exercises within a prescription. One participant completed the task by choosing a collection of exercises for the client, then subsequently arranging them in the desired order. This contrasts with four other subjects who chose exercises in the order that they wanted the client to perform them. Still, five others directly specified that their prescription could be done in any order. Typically, unordered prescriptions were very conservative prescriptions, and often provided by participants who were fitness instructors. These differences in problem solving technique made choosing a representation more difficult. Figure 4.2 shows an example prescription from Question 1 of the Pencil and Paper Study that was created in order and includes a list organization.

Table 4.2: Results for Question 1 - Create a Prescription

A	B	C	D	E	F	G	H	I	J	**Frequency and Code Description**	
x	x	x	x		x	x	x	x	x	9	Provided prescription as a list of exercises
	x	x	x	x				x	x	6	Provided an exercise parameterized by reps and sets
	x		x			x	x			4	Provided an exercise parameterized by time
						x				1	Provided an exercise to be done as long as possible
	x				x	x	x	x	x	6	Provided some safety instructions
	x					x	x	x	x	5	Provided some descriptions for exercises
			x		x	x		x	x	5	Provided an exercise with a progression
	x		x		x				x	4	Indicated that the number of reps and sets or time performed should change over time
		x	x					x	x	4	Provided a warmup
		x							x	2	Provided a cooldown
	x						x	x		3	Stressed symmetry in the performance of an exercise
	x									1	Specified rest periods
	x									1	Indicated that new exercises should be added in the future
x	x		x							3	Listed Risk factors before prescribing
			x	x	x	x				4	Listed Goals before prescribing
				x						1	Tailored workout to meet Goals
x			x	x	x			x	x	6	Tailored workout to touch on regions of the body
x	x			x	x		x			5	Prescription has no specified order
			x			x		x	x	4	Prescription was written in order
			x							1	Prescription was ordered as a post-process

Simple linear lists appear to be the preferred organizational method for exercise prescriptions. Table 4.2 demonstrates that most of the participants wrote out their prescription as a list of exercises. This contrasts with some current systems for paper handout production, where the prescription is presented on a 2-D grid substrate. Since systems exist using a “grid” representation, this was the first interaction metaphor that we considered using for the prototype. Note that making



2x /week @ minimum
Progress in this order

1) Beginner
D → Goals
→ Fall reduction / fracture risk
→ Balance
→ Visual deficiency
→ Possible Vestibular deficiency
→ Uses cane for ambulation

Warmup
10-15 min walking on treadmill
→ goal is to increase walking capacity w/o cane
Light stretching
→ major muscle groups

Exercises
Squat
→ 2 sets of 15
→ Can use support, but eventual shift to no support
Split squat
→ 2 sets of 15
Step ups
→ 4 directional or 3 directional (2 sets of 15)
→ depending on comfort with back step
Hip abduction w/ band resistance (Walking)
→ 10 reps each side

Abdominal
Planks
→ Front
→ Sides
→ Start at 30 s and advance.
Bridges
→ 2 sets of 10

Figure 4.2: An exercise prescription, as organized by a participant in the Pencil and Paper Study

paper handouts is much more of a layout task than the creation of animated media. From this observation, we developed the idea of representing the prescription as a "timeline," similar to those found in sound or video editing software. However, some exercises have fairly long names, which may hinder the number of items which could be displayed onscreen at once in a horizontal timeline format. This led us to consider the idea of representing the prescription as a "list," which is much like a timeline, but vertically oriented to provide more space for text and images. A list representation is most aligned with the data obtained in the Pencil and Paper Study, and offers the additional benefit of providing enough horizontal screen space that we could display some or all of the cues associated with a particular exercise. In addition, during the Case Study, *T1* and *T2* used lists as their primary organizational structure.

Practical Implications: A clinician's prescription is guided by *goals* and/or *risk factors*. A prescription authoring notation must include mechanisms for recording goals and risk factors for the specific regimen being designed. These should be accessible for reference at any time during the process. In addition, ordering of exercises is important; however, the best order may not be known prior to the completion of the prescription. An authoring notation should provide a mechanism for specifying exercises in order, but should allow for easy reordering as well. A "scratch pad" area for collecting exercises prior to ordering may also be a reasonable approach.

4.4.2 Prescription Parameterization

Repetitions describe how many times an exercise should be performed before taking a rest and sets describe how many cycles of repetition and rest the client should go through. Table 4.2 demonstrates that 60% of the participants parameterized exercises by repetition and sets alone, while 40% parameterized some exercises by total wall-clock time. In Observation 3 of the Case Study, the duration of exercises were typically described in terms of repetitions and sets. During Observation 3, *T2's* emphasis was on form, described in terms of posture and rhythm. Posture and rhythm partially parameterize the type and duration mentioned by Wilmore, where type is the kind of exercise movement itself and duration is how long to do it [16]. An example of rhythm parameterization found in the Pencil and Paper Study is depicted in Figure 4.3. Rhythm is essentially a deeper level of parameterization

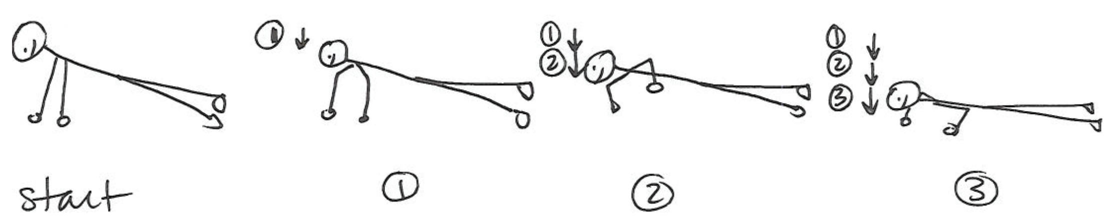


Figure 4.3: Parameterization of the duration for a pushup depicted as a 3-count tempo on the downward motion

Figure 4.4: Parameterization of the 'pushup' hand width to illustrate body posture

describing the timing of a single repetition of an exercise. Type parameterization is exemplified by a description such as "squat to half depth" or directions about posture, as shown in Figure 4.4.

Parameterization of type and duration facilitates the creation of progressions and modifications, which are variations of an exercise to make it more or less challenging. These changes can be as simple as modifying repetitions and sets or performing a different movement. Table 4.2 shows that in the Pencil and Paper Study, 50% of the participants used progressions for the patient. An example of a progression observed during the Case Study would be performing a balance exercise on an unstable surface, such as a towel, instead of the floor. An example of a modification would be performing a pushup with the hands and knees on the floor, instead of just the hands and feet.

While only a small number of subjects specified rest periods within the exercise regimen, a substantial number stressed that it is important to have a day of rest between days of exercise. Additionally, whether or not a subject prescribed the same exercises on each day of exercise varied. This suggests that a weekly or monthly calendar view might be useful to prescribers who wish to give a different exercise regimen on different days of the week.

Practical Implications: An exercise prescription notation requires flexible parameterized components at many levels. Certain parameterizations, such as sets and repetitions are quite common and easily provided with textual / numerical representations. Additionally, the notation should include provisions for specifying rhythm, potentially in several forms, including speeds, counts, or time. For simple exercises, providing parameterization for intensity via resting and playback speed is intuitive and necessary, but gets more complicated if the system aims to support a very general class of exercises. A dynamic medium, such as 3D animation, provides opportunities for additional motion parameterization along the type dimension. A software solution should strive to allow the clinician to vary kinematic properties, such as "width of stance" or "depth of the squat," as these are commonly varied in order to customize the prescription for the client and to provide progressions. This would correspond to an example of type parameterization, which is much more difficult to represent and manipulate than the more simple numerical parameters, such as repetitions and sets.

4.4.3 Cueing

Cues are the mechanism by which the clinician communicates correct *form* and the *sensation* that should (or should not) accompany correct form. Understanding and remembering the cues is crucial for the client to be able to perform the exercise and monitor the correctness of their performance when exercising alone. One of the participants wrote, "I would use both visual and verbal cues in my training." This is consistent with the observations made during the Case Study, where cues were short and often included pointing at body parts. In fact, when asked to *write* some cues, some Pencil and Paper Study participants began verbalizing the cues while pointing at themselves.

Each cue provided in response to our questions was generally short, but contained information about a wide variety of things, such as equipment, safety, posture, rhythm, and balance. Some cues specifically divided the motion into a "set position" followed by a motion, or a transition to a middle point. Cues written by participants were usually presented in a bulleted list format, rarely in prose. These cues often referred to body parts and required specifications of angles, positions, and weight distributions. Angles were sometimes described in degrees while others used the positions of the clock hands. Descriptions of position and weight distribution also came in many forms. Some cues took the form "Do not do...," while others used metaphors to provide clarity. Questions 3 and 5 provided the most insight into cues. During analysis of these questions, we encountered several types of cues, shown in Table 4.3. Question 3 asked for a description of one of the exercises they prescribed, while Question 5 asked the participant to describe how to duplicate the motion in a short video of a pushup exercise. Note that no equipment was used in the video. A response to Question 3 is shown in Figure 4.5.

Table 4.3: Codes applied to Questions 3 and 5 in the Pencil and Paper Study

Code	**Q3**	**Q5**	**Description**	**Example**
Sensation	6	9	Description of what the client should be *feeling*	"Feel the work in your quads"
Posture	5	9	Description of proper form for an exercise	"Suck in your abdomen"
Equipment	5	-	Reference to equipment necessary for the exercise	"Stand in a corner with a chair"
Rhythm	4	5	Direction on how to time the movement of the exercise	"Slow and controlled"
Resting	1	5	Reference to when or how long the client should rest	"Take a break"

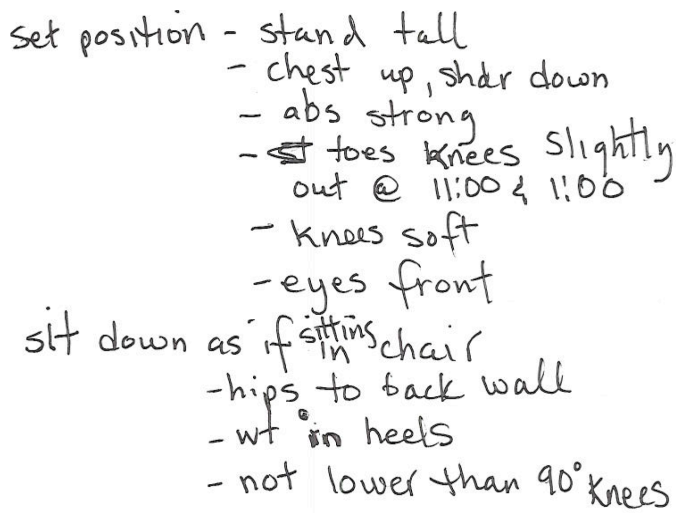


Figure 4.5: A response to Question 3 from the Pencil and Paper Study illustrating different types of cues

Approximately half of the subjects provided safety precautions with their prescriptions in Question 1 (Table 4.2), and just under half provided provided safety information for Question 2, which asked *when* the client should exercise. Results from analysis of Question 2 appear in Table 4.4. It should be noted that when the subjects provided cues for an exercise, safety cues always came either first or last, never in the middle. While the frequency of safety cues may be inflated by the fact that the patient history provided described a person with a large number of risk factors, it is clear that instructions on safety are important in this field. Several participants advised performing balance exercises while gripping a stable chair, if necessary, but then they advised not using the chair as soon as they felt comfortable doing so. This is an example of equipment cues being used in modifications or progressions for an exercise.

Table 4.4: Results for Question 2 - When to exercise

A	B	C	D	E	F	G	H	I	J	Frequency and Code Description	
x	x	x	x	x	x				x	7	Do some exercises N times a week
	x				x	x	x		x	5	Do some exercises N times per day
x		x		x	x			x		5	Do some exercises on with rest days between exercise days
		x	x	x					x	4	Suggested some safety precautions
x		x						x		3	Prescribed days of the week (e.g. M-W-F) to do all or part of exercises
x								x	x	3	Exercises differ from day to day within a week
			x					x	x	3	Provided a warmup
								x	x	2	Provided a cooldown
	x								x	2	Suggested a possible time of day
x								x	x	3	Separated Ex into classes (e.g. balance, strength, etc)
x								x	x	3	If so, ordered by class
			x		x					2	Separated Ex by body part/muscle group
			x		x					2	If so, ordered by body part/muscle group
	x									1	Order does not matter much
								x	x	2	Drew a picture

Practical Implications: An exercise prescription notation must include mechanisms for providing descriptions of each exercise using cues. Clinicians need a notation that facilitates providing cues to be presented textually, verbally, and/or visually (e.g. arrows or highlighting), although further study is needed to determine the most appropriate notations for specifying cues and their presentation to the viewer. For example, in a 3D animated sequence, “pointing” can be accomplished using secondary objects, such as an arrow or a finger icon. Another alternative is to simply highlight the body part of interest with a contrasting color as suggested by a participant, shown in Figure 4.6.

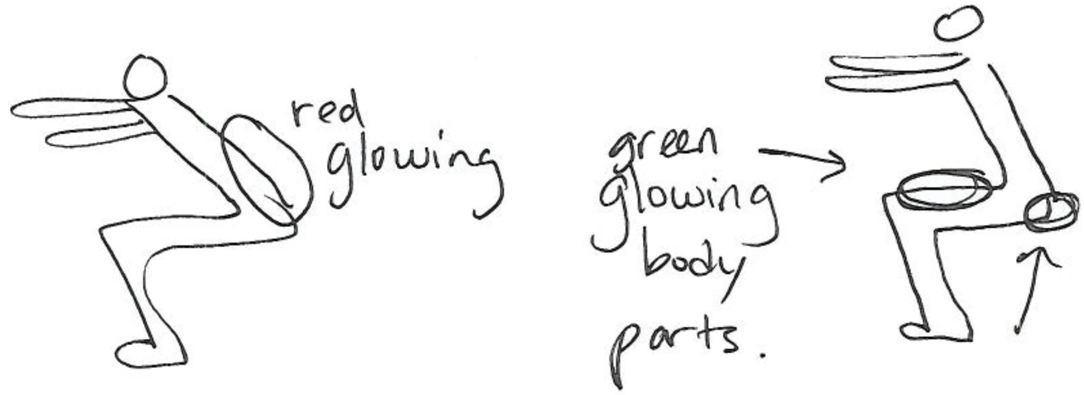


Figure 4.6: A bad sensation to experience during a squat (left), compared with a good one (right)

4.4.4 Reusable Abstractions

It became clear from the Case Study that abstractions were important in specifying exercise regimens, leading us to create Hypothesis 3: Clinicians need to create reusable abstractions. As in traditional programming, these abstractions provide several advantages for the clinicians, such as: **1)** Time savings, **2)** Management of complexity, and **3)** Interchangeability. During Observation 3, *T1* explained the regimen to *P* and the protocol terms were *rarely* used. When communicating with the client, the goal is to explicitly describe each exercise in its entirety. No steps were skipped because the emphasis is not communication efficiency, but completeness.

The findings from the Case Study are supported by the first question of the Pencil and Paper Study (Figure 4.1). This question was left open ended in an effort to discover the important aspects of an exercise prescription organization

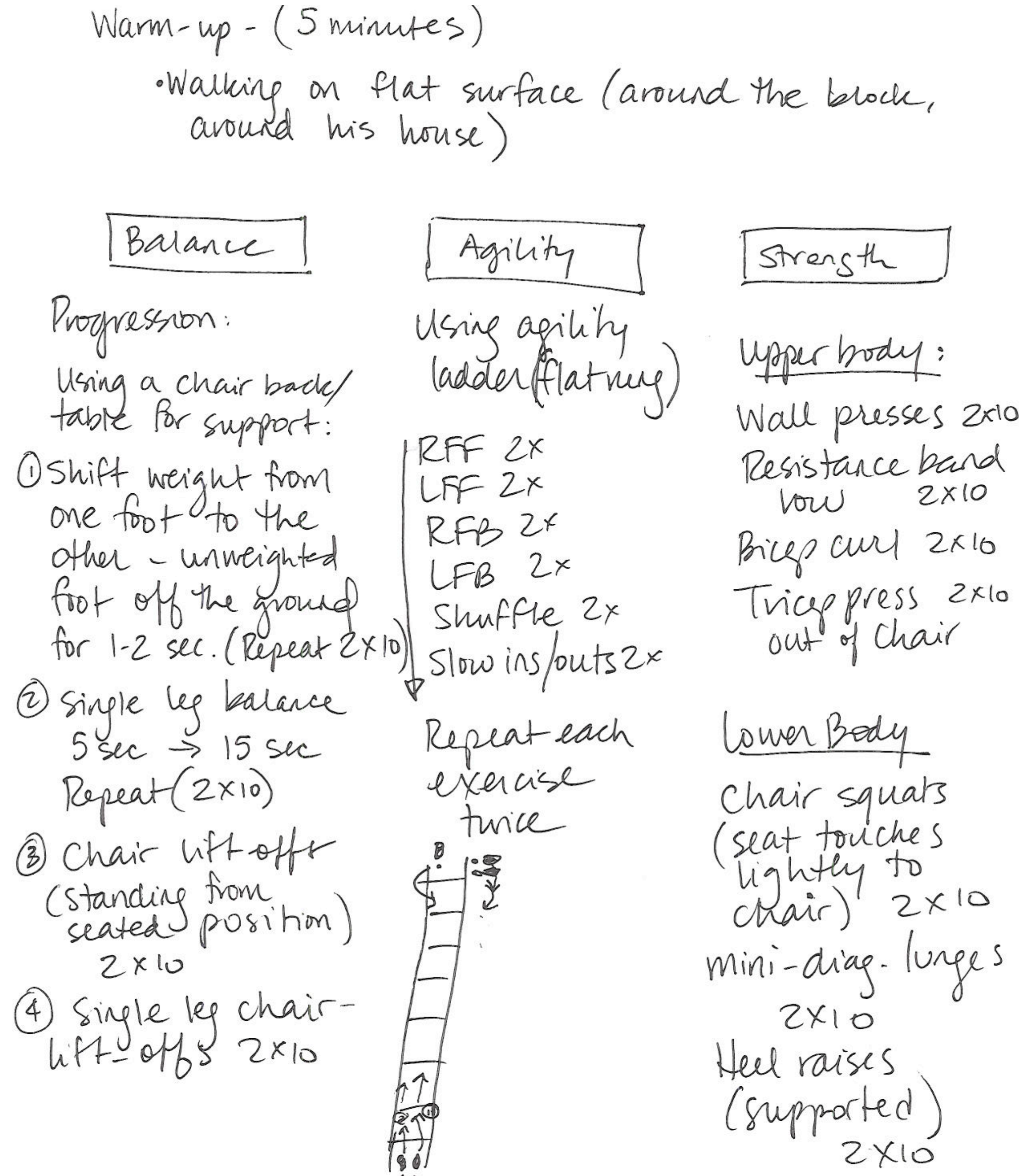


Figure 4.7: A prescription that uses goal-based abstractions to organize exercises

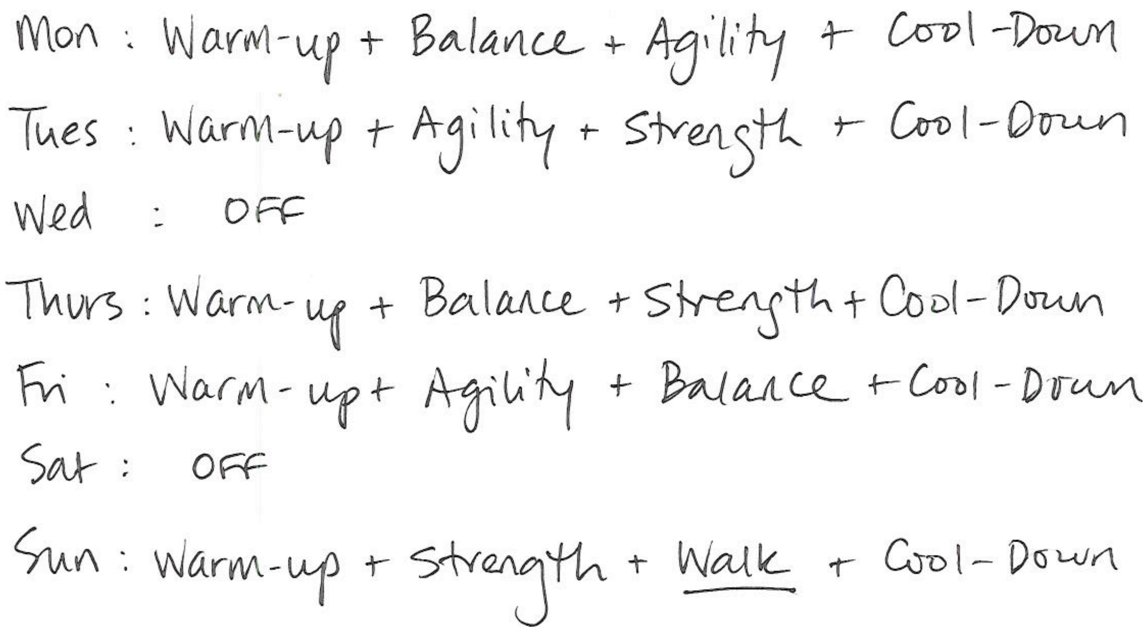


Figure 4.8: An example illustrating how abstractions can be composed to generate concise weekly exercise programs

and contents. Table 4.2 illustrates that participants used some form of abstraction in 50% of the responses, with examples appearing in Figures 4.2 and 4.7. In some cases, the abstraction was a grouping of exercises by targeted body part, such as "abdominal" or "lower extremity," while in others, the abstraction was based on a goal, such as "core strengthening" or "balance." Figure 4.8 shows how the participant who created goal-based abstractions used them to create a very concise representation of a weekly workout program. Participants also used abstractions representing the beginning and ending exercises, termed "warmup" and "cooldown," as can be seen in both Figures 4.2 and 4.7.

Less than half of the subjects provided an explicit "warm-up" or "cool-down" associated with their prescription, with a warm-up being slightly more common

(Table 4.2). The patient history we provided detailed a client with many risk factors, in fact one participant from early in the study even expressed worry that the client potentially should not even be exercising. After that user study, we decreased the number of health problems mentioned in the patient history, but it is possible that the prescriptions that many subjects provided were conservative enough that they felt warming up was not necessary. Nonetheless, warm-ups and cool-downs are an important aspect of exercising, particularly if the client desires a strenuous regimen. However, note that a warm-up or a cool-down is essentially composed of a set of exercises. This means that if the system can represent an exercise regimen, warm-ups or cool-downs can be represented as well, provided that necessary exercises, such as stretching, are available in the database of exercises available to the clinician.

Practical Implications: Notations for specifying exercise regimens should provide mechanisms for abstracting groups of exercises into protocols. This feature will promote reusability and interchangeability, saving time and effort in devising new exercise regimens. A clinician may attend to a large number of people on a regular basis, many with the same injury and/or goals, and the use of protocol abstractions promotes efficiency. This efficiency is necessary so that the clinician can spend adequate time on assessment and demonstration, while still being able to take the next appointment on time. Finally, adjustments to protocols are inevitable; therefore, care must be taken to allow clinicians to easily change protocols, as well as swap protocols in a regimen.

4.5 Threats to Validity

The patient history that we provided for Question 1 of the Pencil and Paper Study detailed a client with many risk factors. One participant from early in the study expressed worry that the client potentially should not exercise at all. After this particular participant, we decreased the number of health problems mentioned in the patient history to avoid this particular reaction. It is quite possible that the prescriptions provided during that first part of the study were overly conservative, and not representative of a "typical" prescription. Adjusting the questions presented to the participants adds a confound to the data analysis, but we were willing to make that tradeoff to reduce the risk that the questions would be misunderstood or unanswerable.

Since the study was done in a lab while being observed, there could have been a bias introduced due to the setting or investigator. Similarly, in our study, the client was not real, hence there were no consequences for providing an unworkable prescription. As a result of the client not being real, the client was not present, meaning that the knowledge of the client could not be assessed. Further, some participants may have preferred to present their prescription via a demonstration, rather than text and pictures. Lastly, our sample size of 10 participants might be too small to generalize our results.

Chapter 5 – Prototype Description

The two previously described studies informed the design of a prototype solution for authoring and delivering exercise prescriptions with a two stage approach, shown in Figure 5.1. First, the clinician creates an exercise prescription in the office using software designed for prescription authoring. Second, the client watches the exercise prescription in their home using a second software component designed for viewing exercise prescriptions. After the client is done exercising, we would then like to be able to give the clinician data about their client's progress.

We represent each exercise with: **1)** Name, **2)** Type **3)** Repetitions and Sets OR Time (depending on the type), **4)** Cues, and **5)** Motion capture data. In the authoring environment, some additional information is stored in order to draw the canvas, such as a bitmap portraying the exercise, and its position on the canvas. A simple text file is used to transfer the data between the two applications, describing the exercise prescription.

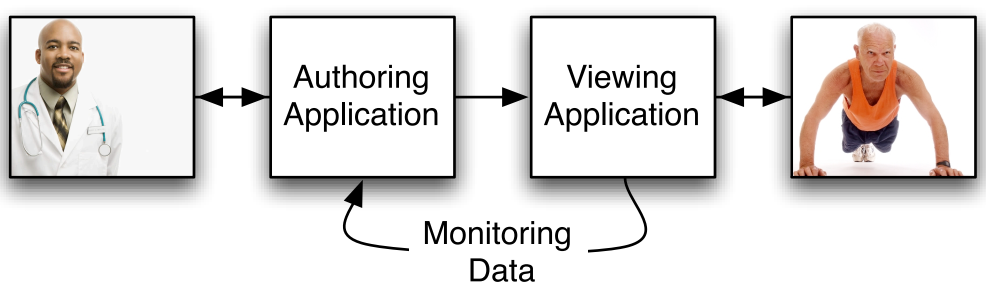


Figure 5.1: An illustration of our proposed workflow

We used an object oriented design, intended to run on the Windows platform. Both applications were written in C++ using wxWidgets[1] for GUI components. For the viewing environment, OpenGL[2] was used to provide graphics support.

5.1 Authoring Environment

The authoring environment employs a drag-and-drop interface where exercises may be chosen from the palette, shown in the left side of Figure 5.2 and added to the canvas, shown on the right side of Figure 5.2. The state of the canvas represents

[1]wxWidgets: Cross Platform GUI Library, `http://www.wxwidgets.org/`
[2]Open Graphics Library, `http://www.opengl.org/`

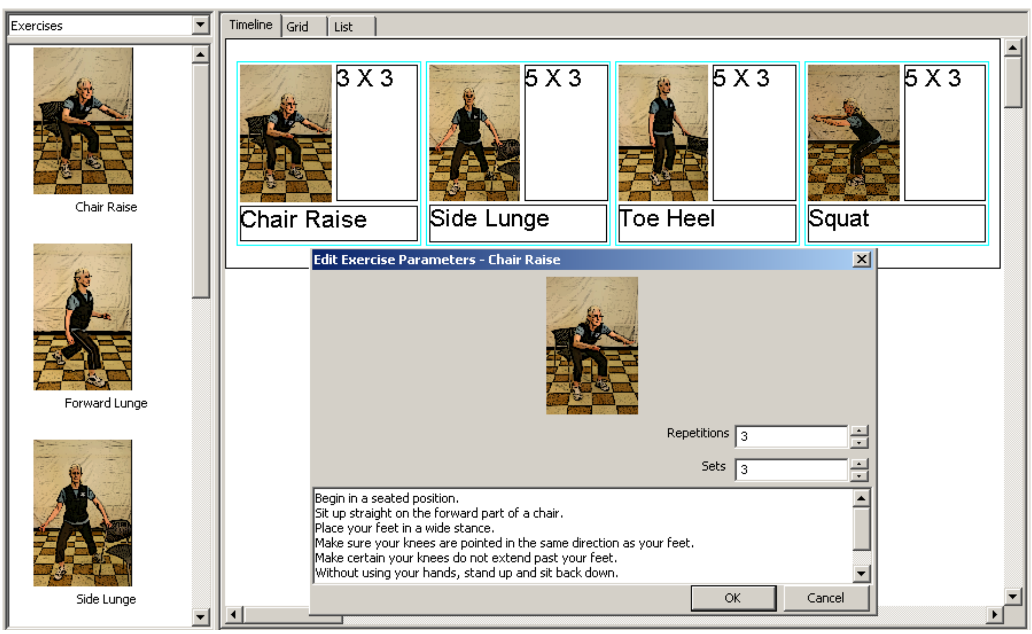


Figure 5.2: Authoring Environment - Timeline View Screenshot. This figure also shows the dialog where exercise parameters can be edited.

the prescription, and items can be reordered or removed individually. Additionally, the whole canvas can be cleared at once. In our prototype, we implemented three different interaction metaphors for the canvas: **1)** Timeline, **2)** Grid, and **3)** List.

5.1.1 Timeline View

Our first metaphor is based on the idea that creating an exercise prescriptions is akin to creating an exercise video. Thus, we decided that a video editing interaction metaphor, similar to Adobe Premiere™ (Adobe Systems Inc., San Jose, CA), might be appropriate. In this view, exercises are laid out in order from left to right (Figure 5.2).

5.1.2 Grid View

The grid view, shown in Figure 5.3, was inspired by an existing system for exercise prescription creation [7]. Note that VHI is designed for creating paper handouts, therefore it uses a 2D layout instead of a linear one. In this layout, exercises are ordered left-to-right, then top-to-bottom. Note that this ordering is somewhat arbitrary and not obvious from the layout itself; however, it does have the property that a prescription with all exercises in one row or one column will have the expected order. Thus, we wanted to observe how users organized exercises on the 2D grid substrate during evaluation. The grid is the only view that does not pack the canvas when items are rearranged, allowing gaps between exercises.

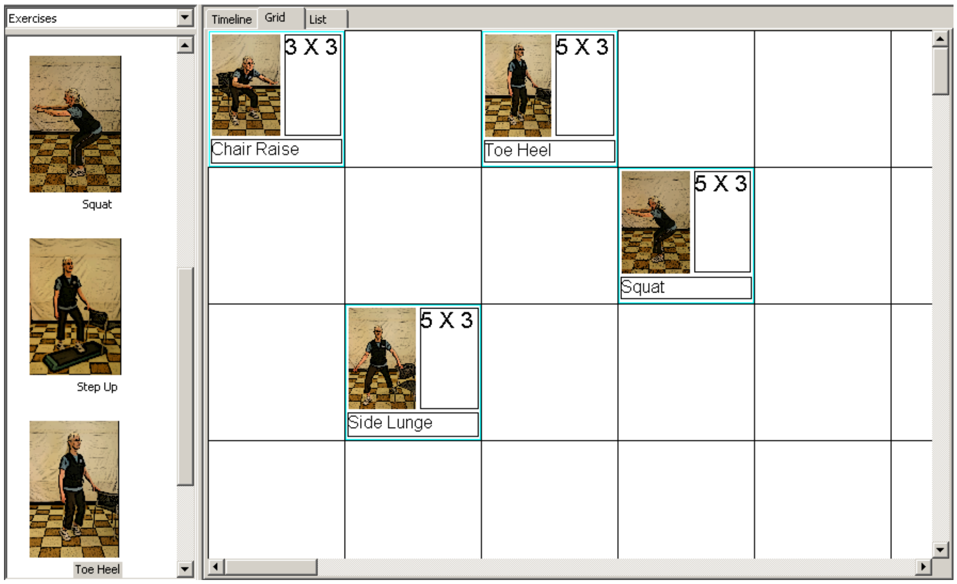


Figure 5.3: Authoring Environment - Grid View Screenshot

5.1.3 List View

The list view, shown in Figure 5.4 was inspired by the responses we obtained from the Pencil and Paper Study. It is similar to the timeline in that exercises are placed in a linear ordering. The main distinction between the two is that the list uses a top to bottom ordering, while the timeline uses a left-to-right ordering. One of the benefits of the top-to-bottom ordering is that the cues associated with each exercise can be shown alongside the name and picture of the exercise.

5.1.4 Other Features

The parameters associated with each exercise, such as repetitions, sets, and cues, can be edited for each item on the canvas, and the dialog for this is shown in

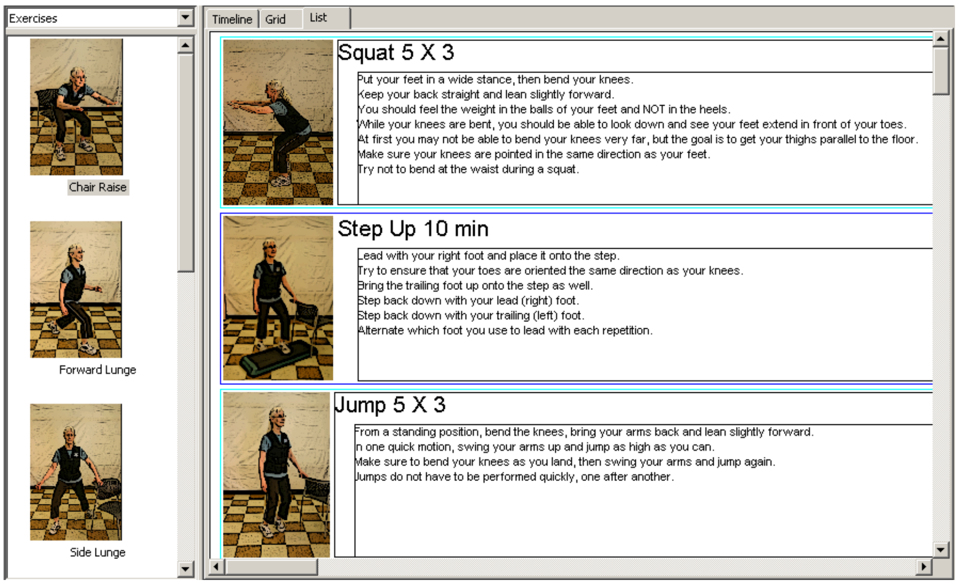


Figure 5.4: Authoring Environment - List View Screenshot

Figure 5.2. In addition to editing the parameters for an individual exercise, each exercise in the palette stores default parameters that will be used to initialize values when an exercise is added to the canvas. The default parameters for each exercise can be edited using a dialog similar to the one shown in Figure 5.2. A default set of cues to describe each exercise was provided in the system, obtained from the Better Bones and Balance Program[3]. To provide the exercise motion data, we recruited an exercise science graduate student to perform the exercises while we captured the motion using a Vicon optical motion capture system.

Much like exercises, the clinician is able to add *prompts* to the canvas. These are “user” dialogs that will request feedback from the client at various points during the exercise regimen. For example, the image in Figure 5.5 depicts a prompt with

[3]Better Bones and Balance Program, `http://extension.oregonstate.edu/physicalactivity/better-bones-amp-balance`

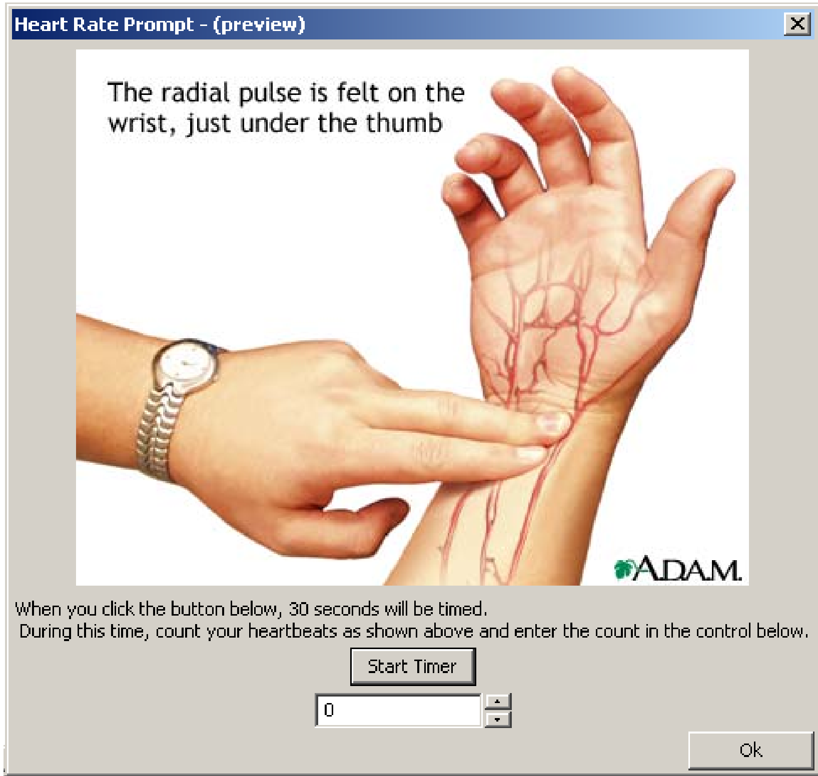


Figure 5.5: An example of a prompt that can be added to a prescription to obtain feedback from the client.

Image Source: `http://www.utmedicalcenter.org/adam/health%20illustrated%20encyclopedia/2/19395.htm`

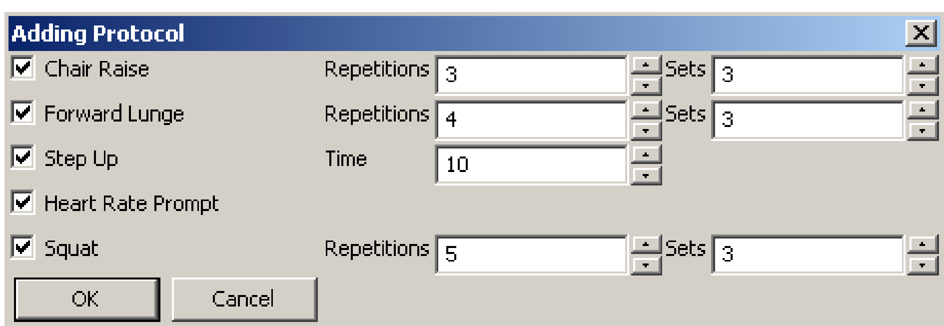


Figure 5.6: A screenshot of the dialog used to add protocols to the prescription

instructions about where the pulse can be felt in the wrist, then asks the client to count beats until a timer expires, then input the number. Other possible prompts include a prompt that calls for the client to rest for a period of time, and one that asks the client for a rating of the difficulty of the last exercise on the Borg RPE (Rating of Perceived Exertion) scale [21].

Protocols can also be added to the canvas, consisting of a collection of exercises and prompts, together with the parameters for descriptions and reps/sets or time that were set when the protocol was saved. When a protocol is added, using the dialog shown in Figure 5.6 the clinician is able to adjust the parameters of the items from the stored defaults, in addition to deselecting any exercise that should be omitted for this prescription. At any point in the use of the program, the clinician is able to save the contents of the canvas as a new protocol. When the prescription is complete, the clinician can save it as a data file for the viewing environment to display. Note that other necessary features, such as specification and storage of Risk Factors and Goals for clients, were not implemented because limited development time was available, and we wanted to focus on other aspects of the prototype during the Think Aloud Study (*Chapter 6*).

5.2 Viewing Environment

The viewing environment, shown in Figure 5.7 plays back the exercise prescription with textual annotations provided by the clinician. Each exercise is animated via motion capture data, and each time the motion finishes a loop, the repetition

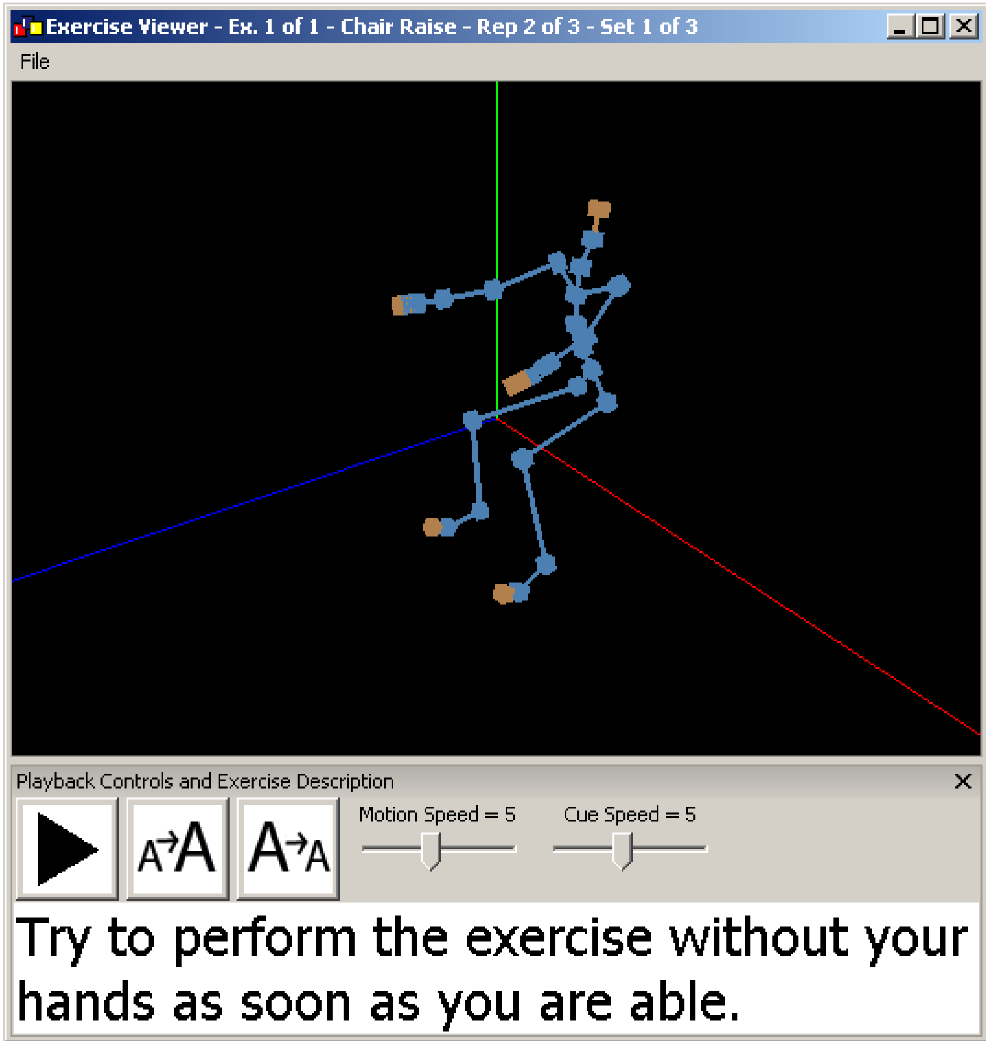


Figure 5.7: Viewing Environment Screenshot

counter is incremented, with sets tracked similarly. Both the cues and the motion are played back on a loop until the required amount of sets/reps or time have been met, with both loops divorced from each other.

The client is able to load, play, and pause the exercise prescription using the button shown in the lower right corner of Figure 5.7. The exercise can be viewed from various angles using camera controls bound to the mouse. Additionally, we provided some basic accessibility features, such as allowing the user to adjust the size of the cue text and the speed of both the cues and the motion. Since the client might be exercising while watching a screen some distance away, it is important that any onscreen text be presented large enough that it is visible. The reason we added the sliders to adjust motion and cue speed is that the slider proved helpful for debugging the motion features of the application In addition, different individuals may require different playback rates. Thus, we decided to leave the sliders in and investigate whether participants in our next study, the Think Aloud Study, found them appropriate.

Similar to the authoring environment, this application is not full featured. Part of the reason for this is that our formative studies included only exercise domain experts. Thus, we were able to learn a great deal about the authoring environment, but not as much about the viewing environment. While there are some obvious improvements that could be made, such as using a triangle mesh instead of a stick figure to represent the animated character, further study is necessary to assess the needs of a client viewing exercise.

Chapter 6 – Think-aloud Study

To conclude our series of studies, we conducted a Think Aloud Study with domain experts in order to assess the strengths and weaknesses of the prototype and to identify usability problems and directions for future work. This study also helped us to determine potential directions for future work.

6.1 Population

We performed the study with 7 participants affiliated with the fitness or rehabilitation fields, with 5 males and 2 females. Of the 7 participants, 5 of them had previously participated in the Pencil and Paper Studies (Table 6.1). The participants were aged 34.3 ± 9.6 (Mean±SD), with 10.7 ± 7.7 years experience prescribing and 9.1 ± 6.7 years experience teaching exercise. Also, we recruited *T1* from the Case Study observations to participate in the Think Aloud Studies. The participants included 3 athletic trainers, 2 graduate students in sports medicine, and 2 physical therapists. They had a combined total of 75 years of experience in prescribing exercise regimens and 64 years of experience teaching exercise/fitness courses.

6.2 Methods

The study was performed in a lab setting with one participant and one researcher present for each session. During each study, we recorded the screen via Morae™ (TechSmith, Okemos, MI) and used a secondary camera to capture gestures. Additionally, a microphone was used to record statements made during the study, and subjects were encouraged to think aloud as much as possible. During these studies, no video of the subjects' faces was captured, nor was any other information from which the subject could be identified.

After the subject signed the IRB informed consent document, participants were given an overview of the screen and video capture setup, then presented with a one page overview of the software and a concise list of the 10 tasks to perform using the prototype. By presenting the list of tasks before starting them, we found that participants asked less frequently about functionality to be examined in a later task. During the tasks, participants completed a questionnaire to collect general information about their preference for the various interfaces in the form

Table 6.1: Previous study involvement of Think Aloud Study participants
Note: PPS = Pencil and Paper Study, CS = Case Study

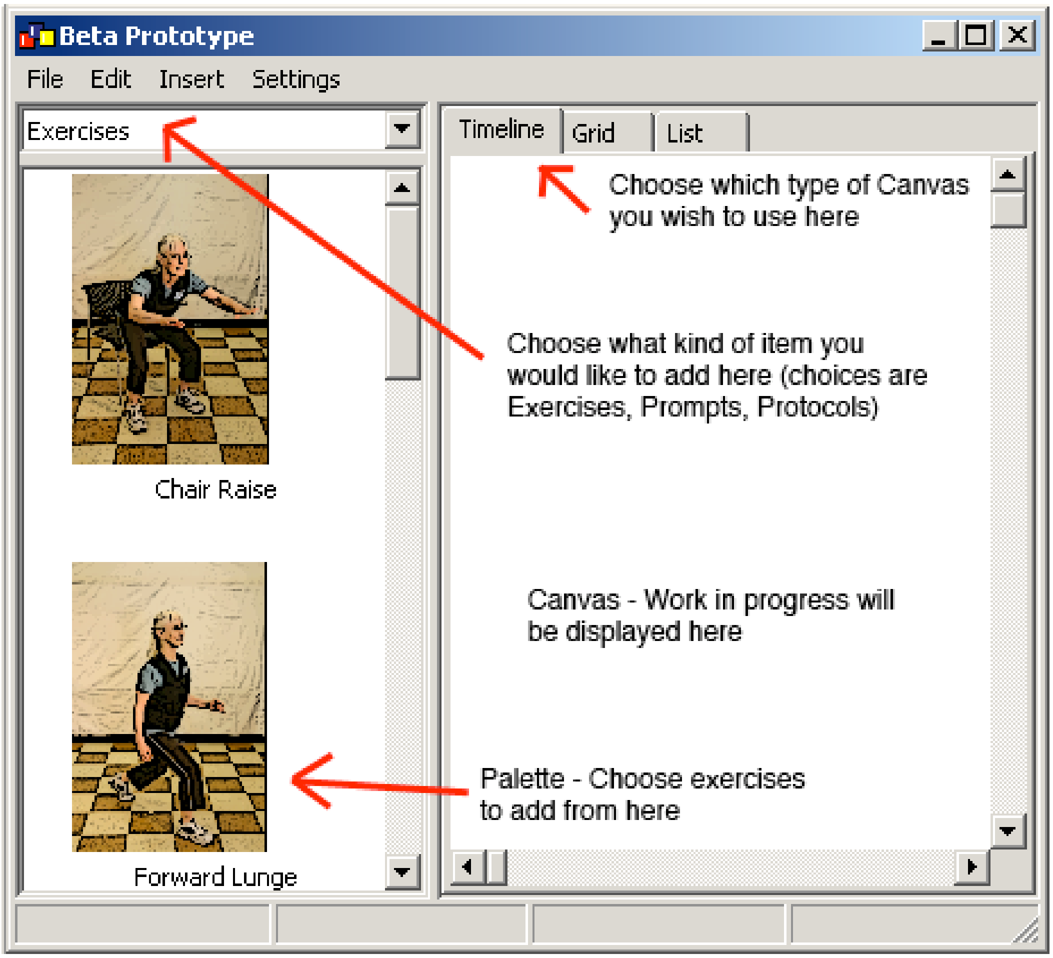
Think Aloud Study ID	Previous Involvement
1	PPS *D*
2	PPS *J*
3	PPS *I*
4	none
5	PPS *H*
6	PPS *G*
7	CS *T1*

Table 6.2: Tasks performed during the Think Aloud Study

1	View the playback of an example regimen
2	Implement a short exercise regimen
3	Delete an exercise
4	Rearrange the exercise regimen
5	Edit the parameters of an exercise
6	Edit the description of an exercise
7	Edit the default parameters for an exercise
8	Add prompts to the regimen
9	Save and load a protocol
10	View the playback of the new regimen

of a simple 1-5 rating, solicit comments on what they liked or did not like, and collect suggestions for changes to the system. After some of the tasks, follow up questions were asked in order to access more details than we might have otherwise obtained. To control for ordering effects, the order in which each canvas was used was randomly determined prior to the study. Upon completion of the tasks, the subject was provided $20 monetary compensation.

The participants performed 10 tasks, shown in Table 6.2, including examination of basic operations, such as adding and removing exercises, as well as more advanced features, such as the creation of reusable abstractions. We ordered the tasks in such a way as to gently introduce the participant to the features of the software in order to minimize the need for a tutorial, shown in Figure 6.1. Some of the tasks included instructions to perform the task with each of the three canvases, in order to better compare and contrast them. For these tasks, the order in which the participant used each canvas was varied to control for ordering effects. A verbatim copy of the tasks is presented in *Appendix D*, without space for responses.



After launching the program, a user will see a screen like the one shown above. On this image, we have labeled all of the major controls. We have provided three different ***Canvases*** which you will be using to compose interactive exercise regimens. Each one is slightly different, and we hope to find which is most suited to this task.

1. **List Canvas** - Inspired by the written communication of an exercise regimen.
2. **Timeline Canvas** - Inspired by video editing, because the intended result is similar to an exercise video.
3. **Grid Canvas** - Inspired by existing software designed for the creation of paper handouts.

Figure 6.1: The tutorial given before the Think Aloud Study tasks

6.3 Analysis

Upon completion of the Think Aloud Studies, each participant had provided ratings and comments in a questionnaire, as well as a recording of their use of the system and utterances made during the study. To analyze the recorded data, we made a first pass to identify and collect important statements. Statements written on the questionnaires were added into the collected statements as well. Then, we made a second pass to ensure nothing had been missed before categorizing the statements by subject. The questionnaires also provided ratings data on a 1(bad)-5(good) Likert scale, shown in Table 6.3.

Table 6.3: Participant ratings for Think Aloud Study Tasks
Note: If an entry is blank, the participant did not rate that task.

		1	2	3	4	5	6	7	Median	Avg	σ
Task 2 - Create prescription	Timeline	5	4	4	3	3	5	5	4	4.14	.90
	Grid	5	4	3	3	3	4	4	4	3.71	.76
	List	5	4	5	5	5	5	5	5	4.86	.38
Task 3 - Delete an exercise	Timeline	5	4	5	5		4		5	4.60	.55
	Grid	5	4	5	5		5	4	5	4.67	.52
	List	5	4	5	5		4	5	5	4.67	.52
Task 4 - Rearrange exercises	Timeline	5	3	5	5	5	5	5	5	4.71	.76
	Grid	5	5	5	3	5	5	5	5	4.71	.76
	List	5	4	5	5	5	5	3	5	4.57	.79
Task 8 - Add prompts	Timeline	4	3	5	4	3	4		4	3.83	.75
	Grid	4	5	3	4	3	4		4	3.83	.75
	List	4	4	5	4	5	4		4	4.33	.52
Task 5 - Edit exercise parameters		5	3	4	4	5	5	5	5	4.43	.79
Task 6 - Edit exercise descriptions		5	3	4	5	5	5	5	5	4.57	.79
Task 7 - Edit default parameters		5	3	5	4	5	5		5	4.50	.84
Task 9 - Save and load a protocol		5	3	4	4		5		4	4.20	.84
Task 10 - View the new prescription			4	3			5		4	4.00	1.0

6.4 Results

Although each participant was able to suggest some areas for improvement, responses to the prototype were generally positive, “I like kinda the way that it moves and the way that it works, other than the sizing of stuff.” (Participant 2). For example, the dropdown menu (Figure 6.1) used to switch from exercises to prompts or protocols was not visible enough. Further, every participant but one tried to delete an item by dragging it off the canvas, which we had not implemented.

The List view was the most popular among Think Aloud Study Participants, with 5 of 7 stating that it was their preferred view. Additionally, Table 6.3 illustrates that, for most of the tasks intended to compare the canvases, the List view garnered higher ratings. As for why these participants preferred the List, three were able to agree that the presence of the textual description of the exercises was very important to see on the canvas. Others indicated that the List layout looks, “...the most natural,” (Participant 3) or “...nicer, professional.” (Participant 7). Participants 3 and 5 both preferred the clarity of the ordering that the List provides as well.

In contrast, the Grid seemed to exhibit confusion about whether the exercises should be arranged in rows or in columns, but was preferred by the remaining 2 individuals,. However, the Grid offers the ability to be adapted to provide a “weekly workout calendar,” (Participant 3) or to become a table where exercise history could be logged. (Participant 6). While our study was focused on a single exercise prescription, several participants expressed interest in a weekly or monthly view. Another novel view idea that we had not implemented is to divide the canvas into three sections: warmup, workout, and cooldown. (Participant 3).

6.4.1 Prescription Size

One of the most interesting things that we learned is that prescriptions are generally pretty small, “Clinically, we try not to give more than 3 exercises at a time. We find that follow-through is not very good when you give them more than 3.” (Participant 5). The participant went on to describe how the 3 exercises would be advanced as the client progresses, and that while the client was being supervised, quite a few more exercises would be used. Another participant had a slightly different perspective, “Most exercise programs aren’t going to have more than 10-12 exercises in them.” (Participant 2). Note that while 10-12 is considerably higher than 3, the reason cited for using only 3 exercises at a time is that follow-through is lacking, and perhaps richer media can help improve this.

6.4.2 Time to Use

It is beneficial that prescriptions are small because not very much time is available to construct media for the client. This is especially crucial when performing a diagnosis, creating a prescription, and explaining it must fit into a 20-30 minute appointment. Participants reported that around 3-10 minutes would be an appropriate amount of time to create their prescription,

> “We do it every day, 5 minutes, we work with the patients, show them the exercises and then ‘Can you just hold, we will give you the exercises.’ ” (Participant 6)

> “Generally, most programs need to be created in 4-6 minutes, with some original protocols taking planning time that is longer, around 30 minutes...When you are doing something like this, there is usually a patient standing right over your shoulder waiting for you to get it.” (Participant 2).

While we did not measure how long it took people to use the system, Participant 3 volunteered, “In it’s current form, I would be confident in my ability to create the program within 10-15 minutes.” However, if the system can be used quickly, but requires months to learn how to use, that is not acceptable either. Participant 6 reported that it would take about 1 hour to learn the software in its current incarnation, and Participant 4 wrote, “I do not think it would take that long to learn the program. I would spend the necessary time to do it.”

6.4.3 Organization and Navigational Aids

The clarity of its ordering was one of the List’s properties that was indicated as being important by participants. One of the unexpected results we found was that existing software does not support rearrangement well. Participants describe their experiences ordering exercises as follows:

> “In the current program we have, we can’t do that [reorganize]. You have to delete back to the one you want to reorder.” (Participant 5)

> “I like to do it 1-2-3-4-5, but I cannot do that, the program picks out the order for me... I know that there is a way you can do it, but I have not figured it out.” (Participant 6)

> “When you are organizing a program, sometimes you just want to get the exercises in the order, because you are already thinking about that kind of strategy, then you can go back and edit the parameters.” (Participant 3)

Additionally, Participant 7 noted that a health history form should be available to view while creating a prescription, providing additional evidence for Case Study Hypothesis 4: Clinicians need to monitor clients’ risk factors and goals.

Several participants indicated various navigational aids that should be included. First, Participant 2 suggested adding tab traversal to move around between interface components in the various dialogs, as well as exercises on the canvas. Additionally, Participants 2 and 3 both noted that they would like to be able to click a button to view everything in the prescription at once, possibly by reducing what is displayed for each item. Last, it may be important to provide a multi-user system, as suggested by Participant 6, “Every time I login as my name, that would be my default.”

6.4.4 Parameterization and Default Values

The most important thing that we learned about parameterization is that, “The most common thing I am going to change is going to be the sets and reps.” (Participant 2). Participant 6 offered a similar perspective, “Almost 50% of the patients you have to customize it, 'I don't think they are going to be able to handle 10 reps and 3 sets, let's cut it down to 7."' This contrasts with Participant 5, who notes "I rarely change these parameters. I pretty much stick with the default, the exception would be to change them for me," but went on to mention that this may not be true of other people. Despite this, the participant suggested putting controls on the canvas itself so that sets and reps can be adjusted without requiring the use of a separate dialog. It is also worth noting that Participant 3 mentioned that sets X reps is the standard notation, and although we got it backwards in the system, no other participants seemed to notice.

In the current system, exercises parameterized by time can only be given integer values in minutes. Participant 4 pointed out that making the units clear like we did helps alleviate confusion, but might limit people artificially, specifically citing balance exercises as usually taking less than a minute. According to Participant 6, providing both seconds and minutes should give all the necessary time ranges, again citing balance exercises as requiring seconds, but also citing aerobic exercises requiring minutes. Participant 6 also mentioned that it would be nice to specify "how many times per day" for each exercise.

One of the questions we had going into the Think Aloud Study was whether or not exercises parameterized by time and exercises parameterized by repetitions and sets were mutually exclusive. To investigate this, we asked participants if they could think of an exercise that could be parameterized either way. Most of our participants were able to provide an exercise that fit into this category, often citing step-ups or fairly complicated exercises where a position should be held for time while performing another motion for repetitions. The prevailing opinion was that providing a feature to reparameterize the exercise might be helpful, but not absolutely necessary.

Currently, when an exercise is added to the canvas, the default values for parameters and descriptions associated with that exercise are used to initialize and create the exercise on the canvas. This contrasts with some other existing systems where parameters must be specified each time an exercise is added to the prescription. Reactions to this design decision were mixed. Participants 6 and 4 indicated that they would prefer that parameters be specified each time an exercise is added, possibly by simply popping up the dialog shown in Figure 6.2, although Participant 6 later expressed doubt about this subject. Participant 1 suggested that the default values should not be provided at first, but when a client has been

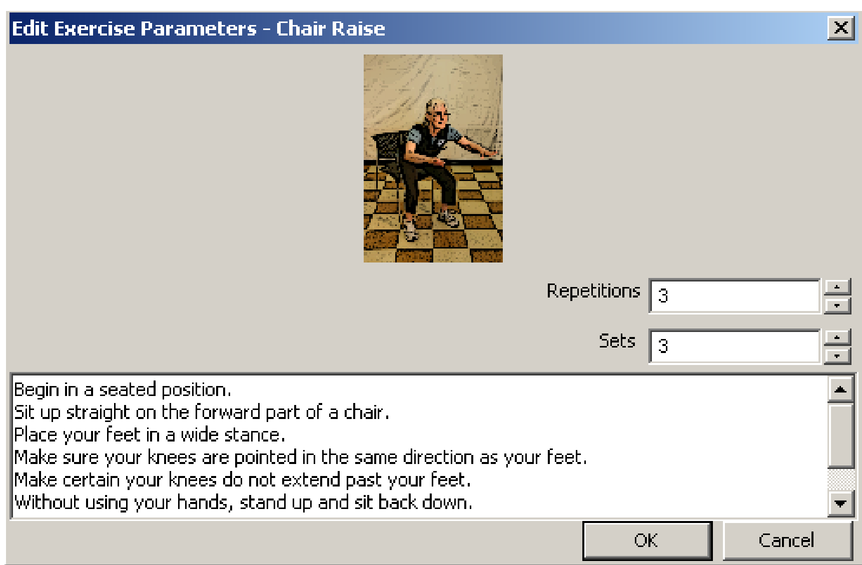


Figure 6.2: The dialog where exercise parameters and descriptions may be edited

seen multiple times, refer to the last prescription to obtain a reasonable default value. Participant 7 found the use of default values "scary" because a client might get a prescription that is much too hard because their clinician did not pay enough attention to the numbers. If default values are to be used, then they should be shown onscreen in the palette to make it clearer that parameters are associated with the exercise and that they can be changed, as suggested by Participant 2.

6.4.5 Cueing

While our viewing environment was fairly simple, it still provided valuable insights on improvements that could be made. The most common request, voiced by 4 of the 7 participants, was to have the cues not only provided via text, but also with audio. One of the major reasons for this is that it provides support for auditory learners, as expressed by Participant 7, "In my opinion, people learn movement from different perspectives. Some people are listeners, some people are doers, and some people need to be corrected." Participants 1 and 3 went so far as to recommend removal of the textual cues, in favor of audio cues. Three of the participants also expressed a desire for the cue text to be placed closer to the actor, along with exercise duration information. In the current system, the current number of repetitions and sets are shown in the titlebar (Figure 5.7), which, in addition to being too far from the actor, was deemed to be in a font that was too small,

> "In terms of the clinician making a program, easy. It's set up really intuitively, you can click on it, adjust the parameters, and you can see the layout really nicely. From the patient or exercise client's perspec-

> tive, I think there's a little too much going on onscreen, and not enough big information." (Participant 3).

Another important idea, suggested by Participants 3 and 5, is that matching the cues to the motion would be helpful. Currently, we play the motion back in a loop, while displaying the cues in a loop, with no connection between the two loops. The participant went on to describe a solution where the client could hover over or click on a body part to bring up cues pertaining to that body part. Note that this solution is limited because the user must remain near the mouse for the duration of the prescription. Another solution is to label the phases of the motion and the cues, then during playback, select a cue based on the current phase of motion.

6.4.6 Prompting and Monitoring

One of the questions that we addressed in our questionnaire was whether other prompts should be available. Participants were able to provide many good ideas, including: water, stretching, calculating a 1-rep max, pain scale, and repetition counting (how many did the client actually perform). Water was the most commonly requested prompt, and Participants 1 and 3 both provided essentially the same idea for its implementation. Rather than being a prompt that the clinician adds like the others, they wanted the water prompt to be on an internal timer that would pop it up every 15 minures or so. Not all prompts should be reserved for the client, however, because Participant 7 noted that having the software notify the clinician of client progress would, "...help whoever prescribes this reassess the situation, and it's going to spark me to progress the client and remind the client to see the trainer again."

Another question that we investigated is whether having prompts act similar to exercises in that they are dragged and dropped into the prescription is preferable. Most participants indicated that they would prefer the alternative design that we had provided a mockup for, where prompts were selected inside the exercise editing dialog. One of the reasons that this design was deemed feasible was that the number of possible prompts was fairly small. One drawback of this approach is that not all prompts are measured "per exercise." According to Participant 7, heart rate is usually measured once at the end. Participant 7 went on to suggest that it might be possible to automatically determine when to prompt, based on internal labels (some exercises are "hard") or whether or not the client has done the exercise before.

Our participants were very concerned with the way these features would be perceived by the client. For example, two participants indicated that they felt too many cues and prompts could overwhelm the client fairly easily. Further, Participant 3 objected to the scale that we chose (Borg RPE Scale [21]), stating that other scales, such as the Visual Analog Scale, exist and may be more effective. When asked about this, Participant 6 replied, "One way or the other, they need to tell you how hard it is, or how easy it is." It is important to note that the current system does not respond to the information that it gets, which is an important distinction for liability reasons. Participant 7 noted this with respect to measurement of heart rate, since if the client provides input that their heart rate is dangerously high, the system should act on that information by recommending that the client call their doctor or at least take a break. However, other types of prompts, such as repetition count prompts, pose much less liability concern. Compliance monitoring alone seems to be a desirable feature, because "...that's one thing we always struggle with, 'have you been doing your exercises.' " (Participant 5). A more well-developed monitoring system is even more desirable, as Participant 3 notes, "That's one of the hardest things about prescribing exercise without being in the same room as the person, that their perception of what they are doing is not always reality." The Wii Fit™ seems to be working toward this goal by providing some basic monitoring with its pressure sensitive plate, but perhaps using a computer vision technique to recognize human actions would prove more fruitful [22].

6.4.7 Abstractions

Reaction to our features to create and use abstractions, termed "protocols," was generally positive,

> "Definitely spend more time making protocols on it, because that saves time in the long run. General patients you can have some protocols set up. Most of our exercises are customized, that's why I like the menu (Fig. 5.6) coming up, so you can make some changes." (Participant 6)

> "I really like the editing popup box when you load a protocol ...It allows you to have a custom design that you can modify very quickly." (Participant 3)

However, Participant 7 expressed desire for the picture associated with each exercise in the dialog. Others were able to provide examples of other manipulations that they would like to perform on a protocol, such as viewing two protocols at the same time, increasing/decreasing the parameters associated with all exercises in a protocol with one command, and restoring exercises that had previously been omitted from the prescription.

6.4.8 Searching and Browsing

An extremely important aspect of exercise prescription software is variety of exercises available for the clinician to choose from. The following quote describes a possible result of having an insufficient set of exercises available:

> "...there are some exercises I like to give that are not there, so I have to go over to the other box, so I have to mix and match, and that's the part that annoys me...I have to go to 5-6 databases to get my patient the right exercises." (Participant 6)

In order to make a large set of exercises available and still usable, features to aid in searching and browsing are important. Although most participants were able to agree that searching by exercise name, major muscle group, or by body part would suffice, most participants did not suggest the same organization for browsing. Participant 4 stressed the importance of being able to browse the exercises in a variety of ways, such as type of exercise, targeted joint, specific to an injury, or perhaps based on the stage in rehabilitation. On the other hand, Participant 3 wanted exercises divided into 5 groups, "multi-joint", "accessory," "core," "upper body," and “lower body.” Several participants (2,5,6,7) wanted the exercises grouped by muscle group or body part, although Participant 5 highlights a potential problem with that organization, “The current program we use right now is by body part and that works ok. Sometimes the one you are looking for is in a certain body part location and it’s not there. Maybe some overlap might help.” Other suggestions we received include: alphabetical order, “action,” goal (weight loss, strength, toning), and type of exercise. While alphabetical order is fairly obvious, it may not be optimal for the user because, “...not everyone calls the exercise by the same name.” (Participant 3). Given the wide range of ideas, it warrants further study to determine which organization schema offers the fastest and most error free way to find the desired exercise.

6.4.9 Content Quality

An important piece of feedback we obtained pertaining to the authoring environment is that the pictures do not convey enough information to the clinician. According to Participants 2 and 7, there is too much “stuff” in the background of the images, and identifying the exercise from the image is difficult without including arrows or pictures of multiple phases of the motion on the same image. Another possible solution is to put animations into the dialogs where exercise parameters are edited, as suggested by Participant 5. Similarly, the motion content conveyed to the client must have a high quality, “Get some people with awesome form to do your demos.” (Participant 3). During the study, Participants 1 and 3 both objected to the form shown in one of the exercises based on the alignment of the knee, though it is possible that this is just an artifact of where markers were placed. Participant 3 also had difficulty assessing the orientation of the body and how it was moving when it was only drawn as a stick figure, suggesting the use of lighting or perhaps more markers during the capture process. Exercises that use equipment pose a problem as well, because some exercise equipment, such as a resistance band or rubber ball, may not be compatible with motion capture.

6.4.10 Debugging

It is important that the client be presented with an exercise prescription that closely matches what the clinician intended to create. To verify this, clinicians may need to be able to debug the prescriptions that they have created. However, note that a clinician who creates an exercise prescription intended to take an hour cannot spend an hour watching it to ensure that it is correct. The only debugging feature we included initially is a slider where the motion speed can be controlled. Participant 1 pointed out that this helps to view the motion and cues associated with the prescription, but it does not help verify the motion is not too fast or slow. Participant 3 suggested putting a bar at the bottom which can be used to slide through the whole prescription, while Participants 3 and 6 both suggested a button to advance to the start of each exercise. Participants 2 and 4 mentioned that providing an estimate of the length of the prescription could be a useful indicator of whether or not a bug exists. Another idea is to incorporate the debugging step with the creation step by having whatever is on the canvas playing constantly in the corner, “The more animated you make it the better.” (Participant 5). This participant went on to state that the debugging step should not be necessary, because “As long as it is set up correctly on the page, it should just run.”

6.4.11 Playback Rate and Resting

While programming an early prototype of the viewing environment, the speed of the motion was dependent on the frame rate, meaning that the motion would play back at different rates on different machines. This prompted us to ask questions about the appropriate rate of playback during the Think Aloud Study after fixing this issue. One of the things that we discovered is that, “speed is exercise dependent.” (Participant 5). The participant went on to note that some exercises, like a squat, should not really change speed, though other exercises, such as stepups, might be performed at different speeds. Even within the same exercise prescription, the speed of two different repetitions might vary, “What’s to say the first repetition and the tenth repetition are going to be the same speed?...As fatigue happens you are going to slow down.” (Participant 1). Clearly, the clinician requires some control over the speed of the motion since the needs and goals of the client are used to inform the speed, “If that is an elderly person with poor balance, then of course the exercise needs to be done really nice and slowly to accomplish maximal learning.” (Participant 7).

Currently, the playback speed controls are available in the viewing environment, meaning that the client has control over the speed of the motion. All participants agreed that the clinician should be able to specify the speed of the motion, meaning that the authoring environment needs to be able to specify playback rates. However, participants did not agree on whether or not the client should be able to adjust speeds, with Participants 4 and 6 not wanting to expose this feature to the client, "I don't like to give too many controls to the client." (Participant 6). Participant 2's suggestion about how to handle playback speed is to have the clinician specify the speed at a coarse level, but then give the client a speed control at a finer grain. This offers the benefit of restricting the client to clinician approved speeds, but still giving the client the ability to adjust if they are sore, tired, etc.

In addition to specifying a playback speed, participants expressed the desire to specify an amount of time to rest, "I'd want to assign rest periods based on what the goals were." (Participant 1). The current system provided a prompt intended for resting exercises, but we did not allow the clinician to specify rest between repetitions or between sets. In addition, we did not include a built in transition time between exercises. Participant 7 notes that this is important because the client might need to change position, get equipment, or clean up equipment. Participant 1 suggested using a mouse click to manage transitions between exercises, offering the benefit of ensuring adequate time to prepare for the next exercise, as well as providing some extra time in case the client falls behind. Both Participants 1 and 3 suggested using a slow motion demonstration of the exercise before the client is intended to follow along, noting that the client would rest during demonstration.

The current system uses a slider (1-10) to specify playback speed. While this should probably work fine for the client, clinicians think about the speed of exercise in different ways. One method we observed is to simply assign an amount of time to do a single repetition. An alternative idea is to divide the motion into phases, and give an amount of time to each phase. Participant 7 described the "classical rhythm" for a chair raise as follows, "2 counts going up, holding at 1 count, and descending in 4 counts (seconds). That is kind of classic, but if this becomes the perfect program, selections need to be made." The participant went on to describe that some exercises, such as jumps, do not fit into this mold.

6.5 Threats to Validity

While our sample size was relatively small, the goal of the study was to gather suggestions and feedback. To accomplish this, we adopted a conversational approach, with one participant and one researcher present for each study. At times, participants would get involved with speaking, and omit rating tasks or subtasks. If the omissions persisted, we would eventually stop reminding them in order to avoid bothering the participant, as well as to allow them to focus on performing the tasks and providing thoughts. As a result, entries in Table 6.3 are missing, limiting our ability to draw inferences from them. Additionally, it should be noted that we obtained no rating beneath 3. This could be an artifact of the one-on-one setting and the involvement in previous studies, possibly causing the participants to avoid giving low ratings. Lastly, some of our participants had never used software for constructing exercise prescriptions, while the rest had only used software for creating static media. This means that the novelty effect may have provided a bias.

Chapter 7 – Conclusion and Future Work

In conclusion, we have discussed the need for notations to allow clinicians to create interactive 3D exercise prescriptions. We have presented studies to understand the requirements of such a notation, as well as the findings of those studies. Additionally, we have shown that the task of creating an exercise prescription has many parallels with programming. Consider that a computer program is a list of instructions that the computer should perform in the specified order, while an exercise program is a similar structure for a human to perform. In effect, an exercise prescription is a small program written by a clinician, performed by a 3D agent, for a client to watch and follow along. However, a clinician might make multiple long prescriptions per day, and should not be forced to watch each prescription in full to verify that it is correct. Thus, debugging an exercise prescription remains a difficult question which should be examined further in future work. In particular, formalizing the domain specific language may provide insight into analogs for certain forms of static analysis, such as type checking.

While we have focused primarily on physical therapists, personal trainers, and athletic trainers, physicians are being encouraged more and more to promote and prescribe exercise. The American College of Sports Medicine, in association with the Cooper Clinic in Dallas, has launched the Exercise is Medicine social marketing campaign to encourage physicians to promote exercise and become educated in exercise prescription [23]. However, without a background in exercise science, most physicians are not equipped to develop exercise prescriptions for their patients without assistance, as noted by Participant 7 of the Think Aloud Study, "Physicians do not want choices, exercise professionals want choices because that is their specialty." In this case, it might be easier for physicians to choose from protocols that have been defined by an exercise domain expert, rather than constructing prescriptions with individual exercises. While examination of the needs of physicians is left for future work, having an expert system built into the software would likely prove beneficial to users who are not exercise experts.

A key obstacle to overcome before motion capture can be used successfully in exercise prescription authoring is that a large number of exercises need to be captured. Along with this motion, some static images are necessary that accurately convey the exercise they represent. In future work, perhaps the image could be extracted automatically from the motion itself in a similar manner as described by Bouvier-Zappa, et. al [24]. Additionally, during our studies we observed that clinicians desire the ability to change kinematic properties of the motion, such as the depth of a squat. Jeyakumar has done work on investigating parameterized blending of motion capture data [25]. More studies should be performed to determine exactly which properties should be adjustable, as well as control for these properties.

While we have focused primarily on a notation for authoring by the clinician, the system must also include a viewing component that allows for interaction with the exercise prescription. Our prototype system included a simplified viewer and we leave further exploration of the viewer requirements for future work. Finally, in future work, we hope to develop and deploy a usable system for both clinicians and clients to determine if we can affect exercise adherence and ultimately, functional independence of the clients.

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APPENDICES

Appendix A – Case Study Data Categories

Category	Description
Communication	Any piece of information that is exchanged during the exercise prescription process. Also encompasses methods that are used to increase the effectiveness of the information exchange.
Media	Any concrete object that the patient or clinician refers to as a visual aid. Examples include anatomical models or forms.
Motivation	An utterance by the clinician intended to motivate the patient to perform an exercise better, or become more engaged in their rehabilitation.
Rationale	An utterance by the clinician intended to make the reason behind an action that is/will be taken clear.
History	Information that was created in the past, but specifically that information which is relevant to the prescription process. Usually refers to the information in the patient's medical history.
Risk Factor	A condition of the patient that may affect the prescription contents based on inability to perform.
Goal	Desire of the patient that may affect the prescription contents.
Detail	A piece of information that is non-obvious that must be made clear to either the patient or the clinician. In our observations, the clinician was usually the one providing Details.
Technical Jargon	Utterances that came up in the process which refer to pieces of information known by domain experts, but not necessarily by the patient. Frequently, this statement refers to specific muscle groups or injuries.
Constraints	Refers to a requirement placed on the implementation of a protocol due to an inability to perform on the patient's part.
Change	Many things about the prescription process change. For instance, the patient progresses along the path to independence. Additionally, the exercises and protocols themselves change as new research is performed.
Modification	In the event that a `Constraint` exists, the clinician will need to adjust the exercises in the prescription. Also, sometimes the form of an exercise must be changed as well.
Process	Refers to anything that requires a sequence of predetermined steps to be taken. This may include legal processes or the implementation of a protocol.
Organization	Refers to anything that is used, or could be used, to maintain structure of information, whether it be data, paperwork, or anything else.

Appendix B – Pencil and Paper Study Question Text

Participant ID __________

This experiment seeks to determine how you, an exercise science domain expert, develop and communicate exercise prescriptions. In order to do so, we will provide a series of questions for you to answer with written words, drawings, diagrams, etc.

For the four questions below, write your answers on the provided blank sheets of paper. Use as many sheets of paper as you need.

1. Please provide an exercise prescription for the person described below. Imagine the prescription as notes to yourself. Use as much space as you need. Feel free to give your prescription using words, diagrams, pictures, etc. - whatever works best for you. You may assume he is available to exercise 5 times a week for 45 minutes at each session.

   > Bill Divine is 69 years of age and resides in his own home with his wife of 34 years. Bill would like to initiate an exercise program to reduce fall and fracture risk because he has been experiencing a steady decline in his balance abilities. He wears eyeglasses for reading only and has a hearing aid in his right ear. Because of his increasing balance problems he uses a single point cane on occasion when he is planning to be out for a good portion of the day. Bill reports no falls in the previous year, though he feels very unstable on uneven surfaces.

2. For the prescription you developed, describe when the client should perform the required exercises on their own. *You should assume for this question that the client knows how to perform each exercise safely and correctly.*

3. The proctors will pick 1-2 exercises used in your prescription. For each exercise, please describe how you would inform a client of how to perform it correctly. If you would refer to any materials, such as a picture, handout, form, etc., you need not create it, but please explain from where these materials would be obtained and how they would be used. Feel free to use words, diagrams, illustrations, etc. as necessary.

4. Since this client will be performing the prescription *at home on his own*, the client must recall how to properly perform the prescribed program. What material(s) would you give to a client to help in remembering when the exercises should be performed, as well as how they should be performed?

For the following questions, you are the exercise expert controlling Maya, a virtual exercise trainer. You are programming the behavior of Maya so that she can take a client through a single session of an exercise program. You may assume that Maya is capable of performing all exercises in any variation and that she is capable of communicating with the client via speech and keyboard/mouse input on the computer (for example, she may ask a question and await a response via the mouse or keyboard).

However, keep in mind that a computer agent does exactly what it is told, and only that. You might think of Maya as a 'naive alien' who will execute your commands literally, lacking the common sense that we all take for granted in everyday communication and that you, especially, take for granted in your expertise area of exercise. For example, a statement such as "demonstrate effort" is too vague and does not convey how to do so.

In general, for each question, take some time to think, put yourself in the place of Maya, and once you've determined a solution, articulate it to Maya.

5. Please watch video #1. The sequence shows a short exercise program. After watching the video, please summarize what Maya should do to reproduce the particular sequence depicted in the video. Remember that you may use as much space as necessary for your words, drawings, diagrams, etc.

6. Please watch video #2. Write a statement that summarizes how Maya should perform a push-up exercise to produce a motion sequence similar to that in the video.

7. Sometimes a push-up is done as shown in the first image, but sometimes it is done as shown in the second image:

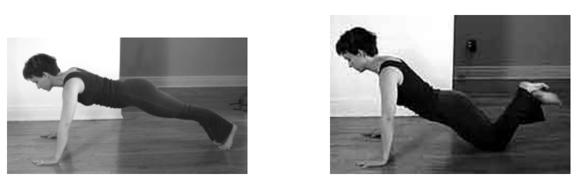


Figure B.1: www.stumptuous.com

Imagine a new client has come to Maya seeking training. Describe how Maya should decide what to demonstrate for the client. Next, describe *what she would demonstrate*.

8. Exercises, such as that shown below, typically have a certain body part or area that they should or should not be stressing or where the exercise ‘should be felt’ or ‘should not be felt’. Summarize how and when Maya should convey this information to a client.

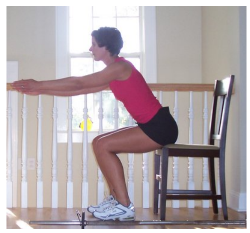


Figure B.2: Chair Squat, z.about.com

9. Imagine an exercise program that asks the client to do 15 lunges. Sometimes a person should stop a particular exercise early, for example after the 8th lunge. Give an example of when this is the case and summarize how Maya should decide when to advise the client to stop. Feel free to give more than one example if you would like.

10. Are there any extra comments you would like to make?

Appendix C – Pencil and Paper Study: Question Comments and Coding Results

We tried to minimize the changes to the questions in order to keep the data consistent between participants. However, some changes became necessary during the early studies, though the questions did not change after Participant *D*. These changes are as follows:

Q1 **Devise a prescription:** This question was changed to reduce the number of risk factors mentioned in the patient history because Participant *B* expressed worry that exercise might be dangerous for the individual described therein.

Q2 **When to exercise:** We added this question after Participant *C* because we were interested in investigating how exercises should be organized in time, and some participants were not providing this information when we asked for an "exercise prescription."

Q3 **Cueing:** From the Case Study observations, we knew cues were extremely important, and wanted to investigate them further. A researcher selected one of the prescribed exercises and asked the participant to describe the exercise in detail. When choosing an exercise, priority was given to exercises which had not been described in our previous studies in order to diversify the types of exercises and cues we could analyze.

Q4 **Materials:** With this question, we attempted to determine what kind of media the participants considered most appropriate for teaching exercise. This question was added after Participant *C* because we were unclear on how the information we had obtained with our lab study would be conveyed to a person in real life. Note that since this question was added late, only data from Participants *D-J* could be coded. Some participants asked if the question was referring to the materials they would actually use or "in an ideal world." In this case, we asked for the answer to both questions in order to determine how available the participant felt ideal media to be.

Q5-6 **Motion Description:** While these questions did not change, the contents of the videos they referenced are not available in this document, and thus should be described. For Question 5, the participant was shown a brief video sequence showing sit-ups and push-ups, then asked to summarize how the character should move to mimic the motion they were shown. To contrast, Question 6 asked the participant to summarize the motion from a second brief video showing a pushup performed with a different timing. The objective was to learn more about how subtle differences in motion would be described, as well as how rhythmic properties of exercises are communicated.

Q7 **Modifications and Progressions:** This question was rephrased slightly after Participant *B* to make it more clear.

Question 3: The proctors will pick 1-2 exercises used in your prescription. For each exercise, please describe how you would inform a client of how to perform it correctly. If you would refer to any materials, such as a picture, handout, form, etc., you need not create it, but please explain from where these materials would be obtained and how they would be used. Feel free to use words, diagrams, illustrations, etc. as necessary.

A	B	C	D	E	F	G	H	I	J	**Frequency and Code Description**	
x		x	x				x	x	x	6	Used a list of cues
	x					x				2	Used a paragraph of cues
x		x					x	x		4	Cues are fairly short
x								x		2	Cues for “Set Position”, and “Movement,” specifically
	x		x		x	x				4	Described necessary equipment first
	x	x			x	x				4	Described how the exercise might change in the future
			x			x	x	x		4	Drew a picture
	x				x	x				3	Described safety information first
		x	x				x			3	Described safety information last
	x				x		x			3	Described an exercise parameterized by time
	x							x	x	3	Described an exercise parameterized by reps and sets
x			x							2	Described correct posture
			x					x		2	Described the rhythm the motion should have
	x									1	Specified rest periods
x										1	Cues are somewhat motivational
	x									1	Suggested a time to do the exercise
				x						1	Suggested that the client should observe before attempting an exercise
x	x	x							x	4	Described where the client’s weight should be carried
x			x						x	3	Described motion using angles
						x				1	Described motion using orientations on a clock face
x		x	x							3	Described motion using up/down/left/right
			x			x	x	x		4	Drew a picture

Figure C.1: Coding Results for Question 3 - Cues

Question 4: Since this client will be performing the prescription *at home on his own*, the client must recall how to properly perform the prescribed program. What material(s) would you give to a client to help in remembering when the exercises should be performed, as well as how they should be performed?

A	B	C	D	E	F	G	H	I	J	**Frequency and Code Description**	
			x	x	x	x	x	x		6	Provide pictures
			x		x	x	x	x		5	Provide explanations of the exercises (maybe in large print)
			x	x				x		3	Provide a video
			x					x		2	Pictures of start position and “half-motion,” specifically
			x						x	2	Provide a list of exercises to be performed
				x				x		2	Provide an exercise calendar or log
			x							1	Have them (the client) write a list of helpful cues
				x						1	Provide a starting point for reps and sets
									x	1	A set of cards, one to describe the program, and one detailing each exercise

Figure C.2: Coding Results for Question 4 - Materials

Question 5: Please watch video #1. The sequence shows a short exercise program. After watching the video, please summarize what Maya should do to reproduce the particular sequence depicted in the video. Remember that you may use as much space as necessary for your words, drawings, diagrams, etc.

A	B	C	D	E	F	G	H	I	J	**Frequency and Code Description**	
x	x	x	x	x	x	x	x	x	x	10	Cues are fairly short
x	x	x	x	x		x	x			7	Formatted cues in a kind of list
	x	x			x	x		x	x	6	Described the motion using "repeat"
		x		x	x	x				4	Described the motion using reps and sets
	x	x	x	x			x	x		6	Described correct posture
x				x	x			x	x	5	Described the rhythm the motion should have
x	x		x		x					4	Described breathing procedures
	x			x	x	x				4	Described the rest periods
x	x	x		x						4	"Do NOT do "
						x	x	x		3	Drew a picture
x										1	Described what was "Doing work"
x										1	Pretend something in order to help form

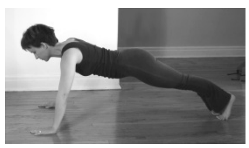
Figure C.3: Coding Results for Question 5 - Motion Description Language

Question 6: Please watch video #2. Write a statement that summarizes how Maya should perform a push-up exercise to produce a motion sequence similar to that in the video.

A	B	C	D	E	F	G	H	I	J	**Frequency and Code Description**	
	x		x	x				x	x	5	Described the motion using "Pause/stop" for a time
			x	x	x	x			x	5	Described the motion using "Steps/phases"
x	x	x							x	4	Described the motion using "Counts"
							x			1	Described the motion as a "gradual movement"
								x		1	Drew a picture

Figure C.4: Coding Results for Question 6 - Motion Description Language, Part 2

Question 7: Sometimes a push-up is done as shown in the first image, but sometimes it is done as shown in the second image:

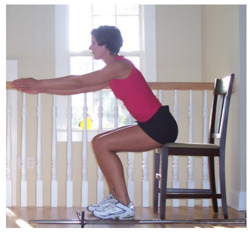


Imagine a new client has come to Maya seeking training. Describe how Maya should decide what to demonstrate for the client. Next, describe *what she would demonstrate.*

A	B	C	D	E	F	G	H	I	J	**Frequency and Code Description**	
x	x	x		x	x			x	x	7	Assess patient's strength, experience, or joint health to inform a recommendation
			x	x	x		x	x		5	Start with modified form, if manageable, try next one
						x		x	x	3	Start with regular form, if too difficult try modified form
x			x					x		3	Offer both exercises
x										1	Say which exercise is easier

Figure C.5: Coding Results for Question 7 - Modifications and Progressions

Question 8: Exercises, such as that shown below, typically have a certain body part or area that they should or should not be stressing or where the exercise 'should be felt' or 'should not be felt'. Summarize how and when Maya should convey this information to a client.



A	B	C	D	E	F	G	H	I	J	**Frequency and Code Description**	
	x	x	x	x		x	x	x	x	8	"Should feel it in"
	x		x	x		x		x		5	"Should NOT feel it in"
x				x		x		x	x	5	"Feel the work/effort/stress/strain"
x										1	"Weight in/on"
				x						1	"Fatiguing quickest"
x										1	"Relax muscles you arent using"
			x	x	x				x	4	Should be conveyed prior to the exercise being performed
				x	x				x	3	Should be conveyed during the exercise performance
								x		1	Should be conveyed after the client tries it out
		x								1	Pretend something in order to help form
			x							1	Use an arrow/highlight body parts
	x				x					2	Point at your own body
				x						1	Tiring/burning sensation
								x		1	Glowing red/green body parts
				x						1	Felt in muscles, not joints
				x			x			2	Should not be painful
									x	1	Maya should ask the client for feedback during exercise
				x						1	Maya should ask the client for feedback at completion
							x			1	Maya should point out poor form
							x	x		2	Drew a picture

Figure C.6: Coding Results for Question 8 - Motion Sensation Language

Question 9: Imagine an exercise program that asks the client to do 15 lunges. Sometimes a person should stop a particular exercise early, for example after the 8th lunge. Give an example of when this is the case and summarize how Maya should decide when to advise the client to stop. Feel free to give more than one example if you would like.

A	B	C	D	E	F	G	H	I	J	Frequency and Code Description	
x	x		x	x	x	x	x	x		8	Pain
x		x			x	x		x		5	Bad Form
x			x					x		3	Dizzy
x			x					x		3	Faint
					x	x	x			3	Shaking
x		x								2	Unprepared
				x						1	Just started exercising
			x							1	Nauseous
									x	1	History of joint pain
				x						1	Bad balance
x										1	Confused
								x		1	Weakness
									x	1	Cramping
									x	1	No longer able to resume start position

Figure C.7: Coding Results for Question 9 - Cessation

Appendix D – Think Aloud Study Directions and Questionnaire

Participant ID __________

Software Prototype Evaluation Study

This experiment seeks to determine how well the software prototype meets the needs and expectations of a clinician who wishes to convey motion information to a client. The purpose of this software is to allow an exercise expert to create rich media for a potentially inexperienced person to use as an aid in a home exercise regimen for rehabilitation. To accomplish this, we attempt to provide a drag-and-drop interface where customized video content can be created using motion capture data. Motion capture is the process of recording movement and translating the movement onto a digital model, and is commonly used in movies and games.

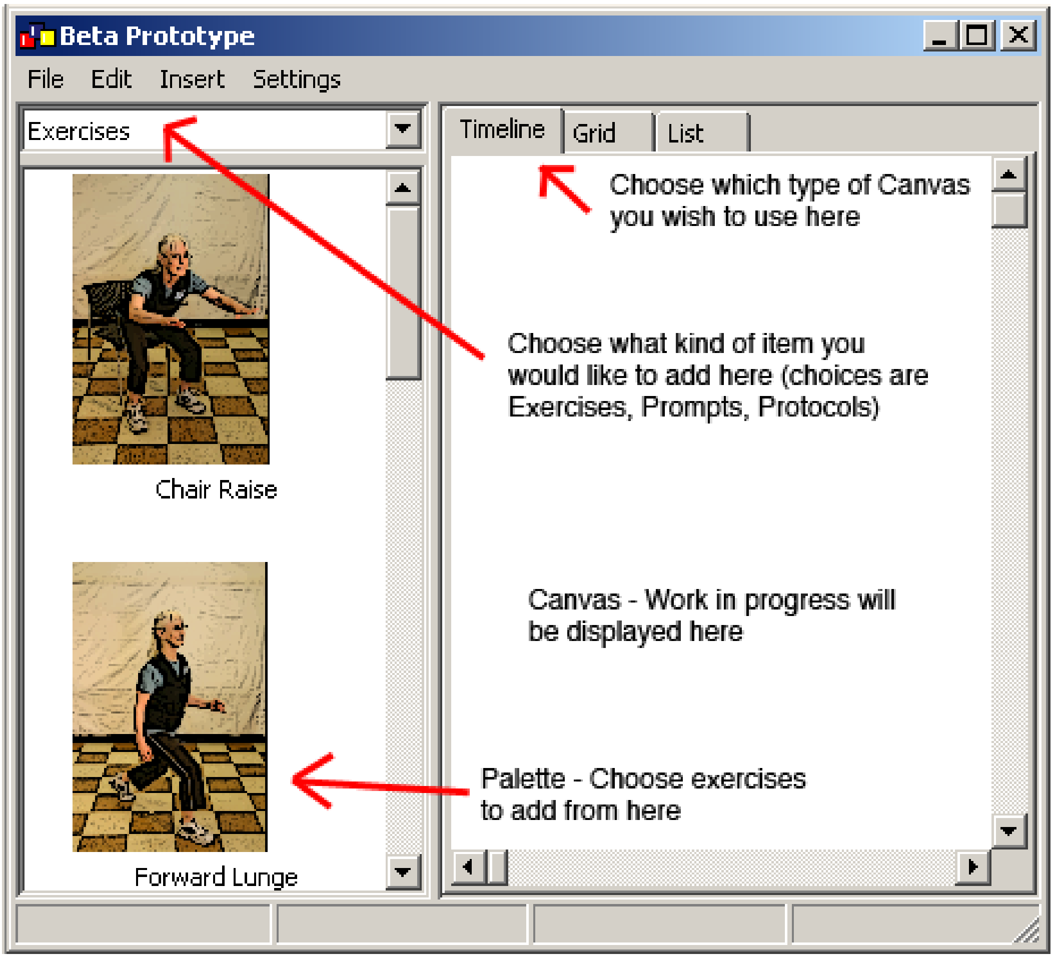
During the course of the study we will provide you with 10 tasks to be performed using a software prototype. After a task is complete, you will be asked to rate your experience on a 1-5 scale indicating how well the task was supported by the system. In addition to this feedback, you will be asked some questions about your experience and given the opportunity to provide any other comments that you have.

The information collected during this study will be useful to further improve the software prototype, as well as to make recommendations about potential future work. Feel free to experiment with the system as you wish, and if the instructions are not clear, do not hesitate to request clarification.

Important! During the tasks, we will be using software to record video of the onscreen events and a microphone will be used to record your statements as well. Thus, we encourage you to think aloud as much as possible. None of these recording devices will be used in such a way that you will be identifiable in the video.

For your information, the 10 tasks you will be performing for this user study are as follows:

1. *View the Playback of an Example Interactive Exercise Regimen*
2. *Implement a Short Exercise Regimen*
3. *Delete an Exercise*
4. *Reorder the Regimen*
5. *Edit Parameters*
6. *Edit Descriptions*
7. *Edit Default Parameters*
8. *Add Prompts*
9. *Save and Load a Protocol*
10. *View the Playback of the New Regimen*



After launching the program, a user will see a screen like the one shown above. On this image, we have labeled all of the major controls. We have provided three different ***Canvases*** which you will be using to compose interactive exercise regimens. Each one is slightly different, and we hope to find which is most suited to this task.

1. **List Canvas** - Inspired by the written communication of an exercise regimen.
2. **Timeline Canvas** - Inspired by video editing, because the intended result is similar to an exercise video.
3. **Grid Canvas** - Inspired by existing software designed for the creation of paper handouts.

View the Playback of an Example Interactive Exercise Regimen

First, watch the exercise regimen motion playback we have already prepared. This will give you better idea of the purpose of the software by providing a chance to see a possible end product. No response is required for this task.

Implement a Short Exercise Regimen

For this task, we will provide you a short list of exercises. Find each one in the ***Palette*** on the left and add them to the ***Canvas*** on the right. For now, do not worry about the number of repetitions and sets to be performed or other exercise parameters because this will be addressed in later tasks. Please perform this task with each ***Canvas*** in order to better compare and contrast them.

Subtask 2.1 - List Canvas

1. Chair Raise
2. Squat
3. Jump
4. Forward Lunge

Subtask 2.1 - List Canvas					
	Bad		Average		Good
	1	2	3	4	5

Comments:

Subtask 2.2 - Timeline Canvas

1. Squat
2. Side Lunge
3. Forward Lunge
4. Toe Heel

Subtask 2.2 - Timeline Canvas				
Bad		Average		Good
1	2	3	4	5

Comments:

Subtask 2.3 - Grid Canvas

1. Jump
2. Toe Heel
3. Chair Raise
4. Step Up

Subtask 2.3 - Grid Canvas				
Bad		Average		Good
1	2	3	4	5

Comments:

Question 2.1 - A typical music player will allow users to search or browse the collection by data such as artist, album, or genre. Supposing our exercise database was very large, how would you prefer to browse or search the database?

Question 2.2 - How long would you estimate that this exercise regimen will take to perform? Explain your answer.

Delete an Exercise

Delete an item from the ***Canvas***. Try to find multiple ways to delete items during this task. Please perform this task with each ***Canvas*** in order to better compare and contrast them.

Subtask 3.1 - List Canvas				
Bad		Average		Good
1	2	3	4	5

Comments:

Subtask 3.2 - Timeline Canvas				
Bad		Average		Good
1	2	3	4	5

Comments:

Subtask 3.3 - Grid Canvas				
Bad		Average		Good
1	2	3	4	5

Comments:

Question 3.1 - How could the way the program changes the position of other items after the delete operation be improved?

Reorder the Regimen

Rearrange the contents of each ***Canvas*** so that they are ordered as follows. Please perform this task with each ***Canvas*** in order to better compare and contrast them.

Subtask 4.1 - List Canvas

1. Forward Lunge
2. Chair Raise
3. Jump
4. Squat

Subtask 4.1 - List Canvas				
Bad		Average		Good
1	2	3	4	5

Comments:

Subtask 4.2 - Timeline Canvas

1. Toe Heel
2. Squat

3. Forward Lunge
4. Side Lunge

Subtask 4.2 - Timeline Canvas				
Bad		Average		Good
1	2	3	4	5

Comments:

Subtask 4.3 - Grid Canvas

1. Step Up
2. Jump
3. Chair Raise
4. Toe Heel

Subtask 4.3 - Grid Canvas				
Bad		Average		Good
1	2	3	4	5

Comments:

Edit Parameters

Using the ***List Canvas***, change the parameters of the exercises to:

1. 10 repetitions and 3 sets of `Chair Raise`
2. 8 repetitions and 2 sets of `Squat`
3. 12 repetitions and 1 set of `Jump`
4. 5 repetitions and 4 sets of `Forward Lunge`

Task 5				
Bad		Average		Good
1	2	3	4	5

Comments:

Edit Descriptions

Using the ***Grid Canvas***, change the description of the `Step Up` exercise to:

```
Stand Tall.
Keep your chin up.
Breathe.
```

Task 6				
Bad		Average		Good
1	2	3	4	5

Comments:

Edit Default Parameters

Select the `Chair Raise` exercise in the ***Palette***, and change its default parameters to 200 repetitions and 100 sets. Similarly, select the `Step Up` exercise and change its default parameters to 2 minutes. The default description for these exercises may also be edited.

Task 7				
Bad		Average		Good
1	2	3	4	5

Comments:

Question 7.1 - Would it be preferable to provide an editing dialog where parameters can be changed at the time the item is added to the ***Canvas***? Explain your answer.

Question 7.2 - Is it necessary to provide a feature that would allow a clinician to change the way an exercise is parameterized within the program? In other words, can you think of an exercise which might be parameterized by both repetitions/sets and time? Explain your answer.

Add Prompts

Add a `Rest Prompt` to the regimen after the first exercise and a `Heart Rate Prompt` after the last exercise. Please perform this task with each ***Canvas*** in order to better compare and contrast them.

Subtask 8.1 - List Canvas				
Bad		Average		Good
1	2	3	4	5

Comments:

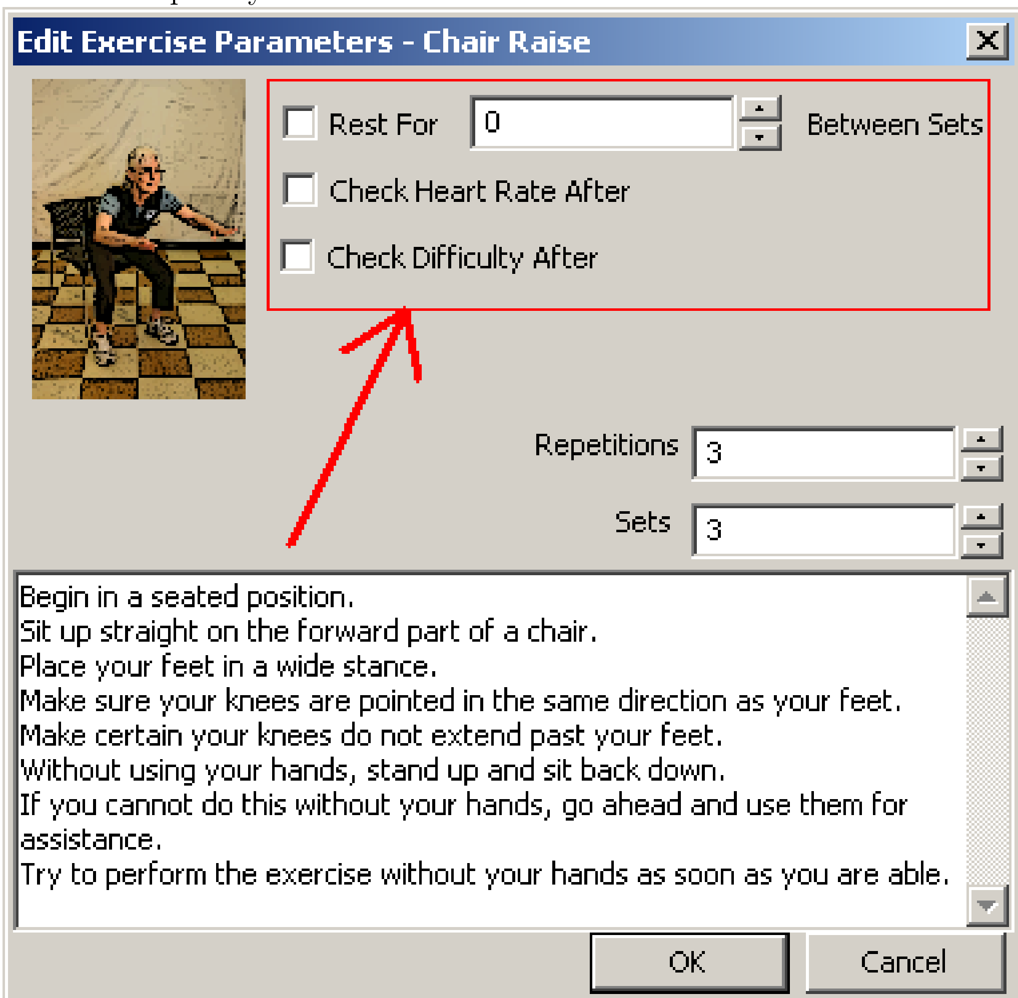
Subtask 8.2 - Timeline Canvas				
Bad		Average		Good
1	2	3	4	5

Comments:

Subtask 8.3 - Grid Canvas				
Bad		Average		Good
1	2	3	4	5

Comments:

Question 8.1 - Would you prefer having controls in the `Edit Exercise Dialog` to turn on a `Prompt` after the exercise, rather than adding a new primitive to the ***Canvas***? Explain your answer.



Question 8.2 - Can you think of any other `Prompts` which might be useful, either to perform a home measurement or otherwise?

Save and Load a Protocol

Having completed a new regimen, it is possible to save your work for easy reuse. To do this, select the ***Canvas*** you wish to save and choose `File` → `Save as`

`Protocol` from the menu. It will be added to the ***Palette*** as "`Custom Protocol`".

Task 9				
Bad		Average		Good
1	2	3	4	5

Comments:

Question 9.1 - How could the way the program responds to the saving and loading of a `Protocol` be improved? For example, would it be preferable to clear the ***Canvas*** before adding the `Protocol`?

View the Playback of the New Regimen

A completed exercise regimen can be saved and distributed to a client for viewing the prescribed exercises (as was demonstrated in Task 1). To accomplish this, choose `File` → `Save for Distribution` from the menu. Once you save it, please use the Viewing application to view the prescribed exercise regimen for this task.

Task 10				
Bad		Average		Good
1	2	3	4	5

Comments:

Question 10.1 - Are the exercises played back at the rates which you expected (ie. is the squat too fast, too slow or just right). Are there cases when this playback speed should be adjusted by the client? (ie. to increase or decrease challenge ?)

Question 10.2 - Suppose that you have created an exercise regimen intended to run for an hour. How could you confirm that this exercise regimen is what you expected to see, with respect to both content and length, without needing to spend an hour watching it?

Question 10.3 - Do you feel that you could efficiently create a regimen with this software, given some practice and a wide variety of exercises? Additionally, how long do you think you would be willing to spend on this task?

Question 10.4 - Imagine that the Viewing Application is able to provide some indicators onscreen to help clarify the cues provided in the description, for example,

an arrow that points at a muscle group or joint. Which of the following seems like it might be the most natural way to specify where the indicators should appear? Feel free to add your own new idea if applicable.
____ Textual markup commands typed into the description (e.g. *arrow hamstring*)
____ Drop down menu where commands may be chosen and added to the description
____ Clicking on a picture of a person where the indicator should appear

Question 10.5 - If you could change the way the keyboard and mouse communicate with the program, what would you change?

Question 10.6 - Can you point out any features you wish you could use that were not available, or have any ideas for a new ***Canvas*** or any other improvements?