Implications for an Exercise Prescription Authoring Notation

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Abstract

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.

1 Introduction

According to the Bureau of Labor Statistics, there were nearly 400,000 individuals employed as physical therapists, personal trainers, fitness instructors, and fitness directors in the U.S. in 2006 [4, 3]. Consumers of their services seek guidance for various reasons, ranging from general exercise to injury rehabilitation, and are typically not experts in the exercise domain. Their inexperience can be potentially harmful if they perform exercises incorrectly, possibly aggravating an existing injury or even causing a new one. Unfortunately, the services of physical therapists, athletic trainers, and personal trainers can become 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 most cases the experts provide exercises for the novices to perform *on their own*.

Paper printouts are commonly used as a communication artifact, but have difficulty conveying information about the dynamic performance of an exercise because they are a static medium. Web sites are often used to disseminate information on exercise as well, sometimes providing animated sequences or videos of exercises. While these may be more effective in showing the desired motion than static illustrations, they can only offer the point of view from the tape

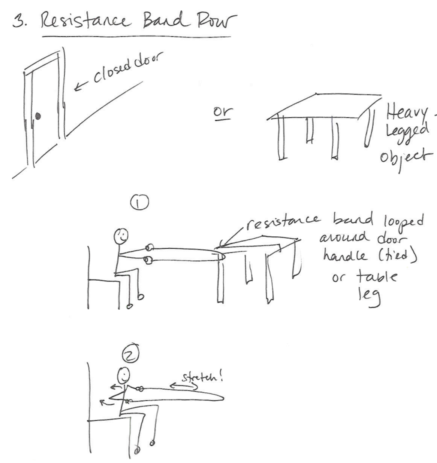

Figure 1. Example drawing from a formative paper and pencil study. Dynamic exercise content contains rich information that must be conveyed to the user.

and the costs associated with producing videos or manually generated animations are high. Additionally, these websites are generally not intended to allow a clinician to customize the content to meet the specific needs of a particular client who may require a customized exercise regimen.

Hence, there exists a need for tools that domain experts can use to efficiently author interactive, individualized, and kinematically correct exercise regimens for 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 to convey 3D animated exercise motion. The series of studies includes: **1)** Case Study,**2)** Paper and Pencil Study, and **3)** Think-aloud Study. We present our findings rooted in support from each of the studies and discuss implications for any notation designed to assist clinicians in specifying physical activity content for their clients. Finally, we conclude with a discussion of possible threats to validity and future work.

2 Related Work

Recently, several popular applications presenting exercise content have surfaced, namely *Yourself! Fitness* and *Wii Fit* [9, 2]. 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, some clinics report using *Wii Sports* as a rehabilitation modality with positive results. Most of the research on these systems focuses on how they can effectively present motion to the user, rather than providing the clinician with control of the content [10].

Fitness video games contrast sharply with the existing content creation systems used by clinicians, which are mostly targeted toward the creation of static media. These 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 one of the leading providers of content of this type, offering both paper cards to be composed on a copy machine and, more recently, an electronic version of the cards [13]. VHI has also added animations to their library, however, these animations are not interactive.

Notations for authoring motion are also desirable for dance choreography. Dance notation, such as Labanotation, has been used 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 and re-enacted by another expert, much like music notation. While this 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 creating motion for many years and the techniques generally fall into three categories: keyframe animation, physical simulation, and motion capture animation. The reader is referred to the textbook by Parent for a more in depth discussion of the methods [6]. Motion capture is a technique that allows the recording of motion and is preferred for exercise prescription because the motion can be recorded from an expert performing exercises with correct form. A motion sequence can then be used as a component in a library from which a clinician can compose a larger exercise regimen.

The ALICE system is an example of end-user 3D agent programming that has been very successful in pedagogical situations [7]. This tool is intended primarily as a means for teaching programming and is therefore not suited to our particular audience.

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. Such a mapping is desirable for our system since it is intended for end users with no programming experience and a large body of domain specific concepts and techniques. Thus, we designed the paper and pencil study to be similar in format to the studies conducted by Pane [5]. 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 [1]. We found these observations to be particularly applicable in our studies.

3 Methods

We performed three studies to understand the exercise prescription process and inform the design of a prototype system. Our first study was a single case, holistic, exploratory case study (CS) intended to answer the question: **What are the information needs of clinicians and their clients during the exercise prescription process?** The case study involved three observations made over a three week period. The observation was conducted in a clinic where the treatment process required that the athletic trainer (*T1*) conduct an assessment, devise a prescription, then pass the patient to a junior trainer (*T2*) for demonstration of the necessary exercises. The initial observation was of the first visit of a patient (*P*) with *T1* and a semi-structured interview with *T1*. Our second observation was of the meeting between *T1* and *T2* where they discussed the diagnosis and a plan for treatment. Finally, we observed *T2* during a training session with *P* where *T2* demonstrated the exercises to *P*. The patient, *P*, then had an opportunity to perform the exercises and ask questions, while *T2* provided feedback.

Based on the findings from the case study, 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 paper and pencil study (PPS) similar to that used by Pane to understand the language of novice programmers [5]. 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.

We performed the study with 10 participants affiliated with the fitness or rehabilitation fields ranging in age from 25 to 56, 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 local fitness club. They had a combined total of 78 years of experience in prescribing exercise regimens and 97.5 years of experience teaching exercise/fitness courses.

The two previously described studies informed the design of a prototype solution for authoring exercise prescriptions with three different interaction metaphors. We conducted a final think-aloud study (TAS)to better understand the tradeoffs between the three metaphors and identify usability problems with the prototype. Participants were presented with several tasks to complete with each of the three prototype implementations. The study was performed in a lab setting with one participant and one researcher present for each session. Four participants evaluated the prototype, three of whom had also been participants in the PPS. Their ages ranged from 25 to 38, with three males and one female. They had a combined total of 27 years of teaching experience and 26 years of prescribing experience. After the think-aloud portion of the study, participants completed a questionnaire to collect general information about their preference for the various interfaces, to solicit comments on what they liked or did not like, and to collect suggestions for changes for the system.

4 Analysis

We analyzed the paper and pencil study questions using an open coding approach. Since each question was designed with a different goal in mind, we analyzed each question with an independent set of codes. For each question, we developed a code set and two coders then independently coded a subset of the data. We used the Jacaard index to compute agreement since we allowed multiple codes to be assigned to an answer. 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.

5 Results

While many of our initial hypotheses regarding exercise prescription were confirmed, several new questions were brought to our attention and led to several interesting findings. Our most important lesson from the studies is that communication is the most important component of exercise prescription. As stated by one of our case study participants,

> *… 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. In addition, expert to expert communication is an important concept that must be considered because multiple clinicians may share the treatment of a single client. In the following sections, we present the 5 most important lessons learned about the exercise prescription process with a focus on support for communication and with practical implications for each of our findings.

5.1 Parameterization of Exercises

Exercises are parameterized at multiple levels. 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" [14]. 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 used. In this section, we examine how the experts in our various studies parameterized exercises along these dimensions.

In the CS, the duration of exercises were typically described in terms of repetitions and sets, where 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. A paper handout with pictures and descriptions of the exercise was notably absent from the artifacts. 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 this, *T1* showed an exercise that used a piece of equipment that, according to *T1*, was no longer on the market. While descriptions and illustrations may be useful for representing the *type* dimensions, *T1* desired the ability to adjust the *visual* depiction of the movement when appropriate.

During Observation 3, *T2's* emphasis was on form which was described in terms of postures and rhythm. Posture and rhythm 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. An example of rhythm parameterization is describing the down motion as "down on 2 counts". Rhythm is essentially a deeper level of parameterization describing the timing of a single repetition of an exercise. Type parameterization is exemplified by a description such as "squat to half depth" or "feet shoulder width apart'.

The PPS analysis provides further support of these parameterizations. In the PPS, 60% of the practitioners parameterized exercises by repetition and sets while 40% para-

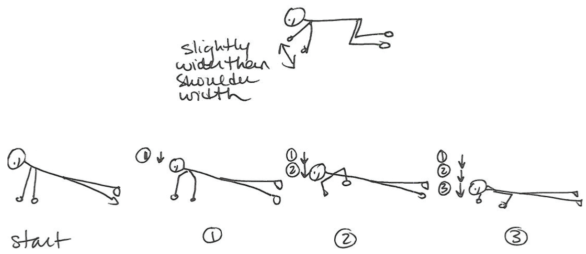

Figure 2. The top illustration taken from the PPS shows a parameterization of the 'pushup' hand width. The bottom image shows a parameterization of the duration for a pushup depicted as a 3-count tempo on the downward motion.

meterized some exercises by total wall-clock time. There were also several examples of illustrations where the practitioners depicted a parameterization of the exercise posture or form as shown in Figure 2. The use of parameterization was also supported in the TAS. During a TAS session, one participant stated, "The most common thing I am going to change is going to be the sets and reps."

Parameterization facilitates the creation of progressions and modifications which are variations of an exercise regimen to make it more or less challenging. These changes can be as simple as modifying repetitions and sets or a more complicated modification to the actual movement performed. In the PPS, 50% of the participants indicated progressions for the patient.

All participants in the evaluations indicated that allowing the clinician to adjust the speed of the motion was desirable. They typically wanted to specify speed as the number of seconds a single repetition should take. A more advanced form of this specification suggested by a participant is a "tempo," usually consisting of three numbers, a time for the first phase of the motion, a time to hold a position, and a time to return to the start position (Figure 2).

A parameter that was present in the PPS but absent in the other studies was *rest interval*. During most of the evaluations, participants requested more features to allow them to specify rests, stating, "I'd want to assign rest periods based on what the goals were." While several participants noted that rest intervals could be specified textually in the description of the exercise, in addition to the rest prompt we provided, they wanted more control over this.

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. 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. 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. Additionally, the notation should include provisions for specifying rhythm in several forms, including speeds and counts.

5.2 Reusable Abstractions

It became clear from our case study that abstractions were important in specifying exercise regimens. 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 2 of the case study, *T1* and *T2* discussed which "protocols" would be prescribed to *P*. In particular, *P* would be put on "modified lower extremity," "modified trunk," and "balance progression" protocols. This implies that clinicians create reusable abstractions called protocols that consist of a collection of exercises. These abstractions allow the clinicians to manage the complexity of their conversations and to reuse portions of previous prescriptions. The protocols also presumably facilitate interchangeability. For example, consider a client that may require a "lower extremity" protocol. There may be several protocols designed for lower extremity strengthening. If the client has a particular injury, then one "lower extremity" protocol may be more appropriate than another and can be swapped in as a replacement without affecting the overall regimen.

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 had shifted from efficiency to completeness.

These findings are supported by the first question of the PPS. The participants were given a brief patient history for a fictional character, detailing risk factors and goals. They were then asked to provide an "exercise prescription" for this person. This question was left open ended in an effort to discover the important aspects of an exercise prescription organization and contents. In 50% of the responses, participants used some form of abstraction as seen in Figure 3. In some cases, the abstraction was a grouping of exercises by targeted body part, such as "lower extremity," while in others, the abstraction was based on a goal, such as "core strengthening" or "balance." Participants also used abstractions representing the beginning and ending exercises, termed "warmup" and "cooldown."

Based on the heavy use of abstractions in the CS and PPS, we included basic abstraction mechanisms in our prototype notation. During the TAS, participants were very positive about our representation of abstractions, with one stating, "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."

The importance of abstractions was highlighted during the evaluations when a participant stated, "When you are doing something like this, there is usually a patient standing right over your shoulder waiting to get it." The same participant later wrote, "Generally most programs need to be created in 4-6 minutes, with some original protocols taking planning time that is longer, maybe half an hour." During the evaluation, one of our questions asked how long the participant felt it would take to prepare a prescription with our software, provided a sufficient exercise database. Most participants provided estimates in the range of 10-15 minutes.

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, modifications to protocols are inevitable, therefore, care must be taken to allow clinicians to easily change protocols, as well as swap protocols in a regimen.

5.3 Prescription Process Organization

Simple linear lists appear to be the preferred organizational method for exercise prescriptions. *T1* and *T2* used lists as their primary organizational structure. Recall that the first question of the PPS requested that the clinicians provide a prescription for a fictitious client, which provided an opportunity to observe the organizational structure of the participants. 90% of our participants organized their prescribed exercises in a simple linear list. We were also able to observe how the exercises were *ordered* by the participants. In 50% of the cases, participants specified no ordering. 40% of our participants provided an explicit ordering of execution, and in one case, the order of the exercises in the list was determined as a post-process. During the TAS, one participant mentioned, "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." Figure 3 shows an example prescription that includes a list organization with grouping by various abstractions.

Many of the clinicians prefaced a prescription with important information. In Observation 2 of the case study, the first piece of information that *T1* communicated to *T2* was

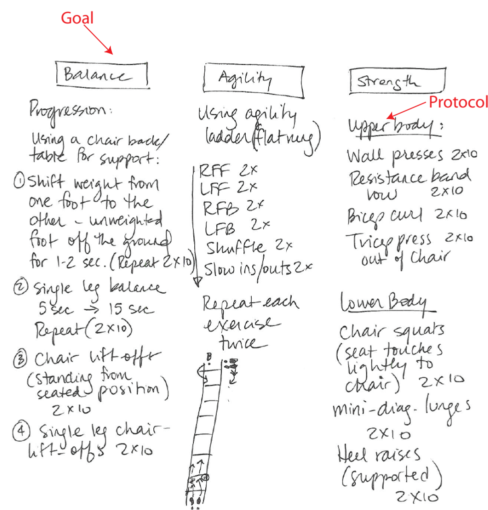

Figure 3. Portion of an exercise prescription as organized by a clinician in the paper and pencil study. Note the goals at the top with a list of exercises following each goal. The strength exercises are organized into protocols. Cues are provided in the balance goal along with a progression.

information about the "risk factors" of *P*. Additionally, risk factors were among the information present on the document that *T1* and *T2* referred to throughout the observation. After describing the results of the examination performed during Observation 1, *T1* began to identify the goals of the rehabilitation in terms of muscle groups to strengthen. This observation is supported by the paper and pencil study results where 50% of our participants started a prescription with a list of goals and/or risk factors. Presumably, this information was used by the participants to help guide them in choosing the specific exercises for the regimen.

In our prototype, we implemented three different interaction metaphors: **1)** Timeline (similar to video production software) **2)** Grid (similar to paper handout creation software), and **3)** List (similar to the written responses from the paper and pencil study). Three of the four TAS participants preferred the list over the other formats because this format allows for a natural placement of description beside each exercise icon. The one participant who preferred the grid over the other formats cited the fact that a longer prescription could be fit onscreen with no scrolling. This participant also used the extra space as a 'scratch area', placing exercises that might or might not become part of the final prescription. One participant indicated, "I could see this [grid] being useful to organize a weekly workout calendar," while another participant also requested a weekly view.

Practical Implications: A clinician's prescription is guided by *goals* and/or *risk factors*. A prescription authoring notation must include mechanisms for recording goals

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

Table 1. Codes applied to questions 3 and 5 in the PPS.

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.

5.4 Cues

Physical cues are present in nearly every aspect of exercise prescription communication. 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. To facilitate this, both visual and verbal cues are used in training.

Posture cues typically refer to body parts and were generally described in terms that the client could understand. While the clinician sometimes uses terms that are familiar to the client, they sometimes prefer physical "pointing" to eliminate all ambiguity. For example, rather than saying "you should feel this exercise in your quadriceps", the trainer would say, you should feel this "here" and point to their own or the client's quadriceps. During Observation 1, *T1* used an anatomical model of a human knee to clarify to *P* the details of the diagnosis and treatment. Even when the participants were asked to describe an exercise on paper, several of them began verbalizing the instructions and pointing at themselves.

To better understand the use of cues, we considered two questions from the paper and pencil study. Question #3 asked the participant to describe how you would inform a client how to perform a particular exercise from his or her prescription correctly. In question #5, the participant was asked to watch a short video showing some exercises. They were then asked to summarize what a virtual agent should do to reproduce the motion. We coded these two questions based on a set of codes we devised to describe cues: equipment, posture, rhythm, sensation, and resting (Table 1).

In question #3, posture cues appeared in 50% of the re-

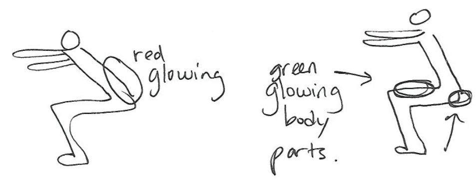

Figure 4. Example of the depiction of both bad (red glowing) and good (green glowing) sensations for a squat exercise.

sponses while in the more explicit question #5, posture cues appeared 90% of the time. In addition, in question #3, 60% of responses contained sensation cues, while 90% of the responses to question #5 included sensation cues. Rhythm cues appeared in 40% and 50% of the responses, respectively. No equipment was used in the video for question #5, therefore no responses included equipment cues. The first question, however, allowed for the description of an exercise chosen from the clinicians' prescription and in 50% of the cases, they chose to describe equipment use for the particular exercise.

Because it was unclear how to best allow clinicians to provide cues, we did not include a notation component specifically for cues. Clinicians could, however, provide cues in the textual descriptions for each exercise. In the TAS, clinicians were given a simplified viewer for 'watching' the 3D exercise regimen that they had authored. In this viewer, the exercises were performed by a 3D stick figure and the textual descriptions were presented on the screen. Participants indicated that it would be desirable to have the program speak the cues, with some advocating the removal of the visual cues. Their reasoning for this is that it might be overwhelming to watch the motion while reading cues. Several participants commented that presentation of the duration information and cues should be displayed bigger and closer to the actor. Figure 4 shows an illustration from the PPS that demonstrates how one participant envisioned sensation cue presentation.

Practical Implications: As discussed previously, 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 as text, spoken word, or visually (e.g. arrows or highlighting). 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. While it is clear that a mechanism for each form must be provided, 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.

5.5 Monitoring and Logging

An important component of any exercise prescription is tracking a client's progress. During Observation 3 of the CS, *T2* presented *P* with a card to record the number of repetitions and sets completed for each exercise. This information about the progress of the client could prove useful to a clinician trying to adjust a prescription for a recurring client. Additionally, this information provides positive feedback to the client as he/she observes improvements in strength and performance.

Our prototype included a prompting notation to allow the clinician to request important information. For example, clinician's could insert prompts to request a measurement of heart rate or difficulty of an exercise.

Practical Implications: Clinicians who repeatedly see a large number of clients can benefit from a software system which helps them track their clients. A notation for exercise prescription must include components for inserting various forms of prompts for the clinician to request information from the client. While this information is necessary for the clinician to track, it can also prove to be useful in keeping the client aware of his or her own progress. The notation should also provide mechanisms for creating and displaying progress visualizations to the client.

6 Discussion and Threats to Validity

We have presented three studies designed to understand the process and language of exercise prescription. Analysis of the study data resulted in several findings. We have discussed the most salient of those findings including the need for parameterization, abstraction, organization and logging capabilities. One does not have to look hard to see that the exercise prescription process has much in common with computer programming.

In particular, we have shown that the exercise prescription process requires several concepts that parallel parts of computer programming. A computer program is a list of instructions which the computer should perform in the specified order, while an exercise program is a similar structure for a human to perform. The clinician uses abstractions to manage complexity, to promote reusability and increase efficiency. The instructions of the program, the exercises, are parameterized in several ways, as discussed in Section 5.1.

While we have focused primarily on clinicians in this paper, 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 [12]. However, without a background in exercise science, most physicians are not equipped to develop exercise prescriptions for their patients without assistance. Thus, a notation for authoring exercise prescriptions must contain mechanisms for aiding in building and debugging the prescription.

Debugging an exercise prescription remains a difficult question to address. Consider that a clinician might make multiple hour long prescriptions per day, and should not be forced to spend an hour watching each prescription, as carried out by the 3D agent, in order to verify that it is correct. While adjustable playback speed, or a time scrubbing slider, or a total time estimate might be helpful, creating bug-free exercise prescriptions is still a challenge. Although we have not explored the details of an underlying notation for exercise prescription, we anticipate that our findings will lead to a notation where we can enforce concepts such as type checking. Such a notation will allow us to build in constraints to help non-experts, like physicians, avoid prescription errors such as sequencing two exercises that should not occur back-to-back.

Several other interesting notation requirements were indicated by the three studies. First, our findings, particularly from the PPS, imply that an icon based interface is appropriate. This is not a surprise considering that the current state of the art software tool for creating static prescriptions on paper is an icon based drag and drop application. While exercises would be represented with icons for each, we anticipate that other necessary components such as prompts would also be represented with an icon in the visual notation.

6.1 Threats to Validity

Our CS attempts to assess the information needs of clinicians, which are not directly measurable because they are stored in clinicians' heads. We collected multiple sources of evidence, including observations, interviews, and artifacts, according to a case study protocol, and stored the data in a case study database.

The largest 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. 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.

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 ensure that our inferences were based on evidence. In addition to this, we considered rival explanations in contrast to our hypotheses to help improve internal validity, though they are not presented here [11].

Due to the fact that the case study follows 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 [15]. To the best of our knowledge, no one has conducted a case study like ours, so it could be described as revelatory. Additionally, obtaining patients to observe was difficult, due to patient privacy rights.

In the PPS, the patient history that we provided for question #1 detailed a client with many risk factors. One participant from an early 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 study were overly conservative, and not representative of a "typical" prescription.

7 Conclusion and Future Work

In conclusion, we have discussed the need for notations to allow clinicians to create interactive 3D exercise prescriptions and we have presented studies to understand the requirements of such a notation. We have shown that, 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. While we have focused primarily on a notation for authoring by the clinician, the system must also include a viewing component which allows a client to interact 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.

8 Acknowledgements

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References

[1] B. A. Myers. Authoring interactive behaviors for multimedia. In *Proc. 9th NEC Research Symposium*, 1998.

[2] Nintendo. Wii fit. [Online; accessed 26-June-2008; http://www.nintendo.com/wiifit/launch/].

[3] B. of Labor Statistics. Occupational outlook handbook, 2008-2009 edition - fitness workers. [Online; accessed 26-June-2008; http://www.bls.gov/oco/ocos296.htm].

[4] B. of Labor Statistics. Occupational outlook handbook, 2008-2009 edition - physical therapists. [Online; accessed 26-June-2008; http://www.bls.gov/oco/ocos080.htm].

[5] J. F. Pane. *A Programming System for Children that is Designed for Usability*. PhD thesis, Carnegie Mellon University, Computer Science Department, Pittsburgh, PA, May 3 2002. CMU-CS-02-127.

[6] R. Parent. *Computer Animation Algorithms and Techniques*. Morgan Kaufmann, 2008.

[7] R. Pausch et al. Alice: rapid prototyping for virtual reality. *Computer Graphics and Applications, IEEE*, 15(3):8–11, May 1995.

[8] J. Pforsich. *Handbook for Laban Movement Analysis*. 1977.

[9] responDESIGN. Yourself!fitness. [Online; accessed 26-June-2008; http://www.yourselffitness.com/default.aspx].

[10] J. Sinclair, P. Hingston, and M. Masek. Considerations for the design of exergames. In *GRAPHITE '07: Proceedings of the 5th international conference on Computer graphics and interactive techniques in Australia and Southeast Asia*, pages 289–295, New York, NY, USA, 2007. ACM.

[11] A. L. Strauss. *Qualitative Analysis for Social Scientists*. Cambridge Press, 1987.

[12] The American College of Sports Medicine. Exercise is medicine. [Online; accessed 5-May-2007; http://www.exerciseismedicine.org].

[13] V. H. I. (VHI). Brief history of stretching charts, inc. / vhi. [Online; accessed 26-June-2008; http://www.vhikits.com/AboutVHI.aspx].

[14] J. Wilmore. Exercise prescription: role of the physiatrist and allied health professional. *Archives Of Physical Medicine And Rehabilitation [Arch Phys Med Rehabil]*, Jul; Vol. 57:pp. 315–9., 1976.

[15] R. K. Yin. *Case Study Research: Design and Methods*, volume 5 of *Applied Social Research Methods Series*. Sage Publications, 3rd edition, 2003.