A MOTIVATIONAL TOOL THAT UTILIZES THE PSYCHOLOGICAL, SOCIAL AND PHYSICAL FACTORS THAT PROVIDE AND PREVENT MOTIVATION TO CREATE AN ASSISTIVE, IN-HOME TOOL FOR USE BETWEEN OFFICE SESSIONS WHILE UNDERGOING PHYSICAL THERAPY

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LIST OF ABBREVIATIONS

ACL	Anterior Cruciate Ligament (ligaments which connect upper and lower leg bones)
BP	Blood Pressure
EL	Electroluminescent
HEP	Home exercise program
HCI	Human-computer interaction
LED	Light emitting diodes
MAGGi	Motivational angle gauge goniometer – Leg Brace
M. A. T. T.	Motivational Assistive Therapy Device –Tabletop Device
O2	Oxygen level
PC	Personal computer (a desktop or laptop used at home or in the office)
PT	Physical Therapist
ROM	Range of Motion
TKA	Total Knee Arthroplasty or Total Knee Replacement

SUMMARY

The physical body is the one thing we have with us from the day we enter life to the day we depart. Most of us take for granted the fact that our bodies and all the systems therein do what we expect them to without pain or discomfort. It is important to keep this vessel as functional as possible. In this society where independence and mobility are highly valued, it is often thought that the body needs to be in working order to take full advantage of the world around us. It is easier to live when the body is in complete working order since our society is one designed for those with independent mobility. Although it may be difficult to see directly after an injury, quality of life is enhanced when mobility is regained. Reduced functionality leads to physical and emotional debilitation.

Reduced functionality may occur from an accident, disease, injury or genetic abnormalities. According to The Disability Statistics Rehabilitation Research and Training Center, the fourth most common condition (4.6% of all conditions) which causes individuals to limit activities, is the impairment of lower extremities, greatly effecting quality of life (Persoon, 2004 and Rikli, 2005)

Among the lower extremities, impairments, knee joint injuries and chronic pain are common. A 2003 interview from ABC television quotes Scott Lephart, Ph.D. as saying**,** knee injuries are "occurring in epidemic proportions." "Knee injuries constitute only about 15% of all sports injuries but are 50% of visits to sports doctors, indicating that when they happen, they are usually significant." (McLaughlin) This project will focus on lower extremity injuries since it is the largest orthopedically limiting condition.

Physical Therapy is one of the medical options used to regain normal functionality of an injured body part or to reduce chronic pain from a musculoskeletal condition. Patients are referred to PTs by a physician, orthopedist or surgeon after an injury. The referrals come after a physician has confirmed that a patient needs to regain functionality and reduce pain after surgery or the incident of chronic pain. Patients may be seen at a variety of locations including the hospital (both in-patient and out-patient), a private PT office, at home, in a nursing home, or in an athletic center.

The profile of patients who see PT's is changing and growing. The population of the United States shows a breakdown of 49.1% and 50.1% males to females. (Hicks et al., 2004) In therapeutic settings, the genders are unequally represented with 44.2% of patients being male and 55.8% being female. It has been hypothesized that more women are participating in sports and suffering subsequent injuries (Brisette, 2004 and abclocal.go.com).

Compared to their representation in the U.S. general population, middle aged (50-74) and older (74+) adults were overrepresented in the demographics of those seen by a physical therapist. Most frequently seen patients were middle-aged adults (50-74) and young adults (20-49). The population is living longer and, through modern medicine, is able to live with chronic and disabling conditions. These conditions require treatment possibly resulting in the rise of patient statistics weighted towards the older population (Brisette, 2004).

A patient participating in a course of physical therapy has not only to contend with the physical ramifications of an injury, but also the psychological issues (Uppal,

2003). While bones, ligaments and cartilage are healing, patients are required to participate in a series of exercises both at home and in a therapist's office. While rehabilitating at home, patients may find it difficult to remember, make time or feel motivated to do these exercises. These issues are a large obstacle on the path to wellness.

The design solution presented in this thesis looks at the factors which influence motivation including community, positive and negative feedback, tracking and goals. The proposed solution will incorporate information from the fields of psychology, wearable technology and physical therapy. (Figure 1)

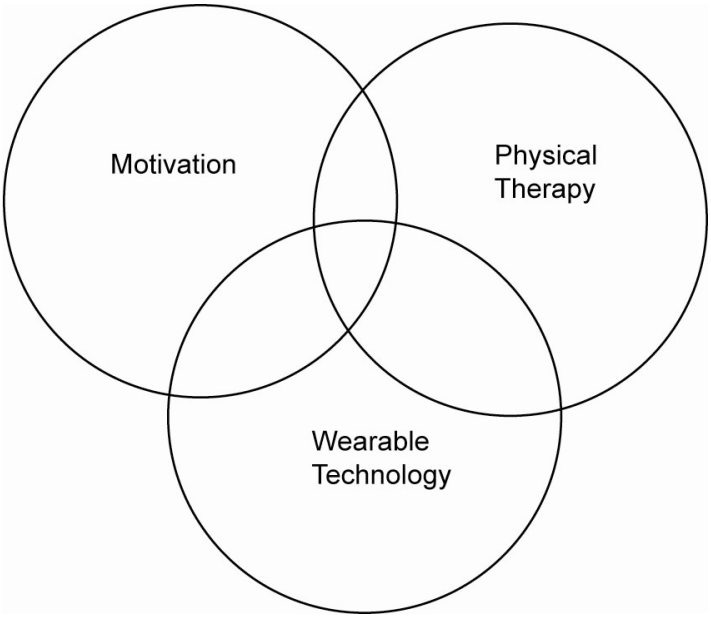

Figure 1 -Research areas of interest

Pain and injury do not necessarily motivate individuals to participate in a course of a HEP (home exercise program) which can eventually lead to better health. Knowing a product will make you feel better does not make you use it. A goal is not enough. To further motivate individuals, aspects of fun, community, autonomy and competence can

greatly improve a person's desire to heal (Uppal, 2003 and Deci-Ryan and Coleman, 1998). A customizable, networked solution is proposed where individuals may use one, two or all three parts of an integrated system to track daily and overall progress, work with a buddy and communicate with a therapist. It is hypothesized that with this system, patients will be more motivated to participate in at home physical therapy to regain full functionality.

The research and design process took part in various stages. Processes moved from the general to the specific as research and interviews informed the work. Figure 2 diagrams the process outlined in this text.

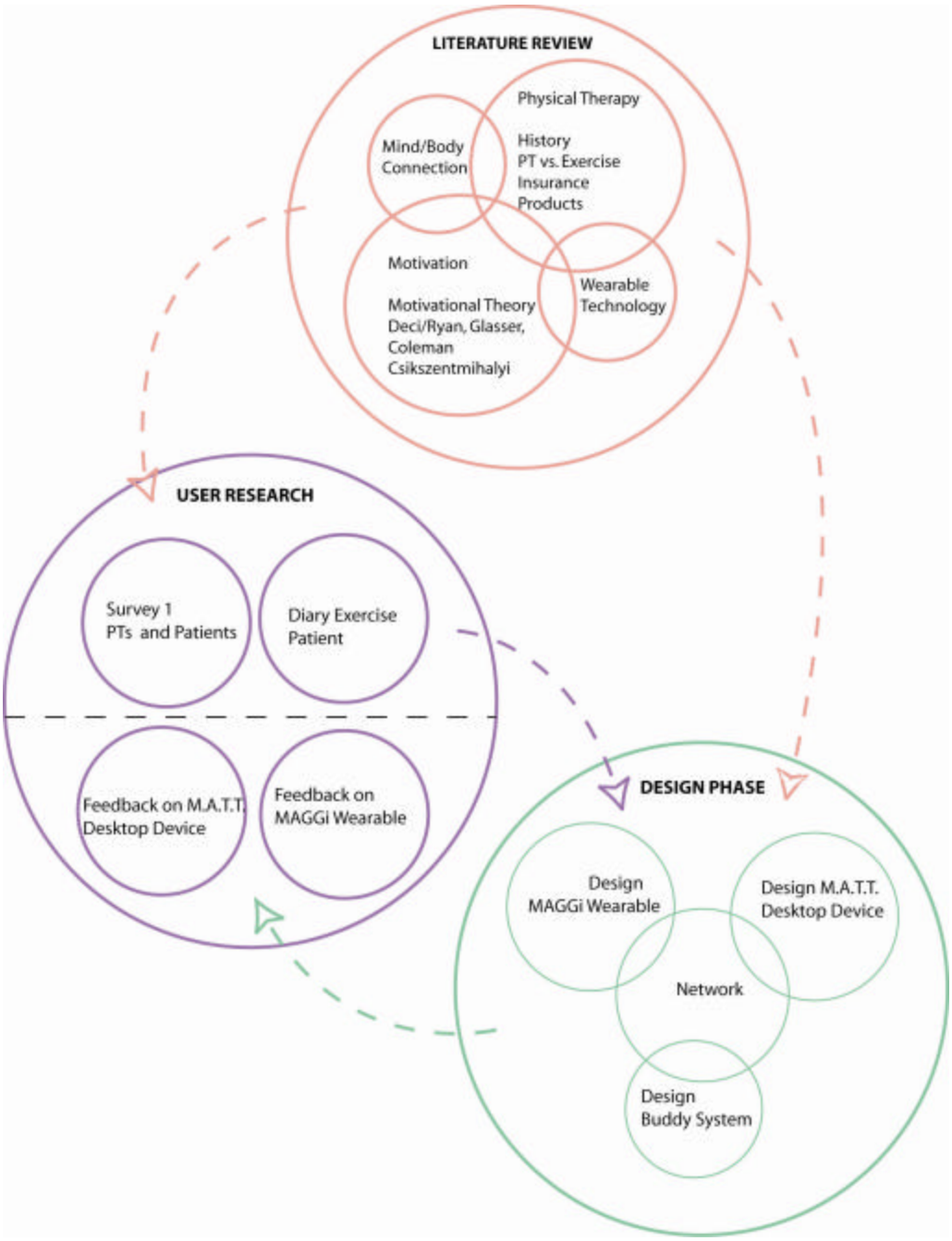

Figure 2 - Research overview

CHAPTER I

INTRODUCTION

With the limited time we have here on this sphere called earth, we should spend some time helping others. Although we essentially enter and leave alone, once we arrive, we are surrounded by people—relatives, friends, or strangers, who can and will help us throughout our lives. Prior to beginning a course of graduate study, this belief governed many things I did as a person and for my career. Since entering graduate school, it has continued as an underlying theme of much of my work. With the following work history and in-depth explanation of the project at hand, I hope to show that, as designers, we have the ability to accomplish the task of "helping." The field of medical product design naturally lends itself to this goal, and it is the area in which I have chosen to focus my career and my studies.

In 1991, while doing theatrical costume work, it became apparent that the adaptations used to help actors don/doff clothing in 30-second costume changes would also work well for people with physical limitations. This led to 11 years following a path of work solving the daily challenges of dressing and finding suitable clothing faced by people with disabilities.

During this time, in 2000, an opportunity arose to work with IDEO's Evanston, IL office on a project with Baxter Pharmaceuticals. A new carrying case was to be designed so that hemophiliacs (99% of whom are male), could carry their "factor" or medications safely and easily should they experience a wound or a

"bleed." This project demonstrated the fantastic blend of design and research, creativity and concrete information used in industrial design.

Realizing there is still much to know, I returned to school in 2002 to further my work in my areas of interest and to find the best way for them to come together in a course of study. This thesis work and three years of studying, researching and designing at Georgia Tech has helped to synthesize the work that may be done at the intersection of medical design, textiles and technology.

The question of utmost interest addresses the needs of a patient undergoing physical therapy. What is the best way to utilize the psychological, social and physical factors that provide and prevent motivation in order to create an assistive, in-home tool for use in between office visits?

CHAPTER 2

LITERATURE REVIEW

Physical therapy, psychology and wearable technology are somewhat disparate fields for study. Each topic will be represented in the following sections. After reviewing relevant literature, design criteria will be presented at the close of each section and used as guidelines for the final design. Researching the background information for each topic allows it to be synthesized into a coherent message; creating new design concepts from an existing knowledge base.

Mind/Body Connection

Early theorists offer philosophical content from which to draw when commencing study on the mind/body connection. The body does not exist independently of the individual. It may not be disposed of as a pen or watch. If the body disappears, so too does the individual. "'…my body' is not 'a' body but that which embodies me." (Luijpen and Koren, 1969 p.156). Therefore, the body must be cared for to continue a human's existence in the world.

As early as 375 BC, Plato talks of the body as a distraction. According to him, hunger, thirst, sex, sleep and pain limit our body and mind. The mind is not completely free when it is attached to a body so in need of care. Plato states it is indeed difficult to allow the mind to work fully and uninterrupted if the body is in significant pain. Death, in his eyes, is the complete release of these bodily limitations. (Gallop, 1988)

Almost 2000 years later, Rene Descartes (1596-1650) agreed with Plato. He theorized that the mind is not attached to the body or physical world and people can only be certain of their own thoughts. Physical reality and mental experience exist in two separate worlds (Dourish, 2001). Descartes' famous dictum "cogito ergo sum" (I think, therefore I am) relates to this mind-body connection. It is said that Descartes believed the actual physical intersection for these two biological processes is in the pineal gland (Dourish, 2001). This simple statement is widely accepted confirming the popular belief that the mind and body are separate, although they are eternally intertwined.

Yet, in day to day life, a mind without a body is not a whole world experience as we know it. The body may not be in top condition or may be missing limbs, but it may be argued that without a physical body, there is no person to experience the world. "We inhabit our bodies and they in turn inhabit the world with seamless connections back and forth" (Dourish, 2001 p. 102). Most humans do move through the world, able to work to a comfortable or average capacity even with a broken leg or while coping with the pain and discomfort of carpal tunnel syndrome. Yet, losing use of a body part can result in emotional trauma (Persoon, 2004 and Rikli, 2005). When the body suffers, the mind suffers, which puts the system out of balance, and creates a downward spiral. Loss of functional ability results in redistributed use of the brain, some of which is compensating for the pain or dis-function of the limb. This distraction denies the mind the opportunity to fully enjoy the world.

Philosophers in opposition to these Platonic and Cartesian schools of thought include Edmund Husserl and Maurice Merleau-Ponty. Husserl (1859-1938) believed

that living in the world is a fully embodied experience. He coined the term "lebenswelt" or life world. The experience of the body and mind are one. Merleau-Ponty (1901-1961) also continued the exploration of the body in the world. He talks of the body as a mediator of our world, binding internal and external experiences into our full life experience. Phenomenologists (philosophers who study human experience) declare that the world is full of meaning and it is only through our interactions with it both physically and socially that the world becomes more meaningful. (Dourish, 2001)

The teachings of Merleau-Ponty fit best into the scenario of physical therapy, where the body is the mediator of our world. The internal and external work together to create a whole experience of the world, and one would not be possible without the other. The mind needs the body and the body needs the mind. To improve the quality of life, we attempt to remove pain and replenish functionality creating the opportunity for a richer and more rewarding experience of the world.

Cues to State of Being

To continue research from the inside out, consideration must be given to exactly how people process information regarding another person's state-of-being, or how a person is feeling, physically and emotionally, in a given moment.

There are internal and external cues to state-of-being. Internal cues include the mind, thoughts, feelings, past experience, pain and pleasure. Two friends standing in near proximity to one another may have no insights to what may be happening in the mind of the other. Instead, the few external clues our bodies project are combined with only what we tell others about our internal state and result in how we attempt to

share our experience of the world. A person may grimace if s/he is in pain or simply hold it in and make no mention. It is very difficult to tell if a person has a headache or had a bad day unless s/he chooses to share that information with another.

The external cues include the physical body and things visible to the naked eye. Body language is a subtle cue that may give insights to state-of-being, whereas a cast on the leg is a significant physical indicator. A bone protruding from a fracture, a purple bruise around the site of injury or stitches at the site of surgery are all clues that one person may get from another or that we may have about our own state without a word ever being spoken. These external cues alert others that there is an injury to the physical body.

Summary

Plato and Merleau-Ponty bring insight as to how humans experience the world. The mind processes what is happening in the body. The mind also helps to regulate what is happening in/to the body. Pain may be present in the body, but it is possible to continue functioning with some degree of pain in the body and mind.

People receive and give internal and external clues to their current state of being. External states of being are visible and physical, however internal states of being are much less difficult to define and discern (unless there are external cues to the internal state such as a grimace.) Both internal and external states are important to monitor while undergoing physical therapy as they may help a therapist better understand a patients needs and limits.

Physical Therapy

History

The job of a PT is to "provide services that help restore function, improve mobility, relieve pain, and prevent or limit permanent physical disabilities of patients suffering from injuries or disease. They restore, maintain, and promote overall fitness and health. Their patients include accident victims and individuals with disabling conditions such as low-back pain, arthritis, heart disease, fractures, head injuries, and cerebral palsy" (www.bls.gov/oco/pdf/ocos080.pdf, ¶ 2).

Dating as far back as 3000 B.C., history offers many precursors to physical therapy where working with the physical body is the course of medical treatment for an injury. Chinese masters used massage for healing the ill and infirm. As far back as 500 BC, Herodicus and, subsequently, Hippocrates and Galen went on to prescribe and espouse the benefits of exercise and athletics to patients with physical ailments.

Physical therapy became part of the culture in the United States in the early 1900s when war broke out in Europe and the poliomyelitis virus hit epidemic proportions leaving many disabled individuals in need of a course of treatment (Moffat, 2003). A useful treatment for those with polio and those with amputations and war related injuries was a program of physical therapy.

In modern society, it is a PT's job to examine patients' medical histories test and measure the patients' strength, range of motion, balance and coordination, posture, muscle performance, respiration, and motor function. A PT may assist in determining a patient's ability to be independent and reintegrate into the community

or workplace after injury or illness. A treatment plan is then developed by the PT to create a roadmap for healing (http://www.bls.gov/oco/pdf/ocos080.pdf).

When a patient and PT work together, there is a standard protocol. A PT will examine the patient physically and ask a number of related questions about living conditions, activity and pain (Pierson and Fairchild, 2002). Since physical therapy is a path to wellness, there are goals and benchmarks along the way. The "goals and treatment should be established cooperatively with the patient and caregiver" (Pierson and Fairchild, 2002, p. 10).

As with any profession, there are particular protocols for PT and the therapeutic process. Among them are developing a plan of treatment, measuring the patient's progress in such treatment, modifying (if necessary) the care routine, and setting and modifying goals. Much of this information is gathered by measuring how close a patient is to attaining the goals and functional outcomes. (Pierson and Fairchild, 2002, p. 10).

Physical Therapy vs. Exercise

Exercise, from the Latin, "to train" is defined as:

• the act of bringing into play or realizing in action

• regular or repeated use of a faculty or bodily organ

• bodily exertion for the sake of developing and maintaining physical fitness

Physical Therapy is defined as:

• the treatment of disease by physical and mechanical means (as massage, regulated exercise, water, light, heat, and electricity) (www.m-w.com)

Although the difference is slight, physical therapy is most accurately specified as regulated exercise to relieve pain or discomfort when information about an ailment is shared by a patient with a doctor. Specific goals are set so that the body can heal and re-train itself in the course of therapeutic work. Rehabilitative therapy differs from exercise because patients have a specific injury and, often, an attainable wellness goal. Those going through rehabilitation are aware that the care will last for a specific period of time. Although focused care from a therapist occurs for a limited time, many people who take part in a course of therapy will have lasting effects of their injury or chronic condition. " If there has been an injury you should never stop exercising" (Essak, 2004).

For the purposes of this study, physical therapy is referred to as the period of time when a patient with pain from a chronic condition or accident is under the care of a licensed PT. The weeks when a patient has monitoring and guidance towards wellness are of utmost interest.

Insurance

Insurance covers a limited number of visits for many patients needing therapy and a PTs time can be costly. As part of the healing process, patients are instructed in a home exercise program (HEP). A HEP is customized for each patient as a part of their plan of care to attain specific treatment goals. These exercises are used to stretch and strengthen every day and to maintain and increase flexibility and strength. These in-between exercises promote progress and keep the patient from sliding backwards in the healing process. "Home exercise is part of the training PTs receive and all PTs are expected to give exercises to their patients" (Essak, 2004).

Although not all patients are covered for a significant amount of time, on average, insurance offers assistance for a reasonable amount of time for patients to see a PT to recover from an injury. A reasonable amount of time is considered 2 to 3 times per week for 6 to 8 weeks (Essak, 2004).

By utilizing mobile wireless technology, perhaps care can be equal or greater in a home setting while costing the patient and the system less money. Several studies have shown that with a knee injury, patients who see a PT regularly during their rehabilitation heal at the *same* rate as those who participate in only a HEP (Kramer, et al., 2003). A device which can further assist patients in safely adhering to a program of at-home therapy with access to a skilled PT can continue to support this trend in healthcare.

Motivation

The motivational process is that "through which' we act," according to Plato. "For this reason, we may say that the fundamental problem for phenomenology will be to describe and understand the deep connection between these two classical approaches to the philosophy of will, that of choice and that of motivation" (Riceour, 1964 p. 75). A person may choose to participate in an activity. The choice is a mental process, a thoughtful moment towards what happens next. Motivation is acting upon the choice. It is important to understand what assists humans in making these choices and, more importantly, what moves a person to action.

What moves an individual to take part in and maintain a program of exercise or physical therapy? Research shows that there is a correlation in drop-out rates for both exercise and physical therapy. Approximately 50% of people who start an

exercise or physical therapy program will continue exercising over time (Dishman, 2003 and Grahn et al. 2004). “It is plain hard work for people to adopt a new behavior and sustain it long enough to achieve their goals” (Dishman, 2004 p. 46). To better understand why there is such a large drop out rate, and why people have trouble following and staying with an exercise regimen, a study was undertaken on literature regarding human nature and motivation.

Author Daniel Coleman writes of *Emotional Intelligence* (1998). Emotional intelligence looks at the qualitative attributes of human nature. The well-known intelligence quotient (IQ) is often looked at on a numerical scale which “indicates a person's mental abilities relative to others of approximately the same age” (www.iqtest.com ¶ 3). Many assumptions are made based on how intelligent a person is or appears to be. However, success in life is not based solely on one’s intelligence. “IQ alone explains surprisingly little of achievement at work or in life (Coleman, 1998 p. 19).

Coleman discusses how our emotional resonance, our ability to be compassionate and understand the feelings of those around us can contribute to our success, or failure in a one or many parts of life. Factors such as, a “striving to improve or meet a standard of excellence”, “aligning with the goal of the group or an organization” “readiness to act on opportunities,” and “persistence in pursuing goals despite obstacles and setbacks” are discussed by Coleman (1998 p. 26). These factors are at the root of human motivation and will play a much stronger part in moving a person to exercise than will their IQ.

Theorist Dr. William Glasser uses his Choice Theory to suggest that individuals act based on five basic needs: belonging, power, freedom, fun, and survival (Uppal, 2003). Similarly, Edward Deci and William Ryan suggest a Self-Determination Theory (2000). Deci and Ryan suggest that there are three basic human tenets that drive the decisions we make and our motivation to act on things: autonomy, competence, and relatedness.

As these theorists are compared to one another, a pattern begins to emerge (Table 1). Glasser is the only theorist to use the word "fun." As humans, the need for fun is a newer aspect of our lives since, in the last few centuries, much of the western hemisphere has conquered day-to-day survival which may have precluded any room for "fun."

Table 1 - Motivational Theory

Glasser Choice-Theory	**Deci & Ryan Self-Determination**	**Coleman Emotional Intelligence**
Fun		
Freedom	Autonomy	Ready to act on opportunities
Survival	Competence	Persistence
Belonging	Relatedness	Committing to goals of a group
Power	Competence	Drive to achieve excellence

Each theorist has a term relating to our need for autonomy or making our own choices. Although the meanings are somewhat different, the ideas of survival, competence and persistence all relate to a similar drive to thrive. The social aspects of human motivation are well documented by each theorist. Part of human motivation

is the knowledge that others are counting on us. Finally, the desire to be competent and powerful pervades the three theorists as well. Glasser, Coleman, Deci and Ryan help to create an initial framework and understanding of the mind as it relates to motivation. The framework begins to suggest a device or system that connects the user to a larger group, and one which leverages the human desire to achieve excellence. Design criteria founded in the work of Coleman, Glasser, Deci and Ryan would include a device which is fun, and allows the user some autonomy. Although motivation itself cannot be created by a device, a product which incorporates these human elements may inspire patients to participate in their HEP.

Flow

The work of Mihaly Csikszentmihalyi should also be considered in the psychology of human motivation. In the early 1990's psychology professor Mihaly Csikszentmihalyi brought the concept of "flow" into the common vernacular (1990). At the peak of ability, humans experience a feeling of transendence and time, space and emotional issues fall away. This "optimal experience" can be achieved at any level of athletic ability. If a patient is working to "…rise a little higher, go a little faster and grow a little stronger," (Csikszentmihalyi, 1990 p. 97) there is no limit to what can be accomplished and the pleasure possible in attempting and achieving one's goals.

As stated by Csikszentmihalyi (1990, p. 97), there are several steps to producing flow through a physical experience:

• set an overall goal, and any necessary sub-goals

• find a way to measure progress towards chosen goals

• continue concentrating and find a way to make finer distinctions in the challenges of the activity

• continue to raise the stakes if the activity becomes boring

Utilizing these steps, a person can achieve flow in even a short jog around the neighborhood. The jogger decides how far s/he will go that day, noting any small landmarks between the beginning and end. If the goal is eventually to jog 5 miles, but start at 2, the jogger will need a system to track the progress, perhaps a sheet of paper with distances run. While jogging, the jogger may also try to get faster times or better strides while still working towards the 5 mile goal. To raise the stakes, a jogger may add weights or change routes for more complexity as the training continues.

These theories translate easily to the process of rehabilitation where patients are indeed setting goals. Unfortunately, there are few, if any, practices in place where the patient can accurately monitor the progress or increase the challenge in a recordable manner.

Belonging, Relatedness, Committing to the Goals of a Group

Social influence may affect a person's commitment to rehabilitation. Motivation to exercise may come from a professional (PT or doctor), a caring friend or co-worker, or a family member such as a spouse, parent or sibling (Carron, et al, 1996). Approximately a decade ago, Carron, Hausenblas and Mack (1996) looked back at studies which had been done on compliance, adherence and social factors. While analyzing previously collected data, it was determined that the most compliant situation was one in which individuals had a health practitioner prescribe an exercise program and where there was encouragement from a spouse or family member. The

candidates least likely to adhere to a program were those who were in a self-selected, self initiated program. This data suggests that the support of a caregiver and family have a significant impact on compliance. It was previously noted that those with internal drive or motivation are more likely than latently motivated individuals to adhere to an exercise program. Data suggests that even those who are internally motivated may be bested in adherence by those who have a prescription for exercise and familial support.

However, the social fabric of our society is changing. People now live further from their nuclear families and many nuclear families spend time apart due to work schedules and travel. Technology (phones, email and air transport) helps to decrease these distances between family and friends, and has begun to develop a new understanding of community.

Community, defined as "a group of people with a common characteristic or interest living together within a larger society," may now be expanded to include members of virtual communities (http://www.m-w.com). Virtual communities are spaces where members are connected by technology, most often online using email, blogs (Web based diaries or logs) and games and are becoming an important part of our social network. Because the Carron study was done in 1996 and included only prior work, there is no mention of virtual networks and societies where people receive support.

There are a multitude of sites in cyberspace where people to go share their pain, joy, sorrow or any other human experience. Of particular interest are www.knee.1.com and www.mybrokenleg.com. These virtual chat sites allow people

with the common experience of a broken or injured leg to leave messages sharing thoughts, feelings and resources. Virtual emotional support is a large factor in these virtual spaces. One woman shared her "PT Graduation," "I graduated from physical therapy yesterday! Woooo Whoooo! I have a few exercises to continue with to build some dorsey flexion and strength but am doing very well. I can do the elliptical now for over 30 minutes and am loving water aerobics. For those of you still healing and recovering, hang in there! It does get better!" (www.mybrokenleg.com). A patient starting physical therapy who is looking for a support network may find both support and community in virtual space from the comfort of his/her home. It is important to note that virtual space may have added value for those with mobility impairments as their ability to go out into the physical community may be limited.

Community Concepts - The Third Place

Although not a virtual space, Ray Oldenburg discusses the concept of a "third place" in his book "The Great Good Place" (1999). It is not home or work, but rather a social gathering spot where neighbors come together. According to Oldenburg, a community is a place where "People work together and cooperate with one another to do things which individuals cannot do alone."

Modern day gathering places in the U.S. include salons and barber shops, coffee houses, bars and the gym. Historically, people have gathered in marketplaces, town squares or the water's edge whether a shipyard or river bank. Parks and outdoor marketplaces as well as places of commerce continue to stand the test of time for community gathering places. The third place houses people of various backgrounds with a common goal. It may be a real space or a virtual place where you can go to any

time of day for a long or short period of time and meet, chat, share stories and give or get support to friends old and new.

Compliance/Adherence

Assigning rehabilitative therapy is the job of the physical therapist, maintaining a routine and a schedule for exercise is the responsibility of the patient. Adherence to a schedule for regaining functionality of an injured limb has been positively correlated to significant improvement in that limb. Many variables affect compliance. Too many exercises deter a patient from following an at home routine (O'Reilly, et al, 1999).

"Variables specifically affecting adherence to home exercise were perceived lack of time and a lack of self-motivation" (Pizzari, et al., 2002, p.90) The home exercise program was reported to be isolating, repetitive, and the perception was that the exercises were not effective. "Adherence is defined as self-directed, and self-initiated behavior, whereas compliance is something required or prescribed by a third party such as a therapist" (Carron et al, 1996, p.1).

Case Studies

To better understand how these motivating factors have been previously applied, products and anecdotes are presented here as successful models of integrating motivational theory.

Creating a Fun Atmosphere

People understand the inherent benefits of exercise; looking better, feeling better and in the case of therapy, pain reduction and increased strength and flexibility. Many seemingly motivating scenarios are used by individuals to try to stick with an exercise program.

• Joining a health club may seem like a financially motivating reason to exercise, though in the past, this has not proven to be so. Interestingly, in the last few years, gym attendance has risen steadily. Those who study these trends theorize Americans now understand how important health is and they are stepping up to do something about it. Further speculation points at the changing club atmosphere where a sense of "community and fun" is being cultivated. (Gale Group, 2003)

• In 2004, a game was introduced called *The Fitness Challenge*. (Figure 4) The game is designed for two users and is based on the goal of exercising three times a week for eight weeks. With a cardboard "scorecard" that can be hung on the refrigerator to track your fitness, cards for betting and star stickers, a pair of individuals wager on their commitment to exercise. This colorful board and wager cards which are written in casual, fun language help to make exercise "fun." The game also employs the buddy system so that users have camaraderie and competition. A satisfied customer shares how to motivate oneself when working alone, a situation more relevant for the therapeutic patient:

Figure 3 - Fitness challenge - www.fitnesschallenge.com

Posted: Tue Feb 22, 2005 4:54 pm Post subject: Playing Alone quote

Playing alone can be fun too! I use the 5 pts a week as my goal and use the wagers for motivation - just like when 2 people play. I use different wagers - such as a manicure/pedicure, new shirt or outfit, day at the spa, etc. I reward myself when I meet my fitness goals. This is a great game and motivational tool - it helps me keep on track!
(http://www.fitnesschallenge.com/forum/viewtopic.php?t=3, ¶ 1)

• A group at the School of Physiotherapy in Australia talked with eleven patients approximately 5 months into their rehabilitation regarding their experience after ACL reconstruction. Interviews were conducted with a stratified purposive sampling to ensure representation of average, above average and below average patients. "Enjoyment of rehabilitation contributed to most of the adherent participants completing rehabilitation outside of the clinic." "…lack of enjoyment was identified

by non-adherent respondents as a factor contributing to failure of home-exercise completion" (Pizzari, et al 2002, p. 98). Home exercise was described as "…boring more than anything…" and "mundane stuff,…not really that stimulating" (Pizzari, et al 2002, p. 98).

Design Objective – Fun
The final product should have a sense of fun. Whether used alone or in a group, the design should offer a non-medical feel that may be slightly playful, with colors that entice the user.

Feedback and Tracking

One of the positive motivators is feedback. As seen above in the Fitness Challenge, tracking progress is used as a marketable and quantifiable way to follow progress in an exercise program. Motivation can be internal or external. Internal motivation (the desire to walk without crutches) which results in external feedback (slowly being able to use an injured knee again) prompts further motivation. This emotional exercise loop is the most common. Since rehabilitative exercise often has profoundly smaller measurable differentials from day to day, it is helpful to have external tracking and feedback.

• Returning to Coleman (1998), a case study is cited in which a golfer was prone to fits of rage. While he was undergoing a program to reduce the outbursts, he began to track his episodes to see how long they lasted, how often they came on, and how intense they were. Several months into the plan, he had an uncontrollable outburst which was upsetting and demoralizing after the work he had done. Yet, after referring to the chart, and realizing how long it had been since the last outburst in comparison

to outbursts before the training program, he was surprised and happy to see that the outbursts had, indeed, been reduced. This feedback gave him positive information with which to move forward.

• A 1992 study on intrinsic motivation towards physical activity (in general), "showed that performance information, given immediately after task performance, increased the perceived competence…" (Rutheford, et al., 1992, p. 19) People have short term memories when it comes to benchmarks and timing. It is useful for patients to quickly and easily track progress.

• "Benchmarking played a significant role throughout the rehabilitation process for nearly all participants." "…when I'd ask some people where they were at, I found I was even better than most people who were so much further than me. …my competitive streak came out…I had to be better than everybody…" (Pizzari, et al, 2002, p. 96)

Design Objective – Feedback
The final design should allow the user to look back on progress and to see how far s/he has come. Feedback may be offered during and after the session. While doing at-home exercise, feedback is useful so that the patient is aware of the progress during the exercise session. After the session, feedback is useful so that patient can see overall progress.

Freedom, Autonomy, Being Ready to Act on Opportunities

• Uppal works with a woman who recently had a stroke and is undergoing physical therapy (2003). Choice Theory is utilized to analyze the best possible approach in dealing with a post-injury stroke patient. It is suggested that the caregiver be honest, yet empathetic, explaining all options and physical ramifications, helping the patient to make the right choice, yet giving the patient the ultimate power *to* make that

choice. The client is given power and freedom. She has a say in what her therapeutic goals are and how she will achieve them. The power the patient is given lies in the opportunity to choose, whether or not to get well, to work towards recovery and how this is accomplished.

• Parfitt and Gledhill (2004) involved 20 individuals in a study undertaken to gauge whether individuals would exercise more if participating in a preferred type of exercise. Participants were asked to choose among low and high preference for a three-types of exercise. One group was then asked to participate in their third choice exercise, and one in the first choice. Those who were allowed the feeling of autonomy (those who were allowed to participate in their first choice exercise) reported a lower fatigue level and had a lower rate of perceived exertion. When tested physiologically, the "work rate remained constant across conditions" (p. 111). This study qualifies motivational theory by showing that freedom of choice can enhance the experience of physical activity by actually decreasing the perception of the difficulty of the task.

Design Objective – Autonomy
The final design should allow the user the opportunity to choose how the exercise program is set up, and the frequency of reporting. Patients should be allowed to work with a PT to choose which components of the system will work best for their needs both therapeutically and personally.

Survival, Persistence, Competence

It is important to note that although there are many externally motivating factors that may have a positive influence on a patient's adherence to an exercise program, internally motivated individuals are more likely to become persistent exercisers (Vaansteenkiste et al, 2004). Persistence and competence are feelings and

traits which are much less tangible and quantifiable than previously mentioned motivating factors. These traits are much more difficult to alter, yet they have a significant effect on the outcome of adhering to and benefiting from rehabilitation.

• A six year study was done conducted with patients in Sweden during an intensive period of unemployment in the country. Patients with long or repeated periods of sick leave who reported musculoskeletal disorders were included. The goal of the study was to determine costs to society and whether motivation was a factor in rehabilitation. It was determined that those who are highly internally motivated progressed more quickly and were less of a financial burden on the medical system. Persons who were latently motivated took longer in rehabilitation and were more of a cost burden on the system (Grahn, et al, 2004).

Belonging and Relatedness

• Businesses and schools are already tapping into the idea of a network of use as a motivational tool. At Xerox Parc in Palo Alto, California, a system referred to as Portholes was implemented in the early 90's (Dourish, 2001). This distributed work group was designed for all members of Xerox Parc to have an awareness of both near and far surroundings. Through an online system, users were able to track people's locations as well as what work is being done on which projects. The workplace becomes smaller, more intimate and less anonymous with such a system in place. The worker is immediately an integral part of a larger system. Motivation may be seen when an individual is aware that a co-worker is putting in time on a project, it is possible that seeing one person work can inspire another.

Positive Feedback as part of the Community Experience

• In 1997, a study by the physical education faculty at the University of Alberta (Kerry) looked at compliance at a fitness facility through control, placebo and reinforcement groups. No intervention was offered to the control group, a letter was sent from the gym to the placebo group, and the reinforcement group received a letter that offered them 1 month of free membership if they came to the facility at least twelve times in the following month. The test proved most positive for the reinforcement group as they had the best attendance of the three. The positive feedback or reward for attending the gym motivated the largest group of users.

• Sales and workplace data have a significant overlap into the field of motivation. *How Full is Your Bucket* (Rath and Clifton, 2004) states that the number one reason people leave their jobs is the feeling of being underappreciated. Positive feedback in the form of praise and recognition has been shown by a Gallup poll to increase individual productivity as well as create workers who are likely to stay with a company longer.

• Timothy Bickmore and Rosalind Picard present an interesting experiment in human emotions (Bickmore, Picard 2004). Their research surrounds the concept of computer agents and caring. Laura, a computer generated exercise advisor with human traits of caring, was created as part of an experiment which looked at how people react to computers that seem to have human emotions. Two groups were created, one interacted with Laura, and one with a common human-machine interface which had no name and was given no characteristics of caring. Sixty subjects had a 10 minute

interaction with the computer for 1 month. At the end of that month, subjects were asked about their response to the interface and the 'affective' computer model.

Although a majority of the subjects were MIT students, very aware of the capabilities and limits of a computer, many still felt inspired, motivated and cared for by the computer which demonstrated behaviors equated with caring and social interaction. It is interesting to look at the 'caring' behaviors in context with the motivational behavior described as "belonging" and "relatedness." The valued caring behaviors are described as "social dialogue," self disclosure, emphasizing commonalities, talking about the past and future and reference to mutual knowledge.

Goal Setting

• In The American Salesman (Sunderland 2004), Gretchen Sunderland discusses the motivating goals used in sales and the power of positive thinking. Visualization, whether it's achieving a sales goal and winning a trip to Hawaii, or picturing yourself on the tennis court back with your foursome and feeling no pain while playing a winning game, can be very powerful.

• In a study undertaken by a group in Australia, it was found that those who were motivated to exercise and stay with a program used return to sport and regaining normal function as a goal driving their recovery; "…if you do all the hard work…you'll be playing again" (Pizzari, et al, 2002, p. 97).

Summary

Motivation and adhering to an exercise program involves a complex set of physical, social and psychological factors. Interconnected factors may or may not be present for the duration of a patient's physical therapy. Building on the known social

and psychological factors, a product design adds to the toolbox of positive forces influencing a patient's behavior.

Confounding Factors of Motivation

It is worth noting that while this study is focused on motivating individuals to participate in at home exercise, there is a segment of the population that may not want to heal; no motivation will be enough to convince the individual to participate in the therapy. Individuals may not want to return to work at a job where they were injured or to a job they disliked. An individual experiencing depression due to or in spite of an injury needs more assistance than an interesting new product to assist in healing both psychologically and emotionally.

Products Used in Physical Therapy

Body work, therapy and exercise require tools which help with strength training and flexibility. To aid in rehabilitation, physical therapy includes weight and strength training machines. (Figure 4) During office visits, patients use machines similar to those seen in an athletic club. Machines help strengthen legs, arms, shoulders and thighs. After working against a machine, a patient may also be required to use oversized balls for balance and strengthening. Large rubber-bands for resistance and weights, though generally lighter than those found in a gym, are common. (Figures 5, 6)

Figure 4 – PT machine, www.nustep.com

Figure 5- Exercise ball, www.therapyzone.com

Figure 6 –Exercise bands, www.therapyzone.com

Measurement devices are used by PTs to gauge a patient's progress. Medical product design for physical therapy is taking advantage of the affordances new technology provides. The goniometer (joint angle measure) allows the therapist to track knee flexibility through a degree of flexion measure. (Figures 7, 8) Available in analog or digital versions the analog version is used by therapists while the digital one is best used in research studies and "tendon jerk experiments" (www.adinstruments.com/products/datasheets/MLTS700.pdf. p. 1).

Figure 7 - Digital goniometer

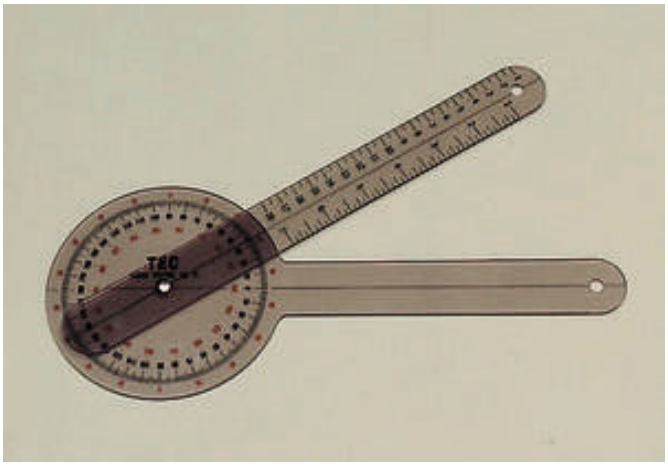

Figure 8 – Analog goniometer

Smart Devices

Adding technology is one of the new ways companies update existing products. Technology is used to create a desirable product to fill a specific need. Although the intention is simplification of use products can still be too complex for the average user to learn. Responsibility lies in research and development to insure the technology is desirable, usable and follows a path of common sense. "Designers…of our medical world now must embrace the idea that our customers are beginning to expect the sophistication and options in their healthcare product…that they find in their normal consumer culture." (Stropkay and Watson, 2003, p. 57)

Two devices which utilize technology in rehabilitation are currently in the research phase. By combining technology and rehabilitative therapy, these devices stand out as innovations in rehabilitation.

Dr. Todd Kuiken and a team at the Rehabilitation Institute of Chicago are looking at ways to measure patient progress as well as motivating them to exercise with a wearable device donned post-surgery (Kuiken et al, 2004). This device is a knee brace used by patients healing from a total knee arthroplasty (TKA) or knee replacement surgery. Patients with in-patient status were given the device which provides feedback reminding patients to exercise in 30 minute intervals throughout the day. (Appendix A)

As stated in the study's intent, the issues that lead to design of this device include the goal of a reduced hospital stay and relying on the patient for self-motivated therapy sessions. The study hypothesized that through regulation and encouragement, the device could keep patients on track with rehabilitation.

Audiovisual feedback in the brace, which was on during certain days and off on others, alerted patients to exercise. The brace was worn continuously throughout the study whether or not the alerts were activated.

The study's conclusion was opposite of what was expected. Patients were more likely to exercise on days when the audiovisual feedback was off, rather than on. One hypothesis may be that since patients weren't waiting to be prompted, they exercised whenever it occurred to them rather than waiting for the prompts at more distant intervals. No control group was part of the study. Work needs to be done to understand the confounding evidence.

Although further research is needed, relevant feedback was reported. Wires were an annoyance to patients, but the beeps which alerted patients to exercise were not found to be particularly annoying. The device offered a delay option when prompting which was heavily utilized throughout the trials. It was requested that the visual display be larger, though no clear data exists on the size of the existing display.

In May 2004, Constantinos Mavroidis presented a research project using fluids to change the resistance of a knee brace. (Figure 10) When subjected to an electrical field, the viscosity of the electrorheological fluids change and become more or less viscous. The change in viscosity provides more or less resistance by altering the voltage using a small battery. The device is currently hooked up to a computer, but will have an internal computer in the future. The designers of this device believe it is important for therapists to have the ability to remotely fine-tune the exercises being done at home by the patient. A therapist may have remote access

to the brace to set viscosity and resistance. No study data is yet available on the effectiveness of this device.

Figure 9 – Knee brace with electrorheological fluid www.robots.neu.edu

From both products (Kuiken and Mavroidis), it can be ascertained that there is a distinct interest in patient motivation and remote monitoring. Utilizing new technologies makes it possible to assist patients and therapists for the most effective experience of monitoring and rehabilitation.

The product market for medical wearables is open and ready for products. A glut of research and prototypes exists for products which can track, monitor, and assist in healing. Very few of these products are commercially available today. Cost-effectiveness, durability, power sources and embedding systems are all issues still under investigation. A short list of wearable projects and products which involve medical and/or motivational applications can be seen in Appendix A.

Medical Wearables

The LifeShirt® System by VivoMetrics® (Figure 10) is one of the more visible products on the market sold as wearable technology. The LifeShirt captures over 100 different types of data from various sensors. These sensors are attached to the body at various points. Cables and a data system are housed in a nylon/Lycra® vest. This vest conforms to the body and allows users to comfortably carry electronic equipment throughout the day. The system is wearable by virtue of pockets sewn into a fabric vest, although much actual hardware is still involved. These remote monitoring systems allow patients to download data so that physicians and medical workers can remotely monitor patient progress. As stated by Dr. Marvin Sackner (2002) in an interview on CBS News, "the LifeShirt [distant health monitoring], allows for a movie of a person's health, not just a snapshot." The LifeShirt provides an opportunity for health professionals to receive continuous data over a series of day to get a more accurate picture of a patient's overall health. A short visit to a doctor does not always offer an accurate picture. Remote monitoring allows for real world settings and data capture providing more accurate data with a cost-effective and less invasive system.

Figure 10 - LifeShirt by VivoMetrics

The SmartShirt (Figure 11), originally developed by Dr. Sundaresan Jayaraman and Sungmee Park of Georgia Institute of Technology, is a glimpse into the future of wearable technology (Newman and Wolinsky, 2003). The technology is now owned by Sensatex, a company working to take this product to a commercial market. Originally created to assist soldiers in the field by monitoring heartbeat, blood oxygen and other physiological data, Jayaraman refers to the shirt as a "wearable motherboard." Information from the SmartShirt can be sent to a doctor's office or hospital monitoring station. Seeing the possibility of a wearable motherboard embedded into a textile reveals the opportunities that lie ahead as this technology becomes more flexible and less bulky.

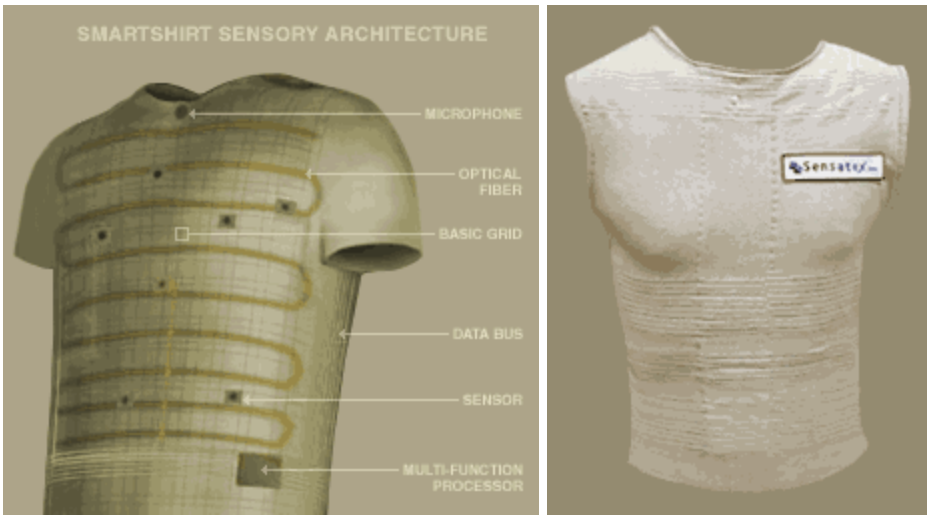

Figure 11 - SmartShirt technology

Wearable Computing

The aforementioned designs are a part of a growing group of products referred to as wearable computing (wearables). Thad Starner of Georgia Institute of Technology and Sandy Pentland and Rosalind Picard of Massachusetts Institute of Technology are leading researchers and authors on the subject of wearables.

Wearable computing refers to any computation or data gathering that occurs on the body. “It is desirable to weave the necessary sensors into forms with which people are naturally in contact” (Picard, 1997, p. 238). A wearable may be in the form of the aforementioned LifeShirt, or in a more embedded system. Many wearables are medical or technical in nature. As computation becomes easier to embed and more socially acceptable, items will emerge on the market that are accessible to the average consumer. (Appendix A)

Items such as Hoodio by the Gap (Figure 12) begin to merge textiles and technology. Introduced in December 2004, this jacket has a radio system in the hood and controls on the front panel. In late 2005, Motorola and Burton, a snowboarding gear company, will have a jacket on the market (Figure 13) that allows the wearer to plug in a phone and an MP3 player and interface with them using controls on the jacket sleeve (Rojas, 2005).

Figure 12 - Hoodio by the Gap

Figure 13 – Burton snowboarding jacket

Looking at this list of projects in the field of wearable technology shows opportunity for wearable applications in the fields of medical and athletic apparel and accessories. The way has been paved, but much room is available for continued exploration.

Technology At Home

Although computing is becoming more ubiquitous, requiring less time with a keyboard and full-processing device, this is still common for many products. Computing assists people at home with activities from correspondence to paying bills or playing games. The home computer no longer sits isolated from data in remote locations. The Internet connects individuals across the street and around the world. A report on December 1, 2004 on National Public Radio stated 137 million of the 209

million Americans over 18 have (www.census.gov) Internet access, and approximately half of those have a high-speed connection.

Most spend some time on the internet daily. In an article from the Atlanta Journal Constitution in 2004, a survey done by Nielsen/NetRatings showed that 51% of those with Internet access are currently using broadband. The number is up 38% from the previous year. Individuals under 35, and particularly those 18-20, have highest usage (59%). This may be due to growing access to broadband in many university settings. Individuals over 65 have the lowest usage, yet one-third (34%) of this population does take advantage of broadband. Not only are a large number of households now online as shown above, but record numbers have significantly faster connections. This allows designers more flexibility with systems that send larger amounts of data back and forth. Although it is important to design for the lowest common denominator, options should be to accommodate the variety of systems in use.

As wearable technology gains prominence, it is important to be aware of the technology available to and used by consumers. Many wearable systems will work best with the ability to send data. This data will be processed through a computer which will upload to

a doctor or professional.

CHAPTER 3

RESEARCH

Target Market

The product being developed will be based on survey data from adults over the age of 18. Both males and females who have a temporary knee injury, chronic pain or who have undergone TKA will be able to use the product. Those with a permanent injury who need a wheelchair or other assistive device will not be a part of the survey data or the intended user group. Users who suffer from cognitive (problem solving, reading, attention, language) or memory impairments are not specifically considered in the research.

Survey 1

Survey Population

A random convenience sample of 16 individuals was used as the basis for a survey on individual experiences while undergoing physical therapy. Participants were required to have undergone a course of physical therapy within the last 12-18 months. This was required to improve the probability that the patient had a clear and accurate memory. Although efforts were made to contact individuals from rural and urban settings with distinct demographic variability, the sample population used in this research was city dwellers.

The survey instrument was distributed through a network of friends and local therapists. Some participants filled out a survey sent out as a Microsoft Word

document via email, others filled out a paper survey. All but one respondent lives in the greater Atlanta area in Georgia. One respondent is from Chicago, Illinois.

Survey Instrument

Having chosen the field of physical therapy for general study, a survey instrument was created to inquire about therapy, technology and home exercise. One survey was specific to the patient experience and one survey asked the therapist specific professional questions. The goal of the survey is to discover how patients and therapists perceive the experience of physical therapy.

When presenting this survey, it was hypothesized that two issues would arise as significant deterrents to physical therapy. Studies on telemedicine discuss travel time as a deterrent for some PT patients to continue with their therapy. It was also hypothesized that patients would be frustrated when trying to do exercises unsupervised at home, and that misunderstanding the exercises might keep a patient from participating in any at home therapy.

Rehabilitation Survey - Patients

Survey Population

The survey (Appendix B) focused on patients with only lower limb injuries. Information was gathered on demographics, the importance of touch during the therapeutic process, general assumptions and thoughts, goals and expectations about physical therapy routines and a patient's comfort with technology. Additional inquiries helped to discover how often and how long patients were involved in therapy and details about their HEP.

Participants

Of the respondents, two were between 18-23, one age 23-34, five were ages 35-44, one ages 45-54, six ages 55-65 and one over 80. There were no respondents between the ages of 66-80. It is interesting to note that although the 35-44 and 55-65 age groups make up 73 % of the respondents, there was only one respondent between the ages of 45-54. This data is fairly comparable to general PT demographics where the age groups who frequent physical therapy include middle aged (50-74) and young adults (20-49) (Brisette, 2004).

Of the respondents, 7 were male (44%) and 9 female (56%). The gender distribution was fairly broad across age categories with no particular correlations to be drawn. Demographic data on PT across the country shows is in close correlation with these numbers stating 44.2% of patients are male and 55.8% female. (Brisette, 2004 and abclocal.go.com).

The group as a whole was well educated with 13 graduating from college and 6 of those with advanced degrees. Income levels were also high with twelve of the sixteen (75%) reporting a household income over $60,000. Two individuals did not respond to this question, one respondent reported household income of $24-$40k and one $41-$60k.

Findings

Athletic injuries were most prevalent. As seen in Appendix, B the survey only inquired about lower extremity injuries. In this sample population, injuries are almost three times as likely to occur on the right than left and are often treated with a combination of therapies; ice or pain relievers. Most sources cite 10-13% of the U.S.

population is left handed. From this survey, it can be seen that approximately 66% of patients injured the right side, yet 87-90% of the population is right handed. Additional research is required to discover whether handedness affects the side of injury in lower extremities. This may be important to note as the design takes shape, though any device should be created for both left and right-handed individuals.

For a better understanding of the process, participants were asked to report how long they had worked with a PT. The majority, twelve (75%), were in therapy over six weeks with six participants seeing a PT for over eight weeks. The average time spent working together was almost two hours a week. Fifteen of the sixteen respondents visited the PT at an office location at some point during the recovery process, one did not answer the question.

To understand if travel was an issue preventing individuals from getting treatment, questions were asked about travel distance. For this group, travel distance to the PT office was fairly insignificant; fourteen (88%) traveled under 10 miles to see a PT and two traveled 11-25 miles. No data was collected on the time necessary to travel these distances.

Although participants were not asked whether they took time off work to see a PT, they were asked if they took time off work, in general, due to the injury. The range for this question was fairly broad, with no single category taking precedence.

When asked if anything would help complete their at home therapy, several patients mentioned how difficult it was to get motivated. Although eight individuals had no particular answer, of those that answered, motivations and reminders were key. Suggestions for motivation ranged from getting a personal trainer, to having

better self-motivation, joining a health club, and 'some kind of reminder'. This question had the most interesting and surprising results and led to the formulation of the final thesis topic.

To better understand the end as well as the beginning of the therapy process, participants were asked why they stopped seeing a PT if they had answered that they were no longer under care. In this case, 13 of 16 (81%) of the participants had completed or were still participating in the recommended therapy. Patients were asked if they have *continued* with their home exercise regimen. Eleven participants (69%) stated they still do the recommended exercises and there was a 27% drop out rate of people actively doing all exercises recommended by the PT after therapy. This self reported rate does not reflect the commonly quoted drop out rate of 50% (Dishman, 2003 and Grahn et al. 2004). However the confounding factor may be that the majority of patients are still under the care of a PT.

Patient surveys showed general comfort with technology, no real desire to be visited in the home by a PT, and no great misunderstandings when doing PT at home.

Again, taking into consideration the fact that the surveys were largely taken by individuals in major metropolitan areas, 100% of the individuals surveyed owned a computer in their home and all but one who had recently moved, had Internet access from the home.

A final portion of the survey asked questions specific to technology and medical care. Survey participants were given the options of "agree, somewhat agree, somewhat disagree, disagree and no answer." When scoring the answers, a Likert Scale of 1-4 was used with 1 for agree, and 4 for disagree. In the few instances no

answer was checked or a question was missed, a zero value was added to the numerical data.

From this data, it is apparent that patients are generally comfortable with technology and have ready access to it. Patients are not interested in home visits from healthcare practitioners, but do feel comfortable receiving medical advice over the phone, when needed. According to the initial survey, when participating in rehabilitative therapy, patients feel touch is important and have no particular issues of confusion or misunderstandings when exercising alone at home without a PT. In a later user feedback session with new subjects, one subject did note that he "got home and couldn't figure out the positions" when trying to replicate exercises given by the therapist.

Discussion

From these surveys, a target market and user application begins to arise. The typical therapy patient is 35-65 years of age and slightly more often female than male. Patients are largely college educated earning over $60,000/year. ‘

The common length of the time in therapy is 6-8 weeks or more for lower limb injuries. On average, patients spend two hours a week with a PT, with a significant number spending three or more hours at the clinic. All of the patients surveyed had health insurance that covered some or all of the physical therapy fees for an average of 13-20 sessions. This metropolitan group is computer savvy and uses computers often for research and communication.

Travel to the therapist and general understanding of at home exercises proved to be minimal or non-issues in the greater picture. However, motivation is the most important part of staying with a HEP between office visits.

Rehabilitation Survey – PTs

Survey Population

A random convenience sample of 11 PTs was used as the basis for a survey on the therapists experience while working with PT patients (Appendix B). These therapists were reached through the Physical Therapy Association of Georgia and a network of professionals and friends. Surveys were taken on paper or electronically via email. Therapists were required to have worked at least three years as a professional. This requirement was set so that PTs would have significant experience on which to draw when answering questions. Although efforts were made to contact individuals from rural and urban settings with distinct demographic variability, the sample population used in this research was city dwellers.

Some participants filled out a survey that was sent out as a Microsoft Word document over e-mail, others filled out a paper survey. Eight of the eleven PTs surveyed were from the greater Atlanta area, with the remaining three from California, Maryland and one did not answer.

Survey Instrument

The gender breakdown of PTs included four male and seven female respondents. There was a fairly even distribution of ages represented covering the general workforce ages of 23-65. Due to the physical nature of the job, it is not surprising to find that there were no respondents over the age of 65.

There are a variety of medical professionals involved in supervising healing and therapy, however in this survey, it became apparent that orthopedic doctors (nine responses), primary care physicians (seven responses), and specialists are most often involved during the time that a patient is seeing a PT.

PTs were asked how many patients they see in an average day, knowing that caseloads may change from day to day due to meetings and scheduling needs. No PT noted seeing less than five patients per day, seven PTs reported seeing eight or more patients in an average day.

The PTs were asked the average number of exercises they give to patients with a lower limb injury. Nine of the respondents said they recommended at least five different exercises, and three said seven or more. One PT gave out an average of 3-5 exercises. Appendix C shows typical exercises given by a PT for a HEP for knee injuries or chronic pain.

To discern comfort and familiarity with various technologies, PTs were asked about what technologies they use in their day to day life. All participants have a personal computer at home and seven (64%) have them at work.

When monitoring patients' progress and overall physiology, PTs use several pieces of physiological data. When monitoring progress throughout the course of therapy, there are four significant measurements; range of motion (ROM), strength (S), and electronic data (ED). Six PTs rank strength as the most important gauge of progress and five rank range of motion.

At times, a medically fragile client may have his/her physiological signs monitored during exercise. The four most common statistics are blood pressure (BP),

oxygen level (O2), pulse (P) and blood sugar (BS). When asked to rank these vital signs, BP was noted as most significant or important to track, with P second. Any monitoring device should have a way to check blood pressure and pulse since low pressure can lead to fainting. Blood pressure can easily (though not continuously) be measured. Aerobic exercise is not the goal of most therapeutic exercise, therefore pulse is not the most important sign to measure.

Therapists showed a slightly lower, but still average comfort with technology, a desire to maintain an office based practice and only a slight concern that patients pushed their therapy, but no real concern of it being a dangerous outcome of a HEP.

PTs were asked a similar set of questions to the patients on a Likert-type scale with boxes to check. The same scale was used as with the patient population: 1 = agree, 4 = disagree. A zero value was given to questions with no answer.

PTs are also generally comfortable with technology, but feel it has a slightly less significant role in their lives now and in the future. Patients and PTs agree on their preference of therapy in an office rather than the home, and the importance of touch to the work. Although patients claim they often do the recommended number of exercises, PTs are less likely to agree that the full exercise regimen is being followed at home.

Discussion

The original focus of this survey was to understand how to help individuals with lower limb injuries more accurately and actively participate in their therapy. However, research showed that are rarely confused about how to accomplish these exercises even when working alone at home. The surveys showed a different problem

taking precedence. Instead of accuracy, patients often spoke of the difficulty motivating themselves to do the exercises and spoke of the desire for a partner or membership to a gym so that therapy would not be as isolated.

All of the PTs surveyed agree or somewhat agree with the statement "I don't think my patients do the recommended number of exercises between visits." Patients confirmed the PTs assumptions when 62% replied they do not always participate in the recommended number of exercises between visits. These statements confirm the need for a device that can count and monitor patient participation.

A product developed to motivate patients, track results and utilize simple technology should be a comfortable solution for most individuals. Although technology can track, motivate and monitor patients remotely between sessions, it is important the PTs have direct, physical patient contact in a clinic or office setting at specified intervals.

Comfort with technology is a final important note. The PTs are slightly behind their patients in both internet and email use. While all patients and PTs surveyed own a personal computer in their homes, only 64% of PTs have a computer at the office.

This initial survey prompted more research on motivation. The literature review was broadened to encompass the topic and a class experiment was designed to help answer the questions: "What motivates people to exercise?" and "What words do you associate with motivation?"

Motivation – Group Exercise

To better understand why it is difficult for some to motivate or participate in exercise or physical therapy, a group of graduate students at Georgia Institute of Technology was polled on their thoughts and feelings about motivation. Since it can be assumed that an entire classroom has not had the direct experience of physical therapy, the question was posed to the group in a way to promote general feedback on the topic of personal motivation.

On Monday, September 28, 2004, a group of 20 students were asked "What motivates you to exercise or study?" The individuals were allowed to work in pairs or alone to answer the question. Students were encouraged to create simple visuals to share their thoughts using interlocking Lego blocks and Playdoh. These materials were chosen to inspire creativity, bring levity to the question, and encourage students to have fun, all while creating a way to share their thoughts. Pen and paper were also mentioned as an acceptable method of sharing ideas.

Participants were given 20 minutes to create a representation of their idea. At the end of 20 minutes, there was a discussion where each individual or pair described their creation. As ideas were presented, a list was created of words that represented various aspects of motivation as well as attitudes about motivation. (Table 2)

Table 2 – Motivators

Negative Motivators	Positive Motivators
Negative Reinforcement	Letting Go
Discipline System	Fun and Engagement
Tricks into an Emotional State	Color/Sunlight/Atmosphere to call attention to the product
Twisting the Truth	Dangling Carrot/Reward System
Apprehension/Last Straw	Symbol or Reminder of Empowerment
Guilt	Friendly/Level Competition
	Cycle/Regimen
	Attaining Goals
	Inertia
	Positive Reinforcement
	Feedback of Level of Accomplishment
	Goals/Feedback
	Discovery and Control
	Laughter – Being Funny

Without prior research on the subject, students noted a majority of the motivators found in the work by Deci and Ryan, Glasser and Coleman. (Table 3) In addition to these common motivators, goal setting was mentioned by five groups. The students also noted a fair number of negative motivators including fear, guilt and mental tricks people play to get things done. These can be closely related to the social factors and the idea of committing to the goals of a larger group. Although it is be difficult to put the ideas into practice, many individuals have a tacit understanding internal and external motivators. Knowing which motivators will work for a particular individual in a given circumstance is crucial to the creation of a motivational, assistive device.

Table 3 - New motivation matrix

Glasser	Deci & Ryan	Coleman	Class
Fun			Fun and engagement Laughter – being funny Letting go
Freedom	*Autonomy*	*Ready to act on opportunities*	Discovery and control
Survival	*Competence*	*Persistence*	Scheduling/Goals Attaining goals
Belonging	*Relatedness*	*Committing to goals of a group*	Positive reinforcement Apprehension/Last straw Guilt Negative Reinforcement
Power	*Competence*	? *Drive to achieve excellence*	
			Accomplishment feedback Reward system Dangling carrot

A closer look at the project suggestions shows how individuals see these motivators being helpful in their lives. The most common suggestion for a motivational tool was a format which offered negative or positive feedback or a reward system.

Motivating Devices

One group decided that a scale, which was brightly colored (suggestions of black and yellow or bright green were made) to catch the user's attention, could be set to lie to you when using it.(Figure 14) Depending on your need for motivation, the scale could be set to read slightly lower or higher than your actual weight. For those who prefer negative feedback, the scale would show them just a bit heavier and inspire them to

exercise more. For those who prefer positive feedback, the scale could be set to read slightly under their weight providing proof that their workout is working and they should stay on track with exercise to continue weight loss.

Figure 14-Scale that tells more or less weight

Another student suggested a newspaper with a creative headline that could work as a motivational tool. (Figure 15) It would provide negative or positive feedback as needed. The designer of this idea stated that it would be very motivating to see your worst fears in print. A copy of a fictitious newspaper, *The Daily Times,* has a headline of "Dan Fails Exam: expulsion from school imminent." Although this was the suggested headline, he also mentioned that, if it would help at other times, the headline could be changed to a more positive message depending on the needs of the student.

Figure 15 - Motivating fake headline

The reward system was evident in another creative option. A plate of healthy food was represented in Playdoh, with a small ice cream cone. The generous plate of healthy food and dessert, were presented as a reward after exercising.

As a way to assist in a plan to stop smoking, one individual created a case to hold a pack of cigarettes which is equipped with a timer. The timer would dispense a cigarette only at designated intervals. A reward system would be in place as well as goal setting.

A final pair of students created a way to represent the feeling when they do and do not exercise. They discussed the initial period, when one begins to exercise and how it starts to become something that is craved instead of dreaded. This internally motivated pair of students shared a feeling of wholeness and accomplishment on the days exercise is completed. They represented this feeling with an abstract creation of a half-shell type base where there are plugs (Figure 16) that drop in and out. Days where a person exercises are described as "full," "complete," and the plug is in place. Alternatively, days where exercise is avoided or forgotten, there is an empty hole, the day is not complete. This pair also created a more amorphous shape. The piece was a blunt square with many holes in it. This

shape represents the blob-like feeling or the spaces where emptiness flows into the body and the participant physically misses the exercise and its affect on the body.

Figure 16 - Representation of the 'empty' feeling of no exercise

This brief creative session was useful for quickly bringing to light what motivates people to exercise and physical action. It is most beneficial to get to a place where there is a physiological need to exercise or participate in physical therapy. While getting to this place, many people find it helpful to have reward or feedback systems in place. There is differing evidence and opinion as to whether negative or positive feedback is more motivating. As stated in the research section, several studies on medical situations and motivation suggest that negative feedback is not the most effective form of motivation. However, in this brief session, there was significant agreement among the group that, although negative feedback is not always effective, there are times, especially around physical exercise, where it can have an impact.

In general, the group came to the conclusion that outside motivation is effective in exercise. However, the question, at the beginning of the session was

posited as a challenge to create something that motivates you. All but one group created an object or reward that is, in itself, motivating. The sole exception was the group who showed how it feels internally when exercise is missed on a particular day. This visual representation of an internal state will be useful to take into account moving forward.

Diary

In late 2004, a second phase of research was begun. Having a better understanding of motivation among the general population, and finding it as a deterrent to exercise, a second formal survey instrument was created. Through an open-ended format, patients would be asked to keep a diary of their mood and their adherence to their HEP. (Appendix D)

It is important to note that the user group for this study was a self-selecting group. Individuals volunteered to take a survey on PT and fill out a diary on motivation. These individuals were already somewhat motivated people simply by the fact that they put the energy into agreeing to be part of a study.

The survey group does not include individuals who may have found therapy too painful, expensive or time-consuming to undergo. One individual who was contacted to participate in the diary exercise called to decline. He had attended less than one week of therapy and simply found the exercises too painful to continue. Those unwilling or unable to participate in PT represent another important user group, but not one represented in this research.

Procedure

A convenience sample of eight individuals undergoing physical therapy was recruited to participate in the diary exercise. Of the eight packages given out, six were returned within the requested period and five had accompanying photographs. Patients were recruited via friends and networking. As an incentive to participate, individuals were offered a Starbucks gift card in exchange for their time filling out the diary. Patients were sent or given a package (Appendix D), which included a short survey about their injuries, consent forms for the University, a diary and a disposable camera (some participants used their own digital camera).

To better understand the environmental factors that co-exist with the psychological factors of physical therapy, patients were asked to keep a diary and comment on weather, amount of pain, what activities they participated in and what motivated them to do their physical therapy that day. The camera was used as an additional device to understand the surroundings in which patients do their physical therapy. The diary also contained a series of pages which prompted users to take photographs of particular environments and to answer questions visually. The pages allowed space for their explanations of why each photo was included. (Appendix D)

Survey Population

The survey instrument was, again, populated by the mid-range of ages, 23-65. All participants lived in a house and all had full-time work. Five participants were female, one male. Because motivation was the focus of this survey, the site of injury was not as critical and patients undergoing physical therapy for any type of injury or

pain were able to participate in the study. In this random sample, two injuries related to knee and foot/ankle problems and three related to shoulder-neck-mid back pain.

Diary entries and feedback

Patients were asked about their goals for the end of therapy. Each participant had an athletic or physical-type goal, a goal to be free of pain or a combination of the two. Knowing this, it may be useful to incorporate a progressive tracking system where the patient can see how the pain has reduced over time, and strength has been regained. A PT may be able to help the patient set realistic time and strength or range of motion goals so that patients have benchmarks along the way to the final goal.

Participants were asked to share their feelings after participating in their daily HEP. People often reported feeling better or at least different, after completing their at-home sessions.

One participant had an interesting series of answers to the question of post-exercise mood. Early in the diary, when asked "did your mood change before or after you exercised?" She stated "no, it never really does", two days later she "felt more limber" and three days later she stated she "felt more awake." In between there was a range of yes and no to the question, then, 17 days later, she stated "more awake, yes, better". (Respondents were only required to answer for 6 consecutive days, however this respondent filled in approximately 3 weeks of the diary). Although she initially assumed that exercise never really makes her feel better, the latter responses indicate that there were days when the HEP has a positive outcome.

Looking at the overall data, a significant amount (44%) of answers were neutral, stating no significant change in the patients' mood. Thirty-six percent of the

entries reported a positive mood after PT, and the remaining answers were not filled in, had no exercise that day or no significant feedback. Change in mood is not a reliable outcome of a HEP and is not a reliable motivator to promote participation.

Participants were asked to share what motivated them each day. Habit, the goal of getting or feeling "better" and actual visits to the PT were most motivating to these individuals. One participant said she was even motivated by the act of looking for a personal trainer. Change of routine also arose as a motivator. The decision to walk on a new path or exercise on a different machine is enough to keep patients interested and motivated.

There is minimal correlation between how a person feels during the day and the motivation or likelihood to exercise. Yet, it is worth noting that one participant stated on two different days her dissipating pain was motivating. "Today I was motivated by the fact that I am feeling better", and knowing the therapy was working was a great motivator. Pain is generally a de-motivating factor to participating in a HEP.

An additional section in the diary exercise asked patients to take pictures of what motivates them to do their physical therapy. Respondents relied on a mix of internal and external motivators. Visualization (internal) was used by some used by one respondent who took a photo of a shirt from a bike race. One individual responded with the abstract photo of a column (internal), "so my back can be as straight as this column." A spouse or a therapist were also noted as motivators (external). An individual who did not insert a photograph stated, "getting back to 'normal' is what motivates me" (internal).

A reminder, whether a physical item, picture or a simple prompt that you are moving towards an end goal is very motivating for many individuals. A reward is received and the timeline, however lengthy, still has a beginning, middle and end. These are important benchmarks so that patients can look forward and backward to see progress and time left to completion. This patient feedback mirrors suggestions by Csikszentmihalyi to, "set an overall goal, and any necessary sub-goals," and "find a way to measure progress towards chosen goals" (1990).

Discussion and Conclusions

Environmental factors such as weather or amount of sleep did not play a significant role in predicting a patient's motivation to exercise on a given day. A patient's mood, or knowing that there was potential to feel "better" after therapy, had no significant effect on motivation. This survey suggested that habit, change in routine and the goal of getting or feeling "better" was most motivating. Participants also used end goals such as a bike race and support from a PT or family member to stay motivated in the healing process. In person visits where a person worked directly with a PT were also motivating to patients.

The design challenges presented by this outcome are:

• track progress

• assist in early habit forming to inspire patients to participate in HEP

• offer camaraderie of a medical professional or other buddy to motivate participation in the HEP

CHAPTER 4

DESIGN PHASE

Design Criteria

Before creating a product to assist patients in physical therapy, a series of limiting factors and design criteria were created based on information gathered in the literature review, survey and diary.

The initial design direction for this project was a wearable device that would assist patients in a HEP. The decision to create a prototype occurred before all of the survey data was collected. At the time, it was assumed that a wearable device that gave patients feedback on how accurately they did their exercises would be the most beneficial product for the PT market. During this time, information was collected that proved other pressing needs in this market segment. As work was being completed on this device, it became apparent that a re-direct would be most beneficial. Using the wearable device, which tracks slightly different data as a starting point, the idea of a networked solution arose – now referred to as the Thera-Network. Two devices and additional computer programs could offer a full-range of products where the patient and PT could choose the most appropriate technology. At this time, criteria were decided for the two devices. The research and development of these devices is shown in the following chapter. To encourage emotional attachment, the devices were given human names: MAGGi (motivational angle gauge goniometer- interactive) is the wearable device and M.A.T.T. (motivational assistive therapy tool) is the desktop device. Table 4 represents the design objectives for different devices that work together creating a network of care for patients under the care of a PT. The third

column is a list of psychological factors found in the motivational research and from the student focus group. The limiting factors are addressed with early prototype designs. Many remaining questions or uncertainties are discussed in user feedback sessions.

Table 4 – Device Objectives

PT Device	Motivational Tool	Psychological Factors
Self-Regulation	Buddy or trainer	Fun
Accommodate 5-7 exercises	Motivator	Belonging
Track ROM and S progress	Simple technology	Autonomy
Track BP and P	Track progress	Goal setting
Involve touch	Feedback	Goals of a larger group
Incorporate accuracy	Baseline or benchmarks	Drive to achieve excellence
PT Buddy	Rewards	Avoid boredom
	Reusable	
	Private vs. public	
	On body/in room	
	Early habit forming	
	6-8 week overview	

Wearable Device - MAGGi

A prototype wearable device was designed based on the initial hypothesis that PT patients would benefit most from a device that assists with physical therapy by acquiring feedback on whether or not exercises are done correctly. A system was developed using a wearable device as a source for feedback during at home exercise. This device houses a series of lights which informs the patient how far s/he should flex or stretch during the exercise. The device allows a patient and therapist to set goals together. These goals are visualized by the glowing strips on the MAGGi.

Electroluminescent strips (EL) light as the user participates in range of motion exercises.

At the outset, the wearable device was intended to invoke a sense of fun and assist the patient in reaching a therapeutic goal. The wearable was not intended to look or function like a knee-brace. Early market comparisons looked at games like MoCap Boxing (http://espnzone.com/sportsarena/) and the Leg Shocker by Fursr (http://www.fursr.com/details.php?id=26&pid=26) to inspire a sense of fun while completing the HEP. Both products use a combination of on body and screen based devices for active participation in virtual sporting. The brainstorming for the wearable reflects this diversion away from the design aesthetic of a "medical" product. (Figures 17-19) Ideas from this brainstorm include a device that allows patients to hit a bell when PT is done correctly, much like the strong man exhibit at a carnival. Ideas where users had bells on the legs to motivate motions and webbing that would create an interesting aesthetic when stretched were also considered. Designing "fun" into the wearable combines Glasser's Choice Theory and Norman's theory; people are more likely to acquire and use a device to which they make an emotional attachment (Uppal, 2003 and Norman, 2004).

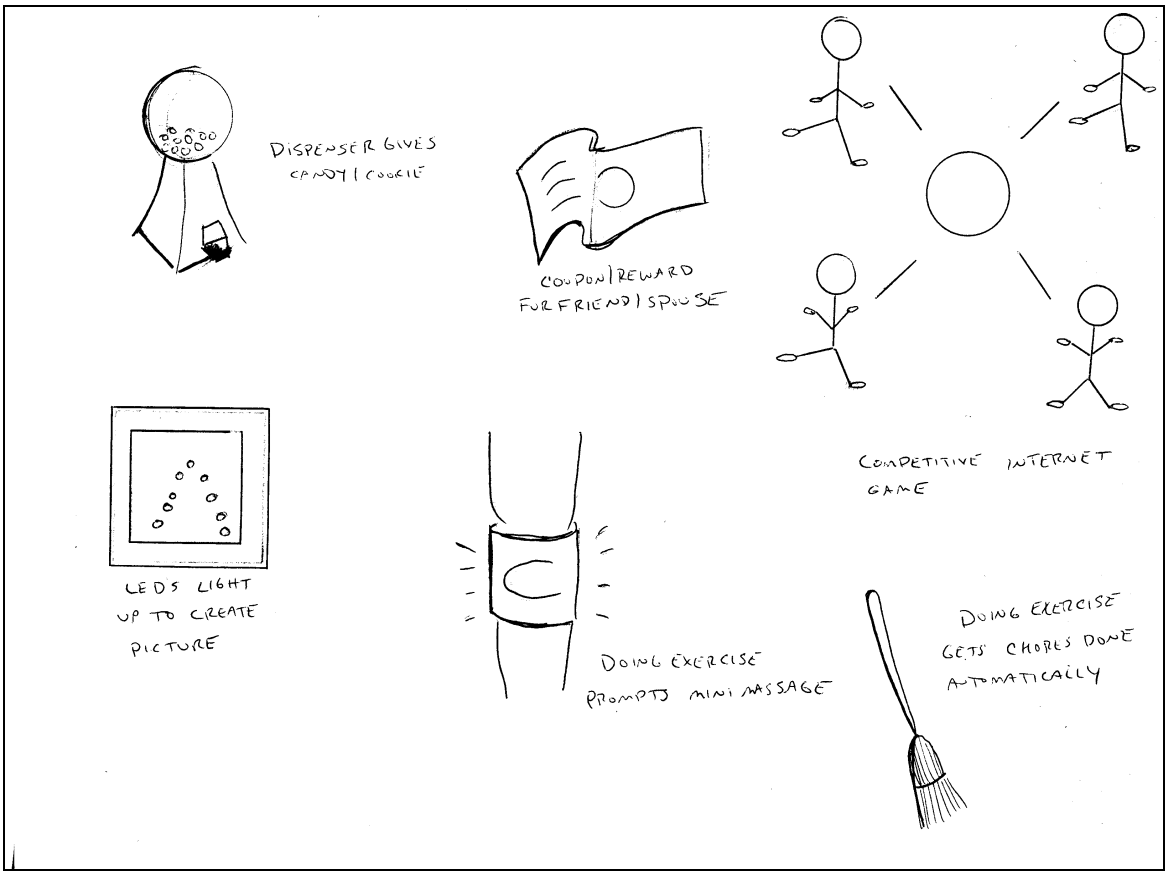

Figure 17 - Early device ideation

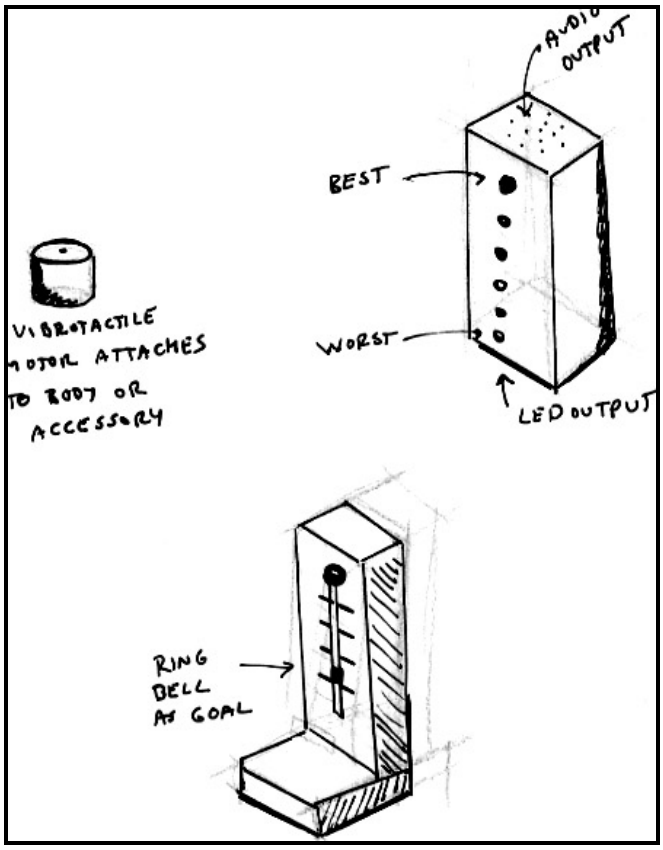

Figure 18 - Early ideation

The wearable device was created to better understand the necessary technology and make a working prototype, as well as creating a pleasing form. Though these more fanciful notions are not entirely out of the realm of technology, a device which measures ROM in the knee requires certain technologies to obtain accurate information. A potentiometer is an easy to use, data gathering device. Considering options for form and function, it was decided that a less complex aesthetic with full functionality for demonstration offered the greatest learning opportunity. The final form factor works with the available technology.

It was decided that for an initial foray into technology, a potentiometer would be the most logical device to measure ROM in the knee. A potentiometer somewhat

limited the design aesthetic as it needs to be accurately placed at the bend in the knee. This brings the design back to a form factor resembling a knee brace. (Figures 19, 20) A small amount of time was devoted to the exploration of knee braces and their structure, though largely for materials and hinging mechanisms. The device needs to be comfortable, durable and flexible, accommodating a wide range of users with various body sizes.

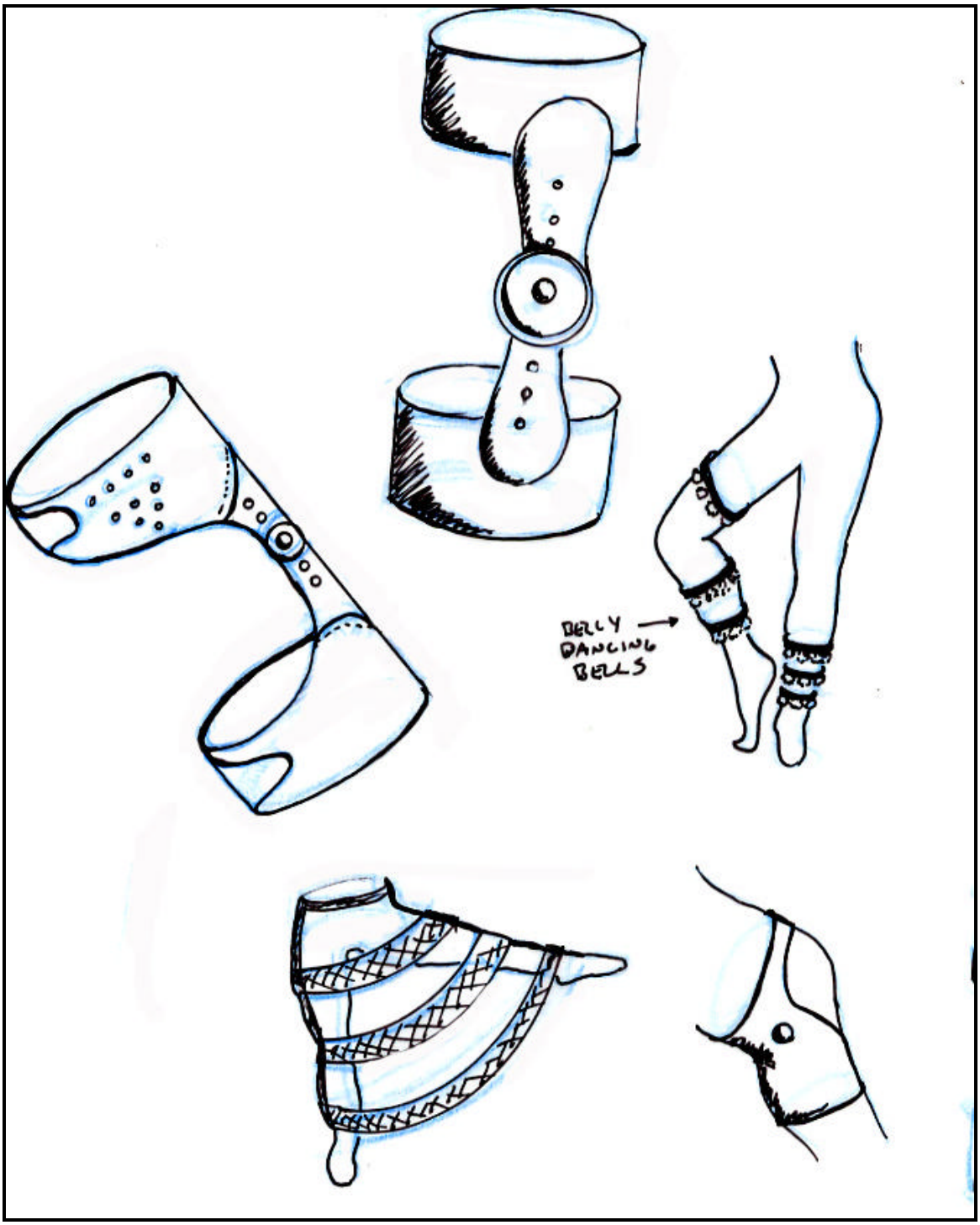

Figure 19 - Early ideation

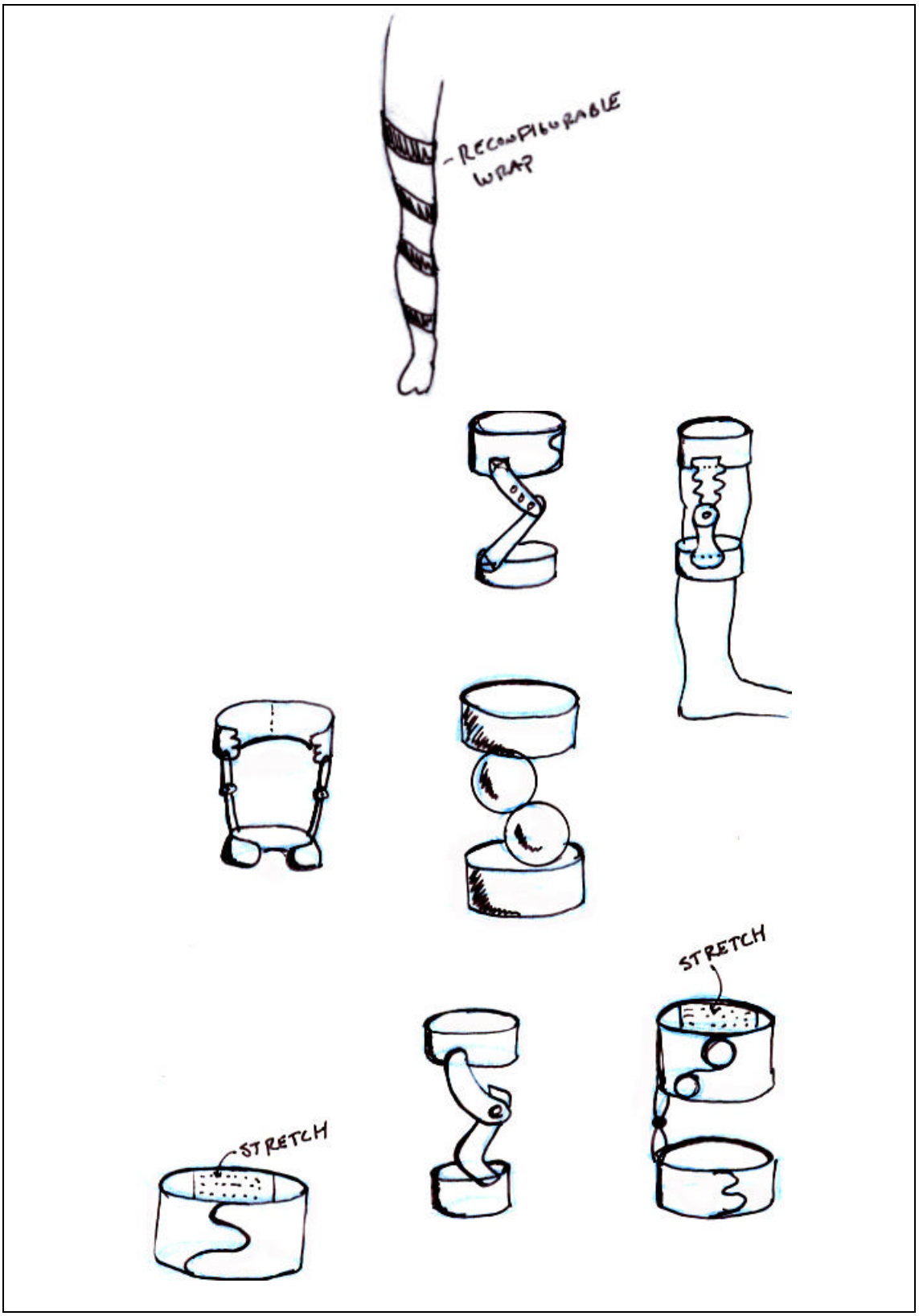

Figure 20 - Hinges and wearables

Early prototypes attempted to move away from the typical neoprene brace. (Figures 21-25). By using fleece, the device is softer and more friendly, and a simple web structure adds a high tech look. A wide array of hinge structures were used in the experimental phase. Because the exercise device is not a product designed for weight bearing or specific orthopedic assistance, it needs to be just strong enough to stay in place during exercises.

Figure 21- Circular hinge

Figure 22 - Fleece prototype

Figure 23 - Fleece and Lycra prototype

Figure 24 - Neoprene prototype with Hytrel

Figure 25 - Web prototype

Hytrel plastic by DuPont, a thermoplastic polyester elastomer, was found to be an easy to use plastic which allowed for quick, functional and appealing prototypes without special machinery. (Figure 26) It comes in a variety of densities and colors, cuts easily with shop scissors or a band saw, and requires no heat to create formed prototype parts. The Hytrel was formed for exact fit around the potentiometer. Due to the softness and malleability of the elastomer, Hytrel can also be run through a sewing machine to allow plastic and fabric to be stitched together. The hinge on the side of the final design was made using Hytrel.

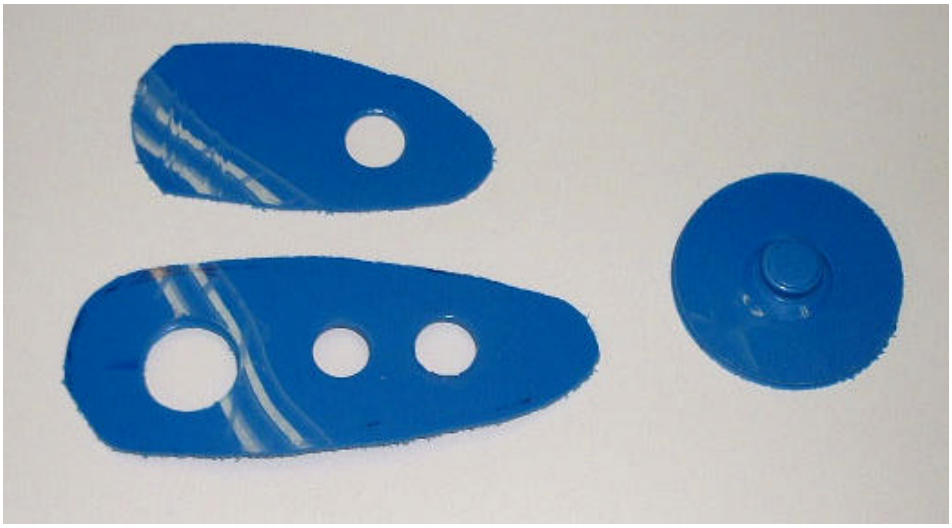

Figure 26 – Hinge of Hytrel

After experimenting with a variety of materials, neoprene proved to be the best commercially available material for this device due to its strength, body and flexibility. For the final model, neoprene and Hytrel were used to create a visual prototype. In order to move away from the overall feel of a medical product, this

device uses more technical colors (black and silver) and opens up the knee space (avoiding the full brace stigma) by using a single sided mechanism. As a final detail, the neoprene is stitched to the Hytrel creating a quilted look, adding a softer, friendlier feel to the product.

Function

Feedback at the time of exercise is shown to be valuable (Paradiso, 2004). To create a working prototype which allows the user visual feedback, low-profile light-emitting diodes (LEDs) were used. Through a series of stitching and tying, LEDs are connected by a conductive thread. Since the thread is flexible and does not break when bent or folded, it creates a more wearable, durable, flexible device. (Figures 27, 28)

Conductive thread is a new technology which has not yet been fully explored or used commercially in apparel or products. The thread was initially sold to repair holes in fencing uniforms as fencing is now scored by electronically sensed touches on the duelers garments. The thread has been used in prior work and functions well in wearables due to its flexibility and conductivity (Coffin, 2004 and Stamper, K. 2004).

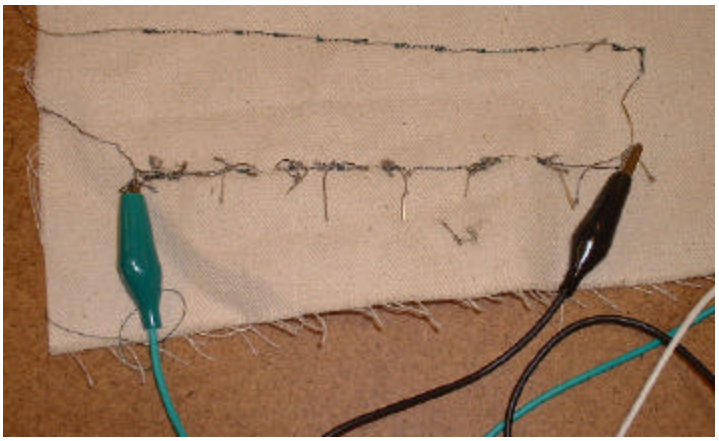

Figure 27 - Using conductive thread to power LEDs

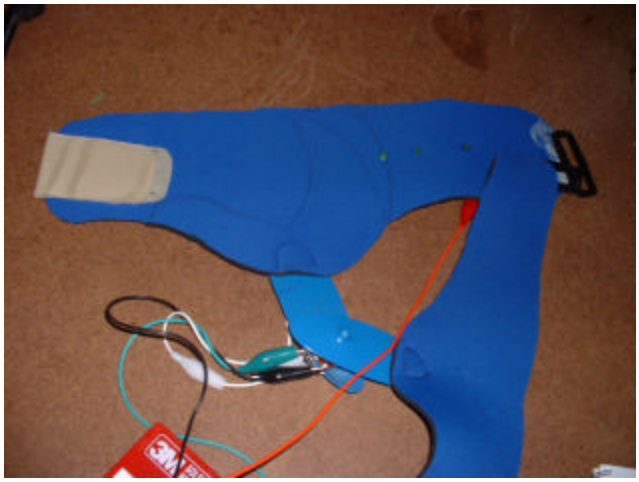

Figure 28 - LED wearable device prototype

After working with the thread and the LEDs, research scientist and engineer Daniel Walker suggested electroluminescent (EL) strips would be a better technology for this product. (Figure 29) EL strips were chosen for the visual indicator due to their flexibility (they can bend around the leg without damaging the circuit which would have been more difficult with LEDs), visibility/glow, low/no profile and the fact that they do not get hot when in use. While creating this device, it was found that EL strips can be successfully sewn into products without damaging their integrity. A

triangle shape was cut out in the neoprene allowing the EL strips to glow in the form of a pyramid using the smallest part as the topmost goal for rehabilitation.

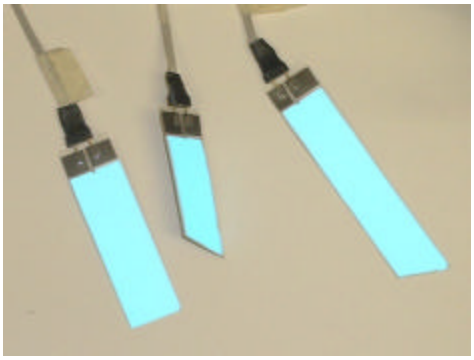

Figure 29 - Electroluminescent strips

As discussed, the potentiometers in the device are used to gauge leg angle. The joint angle potentiometer is encased in Hytrel and placed parallel to the bend in the knee. The device can be set to correspond to target angles in a patient's exercise regimen. When the desired angle is reached, a light is lit offering the user immediate feedback that he/she has reached the required flexion.

Technology

The initial circuit (Figure 30) for this wearable device is comprised of one 12V wall-mount power supply, one 5V voltage regulator, four 10K potentiometers, one operational amplifier (op amp – used as a comparator to simulate digital output), one capacitor, a pre-programmed, animated, EL chip and three EL strips cut to size for the product. The EL strips are run by potentiometers on a breadboard and the animated EL chip. The breadboard housed four comparators which gauge the voltage

produced by the joint potentiometer. This information is then compared by the comparators to the four reference potentiometers which are set at four different angles. The potentiometers were necessary to regulate voltage going to the EL strips. If the voltage produced by the joint potentiometer is higher than a reference potentiometer, the corresponding light will be lit. (Figure 31)The voltage produced by the potentiometer is proportional to the rotational angle. In practice, a user bends the knee during the HEP, the potentiometers read the angle and, when the right amount of voltage passes through, the potentiometers act as a gateway signaling which EL strip should be lighting up at that particular angle.

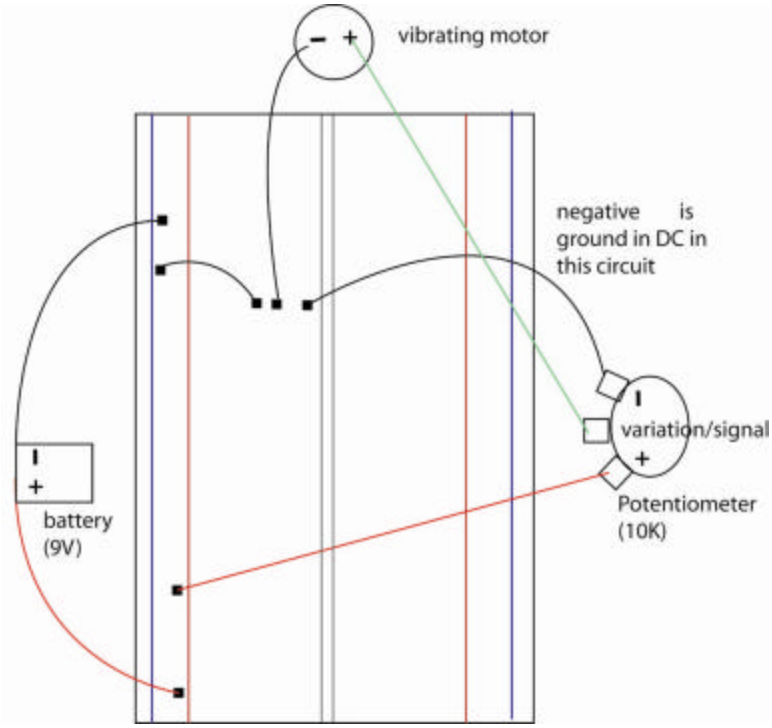

Figure 30 - Diagram of breadboard circuitry

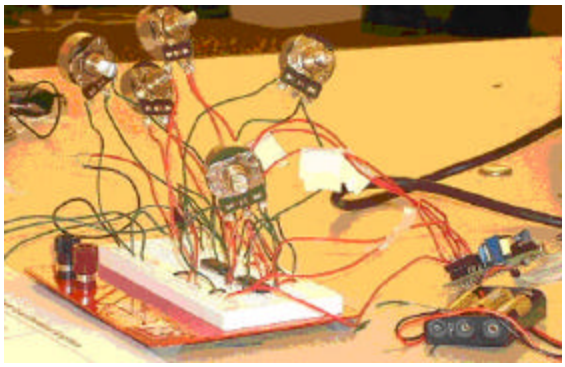

Figure 31 - Potentiometers on breadboard

Potentiometers and a breadboard with a wired system were used for this proof of concept prototype. The potentiometers are very difficult to set and not conducive to remote access by a therapist. In the next phase of design, the breadboard with three potentiometers will be replaced with a coded computer interface. This interface will easily allow physical therapists, whether local or remote, to pre-determine at which angle the EL strips light up. As the patient progresses the therapist may download new goal angles. This connection also allows the therapist to see that the patient is actively participating in the home exercise program. Knowing the therapist has access to the data motivates patients to be more compliant in the HEP, as they are now accountable to a health practitioner.

Feedback

The wearable device, MAGGi, was shown at Demo Day (a day where students share their projects with the academic community and interested public) through the Human-Computer Interaction program on the Georgia Institute of Technology campus. (Figure 32) Although users were not specifically queried on

likes and dislikes, there was a general interest in the product concept as mobile wearable technology by both professionals in HCI and potential users.

Figure 32- Wearable device

To obtain more directed feedback, post-occupancy user evaluations were administered. A convenience sample of six individuals who had seen a PT in the last two years, (five of whom had participated in previous surveys and were familiar with the work being done) agreed to one-on-one hour long interviews. (Appendix F) Individuals were queried on their thoughts regarding the prototype of MAGGi, and three prototypes for M.A.T.T., which would be used during the HEP between visits to the therapist. Feedback was gathered on relevant exercise data, interface design, therapist input, buddy networks and downloading data. (Appendix F)

This user group consisted of individuals with chronic knee pain or those who had a temporary knee injury and were sent to a PT for a program of healing. Most

participants were young to middle-aged adults (approximately 25-43) with one individual in his early 80's.

The older participant had a unique situation since he was a heart patient and wears a pace-maker. His immediate response to seeing an electronic device that could be used during therapy was that he would be unable to use it due to the pace-maker. His doctor told him not to use electrical therapy devices. Upon further discussion, it was understood that cell phones and Walkman-type devices do not disturb the pace-maker and there would be no medical repercussions if the individual donned the wearable device. However, the initial reaction of fear is critical and worth noting.

Device Design

At the outset of each interview, participants were asked to don the device. Only the participant with the pace-maker declined. The knee to be tested was his bad knee and, although it was not wired or plugged-in, he was still wary of putting an electronic device on his body. No discomfort or inhibition was reported by the remaining 5 users when using the device in this form factor. However, when watching the donning process, it became obvious that the users were unsure how high on the leg the device should go and what the exact placement of the potentiometer should be. The two sets of Velcro straps on the thigh often tangled and got confusing. A simpler mechanism is needed to replace the existing design.

The device is intended to be worn next to the skin or over apparel. Most users did not wear a supportive, prescribed brace during their PT even if it was being worn

for pain throughout the day. Since medical support is not generally worn during the HEP session, there is no concern of one device interfering with another.

Interface

The prototype wearable had a series of 3 lights made from EL strips. (Figure 33) The system is very fragile and did not last for a user testing phase. It was also discovered very early that a counter would be useful for the device. Therefore, when testing the device, a computer screen-based interface was used in place of the interface on the device. This interface had three bars (yellow) and a single counter below. (Figure 34) Users donned MAGGi and were asked to look at the computer screen and imagine it as the interface on the wearable on the thigh.

Figure 33 - Final prototype

Figure 34 - Screen interface

Most of the users queried answered that at least some of the exercises suggested by their therapist could be monitored by this device. A black on grey, sans-serif number was used which appeared to be easy to read as no users commented on it directly. Ideally, a set of three counters would be added to the interface. One counter for sets completed, one for repetitions completed (usually 10 reps in one set) and a third counter for hold times (set at five second intervals up to 60 seconds). One user stated he got "lazy in counting" and would make deals with himself. The timer would offer a more uniform and accurate hold time throughout the therapy session. Some users felt that interval audio alerts (i.e. a beep every 10 seconds in a 40 second hold with a different beep at the end) or a tone with a slowly changing frequency would assist the patient in knowing how far it was until the end of the hold.

The visual interface of a pyramid was well-received and easily understood. The "triangle is a goal, you try to hit the goal." However, participants had differing

opinions on the use of pyramid shape for feedback. Users stated the lights were useful to “get a good stretch,” “gauge how far you have come or need to go” or be able to “gauge day to day how many bars were lit up.” One user wanted the triangle to tell you the angle that you got to, rather than using it as a set goal. As an example, the patient would know that bar 3 meant s/he had reached at least a 70 degree ROM. Most users said that at least one of their prescribed exercises had them moving in such a way that it would be difficult to see the interface. Some felt audio feedback would be a helpful addition as long as it could be turned on/off as desired.

One user was not interested in this abstract representation of his exercises. He suggested, instead, a picture of a leg, “somewhat robotic”, so that it was more literal and less abstract. Another user mentioned that he often did his exercises with his eyes closed; making an additional case for audio feedback, either beeps or an actual voice counting out loud. It was also mentioned that the lights should inform via on/off states and not a slight glow or change in color. For those who would like to use a device in the gym or with privacy, a headphone option was suggested.

The wireless power option is a crucial element to the success of the design as well. Exercising on the tether of a power cord is potentially dangerous and uncomfortable. Although the cordless power system is not fully realized, products using nuclear batteries or transducers which harvest energy from motion (Roy, et al, 2005) show the possibility of a wireless therapy device.

Online Community and Remote Access

Thus far, the system allows a patient to begin tracking progress largely in isolation while working at home. As previously stated; communities, guilt, and feedback are external factors that are useful and motivating to individuals. To create a full circle of support, it is proposed that a PT and a buddy have access to patient HEP data. A PT would be allowed access to data to help track adherence, and be available if anything out of the ordinary were to occur. A buddy would be another individual undergoing physical therapy who is likely going through a similar rehabilitative process.

When discussing MAGGi, users were queried on their interest in sharing information through a variety of on-line and remote access formats with a PT or a buddy. If a patient was not downloading data, the PT could check-in electronically or via telephone to determine if there were difficulties prohibiting the patient from exercise. Although electronically sharing information with PTs received positive feedback, patients did not want to be responsible for downloading information. “If I do it, it will be once a week if I have to remember.” Four of five users found the idea very motivating and would be interested in using that networked option. “Yes, it would be motivating to know therapist is getting information. I don’t like it, but it’s motivating!” said one interviewee.

The wearable device is useful as a stand alone motivator, however its value is greater when attached to a system that gathers and tracks the ROM data. To make the most of the system, the data must be sent to a computer program where it can be

processed and forwarded. Data would be shared with the therapist as well as with M.A.T.T. in the patient's home to assist in tracking and motivating. Patients, often reticent to exercise, requested that no further action be required to process the data transfer. Many individuals have a computer at home in a room separate from where they exercise. The ideal data transfer solution is wireless and utilizes an extended, flexible antennae engineered into the wearable which allows a Bluetooth module to send a radio frequency (RF) signal directly to the computer in any room in the home.

HEP-Home Exercise Program

For most participants, the factors limiting the extent of the therapeutic exercise are pain and ability. Therapists do not ask patients to reach a particular numerical goal angle when doing exercises at home, but say to go as far as they are able, or as far as they can without too much pain. One user actually suggested an additional interface button that is activated at the point of pain. This information is then recorded along with the ROM for a PT to obtain a full understanding of a patient's recovery.

Design Criteria

Based on the above user feedback sessions, the following issues are to be addressed in the next generation prototype.

• Two straps on the thigh should be merged into a single strap, without a fold back

• Add a counter. Allow patient to see sets, repetitions and count a hold up to 60 seconds.

• Visual feedback should be in smaller increments, possibly with a more literal graphic

• An option for auditory feedback, tones or voice, would be useful

• Include option to download information directly to PT daily

Additional ideas from users include:

• Self-tracking comparison

• Lock wearable device to hold leg for exercises where a hold time is given

• Option to see daily progress as well as overall information at the end of workout

• Make wearable device washable

• Wireless or plug-in headphones allow audio feedback to be heard privately and in noisy environments

Design Criteria – MAGGi

A final checklist was created to compare the motivational theory and the suggested design for MAGGi. (Table 5) The EL strips double as a motivator for fun, and goal setting and the visual and auditory counters offer feedback and tracking. Additional system devices, the buddy system and the programming software, address the need for autonomy and the option for community support.

Table 5 - Motivational theory – MAGGi

MOTIVATIONAL THEORY	HOW IMPLEMENTED
Fun	Patient tries to light EL strips with exercise
Community	Separate buddy system allows users to track participation in the HEP
Goals	EL strips light when exercise is done, counters track progress
Autonomy	Program encourages PT to set up therapy routine *with* patient not *for* patient
Feedback/Tracking	Reps, sets and holds are monitored and counted, auditory feedback

Buddy System

A screen-based system which could duplicate community for a person who may be exercising at home alone was built and tested by the researchers. A program was created by Kevin Stamper in Python which allows two users or "buddies" to be aware of one another's exercise habits. This simple interface encourages an immediate community of support.

An icon (Figure 35) resides in the system tray program. After participating in the HEP, a patient can go to the computer, right click the icon, and an alert will be sent to the buddy saying "Kevin just did his exercises!"

By putting the buddy system on the computers of the researchers, it was quickly determined that it is important for both buddies to have visual feedback in the

system tray. In the first iteration, there was no feedback to the exerciser him/herself. Future versions would allow for two icons in the system tray, one for each user.

Figure 35 - Buddy icons

Additional alerts tell the patient that new settings have been created or a note if another individual has completed his/her exercises for the day. Knowing a buddy has completed his/her task may be enough motivation to prompt a patient to participate in his/her home therapy.

The idea of a buddy network was not as popular as suggested by background research. Individuals participating in physical therapy tend to view it as a private journey and, thus far, prefer to work independently. This buddy system was deemed "not helpful, I would rather do my own thing." However those who reported using a gym post PT did state that when going to the gym, a buddy was useful. One participant mentioned that he and his wife motivate one another to go on varying days.

Based on this research, the PT process is a very personal and private process, however when a program of 'regular' exercise is undertaken, a check-in system with a friend or a workout buddy is of greater interest. The idea is an optional add-on to the final design.

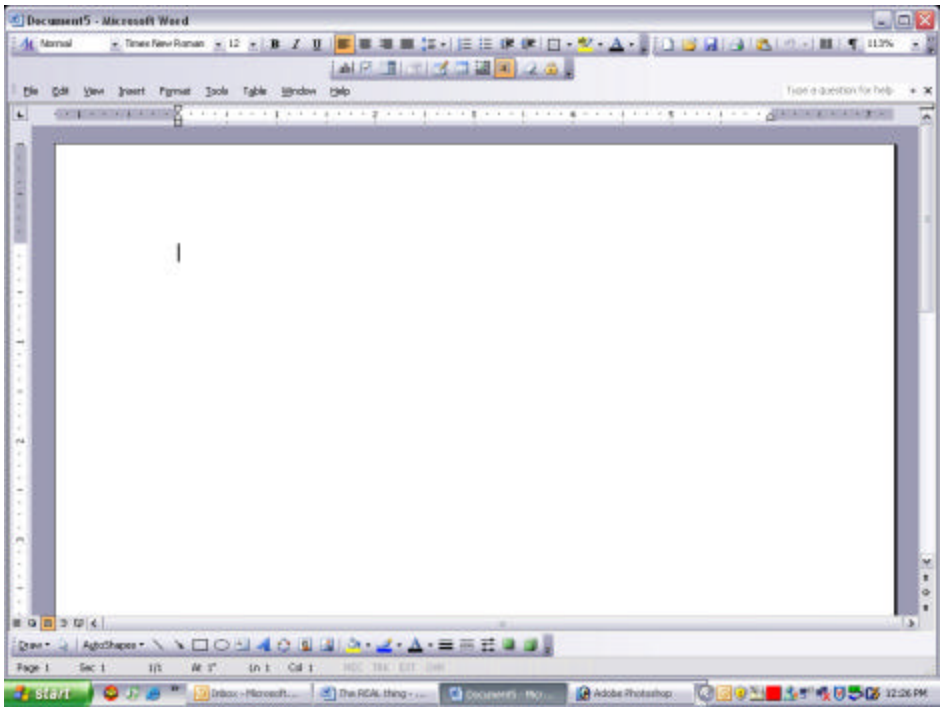

Figure 36-Red Box in lower right corner shows buddy has not exercised

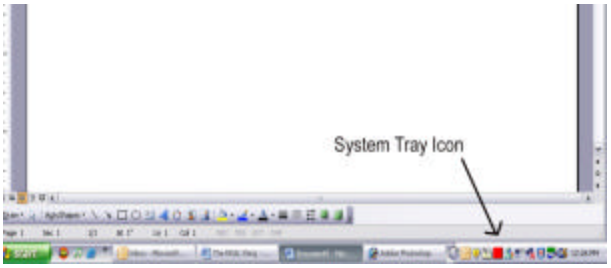

Figure 37 - Buddy system

Motivational Tool – M.A.T.T.

A third component of the network is the motivational assistive technology tool (M.A.T.T.). This component aids in motivating the user through the entire HEP. If the user is not motivated and does not participate in the program, little physical progress can be made, and the patient will not heal as quickly (Grahn, 2004).

Brainstorm Session I

The ideation process presented here is a multi-step process. Brainstorming, prototyping and user testing occur in a cycle, bringing the product closer to a solution that is widely accepted.

BRAINSTORM > CHOOSE, REFINE AND PROTOTYPE > USER TESTING

Prior to creating literal images, abstract representations were rendered of the emotional issues surrounding physical therapy and compliance. (Figure 38) These images help to understand positive and negative geometry. Positive geometry is represented with upward lines and communal circles. Negative, less motivating geometry is linear and separated.

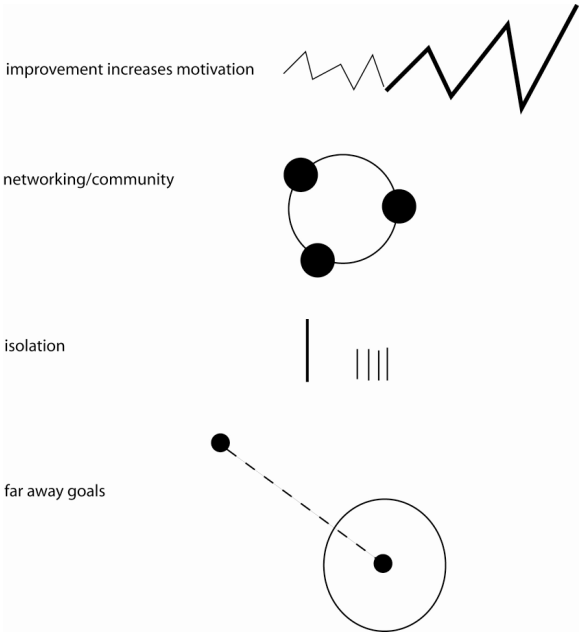

Figure 38 - Abstract representation of emotional aspects

Thumbnail sketches further explore the concrete version of the motivational tool as the opportunity for a wearable reminder. (Figures 39-41) An item that moves from garment to garment and stays with the user during the entire day works as a gentle reminder by glowing, vibrating or offering audio feedback. Common accessories such as belts and pins were designed as well as unobtrusive devices worn on or around the ear. Near body reminders including a wallet card or key fob which users have with them much of the day were briefly explored. Their distance from the body during many times of day decreased their intended effectiveness.

Although these solutions may be a useful accompaniment to another device, none offer the feedback and tracking deemed important in previous research. As seen in the research by Kuiken (2004), a reminder may not be a sufficient motivator to rehabilitative therapy.

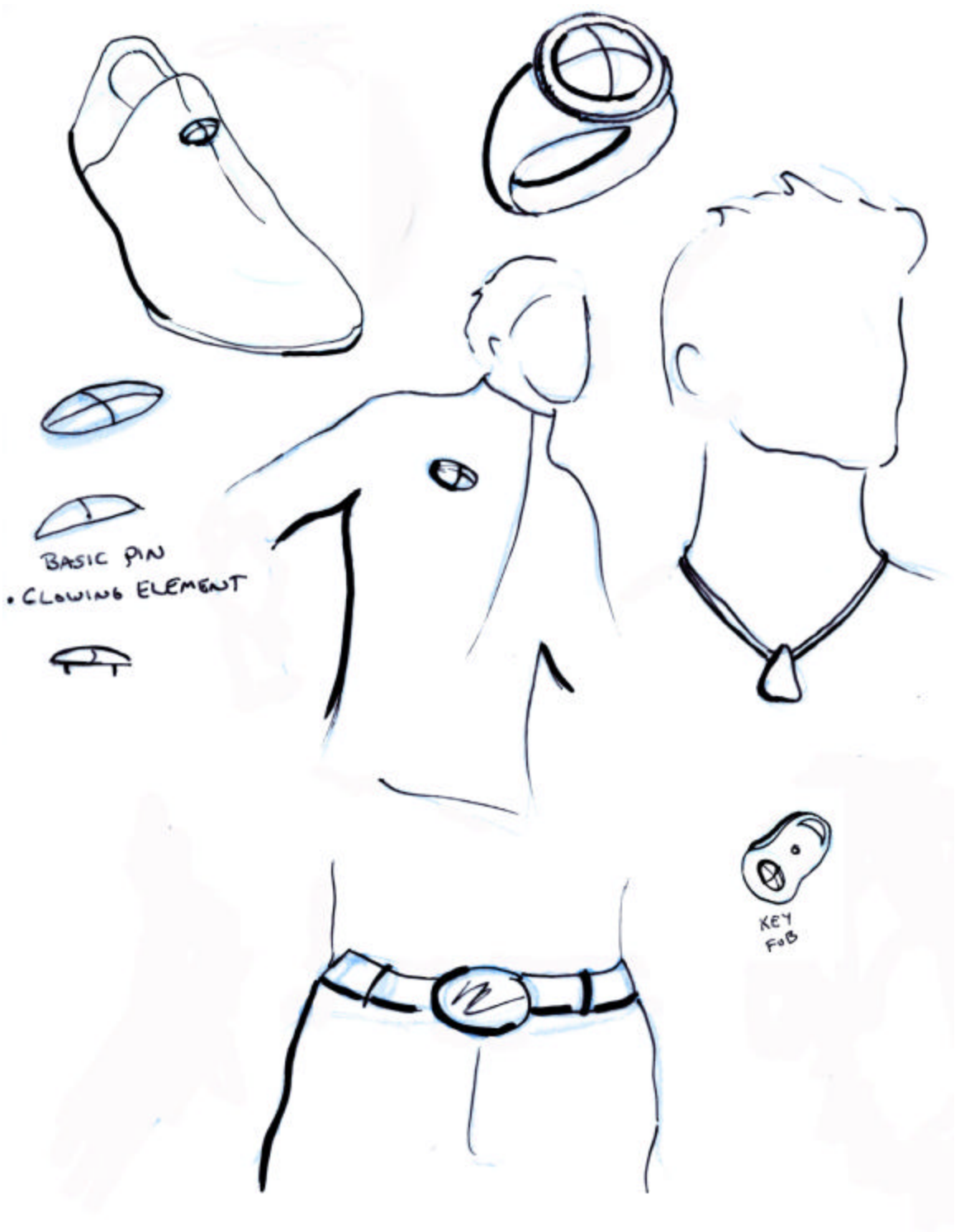

Figure 39 - On body reminder devices

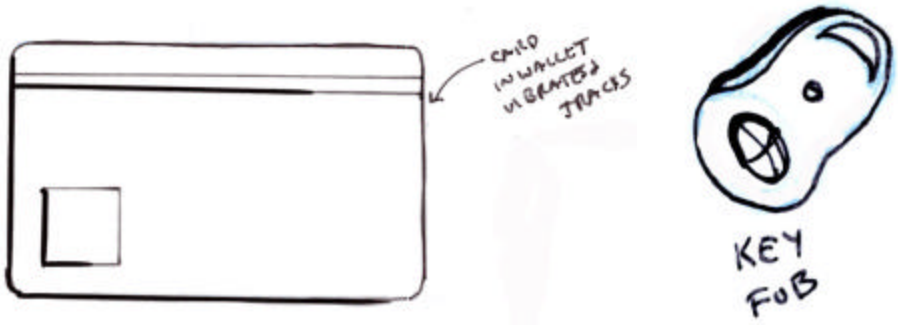

Figure 40 - Near body reminders

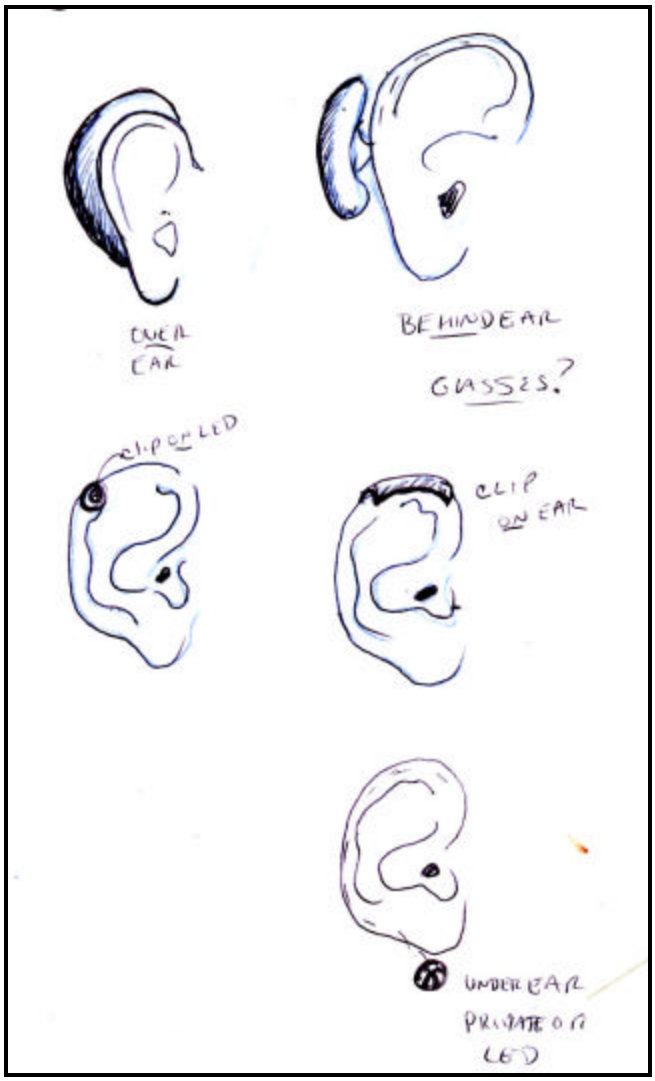

Figure 41 - Over ear reminder devices

To track healing, the parameters of the information collected and the duration of therapy must be understood. Patients may be asked to exercise from once a day to every hour. On average, patients exercise no more than three times in one day. This number is used in consideration of the initial form. Patients are generally under the care of a physical therapist from 6-8 weeks. If eight weeks or 56 days are represented with the opportunity to track exercise up to 3 times a day, a matrix of 168 equally spaced blocks can show all of this information at a glance. (Table 6)

Taking the matrix idea into a 3-dimensional form became the criteria for the final product. Although the basic matrix is not very motivating, and not aesthetically pleasing, it allows a qualitative point of departure for design.

Table 6- Exercise matrix

WEEK	1	2	3	4	5	6	7	8
Monday								
Monday								
Monday								
Tuesday								
Tuesday								
Tuesday								
Wednesday								
Wednesday								
Wednesday								
Thursday								
Thursday								
Thursday								
Friday								
Friday								
Friday								
Saturday								
Saturday								
Saturday								
Sunday								
Sunday								
Sunday								

Based on this qualitative data, a brainstorming session looked at numerous options for intriguing forms which would simply and elegantly display this data. (Figures 41-47)

Some designs offer the user a chance to track only individual progress and others offer an option of the buddy system and social motivation. Every day, the patient can look back at whether the HEP program has been completed as suggested. All of the devices would work via a USB or wireless connection to the computer. MAGGi downloads data to the computer and to M.A.T.T. recording that the HEP was accomplished. M.A.T.T. serves as a visual reminder to participate in the HEP as directed.

In our society, goals have several ubiquitous forms. Three distinct directions began to arise as the shape of a 'goal' was explored for a design aesthetic. One series of designs uses concentric circles, much like a target, to represent goal achievement. (Figures 42, 43) Another series of designs uses the notion of therapy as a climb involving stairs or steps and the concept of walking uphill towards a singular goal. (Figure 44) A third series of designs works to create a sculptural, abstract representation of this quantitative data; creating light sculptures with the information input. (Figures 42, 47). A final series toys with the ideas of showing the data in a more abstract way, utilizing the height of the pegs to suggest how successful a patient has been at completing her exercises. (Figure 44) A final series of designs utilizes objects in their true 3-dimensional form. Using balls or bricks, the patient builds a wall or pyramid or block structure. (Figure 47) Every time a patient participates in physical therapy, another component is added. If therapy is missed, either a block is

skipped, visually creating the understanding of the need for underlying structure, or a block in a different color or texture is added so that the difference is noted.

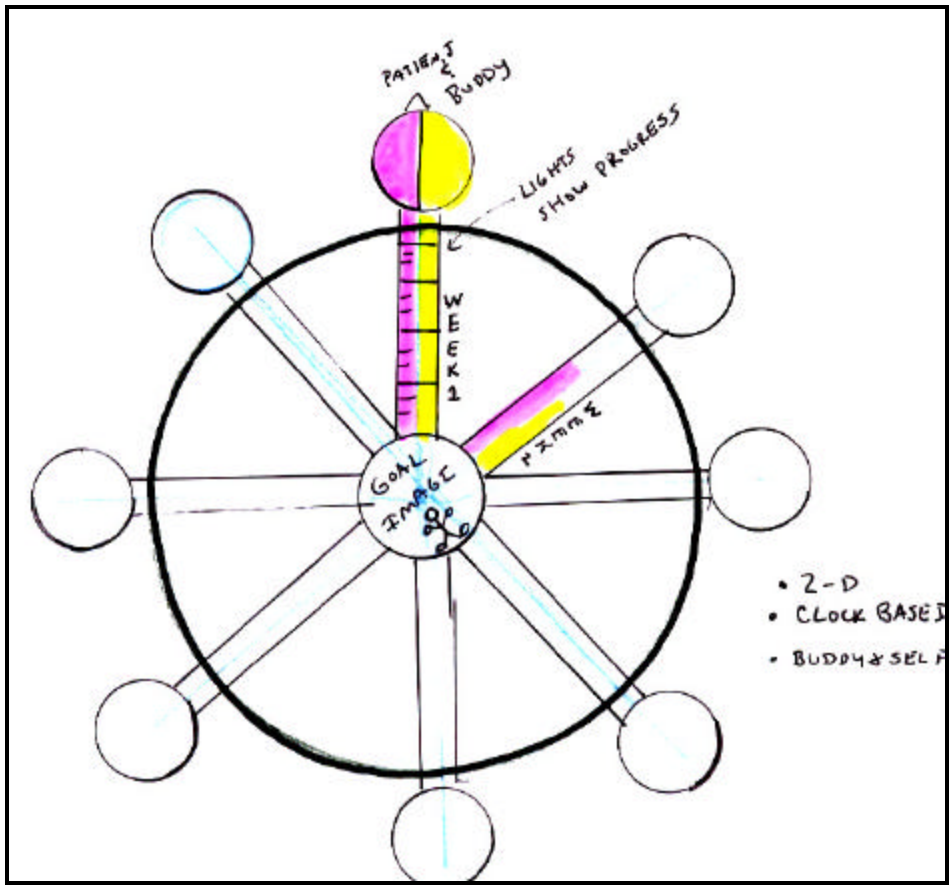

Figure 42 - Circle or target tracking and motivation

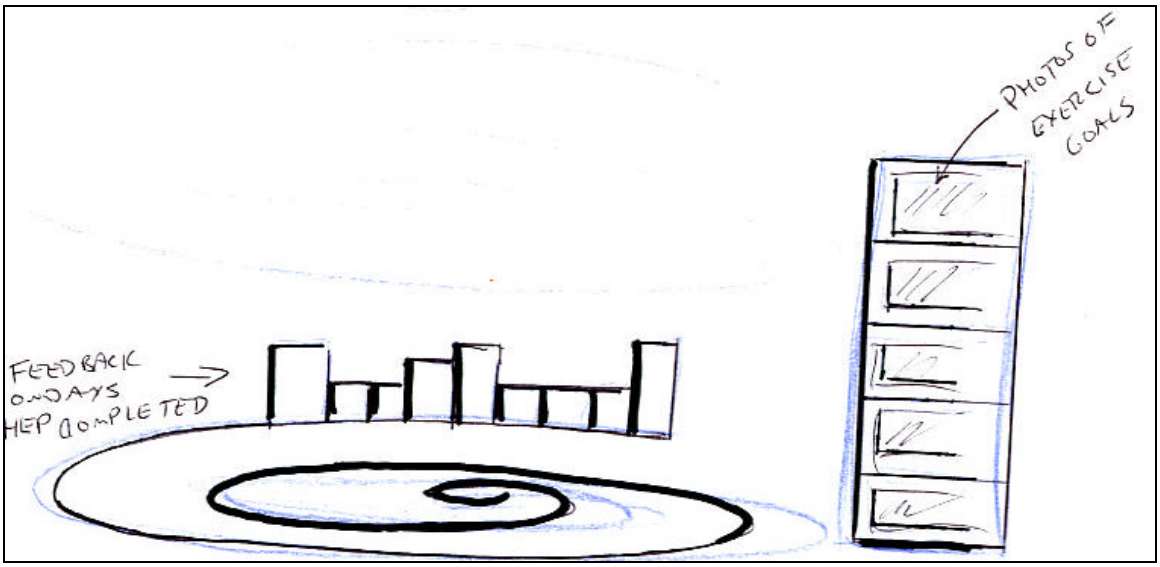

Figure 43 - Target and tower tracking motivation

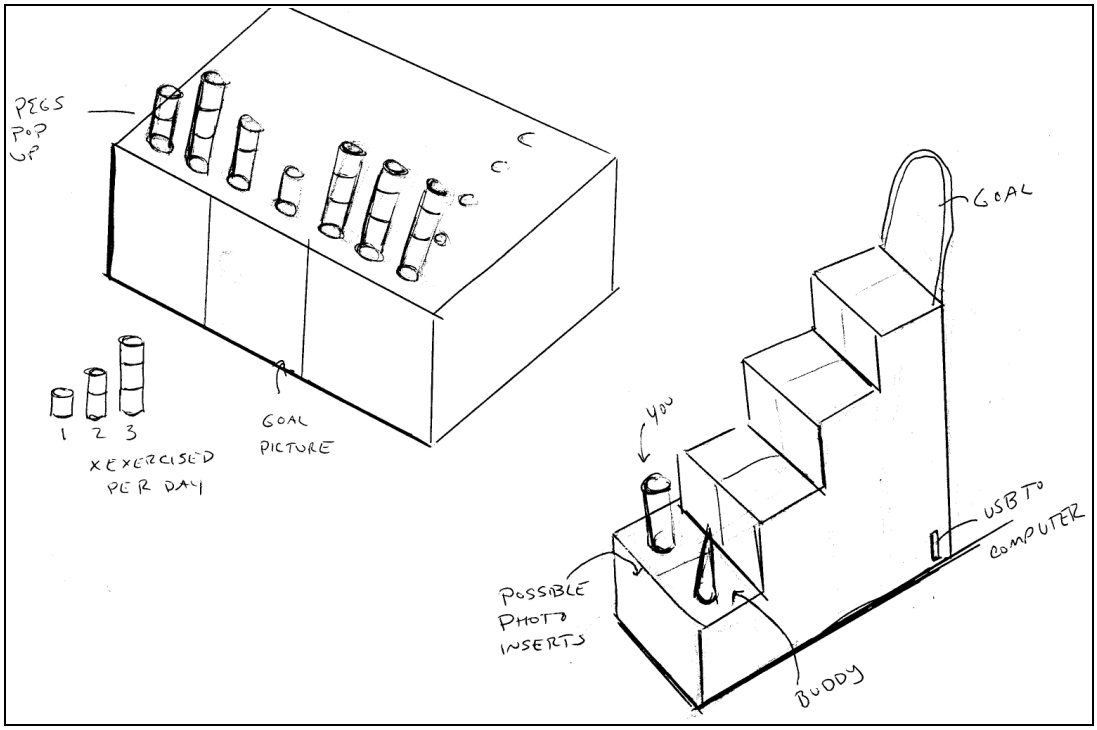

Figure 44 - Stairs and pegs

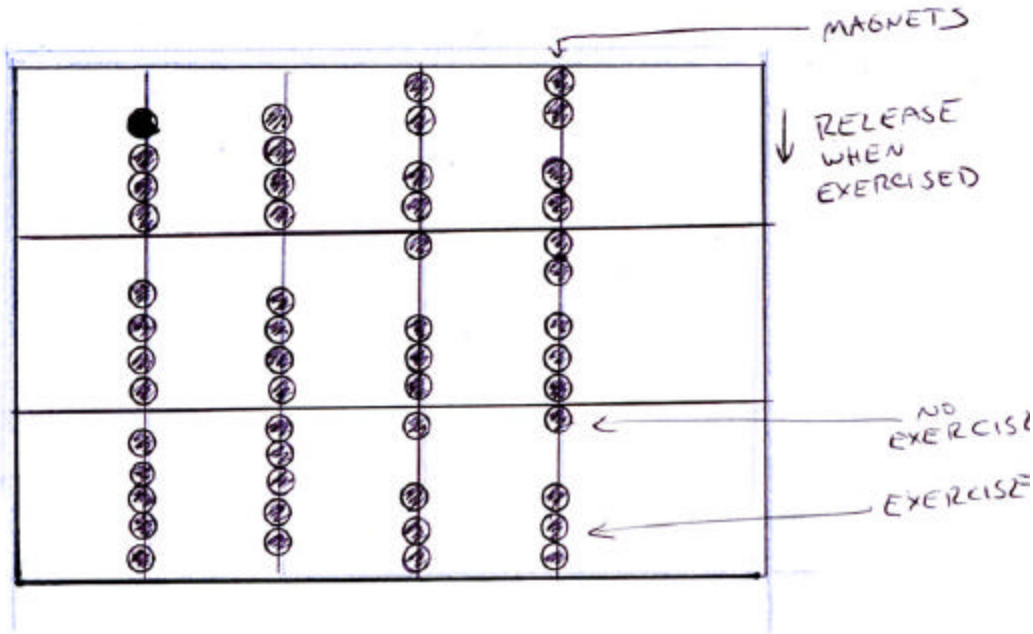

Figure 45- Magnetic calendar

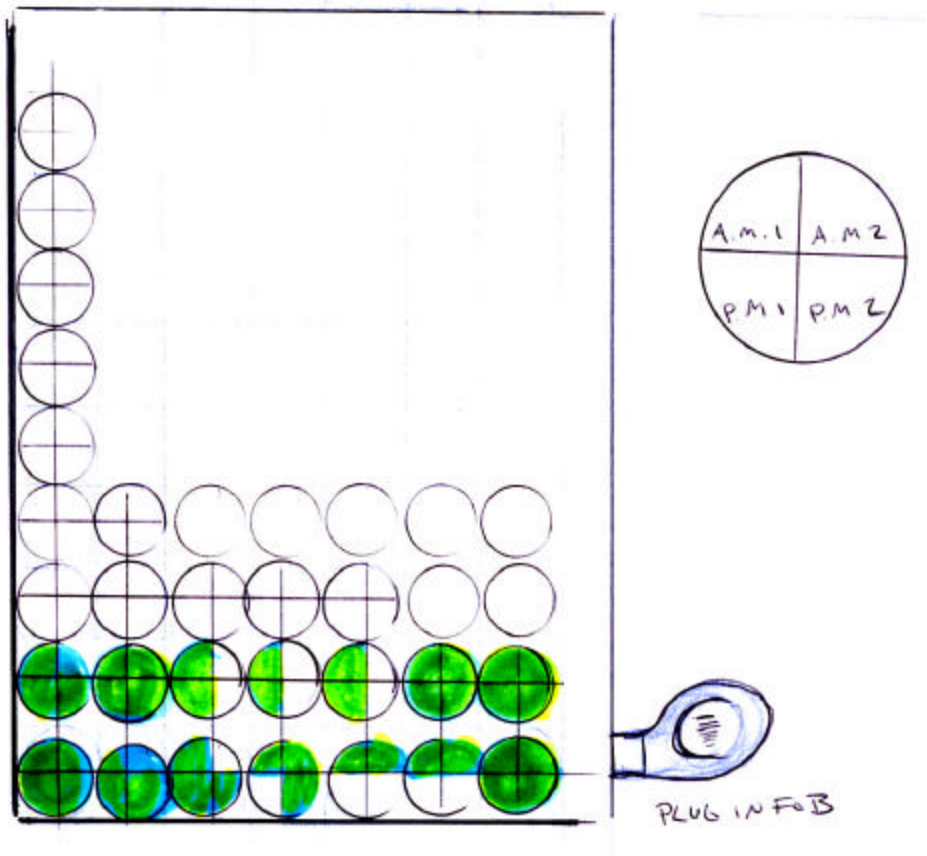

Figure 46 - Data displayed via light sculpture

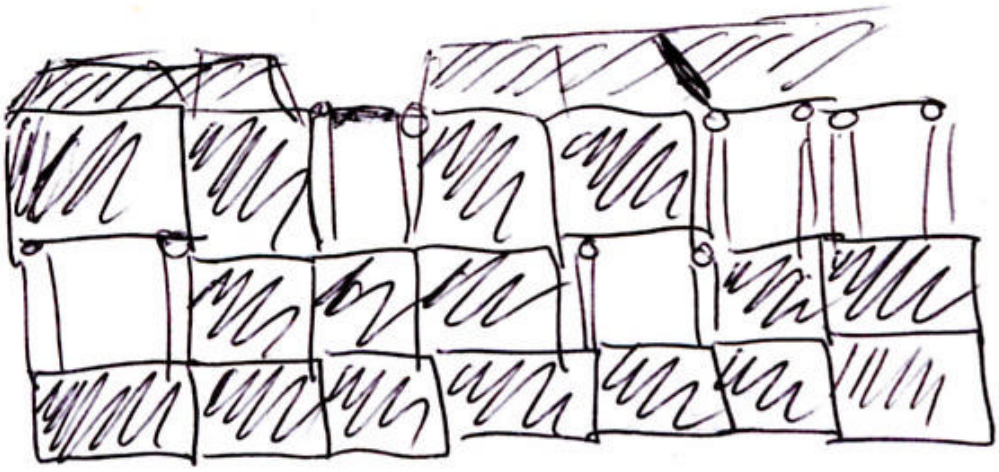

Figure 47 - Block concept

From these concepts, three were chosen to be made into foam core models to present to users for feedback. The Hill, (Figure 49), Target (Figure 51) and Abacus (Figure 51) were transferred to a 3-dimensional format and shared with patients in one-on-one interviews. A further explanation of the form and function of these devices will be shared in the following section.

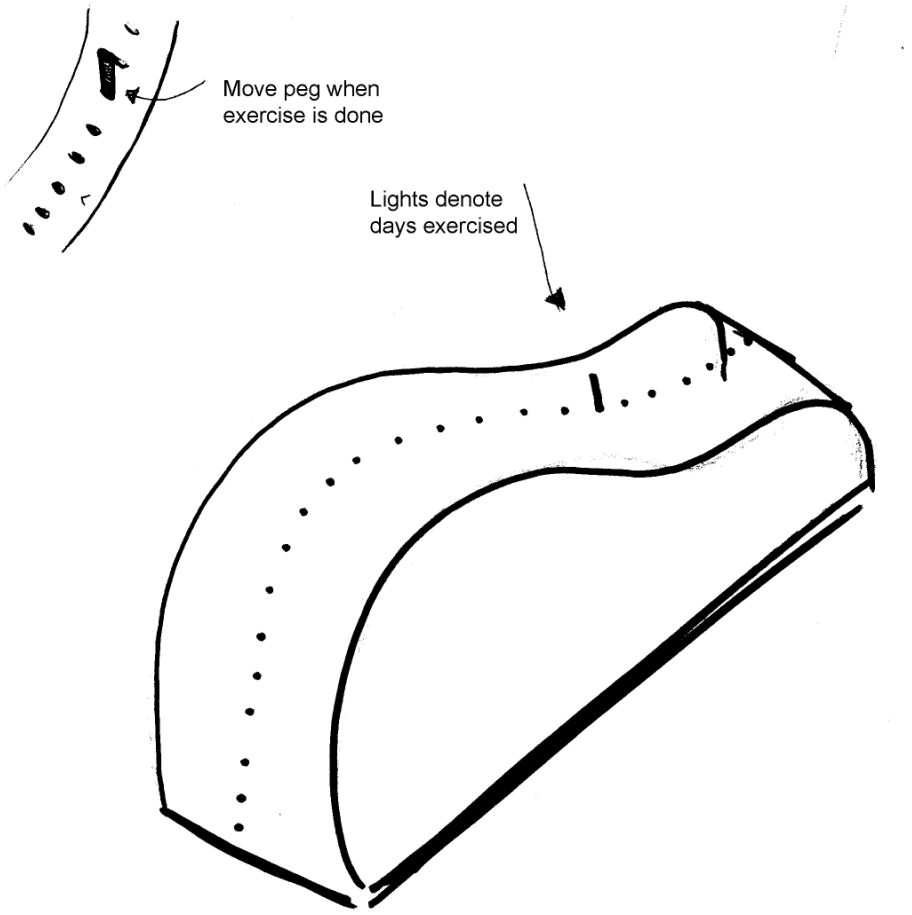

Figure 48 - Hill prototype

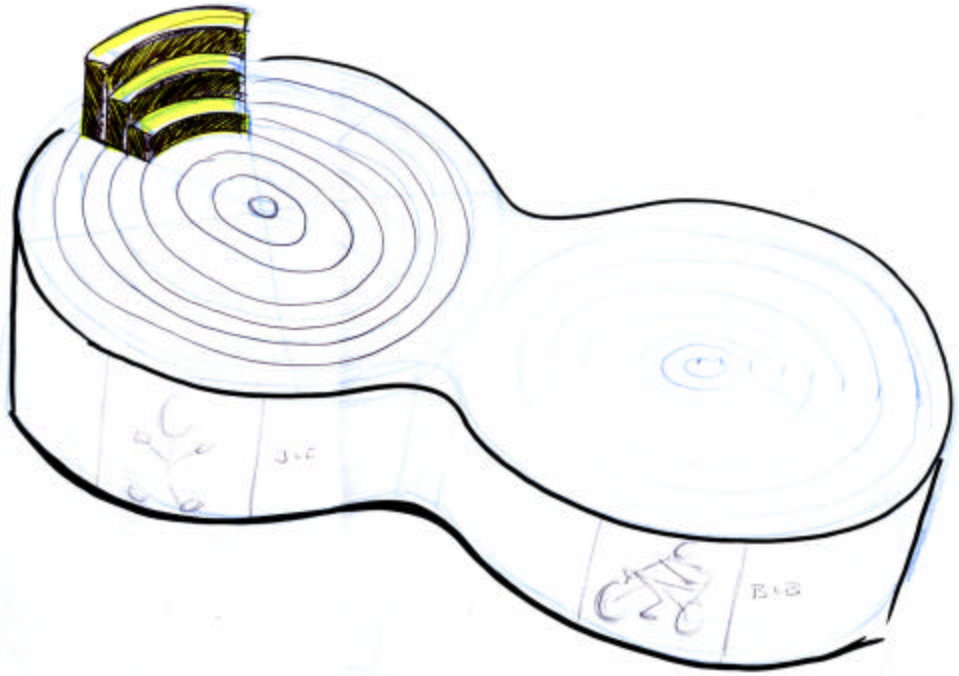

Figure 49 - Target prototype

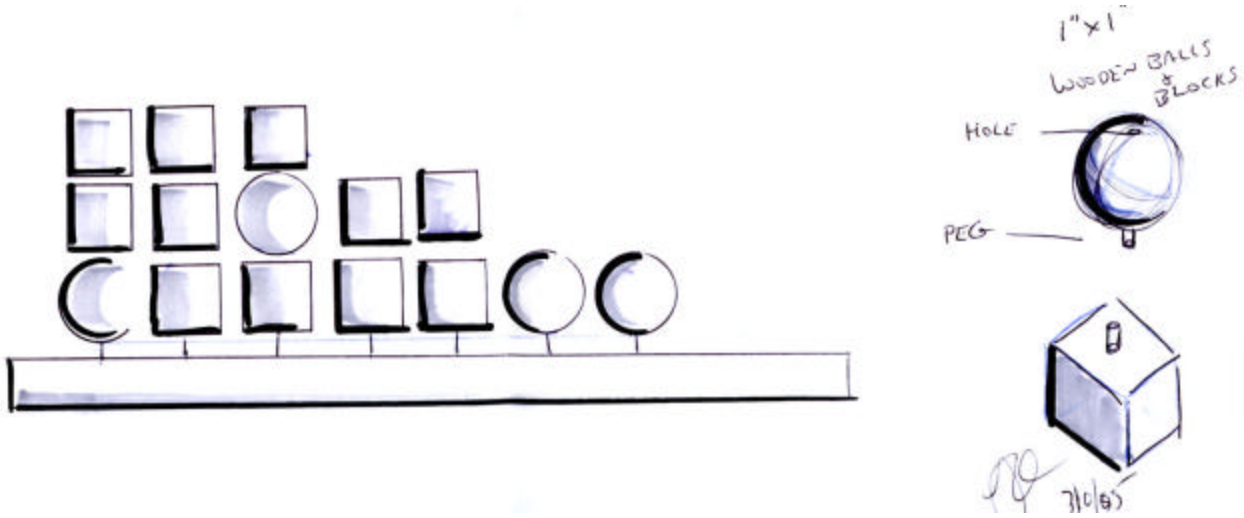

Figure 50 - Abacus prototype

Survey - Motivational Device

MAGGi and the prototypes for the desktop device were taken to the users for feedback. It was explained that, along with MAGGi, patients have the option of a tabletop device that visually tracks the days when patients participate in the HEP. Information was gathered on the appeal of various form factors, whether patients wanted an interactive device and preferences for how to visualize progress.

Interview Population

A random convenience sample was used again. For this series of interviews, patients were selected from the previous surveys on the basis of their injury. Only those who reported knee pain were interviewed.

Goal Setting

At the start of PT, many individuals have a personal goal. PTs have quantifiable goals for ROM and strength returning to the injured limb, where patients have an activity or event as their objective. Of those who filled in the diary pages, goals were stated as "be able to play tennis again," or "to be able to ride the Bicycle Ride Across Georgia again." Other patient goal statements include, "I just want the chronic pain to go away," to "be able to walk up and down stairs without pain." Respondents also stated goals of regaining full flexibility and rotation of the injured joint.

Two patients with significant injuries interviewed in this round reported a series of goals throughout the therapeutic process. One patient noted goals as 1) walk with crutches, 2) run on a treadmill 3) stability 4) being able to do the exercise 5) adding weights 6) playing soccer. As a tangible motivator, this patient shared the

story that shortly after his injury, he purchased a soccer ball to keep in his room as motivation. Other goals mentioned were “being able to snowboard again,” “driving a stick-shift truck,” driving at all and just feeling better. Many patients have distinct goals in mind as they move through their therapy at home and while working directly with a PT.

It is understandable that patients with chronic or more complex pain may not have goals that are as direct and quantifiable. There is often no specific start date for the pain and it may be assumed that the pain may never fully subside. Chronic pain is often a lifelong condition. Pain reduction and increased mobility take precedence with these patients. Patients with chronic pain may state a goal as, “I want to increase the days it doesn’t hurt.”

Tracking

The path to reaching each patients goal can be daunting with physical and emotional highs and lows. The swing of emotions and the range of pain from day to day is visible in patient diaries (Appendix D). Respondent 6 reported “stiff,” “very flexible,” and “stiff” on three consecutive days. Respondent 3 reported a range of physical and emotional differences from no pain to “arm acts like a barometer now.” Of those who participated in the interview, many were interested in tracking their progress. Users showed an interest in reaching a set goal, keeping track of repetitions over a number of weeks, and seeing what days were missed and possibly why. Three of the users spoke of a specific interest in calculable data or tracking systems, two mentioned the preference for abstract visuals as a method of tracking. There was a general consensus that it would be good to have visually different feedback if a day

was skipped (red or no feedback at all), but many also requested the opportunity to "catch up" and go back to compensate for a day where the HEP was not done and recorded.

Form

Three abstract shapes meant to represent goal attainment, a hill, a target and a calendar, were used as a base form for three initial prototypes. Users were shown the three prototypes and asked to comment on both form and function.

Hill

The Hill prototype (2" x 8" x 6") is designed to assist the patient in imagining the uphill climb towards an apex or an eventual goal. (Figure 52) The image of planting a flag or finishing a successful climb is the driving aesthetic for this piece. A series of lights would be placed in the middle of the Hill. The lights represent each day during a patient's PT. On days a patient participated in PT at the office or for their HEP, MAGGi would send information to the computer and the computer would be attached via a USB cable to the Hill. When a patient completed the expected therapy for a given day, a light is lit and a prompt is given to move a small peg forward one space. This interactivity further encourages the patient. If the HEP is missed during the expected time window, a spot is left dark or blank. When the next expected HEP is completed, the patient would skip the dark spot and move to the next light.

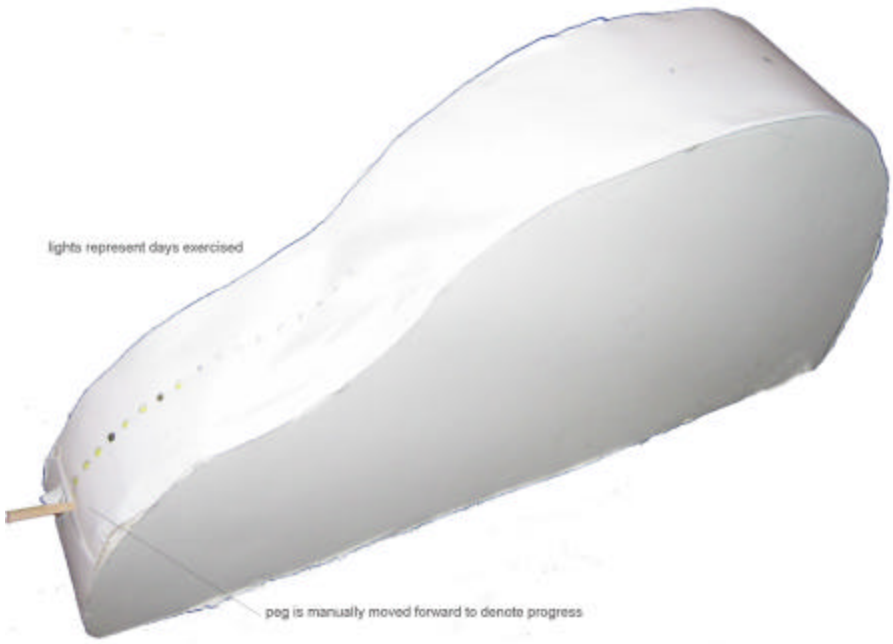

Figure 51 - Hill prototype

The Hill was not generally accepted as motivating or useful. The shape "increases fear" and there are concerns about know knowing how long PT will last. This makes it difficult to gauge where the apex of the hill/end of therapy is for goal oriented users. A manual task, that is moving the peg, is unnecessary and undesirable by users, as long as the device is already working automatically. For most users, there is no added value with interactivity. Conceptually, users are interested in the ability to track progress and have a "countdown to normalcy."

Target

Users were shown a second prototype which is based on goal attainment through the shape of a Target. (Figure 53) Two Targets are placed side by side to represent the ability to track personal progress as well as the progress of a buddy.

Each Target is divided into eight wedges (or eight weeks) with 7 days represented. On average, PTs ask patients to do their HEP 3 times/day (Essak, Stamper and Ringholz, 2005). Modules within the Target allow users to represent therapy done up to three times per day. Moving modules which have three distinct heights, within each wedge, are used to represent 1-3 therapy sessions per day.

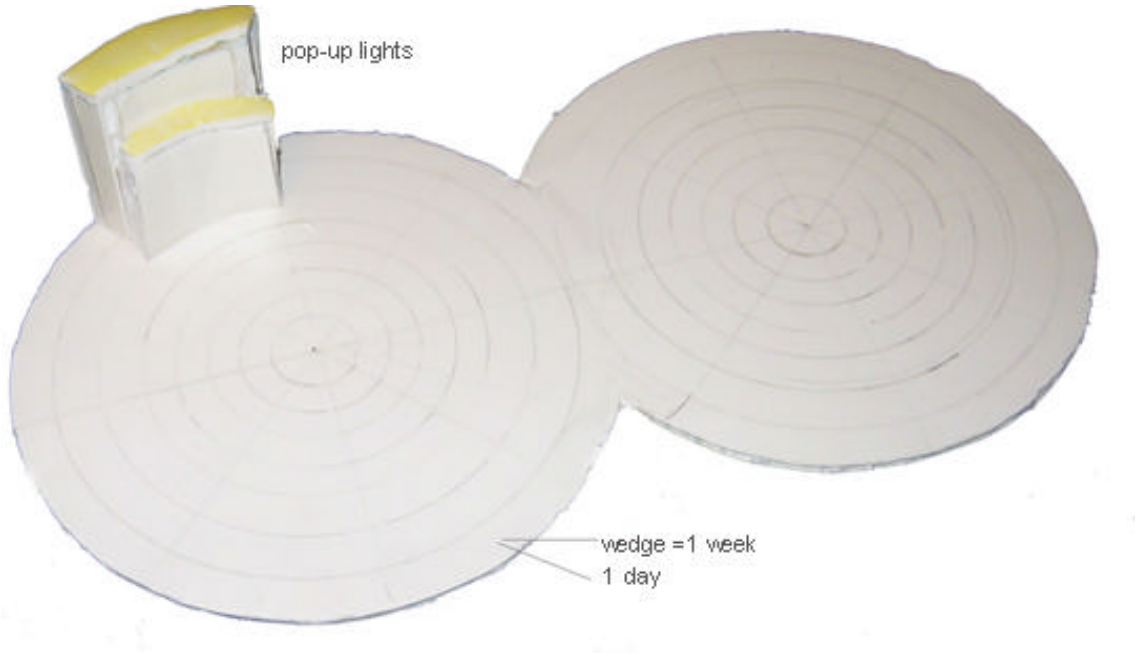

Figure 52 - Target prototype

Conceptually, the users understood the Target as well. Comments such as "like to visually see if you have or have not done exercises" were noted as positive reactions. However feelings of "shame" if people see the device and thoughts that the information is not as direct to read were negative aspects to take into account moving forward. One user commented on the size being too large, although a single section (one circle) of the figure eight (approximately 6" in diameter) was an acceptable size.

Abacus

The third concept presented to this user group is referred to as an Abacus or Calendar design. (Figure 54) As patients go through PT, each session is a building block for the next. If a session is missed, the patient's recovery may suffer. This piece is designed on the aesthetic of stability. Square blocks are used to represent stability, or a day when exercise was completed. Round wooden spheres are used to designate instability or days when no exercise is completed. Since the blocks have four sides, it is possible to record exercise up to four times in one day. The main structure is seven poles across, one for each day, and would allow for six weeks of data to be visible at a time.

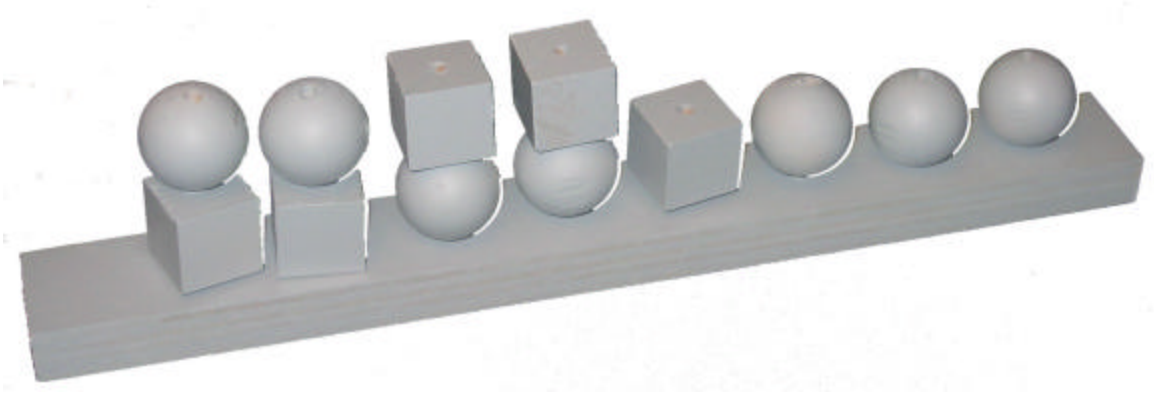

Figure 53 - Abacus prototype

Figure 54- Blocks close up

Information would download from MAGGi to the computer. A USB cable downloads information to the M.A.T.T. In this instance, one, two, three or four sides of the block would light up as designated in the programming stage. A single block would reside on a housing which allowed data transfer. When the user sees the block light up, it can be transferred to the main structure. If no exercise is done in a particular day, a black sphere would be placed on the main structure representing instability and a blank space.

Although the game-like interaction of the Abacus received positive feedback from users, most had concerns about losing the pieces. Users were not interested in the manipulation necessary to use this tracking device, although the 3-dimensional and calendar-like set-up did have intrigue.

Prior to explaining the significance of the blocks, users were shown square and round blocks. They were asked which one would represent a day you completed your HEP and which would represent a day when you skipped your HEP. All users chose the sphere to represent "completed" and the square to represent "skipped." However, when the concept of stability was explained and users were told the function would be the opposite of their assumptions, there was full acknowledgement that this would be an equally acceptable representation. An added functionality was suggested by one user who suggested that if you do a full week and stack it, the lights should change color offering positive feedback.

Placement

When asked where patients would place the device, they mentioned a "prominent spot" so it would be seen constantly. However, one user did mention earlier that there could be "shame" involved in having a friend or relative see how you are progressing with exercises. Locations for placing the device include by the bed, in the kitchen, by the computer in the bedroom and on a much used table in the living room.

Design Objectives

Based on these interviews, a desktop motivational device should:

• Be placed in a spot that is easy to see (bedroom, kitchen, living room)

• Blend in aesthetically with living spaces such as a bedroom, kitchen or living room

• Have a footprint no larger than 6-8", but be large enough to see/read

• Automatically track and display data

• Not aesthetically reiterate the "climb" of physical therapy

• Be customizable to times exercised per day and number of weeks visible

• Allow interested users to gather more detailed data on overall progress

• Have separate visuals for exercise vs. no exercise

• Allow for "catching up"- or adding HEP data retroactively

• Potentially offer shorter time period displayed (one month or so) with more granular data

Looking at the objectives, the suggestions and desires of the users can be incorporated into a final design. The device will continue to represent if/when a HEP was done and will add quantifiable information on ROM. BodyMedia (www.bodymedia.com) is a company which offers on body data tracking for those interested in tracking their progress in physical workouts. The data is tracked with an on-body wearable that downloads to a computer interface allowing users to see complex data charting progress. The addition of software program akin to that provided by BodyMedia can be loaded onto the home computer to more accurately track the granular data for the user and the PT.

Using these design objectives, a final brainstorming session was held to determine how to present this information in a convenient, easy-to-read format within an aesthetically pleasing form.

Final Concept: Motivational Tool

Given the feedback from the six user interviews, a final concept was developed. This desktop motivational tool works as part of the Thera-Network to motivate and track users over the course of an extended HEP while under the care of a PT.

Looking back at the first round of prototypes, the Hill form seemed daunting to users, and the Abacus had too many manipulables. The Target was generally

acceptable with the removal of the buddy system. Users talked about the desire for automatic representation on the M.A.T.T. and the desire for quantifiable data. Work was re-focused towards visualizing the data and making the user aware, at a glance, of their progress.

A final brainstorming session ensued where ideas were discussed on the best way to visualize this data as well as making the device fun for the user, an aspect not well addressed in previous designs. It was important that the system be customizable for various therapeutic needs.

A screen based system addresses the wide variety of user needs. The system returns to the original matrix form, however the visible data is cut down from eight weeks of visible data to four. (Figure 56) Four weeks was suggested as an ample amount of information by patients who were interviewed. The screen is divided into four rows and seven columns. Each row is subdivided into three smaller, equal partitions. This allows the view of a full month of input: up to three times a day, seven days a week, four weeks at a time. (Figure 57).

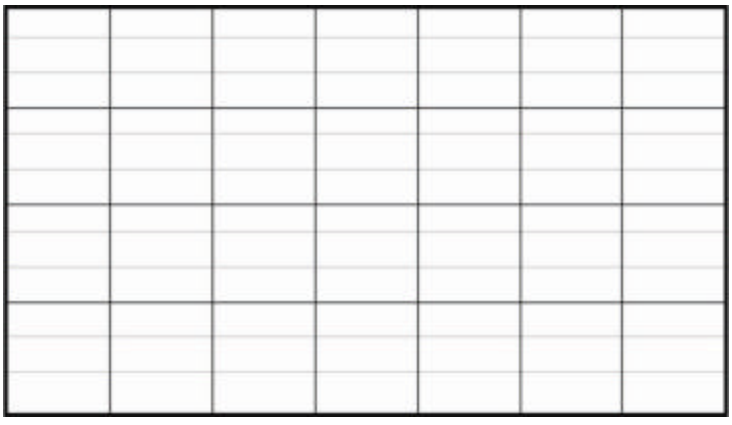

Figure 55 - Basic grid

The arrows on the right (Figure 57) allow the users the option of looking at data from previous weeks when the patient is in therapy for over four weeks. Weeks are noted in the circular windows to the left. Weeks are counted from the bottom up to promote the visual indicator of building strength as in the prototype Abacus design.

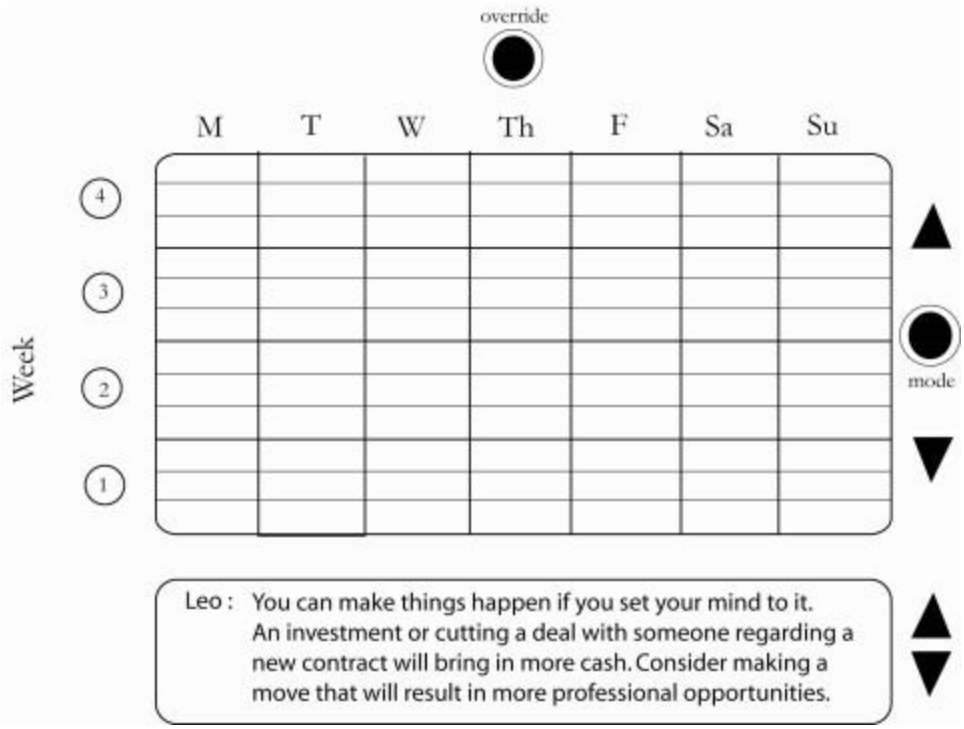

Figure 56 - Front view of original data screen

After the patient participates in the HEP, data is sent from MAGGi to M.A.T.T., eliminating the need to turn on the home computer or have it running at all times. When the home computer when is turned on, data is output from M.A.T.T. to the computer where it is logged and, eventually, sent to the PT. M.A.T.T. also has the option of a direct download through an internal modem.

To motivate users, a personalized interest program is chosen by selecting one of four programs on the knob. (Figure 58) Each program gives the user a small reward each time the HEP is completed. The programs options include a full-length story, humor, a word-a-day or a horoscope/fortune. The full length story reveals one line of text at a time in the viewing window, rewarding the user with more of the story every time the HEP is completed. Humor offers one-liners one at a time, metes them out in three parts so that only at the end of a series of therapy sessions does the user see the entire joke. Assuming the user stays on track, each day shows a different joke from beginning to end. Text displayed follows in order, finishing one joke or horoscope before moving on to the next. If the user skips an exercise, the related rectangle remains black, a completed session of the HEP turns the rectangle blue. (Figure 59)

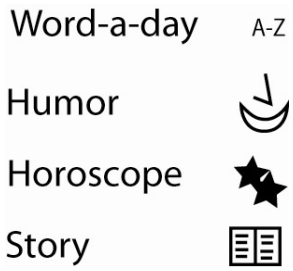

Figure 57 - Knob icons defined

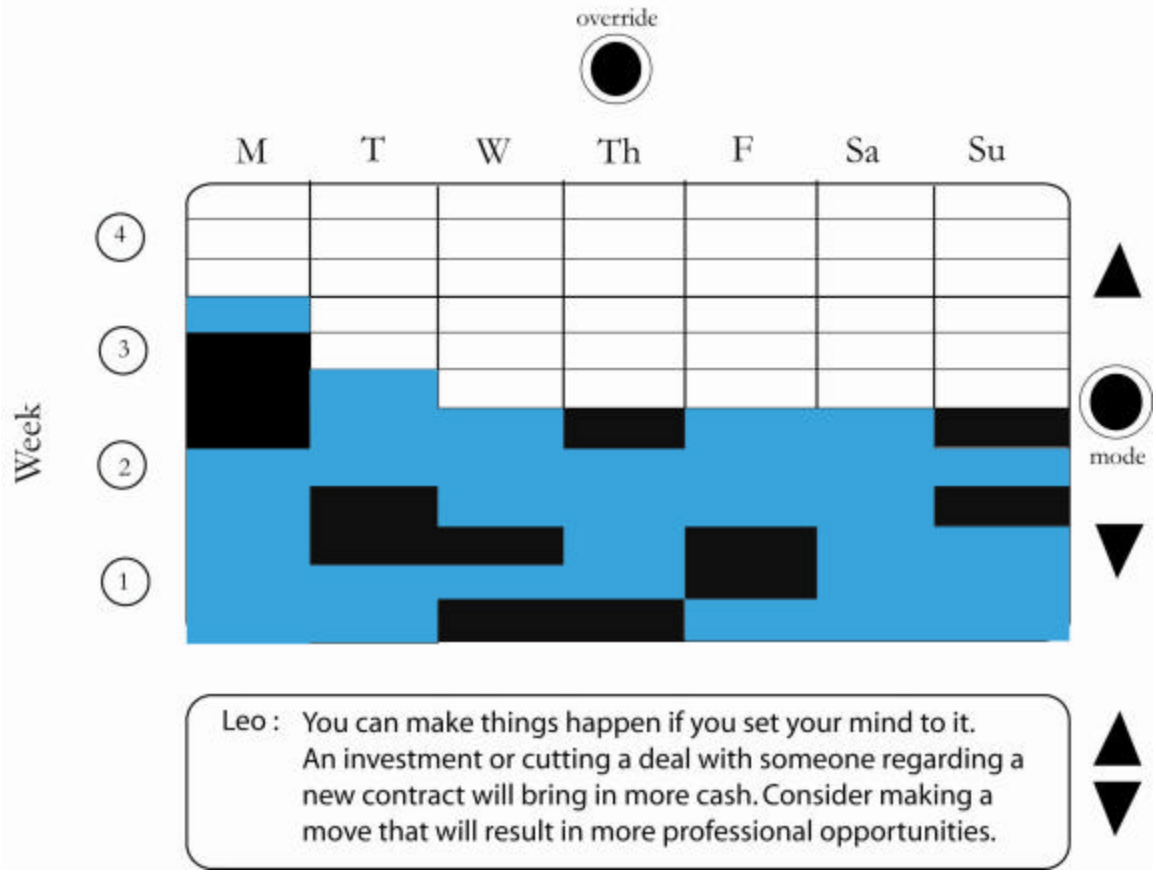

Figure 58 - Sample of 2 weeks graphed data

A screen based system allows the user to customize a reward and affords the ability to switch modes. Users commented on the desire for more factual, numerically based data. With the touch of a button, users may switch modes from reward feedback (jokes or stories) to visual numerical feedback on progress with ROM. (Figure 60) The ROM is represented as a series of two numbers akin to the recording tools used commonly in physical therapy. The front number represents extension and, in an ideal situation, the goal would be zero degrees. The second number, where the goal is often 120 degrees, represents flexion.

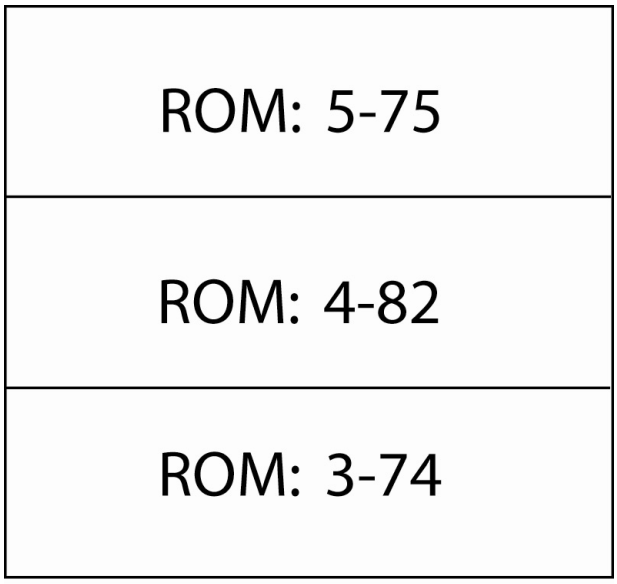

Figure 59 - Sample data screen

When a patient is ready for a HEP, the patient and therapist sit down together and map out a plan. Working with the final plan, the therapist makes any changes to the devices default settings to customize M.A.T.T. for each patient. The default settings allow the light to trigger for up to three sessions of HEP each day. It is the job of the therapist, working with the patient, to determine how many sets and repetitions of which exercises will need to be accomplished to receive a reward.

At the end of the HEP, the data automatically transfers from MAGGi to M.A.T.T. (Figure 61) through Bluetooth technology and lights up the appropriate rectangle. When used in the home, the patient does not need to turn on the computer after each session. M.A.T.T. provides simple, quantifiable feedback as a stand alone. Knowing that the average user checks email approximately once a day, M.A.T.T. is designed to store the data locally and send it, via Bluetooth, to the home computer

when it is turned on each day. When email is checked, data downloads to the PT. This data is small enough to be downloaded through dial-up or broadband connections. If there is no home computer or no desire to network this way, M.A.T.T. is also equipped with data ports allowing direct dial-up, DSL or cable connections. The PT may utilize dial-up or broadband to upload the data in the office as well.

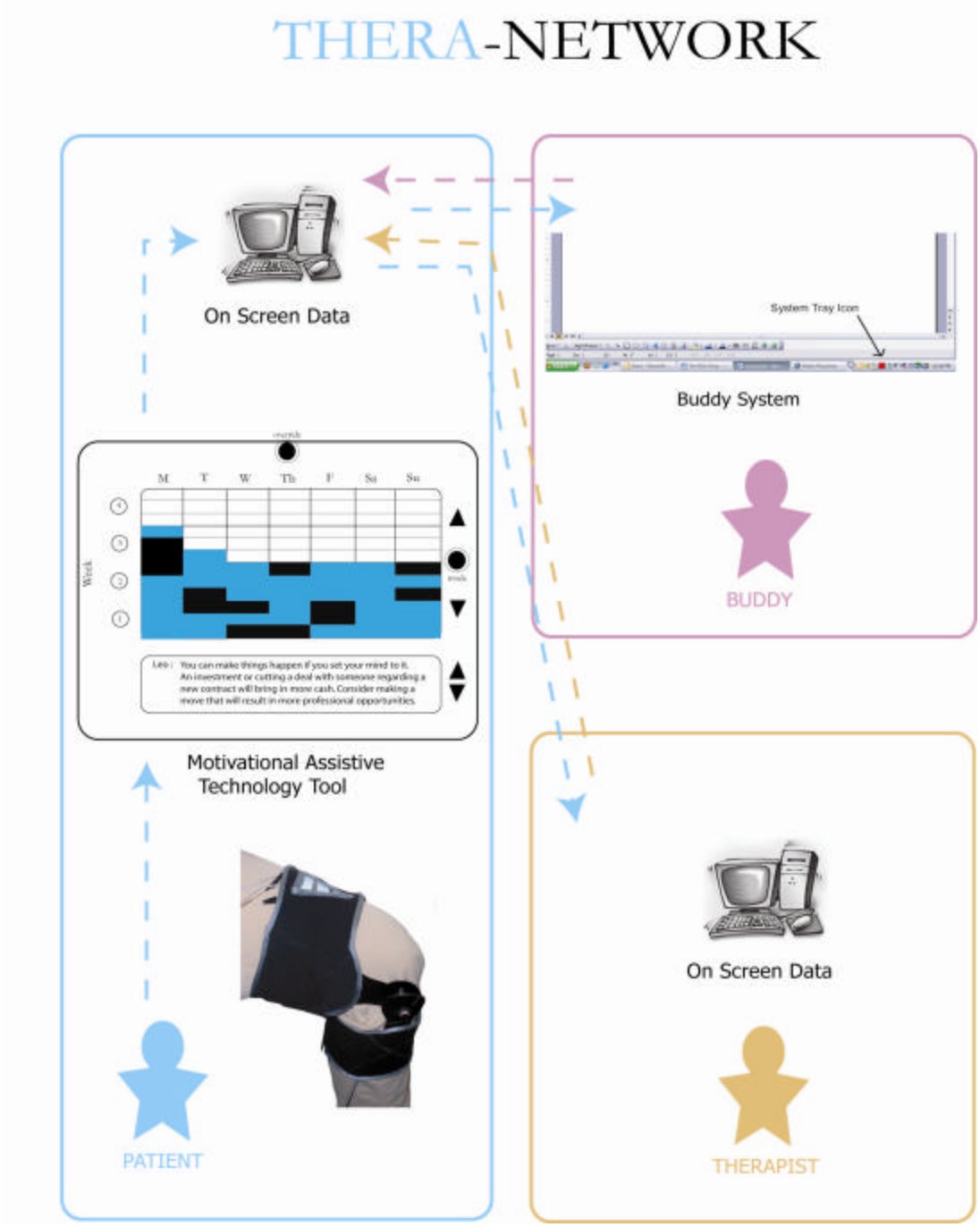

Figure 60 - System overview

Each time the therapist logs on, information is uploaded from patients using the device at home. PTs will need to look at the data screens several times a week to obtain a quick overview of patient compliance and progress. If something looks incorrect, or a patient has been non-compliant for a number of days, the PT may choose to call or email to check in and be sure there are no critical medical issues or to offer encouragement and support. Users noted therapist support as helpful to their recovery, “This is Jessica, my therapist. She keeps me motivated by telling me that I'm doing a good job.”

A single override button is available for the patient. (Figure 57) When this button is pushed, the arrows switch from scrolling by week to scrolling by block. When the button is pushed again, it activates or de-activates a block as needed. This option may also be used if the patient prefers not to use MAGGi to send data, but to instead manually record when PT is accomplished.

It has been discussed that users of any object need to make an emotional attachment to completely enjoy them and continue using them. By offering customizable rewards, M.A.T.T. begins to meet a user’s personal needs. In addition, an optional voice prompt would be available so that the device may become more of a buddy. Audio interfaces also allow those with limited vision to benefit from a device.

Putting the screen inside a pleasing form will assist users in befriending the device. The M.A.T.T. interface was created so that it may fit into a variety of form factors. This functional device may be put into casings of any material including wood, plastic or metal. The suggested form blends into any room in the home or office.

Form Development

For an anthropomorphic device, one form suggests a person who is stretching, or reaching. (Figure 62) This playful, person-like structure allows the patient to put an inspirational photo or picture in the ellipse area where the head would be. The body provides a housing for the device which could stand on a table in any room and act as a reminder for a patient to exercise.

Some users may be interested in presenting the information in a game-like setting. The interface screen would be propped up on four legs to look like a miniature game table. (Figure 63) A range of exterior designs such as a frame which allows the device to hang on a wall as a temporary artifact. (Figure 63)

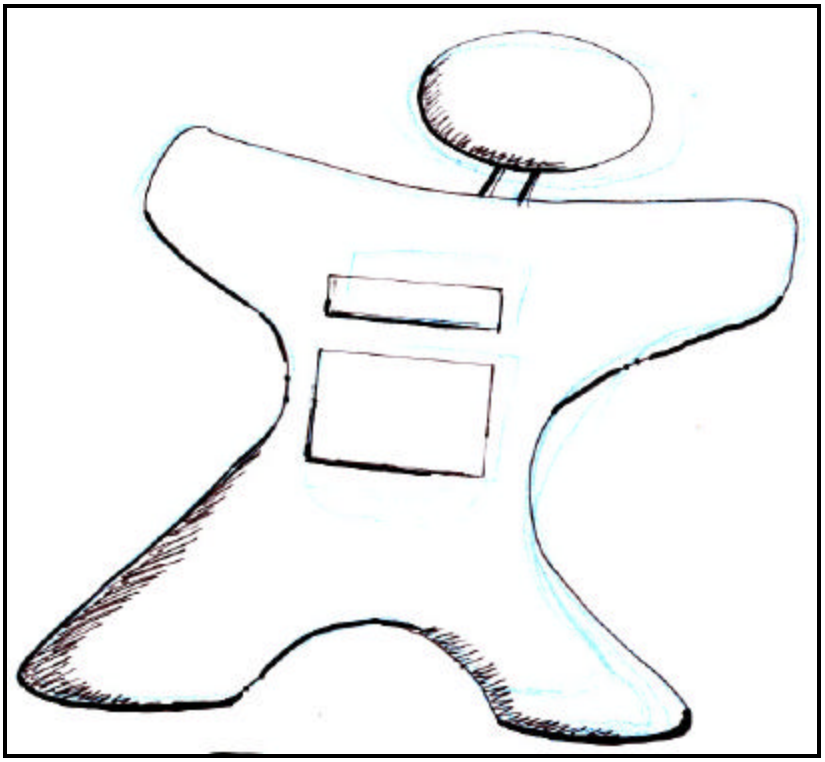

Figure 61 - Friendly form

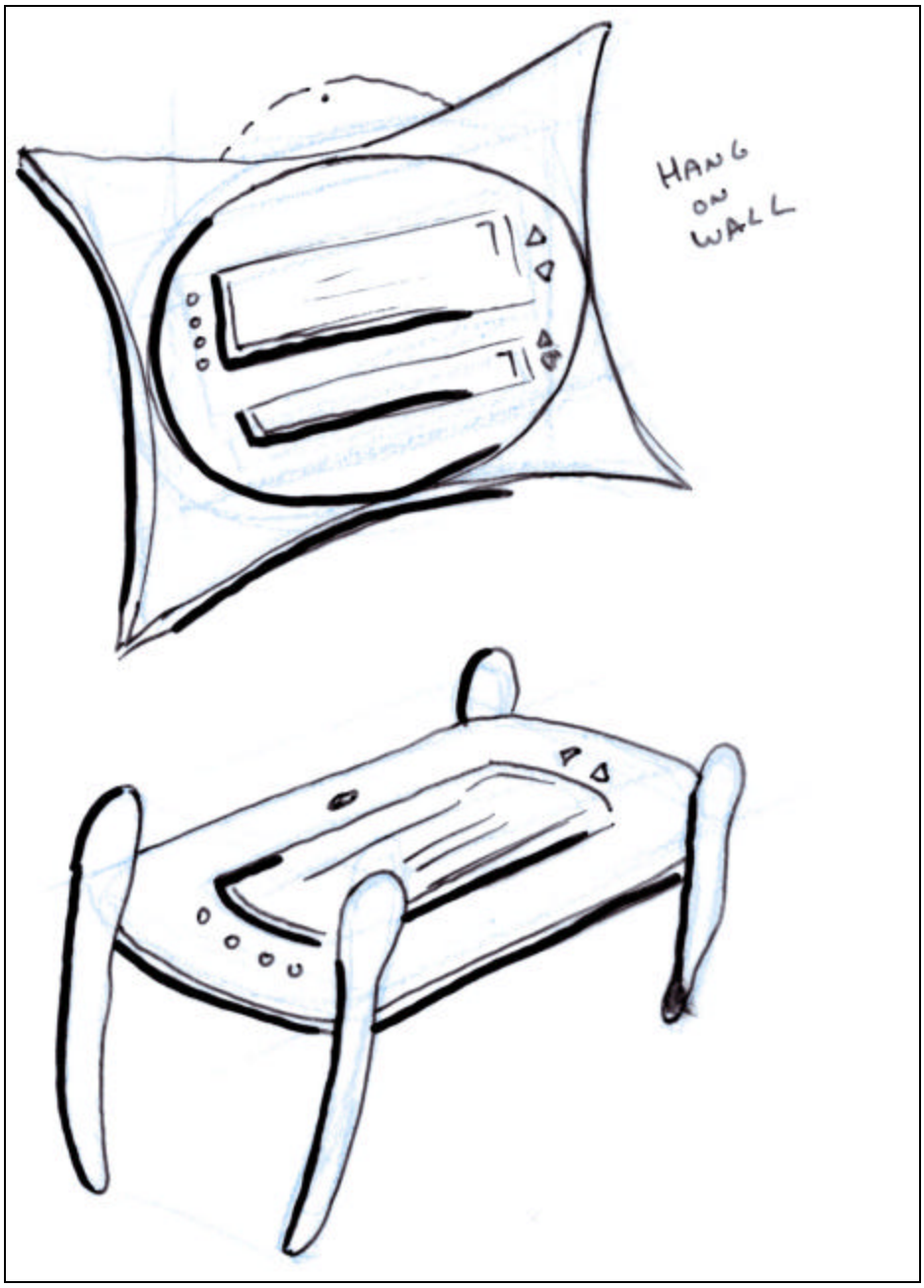

Figure 62 – Form studies for M.A.T.T.

The final form is based on the potential need for portability, simplicity, and the need to fit into a variety of environments. A clamshell design affords the user discretion (enables the patient to close the device if desired) and portability. (Figure 62) Portable games, laptops and cell phones provide a design language for this form.

(Figures 61-63) Products including the apple AC adapter are inspiring in line and form. (Figure 57)

Figure 63 - Clamshell, http://www.applebits.net/~applebit/cgi-bin/cart.cgi/POG3IC3662CD.html

Figure 64 - Portable game, http://www.korporate-creations.com/prodpage.cfm?CategoryID=17923&CFID=12437713&CFTOKEN=61091067

Figure 65- AC adapter for apple computer

, A final series of sketches takes into account these existing forms and concepts. The round shape is friendly and inviting as shown in early abstract renderings and reiterated by users when queried about their feelings of the shapes in the Abacus device. The device must be thick enough to house the necessary technology and have a wide enough base not to tip when manipulated. The final design is a low, flat, elliptical form. (Figures 67, 68)

Figure 66 - M.A.T. T. ideation

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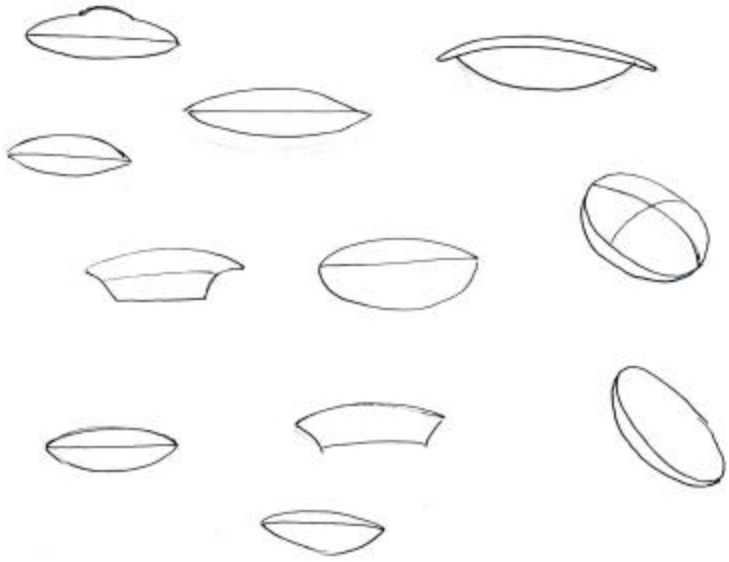

Figure 67 - M.A.T.T. parting line study

The 6” diameter elliptical shape sits unobtrusively on any flat surface. When opened, the patient sees the screen based data and related buttons on a horizontal plane. (Figure 69) To change the mode, a knob is located outside the case on the bottom in the center. (Figure 70) Inside of the lid is a 3.5” x 5” space for a custom image of a goal, reward or other inspirational picture. (Figure 69) The rear view (Figure 72) shows adapter plugs for power and a modem.

Figure 68 - M.A.T.T. open

Figure 69 - M.A.T.T. screen close up

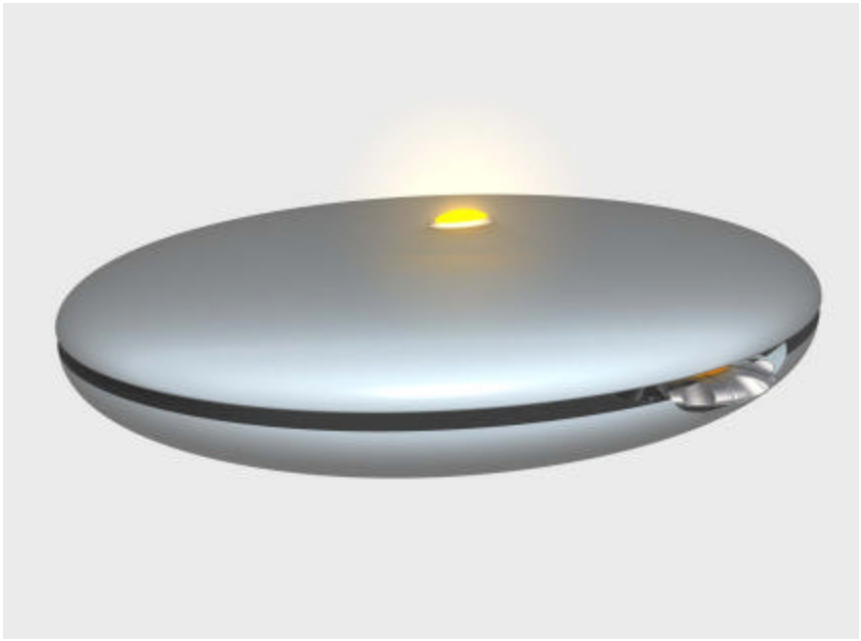

Figure 70 - M.A.T.T. closed

Figure 71 - M.A.T.T. rear view

Figure 72 - M.A.T. T. front view

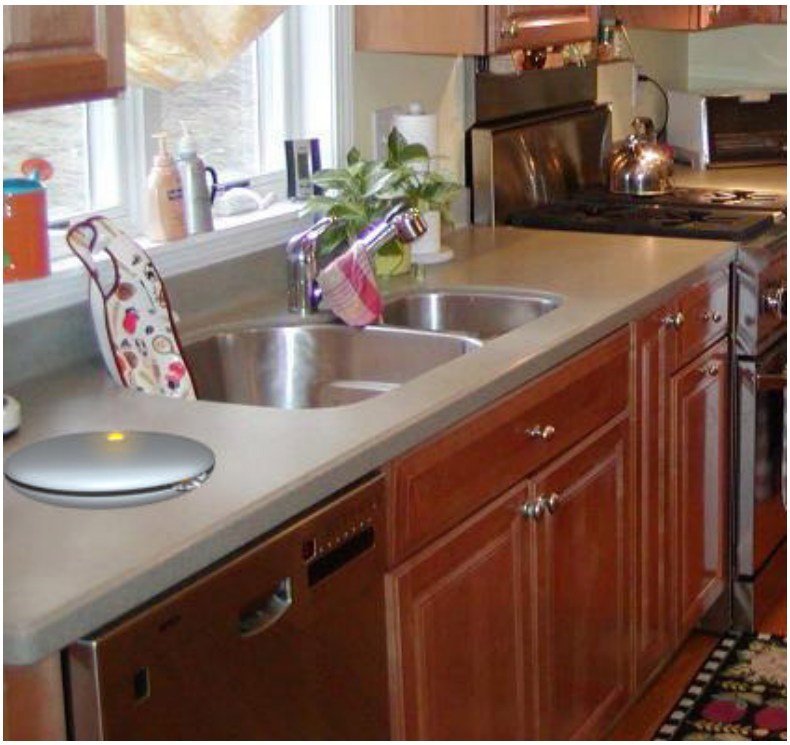

Figure 73 - M.A.T. T. in kitchen environment

Figure 74 - M.A.T.T. in living room environment

Packaging

MAGGi, M.A.T.T. and the Buddy System are designed to work as a package. An established color palette creates a uniform look for the products. (Figure 77) MAGGi is black with silver accents and aqua colored EL strips. M.A.T.T. is largely a pearlescent, matte blue with silver and darker blue accents. Lighted portions of the device appear amber in color. The colors afford a device that blends into any room and fits the contemporary aesthetic for electronic devices. The colors are calming with a technical feel allowing the patient to take the activities seriously, but not attach an undue amount of thought to the fact that they are using a medical device.

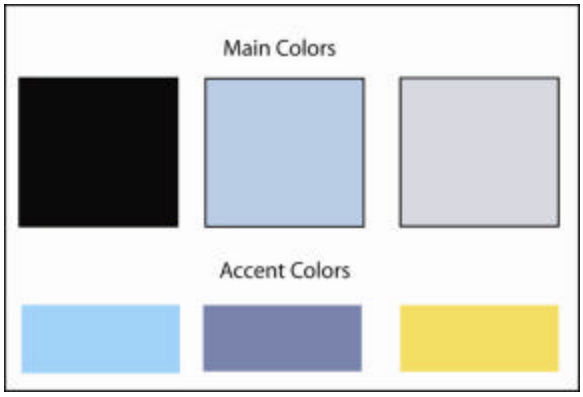

Figure 75 - Color study

The medical nature and direct therapeutic tie in suggest that the system only be available from the office of a licensed PT. To ensure that patients take care of these highly technical devices and can easily transport them from the PT to home and back again, a rigid or semi-rigid casing is an ideal carrying case. This lightweight yet rigid case offers molded foam inserts where each device can sit. (Figure 78)

The design presented here is a cursory suggestion. Although the packaging is not fully addressed here, it is an integral part of the system. The product comes together as a full package and the patient can easily care for and transport the devices.

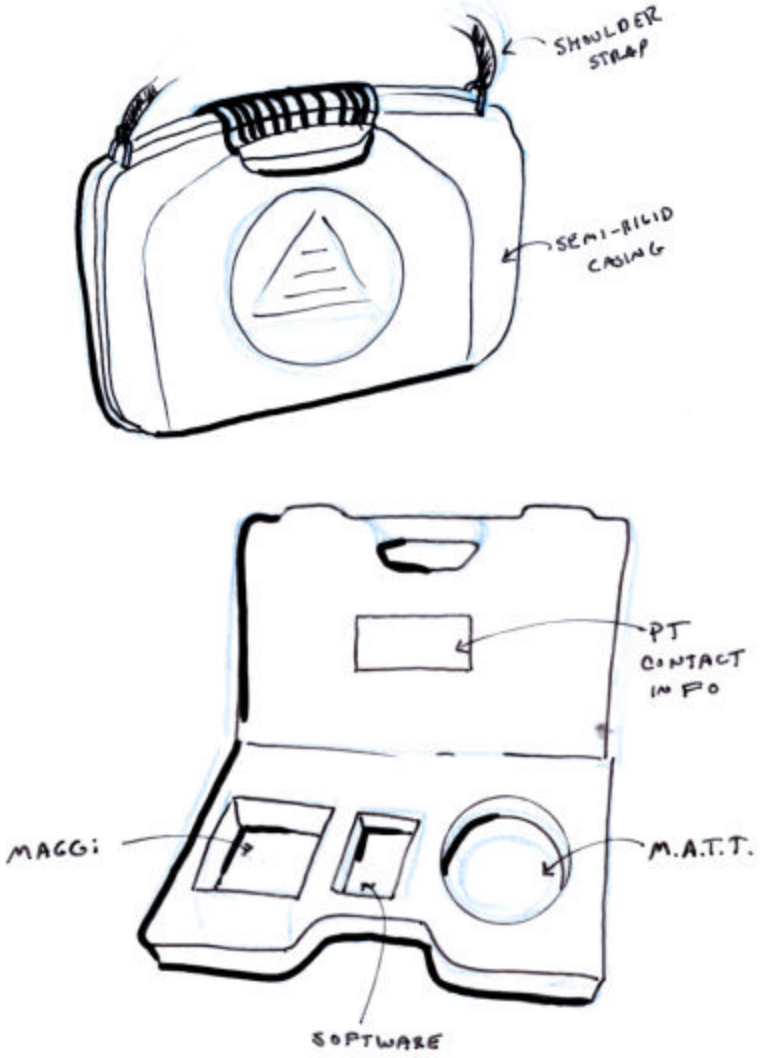

Figure 76 - Case concept

Design Criteria – M.A.T.T.

Final checklists are applied to user criteria and the suggested design for M.A.T.T. By Implementing user needs inside an aesthetically pleasing form creates a product from which all users can benefit. The basic tenets of motivational theory are once again presented along with how they have been addressed in the final design.

Table 7 - User criteria

Design Objectives	Objective Addressed
Blend in aesthetically with living spaces such as a bedroom, kitchen or living room	Pearlized, neutral tones fit in many living spaces
Have a footprint no larger than 6-8", but be large enough to see/read	Footprint is 7" diameter, font is 14 pt.
Automatically track and display data	Display screen
Not aesthetically reiterate the "climb" of physical therapy	Elliptical form
Be customizable to times exercised per day and number of weeks visible	PT may change settings
Allow interested users to gather more detailed data on overall progress	Mode change
Have separate visuals for exercise vs. no exercise	Bar graph
Allow for "catching up"- adding HEP data retroactively	Override button
Potentially offer shorter time period displayed (one month or so) with more granular data	Scroll and mode changes

Table 8 - Motivational Theory

Motivational Theory	How implemented
Fun	Users are rewarded with humor, stories or horoscopes
Community	Buddy system allows users to track participation in the HEP
Goals	Space is provided in the lid for an inspirational image
Autonomy	Program encourages PT to set up therapy routine *with* patient not *for* patient
Feedback/Tracking	Visual graph of HEP completed shows user progress at a glance, mode switch allows tracking of more granular data

CHAPTER 5

SYSTEM OVERVIEW

Physical therapy is one area of medicine where there is room for improvement. Individuals from all demographic spectrums may, at some time in their lives, find themselves suddenly temporarily or permanently disabled due to accident, injury or illness. This project is an initial step to understand the complex issues including the physical and emotional factors experienced by a patient in a rehabilitative course of care.

As proposed the Thera-Network is a system of device which can work independently or interdependently to assist patients in rehabilitation to get the most out of their HEP. MAGGi can work as a stand alone by assisting the patient with the day to day HEP. The device can offer visual and auditory feedback, track sets and repetitions, and count hold times. As a networked device, the wearable device can send data directly to a desktop device which will track and graph progress. The wearable device can also send information via Bluetooth directly to a PT through a home computer if the patient is not interested in a desktop device.

Although they are best used together, M.A.T. T. may be used with or without MAGGi. M.A.T. T. may be used as a stand alone, but requires work on the part of the patient. When the patient has finished the HEP, s/he must press a button on the device to record a completed session. No information on ROM can be stored without MAGGi, but daily participation can still be noted through visual indicators. When

used together M.A.T. T. and MAGGi offer feedback and tracking for HEP sessions completed and ROM.

Based on feedback from the research in this project, a simple buddy system is included as an option, but is not a major feature in the network. A desktop icon will show up on the computer alerting a patient that a buddy who is also going through a course of physical therapy has completed his HEP. Using this system, patients are never in competition to heal, but merely supporting one another and acting as a gentle, motivating reminder.

For more detailed tracking and information, the patient can opt for a software package for the home computer. PTs will have a separate system on the office computer that allows them to track patient data and presents alert windows if a patient has not sent data for a significant period of time (that time to be determined by the PT and patient).

CHAPTER 6

CONCLUSION

Thesis Goals

Healing cannot happen in a timely manner without patient participation. It has been shown that quality of life suffers when an injury affects a person's mobility. (Persoon, 2004 and Rikli, 2005). The system approach of the Thera-Network is suggested to reduce the time and cost for a patient to quickly heal and regain a comfortable quality of life. Reduced time in physical therapy and a potential decrease in office visits, shrinks the cost of care for both patient and provider.

A patient motivated to participate in the HEP, heals more quickly has less of a financial deficit. By using the Thera-Network, the complexity of following and tracking a HEP is reduced. The system design, functionality and aesthetic are guided by the principals of human motivation and the needs of a HEP

As mentioned by the several students in early research, exercise and therapy need to become a habit. The process needs to be ingrained so that it is physically missed if not completed. One respondent in the diary exercise noted, "…it is a habit, like sleeping, that I do every day without thinking."

Through a system of feedback, tracking and rewards, the Thera-Network aims to motivate the patient so that the HEP becomes part of a daily routine. The added functionality of a buddy system helps patients part of a greater community. Knowing that the PT will be accessing data to track compliance and offer support along the

way helps patients feel more positive about the rehabilitative experience as s/he regains health and mobility.

Limitations

Continued development and refinement is needed before the proposed product is marketable. Although the psychological needs of both patient and caregiver have been addressed, additional investigations are needed regarding the suggested technology and the computer interface.

Technology is catching-up with design innovation. Although Bluetooth has been shown to work long range, work still needs to be done to perfect this system.

One of the largest hurdles for wearable technology is washability. MAGGi needs to be washable or cleanable. Wash tests were done with the conductive thread and it still conducted electricity after continuous washings. The EL strips, Bluetooth modules and other embedded technology necessary for the device are not inherently washable.

Security continues to be an important issue, especially in the arena of medical product design. Transmitting data over wireless technology requires great care and security measures. Personal medical data sent via electronic transmission must be encoded so that it can only be viewed by the intended parties.

Market Opportunities

Rental Equipment

Due to the temporary nature of the injury for this user group, the final product is designed as a rental unit. Outpatient clinics are able to purchase the equipment to share with their patients to use at home between visits. A fee, covered by insurance, is

assessed in addition to the normal therapy billing. Based on the fact that some insurance companies cover the cost of knee braces and therapeutic equipment, this is a realistic scenario. (Edwards, 2005)

Expanded Marketing

Although the product suggested here is created to motivate individuals undergoing physical therapy, it is a concept with broad appeal. According to a study done by the School of Nursing at the University of Louisville in Kentucky, 60% of the population does participate in "regular physical activity"(Speck, et al 2003). This same study also states that in 1997, only 15% of adults over 18 participated in at least 30 minutes of activity 5 days or more a week.

The Thera-Network is useful for many who have goals of physical betterment. M.A.T.T. and the buddy system are adaptable across a wide platform of physical activity. America has become a lazy society with more obese citizens than ever before (Center for Disease Control, 2004). The Thera-Network is useful for all individuals who could benefit from an exercise program. The aging population will benefit from a motivator to track exercise as well as only 30% of older men and 15% of older women participate in regular sustained activity classified as exercise (Morey, et al., 2003 p.351).

Research shows additional motivation is required for participation in physical therapy which has specific goals and healing properties. It can be extrapolated that if people are in need of motivational assistance for medically necessary exercise, they are likely to need a motivation to exercise for weight loss and physical stamina. The Thera-Network is adaptable for a person who would like to track a daily or weekly

exercise routine. Given a chance at market, the desktop device can work well as a motivational tool for many of life's tasks that may be less than desirable.

Summary

This project began as an exploration into telemedicine and virtually connecting patients and PTs. As the research continued uncovering the complex issues surrounding physical therapy, home exercise, and the patient experience, the project grew in unexpected ways. User feedback led the project in new directions. The wide range of available technology affords a novel design.

What has been presented is a roadmap for a system that allows a patient and PT to remain in constant contact in between office visits. Motivational theory shows the usefulness of a support network and the need for tracking large and small accomplishments. Using M.A.T.T., MAGGi and possibly an on-screen buddy system, a patient has the opportunity for fun, a feeling of accomplishment, connection to a wider community, opportunities for feedback and a feeling of autonomy. Using this system will help patients heal more quickly with a motivating system returning the body to homeostasis where it can experience life to the fullest.

APPENDIX A

WEARABLE TECHNOLOGY MATRIX

Product	Sponsoring Institution	Contact info	Principal Researcher	Brief Description
LifeShirt	LifeShirt.com		Andy Behar	Records breathing, heartbeat, and over 3 dozen measures of cardiac and respiratory function, uses
Biofeedback Knee Goniometer	Rehabilitation Institute of Chicago		Todd Kuiken	knee brace that provides feedback reminding patients to exercise
Motion Aware Clothing (MAC)	Wearable Computing Lab, ETH, Zurich, Switzerland		Tunde Kirstein	wearable tech that reminds users to pay attention to posture
Blood Monitor	Massachusetts Institute of Technology		Alex (Sandy) Pentland	Watch that tests and monitors blood
Wearable Motherboard	Georgia institute of Technology/Sensatex		Sundaresan Jayarman and Sungmee Park	Garment to monitor body's vital signs
WSS 1000	Symbol		n/a	wearable computer with laser barcode scanner inside of a ring worn on finger
Verb For Shoe	Vectrasense Technologies, Inc. Miami, FL		n/a	Shoes embedded with chip, hand made shoes, when chips get within 1 meter of each other, shoes can exchange digital content including pictures and files--shoe is equipped with air bladders, motion sensor and wireless link, and computer. It responds to the activity of the moment (i.e. walking or running)
BodyMedia	Pittsburgh, PA	412.288.9901, sales@bodymedia.com		monitors physiological data via an armband and can be downloaded to a pc
Zona de Recreo	Facultad de Bellas Artes de la Universidad Politécnica de Valencia. http://www.bbaa.upv.es		Diego Diaz	It consists of a multiuser interactive interface system that control a 3D world in real time. The top of this structure has an embedded touch screen controller by a system of sensors allowing the image to change according to the amount of twist of the structure.
Product	Sponsoring Institution	Contact info	Principal Researcher	Brief Description
Virsual				"Virsual" is a wireless, ride-on rocking horse equipped with its own motion sensor device. As riders saddle up a 3D game is activated and displayed on scr
LegShocker	Fursr			The players, before putting on their football footwear, each slip into the LegShocker, a hand-sewn shinpad. A small hammer is activated and hurts the leg each time a player of the opposite team makes a good move against yours or scores a goal. Used with Playstation
Smart Jacket	Cornell University	led6@cornell.edu	Lucy Dunne	jacket that automatically heats and lights up when it is cold and dark and also contains a pulse monitor to measure activity level for joggers and walkers.
FitSense	Fitsense Technology Corporation			Running tracking system with watch, chest strap for heart monitoring and shoe fob for speedometer
Gait Shoe	Massachusetts Institute of Technology-Media Lab		Paradiso, Morris, Benbasat, Asmussen	Shoe that measures medial and lateral heel pressure, and behind toes with piezoelectric strips, a pair of proximity sensors, and sonar
DiaBetNet	Massachusetts Institute of Technology-MITHril		Sandy Pentland	computer game for young diabetics-uses belt motion sensors, wireless interent and PDA--tracks food intake, activity and B.sugar level in a game format-socialization
Memory Glasses	Massachusetts Institute of Technology-MITHril		Sandy Pentland	Glasses that function as a human assistant, reminder requests, paper organizer, also used as subliminal reminder-more effective this way
	Charmed Technology			
Jacket with Embedded cell phone	Motorola			
MP3 Jacket	Infineon Technologies, Burton, GAP			jacket with built in MP3 player
Protective Jacket	MIT			jacket that delivers 80,000 volt electric shock to potential attacker

Product	Sponsoring Institution	Contact info	Principal Researcher	Brief Description
Electrically Heated Clothing	Tampere University of Technology w/funding from Reima-Tutta, Suunto, Nokia and Tech. Dev. Ctr. Of Finland	kari.kukkonen@tut.fi	Kari Kukkonen etc.	jacket that uses PCB's, temperature sensors, humidity sensors and two battery packs carried on the belt (too heavy for shirt) to sense when wearer is cold
Polartec Heated Blanket	Malden Mills			polar fleece blanket with ribbon-like power bus under binding on blanket. Fine fibers are knit into the blanket eliminating the bulky wires found in previous blankets. Power bus by Natick for the Army.
Hoodio	GAP			jacket with built in radio Water-resistant radio power pack snaps into chest pocket, two speakers snap into hood, built-in tuner and volume controls on sleeve.
Track Suit	Starlab W		alter Van De Velde	track suit that configures data on your heartbeat, body temp and sweat...plays music and adapts rhythm to push harder or slow down,
Gesture Wrist and Gesture Pad	Interaction Laboratory, Sony CS labs, inc.	rekimoto@acm.org	Jun Rekimoto	wristband, pad or finger device that allows input device that recognizes hand gestures and forearm motions
E-Plaid	International Fashion Machines	morth@ifmachines.com	Maggie Orth	electric Plaid combines woven electronic circuits, color-change inks and drive electronics, to add TIME AND MOTION to textile patterns and design. Patterns change color slowly over time, to give you information or change the decor of the room. Electric Plaid is a reflective (it doesn't light up!) color-change medium. Electric Plaid can be combined with IFM's textile sensors, StitchSwitch, to create fully interactive textiles and artworks.
Elroy	MIT			elroy is an illuminating dress that encodes time information. the panels periodically reaarrange their
E-Textiles	Virginia Tech	athanas@vt.edu	Peter Athanas	"e-textiles are fabrics that have electronics and interconnections woven into them, with physical flexibility and size that cannot be achieved with existing electronic manufacturing techniques. Components and interconnections are intrinsic to the fabric and thus are less visible and not susceptible to becoming tangled together or snagged by the surroundings"

Product	Power Source	Motivators	Industry	Remote Monitoring
LifeShirt	1800 mA, cell phone type or AA? Battery	records and tracks data	healthcare	
Biofeedback Knee Goniometer		audio-visual feedback	healthcare	no
Motion Aware Clothing (MAC)		plan different types of feedback for different applications, for example: -people sitting in front of a computer could get visual feedback on the monitor about their sitting posture, -people who have to lift heavy weights could get an acoustic alarm if they do wrong movements, -people in rehabilitation who have to train certain movements could get haptic feedback (like the vibration of mobile phones).	healthcare	yes
Blood Monitor			healthcare	
Wearable Motherboard			military and healthcare	yes
WSS 1000			shipping/handling	
Verb For Shoe			athletics	yes
BodyMedia	charges in docking station	records and tracks data	fitness	yes
Zona de Recreo		visual feedback, physical response	Playground/toy	no

Product	Power Source	Motivators	Industry	Remote Monitoring
Virsual		visual feedback, interactivity	games	no
LegShocker		not getting shocked	games	
Smart Jacket	AA batteries in prototype, suggest lithium for manufacturing		health/sporting/outdoor	
FitSense		set intervals for distance, longer than previous days or same, beep	athletics	yes
Gait Shoe		audio feedback-melody, shuffling gait induces a loud click to cue back to steady pace, other gait defects induced audio to become more rhythmic, less melodic	health, physical therapy	?
DiaBetNet		competition, reminders, network/buddy	health-diabetes monitoring	yes
Memory Glasses		visual, audio through earpiece	health, general	?
Jacket with Embedded cell phone				
MP3 Jacket		audio	entertainment	
Protective Jacket		haptic/tactile	safety	?

Product	Power Source	Motivators	Industry	Remote Monitoring
Electrically Heated Clothing	5 NiMH cells		athletics, outdoors	no
Polartec Heated Blanket	AC, uses same energy as 100 watt bulb	interface	home	no
Hoodio	3 AAA batteries, remove to wash		entertainment	no
Track Suit		music/audio	athletics	no
Gesture Wrist and Gesture Pad				no
E-Plaid			interiors	no
Elroy				
E-Textiles	9V Battery		medical, gait-others	

Product	Worn	Market Status			
LifeShirt		research phase			
Biofeedback Knee Goniometer	knee brace	research phase	Archive of Physical Medicine and Rehabiltation, Kuiken, 2004		
Motion Aware Clothing (MAC)	shirt	research phase	http://www.wearable.ethz.ch/mac000.0.html, Kirstein 2004		
Blood Monitor	wrist	research phase	IEEE, Ferrero, 1998		
Wearable Motherboard	shirt	research phase	Newsweek, Beith, 2003		
WSS 1000	wrist and finger	on market	Pervasive Computing, Starner, 2002		
Verb For Shoe	foot	on market	www.verbforshoe.com		
BodyMedia	arm	on market	www.bodymedia.com		
Zona de Recreo	stand on		http://www.hilbye.org/zonarecreo/contexte.htm		

Product	Worn	Market Status			
Virsual	ride on		www.virsual.com		
LegShocker					
Smart Jacket	jacket	research phase	http://www.lucydunne.com/press%20-%20smart%20jacket.htm		
FitSense	wrist, shoe, chest	on market	www.fitsense.com		
Gait Shoe	foot	research phase	http://www.media.mit.edu/resenv/pubs/papers/2004-05-lb657-Paradiso.pdf		
DiaBetNet	belt sensor	research phase			
Memory Glasses	glasses on face	research phase			
Jacket with Embedded cell phone					
MP3 Jacket	jacket	research and market			
Protective Jacket	jacket/body	research			

Product	Worn	Market Status			
Electrically Heated Clothing	jacket	research			
Polartec Heated Blanket	body	on market	http://new.idsa.org/idea/idea2002/G7020.htm		
Hoodio	jacket	on market, but no longer available	http://secure.www.gap.com/asp/Product.asp?wdid=40&wpid=2611651		
Track Suit	jacket pants	research phase	www.wienerzeitung.at/frameless/lexikon.htm?ID=9179		
Gesture Wrist and Gesture Pad	body	research phase	www.csl.sony.co.jp/person/rekimoto.html		
E-Plaid	wall	custom available	www.ifmachines.com		
Elroy					
E-Textiles	pants, shirt	research	http://www.ccm.ece.vt.edu/etextiles/		

APPENDIX B

SURVEY 1

General

Where do you work?

City

State

Where do you live?

City

State

What is your gender?

☐ Male
☐ Female

What is your age?

☐ 18-23
☐ 23-34
☐ 35-44
☐ 45-54
☐ 55-65
☐ 66-80
☐ 80+

How many years have you been a physical therapist?

☐ Less than 3
☐ 3-5 years
☐ 6-10 years
☐ 11-16 years
☐ over 16 years

Occupational

What is your current work setting?

☐ Hospital
☐ Outpatient Clinic
☐ Rehabilitation Center
☐ Skilled Nursing Facility
☐ Home Health Care
☐ Schools
Other

If you work in home health, how many hours a day are spent traveling to see patients?

☐ Less than 1
☐ 1-2
☐ 3-5
☐ over 6

What is your area of specialty?

☐ Neurological Rehab
☐ Elective Orthopedic Rehab
☐ Non-Elective Orthopedic Rehab
☐ Children's Rehab
☐ Geriatric Rehab
☐ Back Clinic
☐ Other

On average, how many exercises do you give a patient who is recovering from a lower body injury?

☐ 2-3
☐ 3-5
☐ 5-7
☐ more than 7

Which medical professionals do you stay in contact with when working with a patient?

☐ Primary care doctor
☐ Surgeon
☐ Orthopedic doctor
☐ Specialist
☐ Other

On average, how many patients do you see a day?

☐ 3-5
☐ 5-7
☐ 8-10
☐ More than 10

Which of the following technologies have you used before? (check all that apply)

☐ ATM
☐ Self-checkout at a retail or grocery store
☐ Personal Computer
☐ Web cam
☐ Fax
☐ Cell phone
☐ Personal Digital Assistant (i.e. Palm Pilot)
☐ In home medical monitoring devices

Which one(s)?

Do you own a personal computer at home?

☐ Yes
☐ No

Do you use a personal computer regularly at work?

☐ Yes
☐ No

Please rank the following items in order of importance (1 to 3) to gauge progress (1 =most important, 3 = least important)

Range of Motion
Strength
Electronic data

Please rank the following items in order of importance (1 to 4) to monitor during exercise
(1 =most important, 4= least important)

Blood sugar level
Oxygen in blood
Blood pressure
Pulse

32. Please check the appropriate box

	Agree	Somewhat Disagree	Somewhat Agree	No Answer	Disagree
I am comfortable with technology.	☐	☐	☐	☐	☐
Touch is very important to my physical therapy.	☐	☐	☐	☐	☐
I would feel comfortable giving advice from over the phone.	☐	☐	☐	☐	☐
I would feel comfortable giving advice with a phone and video.	☐	☐	☐	☐	☐
I find that my patients push their exercise load and try to do too much too soon	☐	☐	☐	☐	☐
I don't like traveling to see clients.	☐	☐	☐	☐	☐
I don't think my clients do the recommended number of exercises between visits.	☐	☐	☐	☐	☐
I use the Internet often.	☐	☐	☐	☐	☐
I have an email account and check it regularly.	☐	☐	☐	☐	☐
I see technology as a large factor in my life in the coming years.	☐	☐	☐	☐	☐
My patients always do the right number of exercises between visits.	☐	☐	☐	☐	☐
I am interested in a system that would allow me to see a broader view of my clients' health	☐	☐	☐	☐	☐

Thank you very much for your participation. Your information is confidential. If you would be interested in participating in a follow-up interview, please fill in the following information. Any questions regarding this survey should be directed to Janna Kimel 770-661-9996.

Name: _____ Email: _____ Phone: _____

General – please check one answer per question

1. What is your age?

☐ 18-23
☐ 23-34
☐ 35-44
☐ 45-54
☐ 55-65
☐ 66-80
☐ 80+

2. What is your gender?

☐ Male
☐ Female

3. Do you smoke?

☐ Yes
☐ No

4. What is the highest level of education completed?

☐ High school
☐ Some college
☐ College Graduate
☐ Working on or completed post graduate or PhD

5. What is your household income?

☐ Under $25,000
☐ $26,000-40,000
☐ $41,000-60,000
☐ $61,000-$100,000
☐ Over $100,000

6. City and state you lived in during the time of injury

Injury

7. When did your injury occur?
Day Month Year

8. How did your injury occur?

☐ Car accident
☐ Athletics
☐ Falling
☐ Other_____

9. In what part of your body are you experiencing pain? (please check all that apply)
☐ Foot
☐ Ankle
☐ Hip
☐ Knee
☐ Lower back
☐ Other (please explain)_____

10. Which side of your body was affected?
☐ Right side
☐ Left side
☐ Both sides

11. Are you still in contact with a physical therapist?
☐ Yes
☐ No

12. Please explain any other means used to reduce pain i.e., medications, heat/ice, or alternative therapies.

13. Please explain the time a physical therapist (PT) was/will be involved in your recovery:
☐ Initially right after injury only
☐ The entire time I was in a cast
☐ Only once a cast was removed
☐ During a hospital stay
☐ After a hospital stay

14. How long will/did you work with a PT?
☐ 1-2 weeks
☐ 3-4 weeks
☐ 6-8 weeks
☐ 8 weeks or more

15. On average, how many hours a week do/did you spend with your PT?

☐ 30 minutes
☐ 60 minutes
☐ 90 minutes (1 ½ hours)
☐ 120 minutes (2 hours)
☐ 180 minutes (3 hours)
☐ Over three hours

16. My PT worked with me: (Please check all that apply)

☐ in the hospital
☐ in my home
☐ at his/her office
☐ at another location

17. Do/did you take time out of work to visit your PT?

☐ Yes
☐ No

18. How far do/did you travel to your PT?

☐ 0-10 miles
☐ 11-25 miles
☐ 26-45 miles
☐ over 45 miles

19. If you were working before the accident, how much time did you take off of work?

☐ None
☐ 1-2 days
☐ 1 week
☐ 2 –3 weeks
☐ 4-6 weeks
☐ 7 weeks or more
☐ I don't work outside the home

20. During the healing process, were you able to drive?

☐ Yes
☐ No
☐ I don't drive

21. Why did you stop seeing your physical therapist?

☐ Completed course of treatment
☐ Insurance wouldn't cover any more
☐ Too far to travel
☐ Personality – I didn't really like my therapist

22. Do you still do any of the recommended exercises?
☐ Yes
☐ Sometimes
☐ Not at all

Insurance

23. Do you have health insurance?
☐ Yes
☐ No

24. What portion of your PT did your insurance pay for?
☐ Some
☐ All
☐ None

25. How many physical therapy sessions were covered by your insurance?
☐ None
☐ 1-6
☐ 7-12
☐ 13-20
☐ Over 20

26. What, if anything, would you change about your physical therapy sessions?

27. What, if anything, would help you stay on schedule with exercises between visits?

29. Which of the following technologies have you used before? (check all that apply)
☐ ATM
☐ Self-checkout at a retail or grocery store
☐ Personal Computer
☐ Web cam
☐ Fax
☐ Cell phone
☐ Personal Digital Assistant (i.e. Palm Pilot)
☐ In home medical monitoring devices
Which medical device(s)?

30. Do you own a personal computer?
☐ Yes
☐ No

31. Do you have Internet access at home?

☐ Yes
☐ No

32. Please check the appropriate box

	Agree	Somewhat Disagree	Somewhat Agree	No Answer	Disagree
I am comfortable with technology.	☐	☐	☐	☐	☐
Touch is very important to my physical therapy.	☐	☐	☐	☐	☐
I would feel comfortable getting medical advice over the phone.	☐	☐	☐	☐	☐
I would feel comfortable getting advice with a phone and video.	☐	☐	☐	☐	☐
I sometimes push exercise load and try to do too much too soon	☐	☐	☐	☐	☐
I don't like traveling to see my physical therapist	☐	☐	☐	☐	☐
I don't do the recommended number of exercises between visits.	☐	☐	☐	☐	☐
I use the Internet often.	☐	☐	☐	☐	☐
I have an email account and check it regularly.	☐	☐	☐	☐	☐
I see technology as a large factor in my life in the coming years.	☐	☐	☐	☐	☐
I sometimes get confused when doing my exercises at home after seeing the therapist	☐	☐	☐	☐	☐
I prefer going to the therapists office rather than having a housecall for my physical therapy	☐	☐	☐	☐	☐

Thank you very much for your participation. Your information is confidential. If you would be interested in participating in a follow-up interview, please fill in the following information. Any questions regarding this survey should be directed to Janna Kimel 770-661-9996.

Name: _____ Email: _____ Phone: _____

Project Title: *Virtual Therapy: assisting post-injury patients with the rehabilitative process through virtual care*
Investigators: *Wayne Chung, Janna Kimel*

Research Consent Form

You are being asked to be a volunteer in a research study.
•For this research questions will be asked about your general experience with patients undergoing physical therapy for a temporary lower body injury, and about your comfort with technology. At no time will your physical body be part of the research.

Purpose:
The purpose of this study is:
• To better understand the tools used by physical therapists, their views on patient compliance and their comfort with technology. Therapists who have worked in the field for three years or more are eligible to participate in this study. Thirty-five therapists will be surveyed.

Procedures:
If you decide to be in this study, your part will involve:

• Filling out a paper or electronic survey.

Risks/Discomforts
The following risks/discomforts may occur as a result of your participation in this study:
• The risks involved are no greater than those involved in daily activities such as writing a letter or typing an email**.**

Benefits
The following benefits to you are possible as a result of being in this study:
• You are not likely to benefit in any way from joining this study. But we hope that other physical therapists and patients will benefit, in the future, from what we find in doing this study.

Compensation to You

No direct monetary or other form of compensation is offered for participating in this study.

Confidentiality
The following procedures will be followed to keep your personal information confidential in this study: The data that is collected about

you will be kept private to the extent allowed by law. To protect your privacy, your records will be kept under a code number rather than by name. Your records will be kept in locked files and only study staff will be allowed to look at them. Your name and any other fact that might point to you will not appear when results of this study are presented or published.

You should be aware, however, that the experiment is not being run from a "secure" https server of the kind typically used to handle credit card transactions, so there is a small possibility that responses could be viewed by unauthorized third parties (e.g., computer hackers).

To make sure that this research is being carried out in the proper way, the Georgia Institute of Technology IRB will review study records. Members of the Food and Drug Administration may also look over study records during required reviews. The Office of Human Research Protections may also look at study records.

Costs to You

• No direct monetary or other form of compensation is offered for participating in this study.

In Case of Injury/Harm

If you are injured as a result of being in this study, please contact Wayne Chung, Investigator at telephone 404-385-4982. Neither the Principal Investigator nor Georgia Institute of Technology have made provision for payment of costs associated with any injury resulting form participation in this study.

Subject Rights

• Your participation in this study is voluntary. You do not have to be in this study if you don't want to be.
• You have the right to change your mind and leave the study at any time without giving any reason, and without penalty.
• Any new information that may make you change your mind about being in this study will be given to you.
• You will be given a copy of this consent form to keep.
• You do not waive any of your legal rights by signing this consent form.

Questions about the Study or Your Rights as a Research Subject

• If you have any questions about the study, you may contact Wayne Chung, Investigator at telephone 404-385-4982.

• If you have any questions about your rights as a research subject, you may contact Ms. Alice Basler, Georgia Institute of Technology at (404) 894-6942.

If you would like to be a volunteer in this study please respond to this email

Georgia Institute of Technology

PROJECT TITLE: *VIRTUAL THERAPY: ASSISTING POST-INJURY PATIENTS WITH THE REHABILITATIVE PROCESS THROUGH VIRTUAL CARE*

Investigators: *Wayne Chung, Janna Kimel*
Research Consent Form

You are being asked to be a volunteer in a research study.
• For this research questions will be asked about your physical health and your comfort with technology. At no time will your physical body be part of the research.

Purpose:
The purpose of this study is:
• To gain more information into the habits of people undergoing physical therapy. Thirty-five individuals will be asked to participate in this study. Individuals eligible for this study will have been under the care of a physical therapist to heal a temporary, lower body injury during the last 24 months.

Procedures:
If you decide to be in this study, your part will involve:

• Answering 32 questions in a paper or electronic survey.

Risks/Discomforts
The following risks/discomforts may occur as a result of your participation in this study:
• The risks involved are no greater than those involved in daily activities such as writing a letter or typing an email**.**

Benefits
The following benefits to you are possible as a result of being in this study:
• You are not likely to benefit in any way from joining this study. But we hope that others who undergo therapy for a temporary injury will benefit, in the future, from what we find in doing this study.

Compensation to You
• No direct monetary or other form of compensation is offered for participating in this study.

Confidentiality

The following procedures will be followed in an effort to keep your personal information confidential in this study: Your identity will be held confidential,

and all data will be kept in a secured, limited access location. Your identity will not be revealed in any publication or presentation of the results of this research.

Confidentiality cannot be guaranteed; your personal information may be disclosed if required by law. This means that there may be rare situations that require us to release personal information about you, e.g., in case a judge requires such release in a lawsuit, if you tell us of your intent to harm yourself or others (including reporting behaviors consistent with child abuse).

As a result of being in this study, identifiable health information about you will need to be used, generated, and or reported for the purpose(s) outlined in this consent form, and/or as required by law. Federal law protects your rights to privacy concerning this information. As such, there is certain specific information you need to know.

Individually identifiable health information (IIHI) under the federal privacy law is considered any information from your medical record, or obtained from this study, that can be linked to you, and that relates to your past, present, or future physical or mental health or condition. The following IIHI will need to be used, generated, or disclosed (reported) for the purpose of this study:

• information obtained from this study, including information on your accident and injuries.

Your IIHI will be shared with any person or agency when required by law, and by:

• the research team for this study

• GEORGIA INSTITUTE OF TECHNOLOGY INSTITUTIONAL REVIEW BOARD and/or applicable officials of GEORGIA INSTITUTE OF TECHNOLOGY, and/or the federal Office of Human Research Protections for the purpose of assessing compliance associated with the conduct of this study.

Use and disclosure of your health information will be necessary for an indefinite period of time.

You have the right to revoke (withdraw) your authorization for the use or disclosure of your IIHI at any time in writing. If you revoke this authorization, you may no longer participate in this research activity. Revoking your authorization means that all access to, and collection of, your IIHI will be halted, unless the information concerns an adverse event (bad effect) you experienced related to the study. Your IIHI that was collected before you withdrew your authorization can continue to be used and reported.

When you sign the consent form at the end, it means that you have read this section and authorize the use and or disclosure of your individually identifiable health information in the manner explained above.

The following procedures will be followed to keep your personal information confidential in this study: The data that is collected about you will be kept private to the extent allowed by law. To protect your privacy, your records will be kept under a code number rather than by name. Your records will be kept in locked files and only study staff will be allowed to look at them. Your name and any other fact that might point to you will not appear when results of this study are presented or published.

You should be aware, however, that if you choose to answer the survey via email, the experiment is not being run from a "secure" https server of the kind typically used to handle credit card transactions, so there is a small possibility that responses could be viewed by unauthorized third parties (e.g., computer hackers).

Costs to You

As a participant, there is no cost to you. No money, or other form of payment is to change hands.

In Case of Injury/Harm

If you are injured as a result of being in this study, please contact Wayne Chung, Investigator at telephone 404-385-4982. Neither the Principal Investigator nor Georgia Institute of Technology have made provision for payment of costs associated with any injury resulting form participation in this study.

Subject Rights

Your participation in this study is voluntary. You do not have to be in this study if you don't want to be.
• You have the right to change your mind and leave the study at any time without giving any reason, and without penalty.
• Any new information that may make you change your mind about being in this study will be given to you.
• You will be given a copy of this consent form to keep.
• You do not waive any of your legal rights by signing this consent form.

Questions about the Study or Your Rights as a Research Subject

• If you have any questions about the study, you may contact Wayne Chung, at telephone 404-385-4982. If you have any questions about your rights as a research subject, you may contact Ms. Alice Basler, Georgia Institute of Technology at (404) 894-6942.

If you sign below, it means that you have read (or have had read to you) the information given in this consent form, and you would like to be a volunteer in this study.

_____

Subject Name

Subject Signature	**Date**

Signature of Person Obtaining Consent	**Date**

Mean/Mode - Response on Likert-type Scale
1 = agree > 4 = disagree

Survey Question	**Therapist**		**Patient**	
	Mean	Mode	Mean	Mode
Technology				
I am comfortable with technology	1.45	1	1.6	1, 2
I use the internet often	1.73	1	1.38	1
I have an email account and check it regularly	1.3	1	1.19	1
I see technology as a large factor in my life in the coming years	1.75	1, 2	1.62	1
I would feel comfortable giving/getting advice over the phone	2.18	2	1.69	1
I would feel comfortable giving/getting advice with a phone and video	2.27	2	1.5	1
I am interested in a system that would allow me to see a broader view of my clients' health	1.64	2		
Location				
I prefer going to a doctors office rather than having a house call for medical treatment			1.38	1, 2
I would prefer a healthcare practitioner who came to my home for treatment			2.63	4
I don't like traveling to see clients/my therapist	1.36	1	3.75	4
Therapy and Exercise				
Touch is very important to my physical therapy	1	1	1.44	1
I/my patients always do the right number of exercises between visits	3.09	4	2	1 and 2
I don't think my clients do the recommended number of exercises between visits	1.82	2		
I find that my patients push their exercise load and try to do too much too soon	3.09	4		
I get confused by the instructions for exercises when I am not doing them with my therapist.			3.5	4

PT Survey

Subject	Work in	Live in	M/F	Age	Years as PT	work setting	time spent traveling to patients
			1F, OM				
1	Dunwoody, GA	Alpharetta, GA	1	35-44	11 to 16	outpatient clinic	
2	Metro Atlanta	McDonough	1	23-34	6-10 years	hospital, outpatient, rehab center	
3	Germantown, MD		0	23-34	6-10 years	outpatient clinic	
4	Marietta, GA	Marietta, GA	1	55-65	16+	outpatient clinic	
5	Roswell,GA	Alpharetta, GA	1	35-44	11 to 16	hospital, outpatient, rehab center	
6	Conyers, GA	SnelIville, GA	1	23-34	under 3	hospital	
7	Chamblee, GA	Chamblee, GA	1	23-34	6 to 10	outpatient clinic	
8	Marietta, GA	Dallas, GA	1	45-54	3 to 5 years	hospital	
9	Norcross, GA	Cumming, GA	0	45-54	ii to 16	Occupational health care facility	
10	city	city	0	55-65	16+	outpatient clinic	
11	Porterville, CA	CA	0	55-65	16+	outpatient clinic	

Subject	Area of specialty	No. of exercises	Medical profs	#of patients/day
1	non-elective orthopedic rehab	7+	orthopedic dr.	8 to 10
2	non-elective orthopedic rehab	5 to 7	primary care md, surgeon, ortho md, specialist	over 10
3	elective Orthopedic rehab	5 to7	primary care md, ortho md	10+
4	Geriatric Rehab, women's health	5 to 7	specialist	5 to7
5	Geriatric rehab	5 to 7	primary md, surgeon, ortho, specialist	8 to 10
6	elective Orthopedic rehab, geriatric rehab, wound care	5 to 7	primary md, surgeon, ortho, specialist, oncology	5 to 7
7	back clinic and general ortho	5 to 7	surgeon, whoever referred to pt	8 to 10
8	cardio pulmonary	5 to 7	specialist	5 to 7
9	Occupational PT	7+	primary md, surgeon, ortho, specialist	over 10
10	elective ortho rehab	7+	orthopedic dr.	5 to7
11	elective ortho, non-elective ortho, back clinic, other	3 to 5	primary care, surgeon, ortho	10+

Subject	technologies used	pc at home	pc at work	progress ranking	monitoring ranking	comfort with tech
1	atm, self check, pc, fax, cell	1	0	Rom, 5, E	BP, P, 02, BS	1
2	atm, self check, pc, fax, cell	1	0	S,ROM, ED	BP, P, BS,02	2
3	atm, self check, pc, fax, cell	1	0	Rom, 5, E	BP,P,02,BS	1
4	atm, self check, pc, fax, cell	1	1	Rom, 5, E	P, BP, BS, 02	2
5	atm, self check, pc, webcam, fax, cell, pda	1	1	S,ROM, ED	P, 02, BP, BS	1
6	atm, self check, pc, fax, cell, pda	1	1	Rom, 5, E	02, P, BP, BS	1
7	atm, self check, pc, fax, cell	1	1	S,ROM, ED	BP, P, 02, BS	1
8	atm, self check, pc,fax, cell	1	1	S,ROM, ED	02, P, BP, BS	2
9	atm, self check, pc, fax, cell	1	1	Rom, 5, E	P, BP, 02,BS	2
10	atm, self-check, pc, fax, cell	1	0	S,ED, ROM	BP, 02,P, BS	2
11	atm, self-check, web cam, pc, fax, cell, in home monitoring device	1	1	5, ROM, ED	P, BP, 02, BS	1

Subject	touch is important	comfortable giving advice on phone	comfort giving advice phone/video	patients push	don't like traveling to clients
1	1	2	2	2	1
2	1	1	1	4	3
3	1	4	3	2	2
4	1	2	2	4	1
5	1	1	1	4	4
6	1	2	4	2	1
7	1	2	2	4	0
8	1	2	2	3	0
9	1	2	2	1	1
10	1	2	2	4	1
11	1	4	4	4	1

1 = strongly agree

4 = strongly disagree

Patient Survey

Subject	Age	Gender	Smoker	Education Level	HH$	City	State	Date of Injury
1		1FOM	1SON					
2	18-23	0	0	3	61-100	Dunwoody	GA	7/6/2004
3	80+	0	0	4	61-100	Marietta	GA	7/7/2004
4	55-65	1	0	4	41-60	Dunwoody	GA	6/8/2004
5	45-54	1	0	3	100+	Atlanta	GA	Feb-03
6	35-44	1	0	3	61-100	Atlanta	GA	N/A
7	18-23	1	0	1	N/A	Atlanta	GA	4/20/2004
8	55-65	0	0	3	100+	Atlanta	GA	6/6/2004
9	55-65	1	0	2	100+	Atlanta	GA	4-Apr
10	55-65	1	0	3	61-1 00	Dunwoody	GA	4-Apr
11	55-65	0	0	3	100+	Atlanta	GA	4/14/2004
12	55-65	1	0	1	61-100	Atlanta	GA	6/28/2004
13	35-44	0	0	4	100+	Norcross	GA	overtime
14	35-44	1	0	4	100+	Atlanta	GA	7/19/2004
15	35-44	1	0	4	26-40	Chicago	IL	Jul-01
16	35-44	0	0	4	-	Duluth	GA	3/25/2002
17	23-34	0	off/on	3	61-1 00	Sugarhill	GA	2/24/2004

Subject	How	Pain in Body	Side of Body	Pt Contact
1			1LOR	lYON
2	Athletics	Knee	0	1
3	Falling	Hip, knee, lower back, buttocks, inner/outer thigh	0	1
4	Falling then knee replacement	Hip, knee, lower back, buttocks, inner/outer thigh	0	1
5	treadmill	Knee	0	1
6	N/A	Knee	0	1
7	Athletics	knee	1	1
8	Athletics	Knee	0	1
9	Athletics	Knee	1	1
10	overtime	Knee	0	1
11	falling	lower back, foot	1	1
12	total knee replacement	Knee	1	1
13	Athletics	knee	0	1
14	Traveling on 5 country work project	foot, ankle, hip, calf	0	1
15	Athletics	knee	0	0
16	Athletics	Knee	1	0
17	Athletics	foot-Tibia and foot	1	1

Subject	Pain alleviation	Time w/PT	Weeks	Hrs/wk
2	ice, estin, percocet	During and after hospital	8+	3+
3	Darvocet-N, Tylenol, Arthrotec, Heat, ice stretching	right after injury only	3 to 4	3+
4	pain meds after surgery, prior use of anti inflammatories, 2 scopes, 1 cortisone shot	During and after hospital	8+	3
5	N/A	after hospital stay (surgery)	6 to 8	2
6	ice, heat, some pain meds		8+	2
7	ice	after hospital stay	8+	3+
8	ice	right after injury only	3 to 4	1
9		after hospital	3 to 4	1
10	elevation, ace bandage	right after injury only, after hospital stay	8+	2
11	emu oil	entire time in cast	6-8 weeks	2
12	ice, Tylenol	after hospital stay	6-8 weeks	1.5
13	ice, vioxx	n/a	6-8 weeks	3
14	physio 2x wk./McKinley method, massage therapy, pain meds, muscle relaxer	after cast	6-8 weeks	3
15	cortisone, ibuprofen, ice		6-8 weeks	1
16	heat, ice, medications	right after injury only	3-4 weeks	0.33
17	ice, shock and medications	after cast	8+	2
				1.489375

Subject	PT location	Timeoff work?	Miles to PT	Time off work	Drive?	Stop therapy
1		**lYON**				
2	in hospital, in office	1	0-10	7+ weeks	0	n/a
3	at office	0	11 -- 25	Don't work	1 with difficulty	n/a
4	in office	0	0-10	7+ weeks	Not for 3 weeks	n/a
5	at office	1	0-10	1-2 days	1	completed treatment
6	at office	1	11 -- 25	4-6 weeks	1	n/a
7	at office	0	0-10	4-6 weeks	1	completed treatment
8	at office	1	0-10	none	1	completed treatment
9	at office	0	0-10	·	1	completed treatment
10	at office	0	0-10	1-2 days	0	insurance wouldn't cover more
11	at office	0	0-10	none	1	Still under care
12	at office, in home	0	0-10	Don't work	0	Still under care
13	at office	1	0-10	none	1	completed treatment
14	at office	1	0-10	1 week	1	completed treatment
15	at office	0	0-10	none	1	completed treatment
16	at office	1	0-10	1-2 days	1	personality
17	n/a	1	0-10	7+	1	Still under care

Subject	do exercises?	health insurance?	Portion covered	sessions covered	changes to PT
1	**1Y ON** 2 sometimes	1Y ON	1 all, O none, 2 some		
2	**1**	**1**	**2**	20+	nothing
3	1	1	1	Don't know	nothing
4	1	1	2	20+	
5	n/a	1	2	8 to 12	nothing
6	1	1	1	20+	nothing
7	1	1	2	don't know	nothing
8	1.5	1	2	13 to 20	-
9	1	1	1	20+	nothing
10	1	1	2	13-20	nothing
11	1	1	1	13-20	nothing
12	1	1	2	Over 20	-
13	1	1	2	12-Jul	nothing
14	1	1	2	13-20	Get to PT sooner
15	2	1	2	7 to 12	nothing
16	0	1	2	L to 6	-
17	2	1	2	20+	nothing

Subject	stay on schedule	Tech used	pc?	Internet at home?
2	nothing	ATM, self check, pc, fax, cell	1	1
3	personal trainer	self check, pc	1	1
4		ATM, self check, pc, fax, cell, BP monitor	1	1
5	nothing	self check, pc, fax, cell	1	1
6	joining a health club	ATM, self check, PC, fax, cell, pda	1	1
7	nothing	ATM, self check, pc, fax, cell	1	1
8	self motivation	self check, pc, fax, cell	1	1
9	-	atm,self check, pc, cell	1	1
10	-	self check, pc,fax, cell	1	1
11		ATM, self check, pc, fax, cell, pda	1	1
12	-	atm, self-check, pc, fax, cell, pda	1	1
13	nothing	atm, self check, pc, fax, cell	1	1
14	make it simple, then add	ATM, self check, pc, fax, cell, pda	1	1
15	when knee doesn't hurt, I forget to do the exercises, out of sight, out of mind	atm, self check, pc, webcam, fax, cell	1	1
16	some kind of reminder	atm, self check, pc, fax, cell	1	1
17	not working 2 jobs	atm, self check, pc, webcam, fax, cell, pda	1	0-new home

1 = agree

4 = disagree

Subject	comfort w/tech	touch is impt	phone advice	phone+video advice	prefer office to housecall
2	1	1	1	1	na-depends on problem
3	2	1	2	2	1
4	1	1	1	na	2
5	2	na	1	1	na
6	1	4	1	1	2
7	1	1	4	4	1
8	2	1	2	2	1
9	2	1	1	1	2
10	2	1	1	1	2
11	1	1	2	2	1
12	1	1	1	1	2
13	2	4	1	1	4
14	2	1	2	2	1
15	1	2	1	1	na
16	1	1	2	1	1
17	2	2	4	3	2
	1.6	1.4375	1.6875	1.5	1.375

Subject	dislike travel to PT	home health preferred	use internet often	use check email	tech factor in life
2	4	4	1	1	1
3	4	na	2	DIDN'Tanswer	2
4	4	4	1	1	1
5	4	4	1	1	1
6	4	1	1	1	4
7	4	4	1	1	1
8	4	3	2	2	2
9	2	1	2	1	1
10	4	4	3	4	4
11	2	1	1	1	1
12	4	4	1	1	1
13	4		1	1	1
14	4	4	1	1	1
15	4	4	1	1	2
16	4	1	1	1	1
17	4	3	2	1	2
	3.75	2.625	1.375	1.1875	1.625

Subject	always do exercises	confused by exercises
2	1	4
3	1	2
4	2	4
5	1	4
6	2	4
7	1	4
8	2	4
9	2	4
10	1	4
11	2	2
12	1	4
13	2	4
14	3	2
15	4	3.5
16	4	2
17	3	4
	2	3.46875

APPENDIX C

KNEE EXERCISES

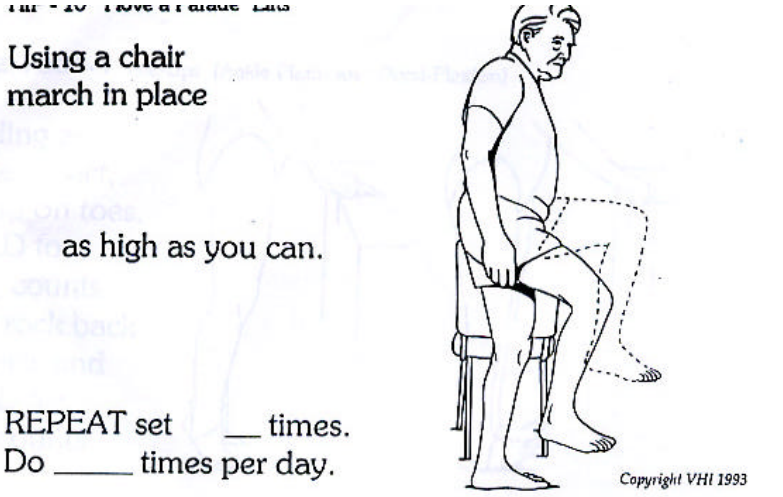

Figure 77 - Knee Exercises

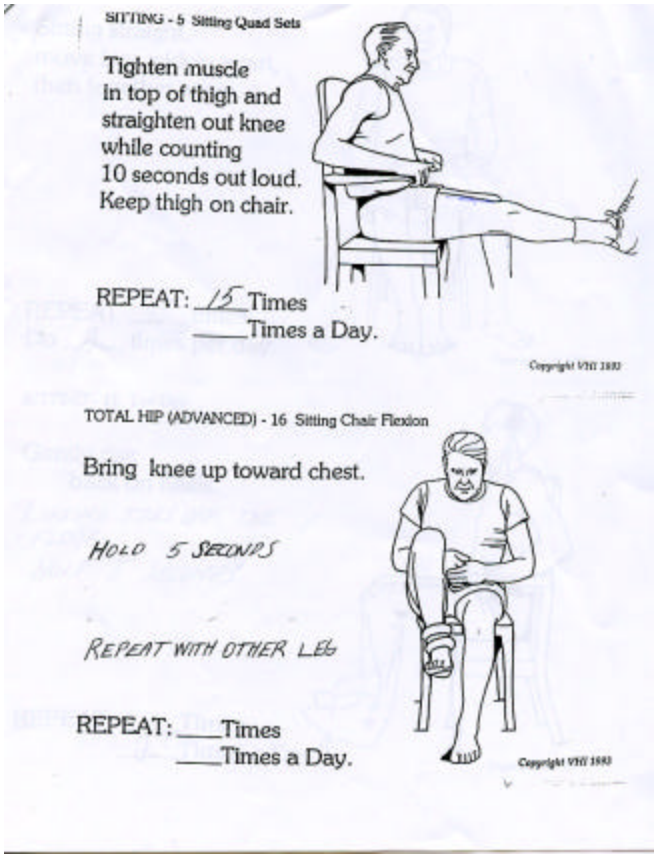

Figure 78 - Knee exercises

APPENDIX D

DIARY

Welcome! Thanks for agreeing to participate in this short exercise. Please fill out this survey, and then follow instructions daily for the remainder of the diary exercise.

Initial Survey

1) Where do you live? City State

2) Gender
- ☐ Female
- ☐ Male

3) Age
- ☐ 18-23
- ☐ 23-34
- ☐ 35-44
- ☐ 45-54
- ☐ 55-65
- ☐ 66-80
- ☐ 80+

4) With whom do you live?
- ☐ Spouse and children
- ☐ Roommate
- ☐ Alone
- ☐ Spouse, no kids at home
- ☐ Children, no spouse
- ☐ Other

5) Do you live in a
- ☐ House
- ☐ Condo
- ☐ Apartment
- ☐ Other

6) Do you work outside the home?
- ☐ Full-time
- ☐ Part-time
- ☐ I don't work outside the home

7) What is your job?

8) How many weeks have you been doing physical therapy?

- ☐ 1-4
- ☐ 5-9
- ☐ 10-15
- ☐ over 15

9) Did you regularly participate in any of the following before your injury?

- ☐ Running
- ☐ Biking
- ☐ Rock Climbing
- ☐ Yoga/Pilates/Tai chi
- ☐ Softball/Baseball
- ☐ Racquetball/squash/tennis
- ☐ Hiking
- ☐ Swimming
- ☐ Walking for exercise
- ☐ Skiing/Snowboarding

10) Please describe any personal or physical goals you have for the end of your physical therapy:

11) What is the location of your injury?

- ☐ Neck
- ☐ Hand/Wrist
- ☐ Arm/Shoulder
- ☐ Back
- ☐ Hip
- ☐ Knee
- ☐ Ankle/Foot
- ☐ Other _____

12) What is the nature of your injury?

- ☐ Sprain or Strain
- ☐ Break or Fracture
- ☐ Hip or knee replacement
- ☐ Other _____

Daily information
Today's Date_____

When you are filling out your diary, consider the following things. You don't have to address each one, but they may inspire you to write.

What's the weather like?
How well did you sleep last night?
Did your mood change before or after you exercised?
Are you in any pain today?
What activities did/will you do today?

Every day, please answer:

What motivated you to do your physical therapy today?
OR, why didn't you do your physical therapy today?

Please describe anything you changed in your routine to keep yourself motivated?

You have been given a camera!

Please take these pictures, and anything else you think might be helpful. Before you take each photo, please take a photo of the page with the Photo number. PLEASE NOTE THAT "EXERCISE" REFERS TO YOUR PHYSICAL THERAPY.

Please describe the photo here:

Please describe the photo here:

Please describe the photo here:

Please describe the photo here:

Please describe the photo here:

Please describe the photo here:

Please describe the photo here:

Optional: Contact information for follow-up/clarification questions:
Phone_____ Email:_____
Name:_____

Subject	Where do you exercise?	Where do you exercise?	A photo that represents your feelings about exercise	A photo that represents your feelings about exercise
1	I always exercise in the den when doing my PT exercises so I can watch TV while I'm doing it. The squats with the big ball are done on the screened in porch.			I do the PT exercises in order to get well. Other exercises are done because I know I need to keep active.
2	This is Body Pros where I work out!			No text (thumbs up picture), no text (big smile)
3	Wall in Bedroom next to bathroom	Wall with pencil marks on it to show my goal each day and to push myself to pass it.		no photo, my feelings are indifferent, you just have to do it
4	I do the exercises on the couch in my living room, also on my bed		Freedom to get back to normal	My daughter put Clifford [stuffed red dog] on my walker-it keeps me happy about doing my exercises
5	desk-where I do my exercises			it is a habit, like sleeping, that I do every day without thinking

Subject	A photo of what motivates you to do your PT	A photo of what motivates you to do your PT	Self-Portrait	Other
2	This is Jessica, my therapist. She keeps me motivated by telling me that I'm doing a good job.	This is Dave, my husband. He motivates me by making me want to get better.	Subject holding cat in front of face near the Xmas tree	
3	no picture-trying to get back to normal" is what motivates me			photo of duffle bag strap used in exercise, kitchen table
4	Cycling-doing the Bike Rid Across Georgia	Being able to do woodworking again	photo of subject, shoulders and above	
5	I want my back to be as straight and thus pain free as this column		just me, smiling, in a sweater because it is COLD outside	

Figure 79 - What motivates you: Cycling-doing the Bike Ride Across Georgia

Figure 80 - What motivates you: To get back to woodworking again

Here are

- my motivation for exercising (i want my back to be as straight - and thus pain free - as this column)

- how i feel about exercising (it is a habit, like sleeping, that i do every day without thinking)

-where i do my exercises...at my desk

Figure 81 - I do the PT exercises in order to get well. Other exercises are done because I know I need to keep active.

Figure 82 - Exercising in living room

Figure 83 - I always exercise in the den when doing my PT exercises so I can watch TV while I'm doing it.

Figure 84 - The squats with the big ball are done on the screened in porch.

Figure 85 - My daughter put Clifford [stuffed red dog] on my walker-it keeps me happy about doing my exercises.

APPENDIX E

BRACE USER FEEDBACK

Brace user feedback
A, B, C, D, E, F

C - Chronic knee pain, Osgood Schlatter's as a child. Causes tension and swelling in knees. Kneecaps are off to the side, hereditary and muscle imbalance, quads and hamstrings.
Constant dull ache. Wore brace with bar to shift kneecap.
Did strengthening exercises and PT did stretching to pull hamstrings out.
Better now, she is more conscientious and aware of how exercise affects the outcome.

D - Mild knee pain about 14 years ago, ignored it. 1995 starting to bother him more, saw PT for 2 mos. 1x/week. Didn't do much at home in between, he was busy. Got home and couldn't figure out positions. Last year his leg hurt and he went to a PT, 2x and got daily exercise, but then moved. Did a lot of iyengar yoga, 1 on 2, more attention, they were more aware of body positions.

E - Ice skating and snowboarding accidents. Sprain or strain injury.

F - Has pacemaker – can use telephone or walkman but not tensor meter – initially wary of using brace due to pacemaker
Saw PT for knee problems, cortisone injections
Use email daily and internet
Had actual PT for 4-6 weeks, that's all Medicare allows
PT assigned different exercises, use pt exercises at part of normal routine at gym

Counter

A - Count reps and timing,
Count hold time
Timer or beep
Awkward positions, can't always see interface
Font: large is good
B - Helpful if it counts reps(1-5): sets(1-10) and hold times (5 sec.)
D - Good to have audio interface, hold time beep at end. Or tone every 10 seconds, or some other input so you know it is working.
Sets not as important as counting, sometimes reps, sometimes need hold time.
Audio would help. Audio can change frequency as you get closer to goal or it can beep on its own.
Get lazy on counting, sometimes make deals with self.
Hold 30+ seconds sometimes
C - Counts hold time, sets and beep if you are slacking
E - Count sets, reps, 2-3 sets, 10-15 reps, hold 10 seconds
Need reset button
F - Do sit ups, 10 sets of 5
At gym, people count off exercises on a paper

Interface

A - Audio and visual is best
More detailed info at top of range
Are 3 lights necessary?
With hip exercises (also used in knee injuries) beep or visual-there is an angle goal
Use interface to tell you the angle you got to rather than set a goal, use as marker rather than goal
PAIN button to record pain
B - In the big picture, lights are motivating
If I had been told an angle of ROM, it would be motivating to get to angle or light, good to quantify
Use angle to gauge how far you have come or need to go. Full ROM is full triangle, maybe 30% is one level, 60% 2…etc.
Audio and visual feedback
Voice counting off?
Often did exercises with eyes closed.
Now doing standing exercises, wouldn't be able to see interface
PT uses travel alarm-build one into device: digital increase/decrease time, digital readout and audio alert
D - Way to measure tension/forces? What am I fighting against? Force?
No real goal, lights useful to get good stretch, show you full scale and watch to see how far you are, lots of bars to a certain point. Smaller increments.
Gauge day to day how many bars?
Can't always see lights when doing exercises.
C - Triangle is goal, try to hit goal
Always set slightly above what you can do, but you don't know that it's set that way
More bars
Weight/rate
If you get the right #, right speed then feedback is positive
Red is a bad color, all others ok
Prefer no glow to some glow vs. always glowing and changing color
Hard to see when doing inner thigh exercises
Auditory would be helpful-maybe be able to put headphones on? Don't want loud beeps at gym and might not hear it over music.
Minimal noise, beep at end only
E - Prefer #s and pictures
Picture of leg, robotic image-more visual
Too abstract
Not difficult to see when doing exercises
Option to turn off audio feedback
Would prefer a visual on the computer
F - Likes the visual on the treadmill, shows where you are on a virtual 'track'.

Exercise

A - Limiting factor was pain, no pre-determined angles
B - Did an exercise lying on bed on stomach, let leg hang off, use gravity to straighten. Hold for 5 minutes. Timer would be good.
Did exercise, hold heel on floor, put out in front of you, then drag in.
Limiting factor just do it as far as you can, or until too much pain. Mostly did just as far as he could.
D - 3 sets of 10, sometimes do 30 second hold
Rubber bands, yoga ball between legs,
No brace used when doing PT, do use neoprene brace if it hurts in general
C - Ankle weights and rubber bands
Used leg extension machine at gym
Down is as important as up
Control mechanism to know up and down
Three sets of 8-10 or 15
No hold time, but hold with stretches, 10-15 secs.
E - Build muscle around knee
Alignment
Bending, flexing
Contract knee muscle
Some go as far as you can, some follow picture (angle)
No brace when doing PT
F *- Trainer at gym keeps you from getting bored*
At gym have small groups and everyone has the same injury
Makes you want to feel better and go again
Good to have trainers at the gym you know and talk to
Likes being with people

Motivation

C - Lights would be motivating
System has to be smarter than me, I can't outsmart it, it needs to challenge me
E - Device does/would help motivate
Goals: reps, feeling better, snowboard again
F - Goes with wife to gym
Feels good
"I can't do exercises at home, I just won't do it."
Motivation is THERE
3 hour deal
$700/yr. (2 people gym membership) is motivating
b/c PT is short term, motivation isn't needed
motivated by weight loss, he lost 10 lbs.
psychologically look forward to gym

some elders mentioned continuing exercise (not therapy) so they can continue to live alone

Device

A - Feels ok
No discomfort or inhibiting
Didn't particularly motivate
B - Cumbersome to put on, use single Velcro strap with overlay, not fold over
Hard to know when it's in place
D - Donning ok, no discomfort or inhibiting
C - Donning, straps got confused (2 at top)
Comfortable
E - Hard to get potentiometer in just the right place, otherwise, ok

Other

B - Would like self-tracking comparison
D - Idea of a button to press when you experience pain is interesting
Focus on doing exercises correctly
Can wearable lock leg to hold, keep stretch to hold?
Also worked on hip flexibility
C - Two phases: see overall at end of workout as well as daily progress
Do exercises in bedroom
Make wearable, washable
E - Do exercises in bedroom
Needs to be wireless
Gets on computer at least 1x/day
Use laptop at home, need to alert auto upload data
F - Camaraderie of elders at gym 10.30-11 am
Haven't met friends really at 2-3 yrs. At gym
Atmosphere is impressive

PT Access

D - Knowing PT is getting information is motivating, accountability creates motivation
C - Yes, it would be motivating to know therapist is getting information. I don't like it, but it's motivating!

Buddy Access

E - Not helpful, would rather do my own thing
B - Not interested
C - Likes buddy at gym, successful in getting her there, but not always as good of a workout

F - Wife is buddy for going to the gym, though he never articulated it that way
Not interested in what the other guy is doing, but it is motivating to see it at the gym

Downloading

D- If needs to be near computer, I probably won't download info as often. Leave alone and auto transmit is OK
C - Use laptop as main computer, can be anywhere in the house.
If I do it, it will be once a week if I have to remember
Every day is easier to remember than once a week
Computer is on enough at home that it would be able to sense availability
It would be best if it could talk to the computer when it is asleep
Prefer confirmation email to a popup window

APPENDIX F

MOTIVATIONAL DEVICE USER FEEDBACK

Motivational Device User Feedback

Respondents:
A, B, C, D, E, F

F - Generally not interested in device
Wife spends a lot of time at a small table in the living room, that's where they would keep it.

Exercises

E - Concerned with building muscle around knee
Alignment
Bending
Contracting knee muscle
Bending flexing, add treadmill etc**.**
Sometimes go as far as you can, some follow the picture

Buddy system

A - Seems less likely I'd use this system
Not good to compete for PT
B - Not interested in buddy system
Injury is personal
Odd to have a buddy for recovery, too personal
D - Buddy better to share experiences with
Knowing isn't enough…personal, useful, reciprocal
Basic or enhanced relationship
E - Not helpful, prefer to do your own thing
F - not interested

PT link

A - Fear of PT finding out I'm not working out as much
Likes talking to therapist for validation, OK to be having problems
B - Tracking ok, but don't download it to PT
Button to send or not send info
E - PT good motivator, like doing your homework
Device linked to therapist would help

Feedback
A - Performance based, not time based
Did I reach goals? Not time tracking
B - Maybe keep track of reps over weeks
Counting # of days/times

Is there a way to go back? Add times exercised
Tracking is intriguing
C - Numbers are dangerous, too concrete
Time feedback is good, reps/weight/expenditure
D - Track record is nice to see how far you have gone
Get a red dot if you skip a day
Track gradations
Duration: weeks, days
Numeric, calculable
One month is enough for an overall representation
Few weeks with smaller granularity
E - General feedback: blue for exercise done, red for exercise not done
Visuals (like models) preferred over numeric info
Not a photo, but something that represents what has been done
F - Likes visual on treadmill at gym, shows where you are on virtual track
Could be good to see what you missed and why
Use blank to represent days not exercised
Can see lights ok

Goals
A - Walk with crutches
Run on treadmill
Stability
Being able to do the exercise
Adding weights
Play soccer…went out after injury and bought a yellow and black soccer ball..kept in his room as motivation.
B - Goals were told to PT, I want to do X miles on my bike
Compare information to goal
Driving truck again-stick shift
Back on bike
Walking without crutches
Walk and not think about knee
Don't need visual to tell next goal
More concerned with strength
C - Not quantifiable goals
Easier tasks
D - Dancing with no knee pain
Improving days it doesn't hurt
E - # of reps
Just want to feel better
To be able to drive and walk OK
Snowboarding again
Fear of developing arthritis
F - Just aim to get it done, no particular goal
Elders do exercise so they can continue to live alone

Milestones

B - Quantity of exercise
20-2x/day
Do reps until you can do it
Got boring when it was accomplished-would switch up exercise and add to it
Numbers are important
Repetitions
Force or something
Evidence of improvement

Compensating Time

A - Allow for catch up factor if you skip a day be able to compensate somehow
D - Yes, compensating would be interesting…a way to get rid of the red dot

Form

Hill

A - Hill increases fear
Goal at the bottom?
Countdown to normalcy
B - Hill: No idea how long I'll be in pt
PT doesn't know how long either
Useful to see progress in some form
A hill with one peg? It automatically does it, light up with no peg is ok
Tell what the light represents
C - Auto vs. Manual: satisfaction of peg, but don't want a negative peg
D - Hill seems big, needs to be smaller, scale down totally
Smaller and not take up too much room
A strip to hang the device or stick it up someplace
Peg is overkill
Use flat hill
E - Prefer automatic light up

Target

A - Prefer target
B - Target: Conceptually ok
Could be shame involved if people see it
Way to represent compensation
Like to visually see if you have or have not done exercises
D - Not as useful, not as direct
Circular strange
Wedges o.K.?
E - Prefer computer screen

½ of target would be ideal size (figure 8 version)

Abacus

B - Calendar abacus: Conceptually good
Wouldn't use: loose parts
Lazy, don't want to manipulate parts
One more thing to do
Minimal manipulation
Worried about losing parts
C - Sphere good, smoother =rewarded with softness
Square would = no exercise
(after stability explained) makes sense
Sphere should be black like a void
Make it electronic
Concerned about losing pieces
Glow on its own
Likes 3-d representation
Likes preciseness of abacus
Simplicity: it is or it's not
Calendar is more motivating
D - Ball would equal good day
(after explanation) square makes sense as stability
Blocks are tangible, good
Added functionality : if you do a full week: stack and light turns blue to positive feedback on accomplishment
As an art object in a prominent place-sculpture
Like blocks
Blocks feel like a game
E - Sphere=exercised, Square = not
Some concern about losing pieces
Computerized Visualization-screen based but similar form
B - Idea for vertical thermometer like fundraising goals

Interactive

A - Likes interactivity
Nice part of reporting is memory aid
Way to record pain?
B - Make it very easy to use
Zero or almost no thought
D - Prefer automatic, maybe options for both?
Lights can be confusing
Forget to do it/lazy

Downloading info

B - at home, computer in sun room
exercise in bedroom or living room
30-40 ft. Bluetooth range?
I wouldn't walk wearable device over to computer – device would say with exercise stuff
Yes, it's motivating
Devices can talk to each other in home - leave out computer (motivation to wearable)
E - Laptop is main computer, need alert to auto upload, that would be easier

Motivation

B - Didn't need motivation, he did exercises and did good repetitions
Saw others – more older people didn't exercise and complained
younger people do exercises
put it in the place where I do the exercises
C - Feel it in body when I don't exercise
Nice to ride for 45 minutes
Personal motivation
Internal not external
D - Things in groups are better
Yes, it's motivating to know someone else did their PT
Like AA sponsor, accountability
F - Fat/heavy people need motivation
He lost 10 pounds which was motivating

Device Location

C - Prominent spot, see it all the time vs. ignoring a piece of paper
D - By the bed? Kitchen? See it when awake, or by computer in bedroom
E - Bedroom-by the bed, use the device and do exercises

Autonomy

C - If I set it up *myself*, I'd use it (as opposed to a PT doing it for you)
Autonomy of power
Sit with therapist and set goals for the week
Find out the minimum and maximum expected from the therapist
Cuts down on deception
"what can you reasonably do this week?"
Informed decision making vs. dictating

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