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Article

Understanding Standing

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Abstract
Using standing as paradigmatic example, this study considers current issues in the movement sciences in relationship to the practice of rehabilitation and movement re-education. The concepts of variety and constraint provide the foundation for inquiring into the anatomical, biomechanical, dynamical, and sensorial bases of bipedal stance. Theoretical issues are related to rehabilitation medicine, clinical techniques, and pedagogical strategy. The rich empirical basis of movement re-education approaches serves as the basis for new research questions and offers clues to rethinking how learning occurs.

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Feldenkrais, standing, movement science, rehabilitation, movement re-education, qualitative

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UNDERSTANDING

STANDING

UNDERSTANDING STANDING

BY

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B.A., University of California, Santa Cruz, 1984
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THESIS

Submitted in partial fulfillment of the requirements
for a degree of Doctor of Philosophy in Kinesiology
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University of Illinois at Champaign, Urbana, 1995

Urbana, Illinois

UNDERSTANDING STANDING

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University of Illinois at Urbana-Champaign, 1995
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To my teacher and mentor,

Heinz von Foerster,

founding father of cybernetics,

whose insight, compassion, and generosity inspires me daily,

and to my maternal grandmother,

Alice Ostrowsky,

dance pioneer and matriarch,

whose impassioned fascination with human movement

began a family tradition I proudly continue.

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Academic colleagues at University of Illinois supported my graduate studies and challenged me to integrate what I learned: Cheryl Cole, Jim Denison, Wendy Heller, Martine Korach, Rebecca Nettl-Fiol, Karl Newell, Karl Rosengren, Syndy Slowikowski, Robert Sprague, Billy Ben Strean. Linda Horn and Cindy Tipping of Saint Agnes Hospital not only made the experiment possible, but were available when I needed guidance and support. Leslie Allison at NeuroCom provided invaluable assistance and materials. Joe Beason gave me much needed assistance with the statistical studies.

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Preface

The following dissertation, submitted in partial completion of the requirements for the degree of Doctor of Philosophy in Kinesiology at the University of Illinois, Urbana-Champaign, grew out my interest in bridging the gap between theory and practice, laboratory and clinic, conceptual knowledge and experiential learning. While this interest began when I was first studying psychobiology, it intensified when I began to study the Feldenkrais Method® of movement re-education, an innovative approach to working with individuals who face neurological and orthopedic problems in clinical settings and private practice.[1] Moshe Feldenkrais, the creator of the method bearing his name, had applied his training in physics to comprehending the biomechanics underlying Judo. He expanded on this understanding of the human design for movement, developing a sensory-based pedagogy with individuals (Functional Integration®) and groups (Awareness Through Movement®). While Feldenkrais' methods were original and remarkably effective, he lacked the concepts and theory necessary for explaining them. This was not a personal shortcoming: he had developed a way of working with others before the world had created a way to talk about it.

[1]The terms Feldenkrais Method, Awareness Through Movement, and Functional Integration are registered service marks of the Feldenkrais Guild.®

Following on my concern about finding ways to explain this work, I entered the masters program in Cybernetics Systems at San Jose State University.[2]

After years of private practice in the Feldenkrais Method movement re-education, I began teaching continuing education workshops to physical and occupational therapists in the United States and Europe. This made my interest in finding ways to articulate the Method particularly relevant. Searching for ways to express the profoundly experiential and non-verbal insights of the Method, I came into contact with recent developments in movement science. These ideas led to my enrollment in the doctoral program of the Kinesiology Department at the University of Illinois, Urbana-Champaign. It was during this period that I encountered the ideas presented in the following pages and developed the framework in which they are expressed.

My clinical, academic, and teaching experience repeatedly confirmed that the Method needed to have a clearer theoretical structure. It also led me to think that existing theory and current research might benefit from exposure to the concerns I had a practitioner. Over the years of course work, research, and study, this idea has proved correct, as I believe this text—and its combination of case study and theoretical argument, of reporting on current research and suggesting future directions—demonstrates. In an effort to show that these ideas can serve as basis for further scientific research, I conducted an experiment in balance and learning. (Since this is

[2]My master thesis, *Articulating Changes* (Goldfarb 1990), was the first and, so far, the only theoretical text written about the *Feldenkrais Method.* In it, I proposed a conceptual framework based on cybernetics and

primarily a theoretical work, my advisor, Gary Riccio, suggested that the report on this experiment be separated from the main text in an appendix, which I have done.)

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systems theory.

Table of Contents

List of Tables

List of Figures

Prologue

Many years ago, a new client entered my office leaning on her walker. In her mid-thirties, Susan had recently undergone rehabilitation for complications following brain tumor surgery. A marathon runner and a busy mom before, she was now struggling just to do the everyday activities that most of us take for granted. Even with the walker for steadiness, Susan had great difficulty walking across my office. She held herself rigidly, walking with her legs moving stiffly at her hips, hardly bending at her knees, and her back nearly inflexible. With her head moving stiffly with her torso, it seemed that her neck and upper back muscles were tightly contracted. I could not help noticing that Susan had lost much of the resiliency and ease we normally associate with intentional action.

Standing and introducing herself, Susan's head movement was incredibly limited as she spoke. Responding to screeching brakes on the street outside, her head turned unevenly and erratically. When she introduced herself, her hand gestures led to a kind of full body quaver that is clinically known as ataxia. Her shaking was so extreme that she had to grab hold of the walker to keep her balance. Tired of standing, she lowered herself unsteadily toward my low work table, losing control at the end of the movement and plopping herself down unceremoniously.

After she had settled, she began to explain, "Since the surgery, my ability to control my body has changed considerably. When I first came back to consciousness, I couldn't move, I couldn't *even speak. After months of rehabilitation, I have begun to regain control. I still have a long way to go."*

I asked, "What are you interested in working on?"

"I have lost my balance," she replied. "Can you help me find it?"

I got up, walked across the room, opened the closet door, and reached into the emergency kit for my flash light. Removing the light, I came back into the room, sat down across from her, and asked, "Okay, let's go look for it. Where did you last see your balance?"

After a moment's confusion, she asked, with an edge in her voice, "Are you making fun of me?"

"No," I replied. "I'm not making fun. I'm trying to point out what's seriously amiss with your request. You talked about your balance as if it were some-thing, an object that could be lost and therefore found again. But balance isn't an object, it's a process. What you lost is your ability to balance, to lose equilibrium and regain it. You've stiffened yourself to make up for inability to compensate for all the disturbances that take you off-balance. Unfortunately, that means that you end up being less able to balance because if you start to go a little off, you're so tight that you can't easily correct for it."

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People talk of standing still, holding themselves up, and having good—or bad—posture. For most, posture is static. We talk about standing, or any other position for that matter, as if it were stationary, as if it were a time when the body is immobile or unmoving. This belief is reflected in the idea the way balance is used as a noun in most sentences.

Unless it becomes difficult to do or subjected to well-considered study, standing is most often taken for granted. However, it is one of the greatest human accomplishments. For the species, it is the result of a long evolutionary process; for the individual, it represents the culmination of the first few years of growth and development. Bipedal standing differentiates human beings from other animals, none of whom have the ability to stay upright for long periods of times. Just as the ability to sit freed the arms of chimpanzees and other primates for social and practical activities, standing frees the trunk and upper limbs from supporting the body and allows us to engage in complex actions and interactions. Standing allows the head a great freedom, allowing us to orient to the space, objects, and people around us while engaging in many different activities.

The incorrect idea that standing balance is static position, rather than an ongoing dynamic process, is particularly dangerous to people who are trying regain their ability to stand. In order to understand how to help those individuals, we must understand how standing operates in normal individuals. In the following pages, we will examine the structural and functional foundations of our ability to balance on two feet. The first chapter presents the anatomical basis of standing posture and presents evidence that standing is a dynamic, rather than static, activity. The second chapter examines the nature of coordination, focusing on issues of variety and constraint. Chapter three offers ideas about the role of perception in the regulation of posture and movement. The fourth applies the concepts from previous chapter to the question of rehabilitation and re-education. In the final chapter of the main text, the epilogue, we return to Susan's case to see how these concepts can be applied in practice. An appendix reveals that the issues and methods of rehabilitation and re-education can be framed as experimentally testable hypotheses.

Chapter One:

A Standing Orbit

What is most incredible about human movement is that most of us somehow manage to govern this complex physical system that is our body. The key word here is complex. Though we can talk about movements as if we could move just a finger or an arm, the fact of the matter is that it is next to impossible to do so in everyday life. Most of the movements we make involve the whole body: intentional action requires the coordination of our entire physical system.

To move your arm, say to extend your hand in greeting, requires more than the action of your *triceps brachii,* the muscle that straightens your arm. Straightening your arm requires that the muscle that normally bends it—your *biceps*—lengthens. If this muscle does not let go, it will interfere with the arm straightening. This gesture necessitates more than the work of this pair of muscles, which are acting as the *prime mover,* or *agonist,* and *antagonist,* respectively.[3] Extending your hand also depends upon the work of the muscles fulfilling the roles of *synergists* and *fixators.*

Synergists help steady a movement or eliminate an unwanted movement. For example, as you open your hand to offer it for a handshake, the muscles located at the

[3]These labels refer to the roles that muscles play in a particular action. At one moment a muscle can be agonist and at the next moment it can fulfill another role.

back of your forearm contract to open your hand by straightening, or *extending*, your fingers and thumb. In terms of the global movement, these muscles also are agonists. The long tendons that connect these muscles to the bones of your digits also pass over your wrist. The contraction of these extensor muscles also would make your wrist bend backward were it not for the counteracting (synergistic) tensing of your wrist flexors.

The fixators, on the other hand, maintain the position of the body while not taking part in what we might call the main action. Though the action of fixators is invisible, without their participation in the action we would not be able to maintain an ongoing posture. For example, your arm is approximately 6-7% of your total body mass (Brunnstrom, 1972), which means that extending your arm requires moving a considerable mass through space. If we do not do something to counteract the resulting change in our weight distribution, we would lose our balance and fall over every time we do just about anything.

Most of the *gestures* we make in our everyday life—opening a door, taking off our shoes, drinking from a cup, brushing our teeth, and so on—require the involvement of the entire body, particularly if we are to maintain some *postural* orientation to the environment. Even when we do not consciously think about shifting weight slightly, tilting the pelvis at the hips, and turning the shoulder girdle, we can do all those things when we reach forward. Making these slight adjustments, we manage to maintain complex postures like balancing on our buttocks or over two legs. Though the compensations rarely are included in our descriptions of action—after all, we do not say, "I maintained my balance when I offered my hand and introduced myself"—postural adjustments are as central to nearly every action as side-effects are part of a drug's pharmacology.

While we can say that many daily activities have both postural and gestural components (Lamb, 1965; Reed, 1982) happening simultaneously, we also must remember that this distinction is doubly artificial. First of all, there is no such thing as strictly local muscle action. While we can talk about a muscle contracting and pulling, via its tendinous attachments, on the bones to which it connects and, thereby, generating the forces that either produce or prevent movement, this is an abstract analytical construct. To understand the intricacy of human movement, we have artificially broken all the simultaneous events down into components (von Foerster, 1973). This reductionistic strategy may be useful in revealing and describing what happens locally, but it hides the necessarily systemic changes that underlie all action (Goldfarb, 1992b).

Movement is not about the action of independent parts, but about changes in interconnecting relationships and their global consequences. The forces generated by muscles reach throughout the body-as-motion-system. Contraction in one place generates forces that travel through the body's compressive members, the bony framework (Goldfarb, 1994b; Reuleaux, 1876), and the tensile members, the vast network of interwoven soft tissue (Rolf, 1977). Even what appears to be changes in some subset of the body's relationships must be nested within a complex, interrelated set of compensations. This means that understanding movement requires an inherently systemic approach.

The globalilty of movement is easy enough to observe: while standing, have a friend stand to your left with his or her right hand lightly on your left shoulder blade. Rest your left hand palm down on the palm of your companion's right hand, so that your hand is comfortably supported there. Start with your right hand and arm relaxed and hanging down along your right side. Move your right hand to touch the front of your left shoulder and then let it hang again. Repeat this a few times. What happens at your left hand and shoulder? Can you feel the echo of the movement through your body? Can your friend?

Secondly, there are many actions where it makes no sense to think of one segment of the body moving in relationship to a relatively still trunk (Feldenkrais, 1948, 1985). These whole body motions—such as raking, opening a door or window, lifting the groceries into the car, and so on—require the action and coordination of the strong centrally located muscles of the body: the muscles of the legs, buttocks, abdomen, back, and pelvis. While these muscles may counteract the disturbances created when moving an arm (relatively) independently, they are part of the overall pattern of imparting motion to objects or other persons. In situations where we act while remaining upright, these muscles serve the dual functions of generating motion and maintaining postural configuration.

After years of study and practice of the martial art Judo, physicist and movement educator Moshe Feldenkrais proposed the concept of *coordinated action* as one aspect that defines efficient motion (Feldenkrais, 1952). Since a muscle's ability to contract is proportional to the number of fibers within the muscle bundle, its absolute strength is related directly to its cross section. In a coordination action, the burden for generating movement rests with the larger, stronger muscles of the back, legs, and mid-section. With the muscles at the body's center providing the major impetus for movements, the smaller, more peripheral, muscles are responsible for guiding and refining the resultant forces. This means that efficient movement requires the coordination of all the muscles throughout the body.

Compare this type of motion with the kind of movement required in most strengthening exercises. Since developing strength requires repeatedly overworking specific muscle or muscle groups (Wells & Luttgens, 1976), the body must be positioned so that those particular muscles are forced to work while the rest of the muscular system cannot—and should not—participate. (Exercises, both those requiring equipment and those performed without equipment, use constraining positions to eliminate movement at all but the muscles which are to be strengthened.) Therefore strengthening exercises that focus on individual muscles or muscle groups are, by definition, based on inefficient movement.[4]

The common view of standing as a stillness, expressed in everyday language, reflects the idea of muscles serving the postural function of fixating. The problem is that the idea of fixation, of static balance, could not be more wrong (Feldenkrais, 1948; Hellebrant, 1942).[5] Generally, the degree of stability is a result of the size of the base of surface, the height of the center of gravity, and the spatial location of the center of gravity with respect to that base. Maintaining a standing posture means keeping our high center of gravity over the small base of support at our feet (Horak & Shumway-Cook, 1990). With three relatively large masses—head, torso, and legs—each balanced on relatively small bases of support: 1) the skull on the spine, 2) the torso (and head) on the hip joints, and 3) the legs (and upper body) on the feet, it is easy to see that we are not designed for being still. Even the slightest movement can take our center of gravity past our base of support, throwing us off-balance. While this design is inferior for static stability, it ideal design for movement: we have a high potential energy and therefore it takes only a minimal effort to go off balance and start moving.

Even when we are standing in a way that appears to be still, the constant unpredictable physiological motions of life, not to mention any small or large

[4] Our sport-oriented culture tends to emphasize (strengthening) exercise, which leads to a social overvaluation of this way of moving (Alexander, 1984). However, the inefficient nature of strengthening exercise means that they should not serve as the basis for evaluating and understanding everyday actions.

intentional actions, take us off balance and require us to actively regain our equilibrium in order to maintain a standing posture. Therefore, standing consists of an unstable equilibrium, one in which we are constantly counteracting all the disturbances created by the movements of life: breathing, reaching, turning, etc. The muscles that perform this function do not really fixate. Rather each muscle's action fits precisely into a complex set of actions that keeps something constant about our global configuration in space (Keshner, 1990). Muscles are not fixed, rather they each work as much as needed to preserve the overall postural organization of the body and the particular relationships between body segments that make up that organization. Each muscle contributes to the overall coordination of posture and gesture; that contribution changes on a moment-by-moment basis. Research in the timing of muscle activity (Cordon & Nashner, 1982; Blen'kii, Gurfinkel, & Pal'stsev, 1967) demonstrates that muscles in other parts of the body are activated prior to an upper limb motion.[6] These preparatoy movements offset the predicatable consequences of an action; other reactions may be necessary to take into account any unanticipated effects or unforeseen changes in the environment or task. Perhaps we might better call this type of muscle action as *compensatory.* Muscles fulfilling this role counter off-balancing influences; at other times, when the whole body configuration is altering, they simply serve the functions of

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[5] Hellebrant, the original researcher in postural sway, is often quoted as saying: "Standing is, in reality, movement upon a stationary base" (quoted in Wells & Luttgens, 1976).

agonist or antagonist.

What is kept constant is not the local length of a muscle or a global rigid shape, but rather a pliable overall state. Standing, for example, has certain attributes (e.g. maintaining the center of gravity over the base of support) that define a boundary that is conserved while other attributes, like the tilt of the head, are free to change (as long as the consequences of those changes can be counteracted). Postures like standing and sitting are the resting places between actions, the launching pads for new movements, and, most importantly, the scaffolding for numerous simultaneous actions. As such, standing is perhaps better thought of as a kind of orbit within which we move, rather than a particular place or static position. Within that orbit, all kinds of changes can and do take place.

Standing, therefore, is not static. Standing is a dynamic activity, one that can be described as keeping the center of gravity within stability boundaries, the crossing of which would make one fall. What we have is a dynamic system that is never still, never quiet. We see this constant act of balancing in the incessant small amplitude, high frequency movement known as *postural sway*. Among the early studies of postural sway were experiments that recorded was recorded the movement of the center of pressure(Hellebrant, 1938; Hellebrant & Fries, 1942), which has traditionally been

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[6]For example, in the Blen'kii, Gurfinkel, & Pal'stsev (1967) study of an arm movement, preparatory changes occurred in the leg muscles 60 milliseconds prior to the intentional activation of the shoulder muscles.

defined as the projection of the center of gravity on a supporting surface.[7] With postural sway, the center of pressure never remains motionless despite any attempts the subject makes to stand still.

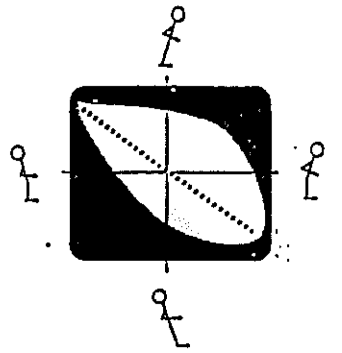

Figure 1. Postural Sway. (From "Information in movement variability about the qualitative dynamics of posture and orientation" (page 332) by G. E. Riccio, in K. M. Newell (Ed.): *Variability and motor control*, 1993, Champaign: Human Kinetics. Copyright 1993 by Human Kinetics. Reprinted by permission.)

Figure 1 shows what would be a typical recording of the center of pressure for a normal subject. The center of pressure is computed by a *force platform*, which is a kind of fancy scale designed to record the distribution of weight. Force plates were first used to investigate the forces generated in walking (Elftman, 1938, 1939). As you can see, the dots, each of which represents the center of pressure at one moment in time, fall in a

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[7]Center of pressure tends to overestimate the amount of movement of the center of mass. Therefore this definition has recently be questioned (K. Rosengren, personal communication, December 13, 1994.)

general vicinity described by the egg-shaped boundary. From their distribution, you can see that they are more likely to fall in the center of that region than at the edges. In other words, postural sway does not vary haphazardly, but rather, it varies within specific limits around a balance point, or *attractor*. This continual wobbling demonstrates the attributes of a nonlinear dynamic system: *global minima* that define places where, like a marble at the bottom of a bowl, the system is most likely to be, and a *performance envelope*, a boundary that defines the activity (Riccio, 1993). While original research in postural sway suggested that the center of pressure oscillated in a figure-eight pattern (Bartenieff, Davis, & Paulay, 1970; Brunnstrom, 1972; Hellebrant & Fries, 1942), more recent research has demonstrated that sway is multistable; in other words, that it varies in unpredictable ways within the performance envelope that defines standing. Depending on the specifics of the position maintained—one-legged or two-legged stance, reaching forward or leaning backward or leaning to one side—and the nature of the surroundings—such as the extent, angle, and firmness of the support surface—the layout of attractors and the shape of the performance envelope vary over time. Any time the boundary's edges are crossed, the system enters a different state: for instance, when the center of pressure travels outside the envelope, you are no longer standing and must either take a step or fall. These persistent properties are independent of quantitative details and can best be described as the kind of topological invariance shown on the graph. While this small, continual wobble has generally been regarded as noise generated by an imperfect system and ignored, we will return to its functional significance later.

So far, this text has been described standing, not explained it. How do we remain standing, especially when it is more like constantly juggling rather than holding still? How do we maintain our posture and balance while engaging in other activities? What are the perceptual processes that make dependable posture possible? What do the answers to these questions suggest about how to improve human function? It is to these questions that we turn our attention in the following chapters.

Chapter Two:

Complexity and Constraint

Standing is a complex balancing act, one in which the mass of the entire body must be carefully kept over the narrow base of support provided by our feet. Mechanically, standing is made possible by the skeletal framework: a human skeleton can be balanced without the aid of muscles or other soft tissue (Royal Air Force, 1959). The bones are compressive structural elements that provide support for our organs and tissues, which either rest on or hang from the skeleton. That means the muscles, while serving as the engines of motion and playing a central role in counterbalancing, do not directly serve the function of support. Furthermore, the bones do not move simply one upon the other as individual levers, but rather act as a unified framework for support.

However, since we human beings are never still, we must actively compensate for the perturbations—physiological motion and intentional gestures—that take us off balance. The only way we can offset these disturbances is through the action of our muscles. There are over 650 muscles in the human body (Crouch, 1978). Like a rope made up of strings that are, in turn, made up of braided threads, each muscle consists of bundles of fibers. Muscles are organized in bundles composed of hundreds or thousands of muscle fibers and the nerve that activates those fibers. These functional groupings are known as *motor units;* the contraction of one of these bundles being the smallest unit of independently regulated muscle action (Kandel & Schwartz, 1981).

This vast collection of elements leads to an amazing number of variables to consider, especially for any whole body action as complex as standing. Somehow, out of the set of all possible movements, we must orchestrate the sequence and amount of contraction to maintain our balance and keep from falling. The rich set of choices and possibilities give our movement refined nuance and rich complexity, but it also creates the problem of handling of this *variety,* the number of possible states that the body-as-movement-system can have (Ashby, 1956, 1960; Beer, 1974). In the movement sciences, the problem of managing this complexity is known as the *degrees of freedom problem* (Reuleaux, 1876; Bernstein, 1967; Schmidt, 1988). The term 'degrees of freedom' refers to planes of action available to a joint: the hinge joint of the elbow has only one degree of freedom as it can only open and close in one plane. By comparison, the condyloid joint of the wrist has two degrees of freedom and the ball-and-socket shoulder joint has three. Adding up all the degrees of freedom available at all the joints, and also considering the orchestration of motor units of relevant muscles, it is easy to see that there is an astronomical number of possibilities to take into account when turning any intention into action.

This potential freedom of movement and expression poses a problem: how can we handle all this variety, all these degrees of freedom? To get a taste for this problem imagine trying to drive a car that, instead of having one steering wheel, had four steering devices, one for each wheel, and that each device controls the direction of each wheel independently. Rather than one degree of freedom, this kooky car would have four degrees of freedom. Imagine, if you will, trying to drive this car around a corner or to parallel park. How could you do it?

This imaginary vehicle points out the difficulty of driving—or regulating—a multi-degree of freedom system like the human body, which is the problem that the nervous system constantly confronts. When we consider the complicated nature of everyday movements—standing, talking, gesturing, and looking around all at the same time—there are simply too many pieces for all of them to be regulated independently; it is computationally impossible.

One way to handle the variety problem, in any particular action, is to temporarily decrease the potential degrees of freedom. This reduction of variety is accomplished by adding a constraint. In the car, the complexity of steering is simplified by having two front wheels yoked together, so that they cannot act independently, and having the combined action of these wheels controlled by the one steering wheel. The back wheels can only spin, so they do not play an active role in the steering of the car. What mechanism could exist for decreasing the number of degrees of freedom involved in movement? Can we imagine an analogous, but momentary, constraint that would serve as a mechanism for simplifying the complexity of human movement?

Researcher Lewis Nashner and his colleagues conducted investigations in the strategies that people use for the maintaining standing equilibrium (Nashner, 1990; Nashner & McCollum, 1985; Horak & Nashner, 1986). In these experiments, Nashner studied how people maintained their balance while standing on a platform that was moved suddenly in the horizontal (forward and back) plane. In order to study the responses, the experimenters attached small electrodes on each subject's skin. These recording electrodes were placed over the muscles of the abdomen, back, buttocks, thighs, and lower legs. Since the electrical activity of muscles changes as their performance changes, the electrodes record the activity of the muscles. Through this kind of procedure, known as *electromyography*, the experimenters could look at how the muscles function in response to the experimental perturbations. The electromyographic record of different muscles' activation was correlated with recordings of the subjects' weight shifts (made by the force platform they stood on), and with the kinematic analysis of concurrent video records.

As explained above, maintaining a standing posture requires ongoing muscular activity to compensate for physiological and intentional motions. For instance, the center of gravity falls slightly in front of the axis of the ankle joint, which means that the equilibrating action of the calf muscles is required to keep us from toppling (Denny-Brown, 1929; Joseph, 1960). While not usually called upon to serve a continuous postural function (Joseph & Nightingale, 1954), the quadriceps femoris muscles of the front of the thigh (and the abdominal muscles) can be called into play when someone stands leaning back with the shoulder girdle behind, rather than over, the pelvis. The muscles of the hips continuously act to balance the pelvis on the legs (Basmajian, 1974), just as the muscles of the trunk counteract disequilibrating perturbations (Klausen, Jeppesen, & Morgeson, 1978). Furthermore, with more of its weight in front of the balance point on which it rests (the *atlas*, or first cervical vertebrae), the head is balanced in unstable equilibrium. That means the neck muscles must work to keep it from tipping forward, yet the amount of work required depends on the exact position of the head and jaw (which are constantly changing).

Considering the number of muscles that play a role in balance, do these muscles function independently or is some kind of temporary constraint imposed on them? Would Nashner's subjects show a random set of muscular contractions, different perhaps during each trial and different from person to person? Or would they exhibit some kind of distinct, stereotypical activation pattern?

Nashner's experiments demonstrated that, out of all the possible responses, compensation for the small disturbances in the moving-platform experiments involved movements of the hip and ankle. Indeed, there were two different compensatory patterns of muscular activation, which he referred to as hip and ankle *strategies*. All compensatory responses involved hip movement, ankle movement, or some combination of the two. The muscles of the trunk, hip, knee, and ankle acted together to control the joints they spanned and their related body segments in what are called *coordinative structures* or *muscle synergies* (Bernstein, 1967).

A muscle synergy constrains the relative activity of muscle groups that span two or more joints, thereby linking them together. The existence of synergetic patterns offers a solution for the degrees of freedom problem by simplifying the problem of movement coordination. Rather than deciding what every muscle should be doing at any one time, the nervous system only needs to make a decision about which coordinating configuration should be used. As temporary constraints, synergies fix the relative motion between muscles, linking them in an overarching coordinated structure, decreasing the degrees of freedom, and, thereby, reducing the variety. Evidence of coordinative structures has been demonstrated in other activities, such as walking (Shapiro, Zernicke, Gregor, & Diestel, 1981) and marksmanship (Artyunyan, Gurfinkel, & Mirskii, 1968, 1969).

We are not limited to adding constraints as the only way to handle variety. We have another strategy available to us: doing more than one thing at a time. In other words, instead of reducing the degrees of freedom available, we increase the complexity of our behavior. In the handshake example, multiple intentions are fulfilled simultaneously: reaching, opening the hand, maintaining balance, speaking, orienting to the social and spatial environment, and so on. The ability to accomplish a multiplicity of complex tasks simultaneously is a hallmark of human movement; one of the central problems faced by individuals with neurological damage or disease is that they have lost this ability.

At any instance when we observe someone in action, we find many things happening at once. Simply standing or sitting and holding a book or manuscript while looking up and seeing the light in the room is no simple task; multiple tasks are being accomplished concurrently. Not only must the tension of arm and hand muscles regulate the shape of the hand to maintain a grip, but turning the head and eyes takes coordinating the action of the eyes in relationship to the head and the head in relationship to the neck and trunk. Of course, the movement of the head is translated through the kinematic linkage of the spine to the chest, pelvis, and lower limbs. Moving the head through space means starting a movement that changes the location of the center of gravity; that change must be counteracted. The spine and ribcage are also affected by respiratory and circulatory motions, which continue at their own rhythms. Though this activity can only be described in linear sentences, it happens all at once. Once we look past any linguistic description, we find a multitude of relationships that must be governed simultaneously.

The multiplicity of movements underlying any complex action is mostly ignored, except by theorists with backgrounds outside of classical movement science (Powers, 1974; Riccio, *in press*). Nested within any action during which we keep ourselves standing is the complex dance ensuring that the scaffolding of the body remains upright while we reach, turn, look, and so on. How each functional sub-activity is related into one organized gestalt is a question that we are only now beginning to ask.

While multipurpose movements offer a way to handle variety, they also present a coordination problem because the performance of one activity can impact on the performability of another. Depending on whether someone is asked to either stand comfortably with his or her arms hanging, touch a button upon being signaled, or read a text, the relative movement of body segments changes(Riccio, Lee, & Martin, 1993). The movement of the head is greatest during normal standing and smallest when the subject is reading. This makes sense given that visual acuity is inversely proportional to vibration (Griffin & Lewis, 1978; Lewis & Griffin, 1978).

Is it possible that one muscle synergy pattern can interfere with another? There are situations when this system seems to not function properly, when people's ability to move and control their movements is limited. For instance, extensive experience in both clinical settings and in private practice with individuals who have chronic back pain (Goldfarb, 1994a) has shown that, most commonly, these individuals suffer from prolonged muscle spasms. Such local hypertonic states are often considered both protective and problematic (Janda, 1992): immediately following an injury, the person unconsciously splints, or braces, in order to deal with pain elicited by moving. This stiffening can be seen as a limiting, or freezing, of degrees of freedom, to make the control of movement simple under duress. The splinting leads to impaired movement and impaired movement makes the person more constrained, less able to adapt to his or her environment and more prone to re-injury. Even worse, the stiffness leads to greater discomfort which leads to further contraction that leads to recurrent pain. This vicious circle—what we call a *positive feedback loop* (Maruyama, 1968)—is evident in many difficult cases of chronic pain.

The existence of persistent forms of muscle contraction has been demonstrated by Janda and his colleagues (Janda, 1980). In one experiment, Janda compared normal subjects with those who had chronic back pain and spasm. Both groups performed abdominal strengthening exercises—a modified sit-up commonly prescribed to patients with back pain—while the muscular activity of the stomach and back was monitored through electromyography. As expected, the normal subjects exhibited a pattern of muscle contraction known as *reciprocal inhibition*: when they contracted their abdominal muscles (the agonists), their back muscles (the antagonists) relaxed. The back patients demonstrated a *co-contraction* pattern: while contracting their abdominal muscles, they contracted their back muscles even more strongly. In this situation, well-meaning attempts to strengthen abdominal muscles led to the already tight back muscles getting all that much tighter. Interestingly enough, the subjects were not aware that they were interfering with their own movement. More on that, and on the role of perception, in the next chapter.

Unlike the situation in which someone does many activities at the same time so that the activities work together, splinting illustrates what happens when someone has an *invariant* pattern laid over the set of all possible movement (Goldfarb, 1993a): the habitual pattern interferes with performance of other movements. Splinting means that the mover's variety has been reduced too much and that he or she no longer has the full range of possibilities available.[8] Another way to say this is that people who have developed habitual splinting are more limited than their skeleton requires. While this response might make sense as an unconscious strategy for dealing with injuries and illness in pre-industrial times, it does not take into account the depth of recovery possible these days.[9]

Splinting also occurs, in a more temporary manifestation, when people learn new movement skills. The process of learning a new skill or ability progresses from freezing to freeing degrees of freedom. When we are learning something new, we tend to stiffen, decreasing the available variety at the moment and making the managing of complexity much easier. For instance, one study (Artyunyan, *et al.*, 1968, 1969) compared novice and expert marksmen, measuring the relative motion of the wrist, elbow, and shoulder of the arm holding the firearm. Novices tended to stiffen the distal joints of the elbow and wrist and move their arms rigidly when aiming. Experts allowed greater relative

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[8]Feldenkrais (1985) referred to these interfering habitual patterns as *parasitic*.

[9]Most people injured in pre-modern times either did not survive the infection associated with the wound or did not recover from the damage physical inflicted. With the advent of modern medicine and

motion at each joint and their arms moved around in a smaller performance envelope than the novices. In other words, the experts' behavior was more differentiated, more refined. In the context of this continuum, post-traumatic splinting looks like incomplete learning: the person immediately constrains movement after accident or illness to reduce discomfort and never learns to free up those degrees of freedom again.

Persistent patterns of tightness serve to interfere with a critically important attribute of human movement: *movablity* (Goldfarb, *in press*). Movability refers to the facility with which we can change our physical configuration. It is the basis of our ability to adjust within a configuration and to change configurations when need be. This ability is based upon the huge potential for movement designed into the human body. When the *tonus*, the underlying contraction of the muscle at rest, increases, it interferes with ease of movement at joints so that adaptability and resiliency suffer. Muscles that are busy contracting to keep some set of relationships relatively constant are serving an ongoing support function. If a muscle is busy keeping a certain level of contraction going, it cannot contract to create movement because it is already engaged. That means that any action that requires its participation will be hampered. For instance, habitual hyperextension of the knees makes for a stable position that leads to delays when bending is required. Most athletes keep their knees slightly flexed in order to preserve responsiveness.

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rehabilitation, people recuperate more often and get better than they would have without intervention. The nervous system's response to injury evolved without that taking this possibility into account.

Variety can be over-damped and the movement possibilities reduced. Without access to our inherent ability to change configuration, we face the world with fewer movement options, stress the same joints over and over, and, because we cannot move efficiently, work harder than necessary. The reduction of variety also applies to what scientists have done when analyzing movement. In an attempt to deal with the complexity of human movement, many experiments have reduced the subjects' variety (Newell, Kugler, van Emmerick, & McDonald, 1989). One classic strategy for simplifying movement has been to observe subjects performing simple, one or two degrees of freedom movements with one limb while fixing the trunk. The study by Nashner cited above (Nashner, 1985) is a step forward in considering the body a multi-segment-system, especially when compared to one of his earlier studies (Nashner, 1976) in which only movement at the ankle was considered. Because of the difficulty inherent in tracking and measuring multiple variables, movement scientists have, until recently, been forced to avoid multi-degree of freedom, multi-criterion movement. With the advent of more technology, such as computer-based motion analysis, and with growing interest in functional activities, this trend has changed (Riccio, *in press*).

However, the most difficult aspects of movement for research to take into account are individual differences[10]. Following Nashner, we can make generalizations about postural strategies, but we ought to remember that in this experiment the focus was on

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[10]See Appendix One for more on the difficulties inherent in taking complexity into account in experimental design.

movements of the hips and ankles, the perturbation was in the sagittal plane, and the activity of only a subset of the body's muscles was recorded. In other words, while we can abstract some broad conclusions from the study, we must not confuse these generalities with the concrete specifics of any one person's behavior.

When it comes to individual action, movement is always particular and there is no such thing as movement in general. Each of us solves the problem of staying upright with our own unique nuances, nuances based on the structural specifics of our bodies (Althoff *et al.*, 1988) and our historical experience. Social aspects, such as culturally specific movement styles (Kluckhohn, 1954; Mead & Macgregor, 1951; Efron, 1972) and perceived appropriateness of various postures and gestures for each gender, introduce another layer of constraints and play a role in the way in which each of us moves. It is these individual differences that make movement education and re-education so fascinating and so challenging.

Chapter Three:

Perception as Action

Standing equilibrium combines deterministic movements and random disturbances. This composite of anticipated and unpredictable aspects makes standing a *stochastic* process (Bateson, 1979). Given the precarious nature of our standing balance and the constant disturbances that affect it, we must monitor our posture and movement ongoingly, sensing any changes in position and tracking the inertial forces generated. On what basis is this monitoring ability built?

Once again, we run into the problem of variety. The nervous system infiltrates the body with a rich network of sensory cells that report on specific events—such as a change in pressure or joint angle—at specific locations (Gibson, 1966). Somehow, the nervous system must make sense of the perception at that moment, a process that requires each sensation to exist in some context. Given that more than one activity is happening at a time, the nervous system is functioning as multi-criterion control system, that is to say, it is regulating behavior according to more than one reference parameter.

Touch sensation is organized according to regions of the skin known as dermatones (Kandel & Schwartz, 1981). Each dermatone is associated with a particular nerve root, thus showing, in this instance, a structural basis for the organization of perception. How does the nervous system take information from all different areas and diverse sensory apparati into account? Is there some kind of constraint on perception as there is on action? The perception of the body at rest and in motion is multimodal: it is composed of visual, vestibular, and kinesthetic sensory modalities. All of these perceptions must be correlated with each other and certain aspects must closely steered. We can ask, what variable or variables must be regulated in order to manifest any behavior (Powers, 1974)?

Standing means keeping our orientation to gravity, which requires that we can sense where we are. The question of orientation in our perception of standing or falling has been historically dismissed in scientific investigations. The classical argument has been that we locate ourselves within some objective or external frame of reference, such as gravity. However, recent studies of visual and vestibular contributions to balance question this idea.

We have known that postural sway increases when an individual's visual perception is unstable, impoverished, or eliminated (Edwards, 1946; Witkin & Wapner, 1950). To investigate the role of vision in standing, Lee and his colleagues built a *swinging room* (Lee & Aronson, 1974; Lee & Lishman, 1975). The swinging room consisted of three walls and ceiling in which subjects were told to stand comfortably. Unbeknownst to them, the room was suspended from the ceiling and could be rocked slightly forward and back in relationship to a stationary floor. Since the room took up the subject's entire visual field, they had no reference against which to compare. Most subjects did not notice that the room moved. The subject's movement was recorded by a specially designed *sway meter*. Lee demonstrated that visual perception played a significant role in maintaining balance. One of the most interesting findings of Lee's studies was that the subjects would entrain their postural sway to the swinging of the room, getting in sync with the room's motion. Another experiment revealed that small children could not compensate for the perceptual disturbance caused by the room's motion. When the front wall was moved away from the young subjects, they leaned forward drastically, causing them to fall or stumble; when the room was moved toward them, they responded by sitting suddenly and clumsily (and looking quite surprised).

While playing an integral role in maintaining equilibrium, vision, of course, is not necessary. As blind people have long demonstrated, it is possible to stand without any reliance on visual perception. How do we correct for constant planned and unplanned disturbances when standing with our eyes closed or after we have lost the ability to see?

In normal standing, the more off-balance we go, the easier it is get further off-balance. If the total body mass is not aligned exactly over the base of support at the feet, gravitational forces act to further increase the misalignment and we accelerate away from equilibrium. Here we have a situation in which movement in different directions has different consequences: movement away from the balance point is easy, movement back towards equilibrium requires effort. That movement is not as easy in every direction creates an asymmetrical topology, a qualitative *direction of balance* that we notice because our vestibular system is sensitive to changing acceleration and because our muscles can sense the increased effort required to stay vertical (Riccio & Stoffregen, 1988; Stoffregen & Riccio, 1988). The question is, are we sensitive to this?

In order to test if these qualitative dynamic characteristics play a role in balance, Riccio and his colleagues (Riccio, Martin, & Stoffregen, 1992) devised an experiment using a roll-axis tracking simulator (RATS). Used in flight simulation, the RATS consists of a seat in a carriage that can be tilted side-to-side. Each subject was securely strapped into a seat and blindfolded to eliminate the visual contribution to balance. The subjects held a joystick that allowed them to control the roll of the device and were instructed to keep themselves upright while the carriage was subjected to perturbations. The subjects did not know that the experimenters had manipulated the balance point and the dynamics of the device so that the direction of balance was skewed, that is, the direction of balance was no longer parallel with the direction of gravity. Thanks to the strong motor and the computer controlling it, the RATS had an artificial balance point that replicated the characteristics of a natural balance point. Therefore, the farther the device was moved from its artificial balance point, the more off-balance it behaved.

Sitting in the carriage, subjects were exposed to constant disturbances, which, if uncorrected, would lead to the box falling. Could the subject's control the balance of the RATS with this artificial balance point? Yes. Even more interestingly, did the subjects perceive themselves as upright or not? When subjects were asked to estimate their tilt with respect to upright, their reports demonstrated that balance predominated over gravity in the influence of uprightness. That is, the tilted, artificial balance felt upright. What does this mean? If the subjects had been oriented to the line of gravity, they would have fallen over, but keeping the device balanced required that they orient to something else. The subjects must have perceived upright as the result of their vestibularly-based perception of the balance dynamics of the experimental device, the only "something else" to which they had access. Accordingly, the experience of being upright is *not* based on some objective, external frame of reference; rather, it is a consequence of ongoing perceptual-motor activity. The asymmetric dynamics of balance define a state space that the subjects were sensitive to and dependent upon. In other words, the perception of upright is dependent on perceiving qualitative changes in dynamics.

This conclusion is consistent with second-order cybernetics, where perception is understood as active rather than passive (von Foerster, 1984) and perceptual experience is constructed as a result of the subject's activity. To investigate this idea, Riccio repeated the experiment, placing a subject in the RATS and having the computer play back the movements experienced by an active subject. In this condition, subjects went through the same exact motions as subjects who actively maintained the device's balance, but they had no control over the RATS. Did the "passengers" have the same experience as the subjects who had control their motion? As it turns out, the passive observers were less certain of upright and were uninfluenced by the direction of balance.

This kind of active perception was suggested by Wiener (1948) in *Cybernetics*:

> "Another interesting variant of feedback systems is found in the way in which we steer a car on an icy road. Our entire conduct of driving depends on a knowledge of the slipperiness of the road surface, that is, on a knowledge of the performance characteristics of the system car-road. If we wait to find this out by the ordinary performance of the system, we shall discover ourselves in a skid before we know it. We thus give to the steering wheel a succession of small, fast impulses, not enough to throw the car into a major skid but quite enough to report to our kinesthetic sense whether the car is in danger of skidding, and we regulate our method of steering accordingly." (p. 113)

Wiener referred to this kind of feedback as *informative feedback*. In the movement sciences, we draw a distinction between *performative* and *exploratory* movements (Gibson, 1991; Riccio, 1993). Performative movements are those in which the mover accomplishes some goal or aim, such as driving a car. The feedback necessary for guiding performative movements provides a report on the progress toward the goal. Exploratory movements inform the mover about moment-to-moment consequences of an activity and orient the mover to a relationship with the environment, such as testing the iciness of the road by gently oscillating the wheel. Thus, exploratory movements provide informative feedback. It should be noted that exploratory and performatory movements are continuously occurring simultaneously.

Exploratory movements and informative feedback are important for stochastic systems that face unpredictable, changing circumstances. Only by introducing slight perturbations into situations that are in constant flux can a dynamic system keep track of its present state. The danger is that, if these exploratory perturbations are too large, they will interfere with whatever activities the system is performing; in control engineering, this predicament is known as the *dual control problem*. Returning to the example of the icy road, it means that if the oscillations on the steering wheel are too big, they will interfere with the driver's ability to control the car. Therefore, exploratory perturbations must be of a different magnitude than the performative movements so as not to interfere with their realization.

Now if we return to postural sway, we might suppose that this variability in movement is not the noise that it has historically assumed to be. Perhaps the constant wobble of human beings is informative? After all, the nervous system must have some way of knowing the current status of the body in respect to equilibrium on a moment-to-moment basis and, as stated above, the body is neither static nor predictable. We know from Riccio's experiment that: "ubiquitous movements can provide dynamical information without interfering with controlled adjustments in posture (Riccio, 1993, p. 29)." Therefore, humans need to be sensitive to the dynamics that provide the information necessary for maintaining balance.

What a marvelous adaptation, to use the body's constant pulses of energy—provided by ongoing physiological processes—in order to generate the informative feedback needed to monitor the system's current and ever-changing state. That means that postural sway functions as kind of exploratory movement that allows the system to learn about where it stands.

The importance of exploratory movements in perception and coordination is generally not appreciated. We are unaware of the ongoing wobble of standing and the role it normally plays in our marvelous sensitivity to balance. This situation is similar to findings about tactile perception, where movement is required for sensitivity but where the role that movement plays in generating sensation is not understood. When we touch a surface, we are left with an impression of its texture, an impression that does not include a memory of the movements involved in touching (Katz, 1989). In Wiener's driving example, we would describe the road as slippery without necessarily being aware of the movement of our hands on the steering wheel, movements that led to that perception. The same thing is true in our kinesthetic perception: we notice an external world, but we do not appreciate the active exploratory process that makes noticing possible.

It is important to note that the studies by Lee and his colleagues and by Nashner and his colleagues deal with a kind of meaningful perception. These are not classic investigations into psychophysics of submodalities or the details of sensor physiology. Following the dictums of ecological psychology (Gibson, 1979), the organism is considered in relationship to its environment and the unit of analysis is meaningful action, rather than abstract movement (Reed, 1982). Instead of taking a molecular approach to perception, one in which we ask what happens at some specific site in the nervous system, these studies looked at the way in which specific aspects of perception contribute to our general orientation and balance.

While these studies demonstrate that both visual and vestibular perceptions play a significant role in our ability to stand and in our ability to make sense out of our experience, we should also note that similar work has yet to be done in the role of the kinesthetic senses. There has been considerable research into which kinesthetic parameters are necessary for motor control: joint angles (Grigg, 1975; Mountcastle & Powell, 1959; Skoglund, 1956), relative muscle contraction (Gardner, 1967; Roland, 1975; Roland & Ladegaard-Pedersen, 1977), location (Keele & Ells, 1972), and acceleration (Fuchs, 1962). There has also been considerable controversy on the role of kinesthetic feedback in movement (Cordo, 1990; Evarts, Bizzi, Burke, DeLong, & Thack, 1971; von Holst & Mittelstaedt, 1980; Polit & Bizzi, 1979). However, all of this research has been done in the context of relatively simple movements and the perception of local changes. Considering empirical study and clinical observation, it is assumed that kinesthetic perception plays a role in the global perception of posture and balance, but this role has yet to be specifically investigated experimentally. What we know of the role of perception comes from subjective experience and from empirical evidence gathered in the movement re-education and rehabilitation settings, as discussed in the following chapter.

Chapter Four:

Navigating Changes

Beginning with the polio epidemic earlier this century, rehabilitation therapists and movement re-educators considered different approaches for dealing with disease and damage. After the development of the Salk vaccine, physical therapists turned their attention to other problems, bringing with them the techniques they had been using to treat one set of problems and applying them in other situations. The site-specific muscle re-education strategies that had once worked with polio (Kendall & McCreary, 1983) did not succeed with problems presented by the World War II battle injuries and by diseases such as closed head injuries or cerebral palsy. The lack of success was due to these kinds of difficulties resulting from neurological damage in the brain rather than in the peripheral nerves, as is the case in polio.

New problems led to new treatment approaches. Physical therapists turned to the study of neurophysiology, attempting to adapt theoretical concepts to clinical treatments. The resulting approaches each based the rationale for their treatment protocols on a theory of the nervous system and its role in motor control. For instance, *Neurodevelopmental Therapy* (NDT), which developed out of work done with children with cerebral palsy (CP) by the Bobaths and their colleagues, assumes that problems controlling movement are caused by the interference by primitive reflexes (Bobath, 1971; Bobath & Bobath, 1967). These reflexes, such as the *tonic neck reflexes*, are evident in the early development of human movement. It was theorized that part of the process of development is the nervous system building more complex ways of moving on top of these reflexes by inhibiting them. Cerebral palsy is thought to resemble the situation that occurs when the higher brain centers of the cortex are no longer functioning and so these reflexes are no longer being inhibited (Fay, 1948, 1957; Magnus, 1925). For instance, when a child with CP bends her elbow to bring a spoon of food toward her mouth, her head turns away from the bending arm with a sudden jerk, making it impossible to feed herself. This response is attributed to the *asymmetric tonic neck reflex*. The therapeutic strategies developed to deal with the situation were based on the idea of inhibiting pathological reflexes and facilitating more normal patterns.

NDT is just one example out of the several neurologically-oriented therapies, which include *Proprioceptive Neuromuscular Facilitation* (Knott & Voss, 1968) and the work of Rood (1956) and Brunnstrom (1971). All these methods shared a neurological orientation based on a hierarchical model of the nervous system and reliance on sensory stimuli as a way of eliciting certain movement patterns. Though these therapeutic approaches continue to be practiced and taught, their efficacy has been recently called into question (Gordon, 1987). In particular, these approaches have shown limited transfer of learning from the therapy setting to everyday movement. New approaches to rehabilitation have been developed to address the lack of carry-over noted with neurologically-oriented interventions (Carr & Shepherd, 1987). Most recently, therapists have been drawing on changing ideas of the nervous system and investigations based on dynamic systems theory and ecological psychology. The resulting approach, known as *the motor learning model*, emphasizes the analysis of the components that underlie functional activities and argues that task-specific training is necessary (Carr & Shepherd, 1987).

One of the ideas of the motor learning model is that abnormal movements, such as those seen after a stroke, are adaptations to movement limitations (c.f. Riccio & Stoffregen, 1991). In other words, the abnormal synergies seen in stroke patients are patterns of movement learned in response to the constraints imposed by the cerebral hemorrhage. Following on research with surgical deafferentation of monkey's limbs, Taub (1980) proposed the concept of *learned non-use*. Learned non-use refers to the way in which the monkeys would rely on their intact upper limb to compensate for the deficits brought about by the surgery. However, if the unaffected limb was restrained immediately post-op, the deafferentated limb was used in functional activity. Grimm and Nashner (1978) have referred to this phenomenon as the nervous system making the "best mix" of remaining neurological subsystems. Learned non-use suggests that at least part of the problems encountered in post-stroke rehabilitation are due to the strategies adopted by the person immediately following the stroke.

Learned non-use resembles the way in which people respond to injury, accident, and surgery. Though other problems, such as muscle weakness (Sahrmann & Norton, 1977; Tang & Rymer, 1981), are encountered in rehabilitation, the reactions to limitations and dysfunction are central to the problems encountered in rehabilitation (Goldfarb, 1993a, 1993b, 1994a, 1994b, 1994c). In the case study presented in the introduction, we can see that Susan's balance difficulty is due to her solutions to the problems of being unstable and having difficulty in controlling her muscles. Learned reactions and unconscious solutions are also central to the dysfuntion encountered in more traditional orthopedic problems. For instance, following bunionectomy (surgery to remove an abnormal bone growth on the base of the big toe), the patient unconsciously changes her gait to avoid placing pressure on the surgical site. In order to accomplish this, she must constrain the movement of her ankle, hip, and spine, which leads to a configuration of habitually contracted muscles. The perseverance of these relationships limits the ways in which she can move. This constraint becomes habitual and insidious as it is incorporated into all other actions. It is important to note that these tight muscles are *not* the cause of the problem, rather they are a *consequence* of the ongoing functioning of the nervous system.

Seen this way, many of the movement problems encountered in rehabilitation and re-education are not caused by what we cannot do, but what we *cannot stop* doing.

Whether the problem is of orthopedic or neurological origin[11] and whether the resulting movement limitation is described as muscular splinting, limping, or abnormal reflexes, the result is the same. Certain degrees of freedom are frozen so that out of the set of all possible movements, a specific configuration is maintained no matter what. These invariant configurations, such as the ones found by Janda and those experienced by stroke patients, interfere with our ability to navigate in a three-dimensional, gravitational environment populated with organisms, objects, and events.[12] Variety has been excessively constrained and action becomes undifferentiated.

Learning new movement requires that the mover coordinate an increasing number of degrees of freedom (Bernstein, 1967). Through the process of active exploration, the mover investigates the performance envelope and attractor regions that underlies a new movement pattern (Newell *et al.*, 1989). That exploration requires variability, that is to say, it requires making small changes in the way one moves so that the consequences of those changes can be tracked and noted (Riccio, 1993). Habitual movement patterns keep certain degrees of freedom invariant, thereby interfering with the process of differentiating and correlating the relationships that underlie new coordinations. No matter what the mover tries to do, he or she ends up moving in the same way.

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[11]Even with injuries, the person responds to the local problem by making global changes in his or her movement. Therefore, orthopedic limitations have neurological consequences.

[12]Identifying these invariants requires a unique set of assessment procedures and evaluation guidelines (Goldfarb, 1993a, 1993b) such as those offered by the SPIFFER model (Goldfarb, 1994b, 1994c).

Invariant patterns interfere with exploratory movement and with variability in movement. Variability is not simply a trivial attribute of movement, it is central to the development of new abilities. For example, Goldfield (1994), looked at children who were not yet crawling and evaluated the presence of various precursors to that ability. He found that children who showed the highest variability in ways of locomoting—used the most different kind of precursor locomotor patterns—were more likely to be earliest to crawl.

Concurrent with the development of the neurological approaches to rehabilitation, other methods of movement re-education were being developed outside the domain of medical practice. Often they were started by individuals, including F. M. Alexander (1932), Elsa Gindler (Hanna, 1980), and Moshe Feldenkrais (1949), who faced physical problems and found no assistance from standard treatment. These approaches took a whole body perspective of movement, emphasizing the role of self-perception and awareness in developing new ways of moving. Both Alexander and Feldenkrais emphasized different ways of attending to self motion. In the Feldenkrais Method, this difference is most clearly seen in the distinction between doing and learning. In everyday activities, we attend to *where* we are going and to what task we are accomplishing; in learning, we attend to *how* we are going and we explore different ways of getting there. Simply said, learning is process oriented and doing is goal directed. This distinction reflects the distinction made in Chapter Three between exploratory and performatory movements.

One of the central insights of Moshe Feldenkrais' (1972, 1981) approach to movement re-education is that undifferentiated movement is linked to undifferentiated perception. In other words, where there are habitually frozen degrees of freedom, there is a lack of perception of those limitations. A limitation in movement variety has an equivalent consequence in the variety of perception. The problem is not simply that the person has diminished the domain of variety and interfered with her ability to adapt, but that there are also sensory consequences. While a habitual movement pattern is what an observer cannot help but notice about someone else, it is often the very aspect of movement that the mover cannot perceive about him- or herself. The mover has become habituated to the constant stimuli of the invariant and is no longer aware of it.

Another way to say this is that if certain aspects of movement are never explored, then sensory feedback is limited. Since perception plays a role in guiding movement (Cordo, 1990; Powers, 1974), the distortions resulting from habitual movement interfere with changing those habitual patterns. This is especially true because the problem with learning how to move differently is not just a matter of learning a new pattern, it requires discerning what is already occurring so that the mover knows what to change.

This is the crux of the problem, then: the mover is not aware of what he or she is doing. While this may be considered normal, since most of us do not know how we do what we do, the situation becomes problematic for anyone trying to change an invariant pattern. The problem encountered in learning a new way of moving is that a previously established, habitual pattern interferes. It is not possible to simply *do* something new. Learning a new movement means learning about what is already happening, so as to understand what to change. How do we develop an awareness of how we are moving and the other ways in which we can move?

If information is a difference that makes a difference (Bateson, 1979), then learning is finding out which differences matter. Therapy and re-education must have strategies for circumventing frozen degrees of freedom and freeing them. Once the degrees of freedom have been recovered, the student can explore the relationships that underlie a new movement possibility: how the movement of certain segments affects other parts of the body, what constraints are inherent in the body's design, and how different segments can work together. By engaging in this type of investigation, which one could argue reflects the playing and exploring that babies and toddlers engage in regularly, the student maps out the topography of a new pattern, searching for attractors, probing gradients, and identifying boundaries. This is a form of trial and error learning where the trials consist of delving into the sub-relationships nested within an overall action pattern. Learning involves perceptual differentiation of this event substrate (Gibson, 1992). By finding out which combinations do not work and which do, the student eliminates unworkable coordinations and learns what the control parameters are.[13]

A pedagogy based on exploration and variability is fundamentally different from most approaches to physical education and rehabilitation in which the teacher or therapist tries to reduce the student or patient's variety by eliminating all but the desired behaviors. The link between undifferentiated movement and undifferentiated sensation leads to a new way of teaching movement: one based on exploring movement options and refining self-perception. The student's ability to make his or her own judgments is relied upon so that it is not considered the teacher's job to instruct the student on which outcome to select. Instead, the teacher guides the student through a process of exploring the domain of sub-relationships significant to a desired movement gestalt. The student's attention is directed to the consequences of different ways of moving so that they can evaluate different ensembles of action, assembling combinations and constraints until a new pattern can emerge. Like exploring a new terrain, this investigation leads to an understanding of the lay of the land—the topography of a movement—and reveals the best ways to navigate through it.

If the nervous system is functioning in such a way as to interfere with exploration and perception, what means do we have of eliciting new movements and refining

[13] Failure, rather than being a sign of inadequacy or deficiency, is a necessary part of the process of learning. Constructing a new coordinative structure requires exploring underlying relationships to find

awareness? Improving function depends on differentiating kinesthetic perception, and improving perception means engaging in exploratory activity to break the sensory blindness due to habituation. Utilizing direct manual contact or verbal instructions (i.e., movement constraints), the therapist, teacher, or coach guides the student or patient to explore specific aspects of movement. These explorations are designed to develop the students' awareness of habitual muscle synergies and elicit new patterns of movement.

Whatever the diagnosis, the process of change focuses both on becoming aware of the current pattern of muscle tonus (and its inhibitory consequences) and on exploring the unused, and until recently inaccessible, degrees of freedom. One resensitizing strategy is to have the student perform unusual movements in unlikely positions. This serves to break habituation and introduce new ways of perceiving. Another strategy is to have the student explore while in a constrained configuration; the addition of constraints both simplifies the motor control task and highlights specific aspects of dynamics. Such constraints inhibit habitual action and free up unused degrees of freedom.

Emphasis is placed on exploration, not performance. The mover is asked to proceed slowly and gently so that he or she can tune into the qualitative aspects of the movement. These qualitative aspects, such as the smoothness and relative ease of motion, provide the criteria by which the mover can identify new attractors and select

out which ones work and which do not. Learning what doesn't work, which could be seen as a temporary between movement options (cf. Riccio, 1993). Following the dictates of the Weber-Fechner law of psychophysics (Geldard, 1972; Bateson, 1991), which states that sensitivity is inversely proportional to pre-existing stimuli, effort is reduced to increase the ability to make finer distinctions.

To demonstrate how these ideas apply, we will return to Susan's session in the following section.

failure, is a necessary part of the process of eventually succeeding.

Epilogue

After discussing her situation, I asked Susan to stand at her walker again. Once she was standing, I placed my hands around the top of her pelvis. Moving her ever so gently from side to side and then back and forth, I investigated her movability. Her trunk was stiff, resisting even the smallest perturbation. Holding her shoulder with my right hand, I attempted to move her pelvis independently, which proved impossible.

Having seen how she responded to my tactile suggestions at multi-segmented movements, I asked her to move her right hip forward. She rotated her hip and her shoulder together in an undifferentiated movement. When I asked her to bring her left leg forward, she stiffly moved her leg, hip, and trunk together. Her trunk is so fixed that she cannot translate her pelvis from side to side. Whatever movement I called for elicited an undifferentiated response.

"Do you notice how difficult these movements are?"

"Yes. With all this tightness, I don't seem to be able to steer myself too well. I move as one piece."

"Exactly. It seems that you have a hard time sensing the different parts of yourself and how they move in relationship to each other."

"That's right. What can I do about it?"

"The first thing that has to happen is that you have regain your ability to perceive the relative motions that are possible. Let's see if we can begin with that. Would you please lie on your side on the table."

Susan sat again and, with considerably difficulty, came to lying on her right side. After putting a pillow under her head, I placed one hand on her pelvis and one hand on her shoulder. Slowly moving her shoulder forward, I pointed out that her pelvis rolled forward simultaneously. Then I moved her pelvis backward and pointed out how her shoulder came back and her head had rolled toward the ceiling. Once the lack of relative movement has become quite obvious, I began to palpate the muscles of her abdomen, buttocks, back, and shoulder girdle.

"Can you feel how tight these muscles are?"

"Yes. I'm surprised that all the places you touch are so contracted."

"It is this stiffness that interferes with your ability to stand and balance. Let's see if we can find some movement to build on."

Returning to the shoulder, I began to explore very small movements in order to find in which directions she retained some movability. I placed her left hand on the table in front of her so that she grabbed onto the edge of the table. Without force or insistence, I explored the motion of her shoulder proximally in relationship to the constrained hand, finding that there is some ease in the upward direction. Beginning with that, I explored other vectors, going up and slightly forward, up and slightly back. Then I held her shoulder blade fixed and explored the degrees of freedom available at her shoulder. Having explored the independent movements, I then began to *investigate the way in which her shoulder and arm could move in relationship to each other. For instance, the elbow could move toward the ceiling while the shoulder glided backwards, toward the spine, or the shoulder could move forward, away from the spine during the same arm motion. Staying within the range of ease, we inquired into each of the possible combinations.*

Bringing her arm to rest back on the table, I continued to move her scapula, this time constraining her ribcage. In this way, I thought that she would begin to sense the different ways in which she could move. Continuing to move the shoulder, I fixed her spine, first at the lower back, then between her shoulders, and, finally, at the top of her upper back. Reversing my strategy, I then held her shoulder still and began to explore the movement of her spine and ribcage in relationship to her shoulder. Returning to the initial test movement, I held her pelvis still and moved her shoulder. Lo and behold, there was some movement of the shoulder girdle independent of the pelvis and chest.

Having explored the variety of movements possible between the shoulder girdle and ribcage, I turned my attention to her pelvis. I lifted her left foot, rotating her leg internally at the hip and noting that this movement was both limited in range and difficult. Lifting from her knee, I attempted to externally rotate her hip. Instead of eliciting movement at the hip joint, her pelvis and back moved as a piece and she started to roll backwards. Obviously, internal rotation was much easier. Having noted which direction is easier, I explored moving her leg in relationship to her pelvis and vise versa. The rotation of the leg became easier in both directions. I then guided her through moving her pelvis in relationship to her ribcage and spine and then her ribs and *spine in relationship to her pelvis. At each step along the way, I identified and facilitated the easier movement, knowing that when I returned from the direction of ease we were moving in the opposite way.*

After having done all this, I lifted her leg and rotated both ways. Her leg felt lighter and moved more easily. Once again, I place my hands on her pelvis and shoulder to explore their relative motions. They moved more independently; Susan took a deep breath. I asked her to roll on her back and tell me what she noticed.

"My left side is lying flatter on the table. It feels warmer and I can sense it more clearly." Lifting her first left and then right arm, she remarked, "My left arm is so much lighter."

I asked her to roll on the left side and proceeded with a similar process on the other side. We had worked for almost a half hour on the right side, but on the left the changes came quicker. In about fifteen minutes, I felt that her left side had developed as much movement as the right.

"Would you slowly come to sitting?" I asked.

Susan sat up with some difficulty, but overall the movement was smoother and appeared less difficult. I brought the walker back to her and, after giving her a few moments to adjust to her new configuration, I asked her to come to standing. She stood and looked around. Her head moved easily. Without my asking, she translated her pelvis right and left. Though the range was small, her pelvis moved independently of her shoulders now.

"It feels easier to stand. And I can feel my legs and hips a little more clearly."

This was the beginning of our working together, which we did twice a week for the next eight months. Though Susan never fully regained her ability to walk without assistance, she did progress from using the walker to using a cane. As her stiffness decreased and her ataxia diminished, she began to use the cane with considerable ease. By the time we finished working together, she could take several steps without needing any assistive device and she could stand comfortably on her own.

Appendix One

This experiment investigated the consequences of constrained movement on postural strategies. The purpose of this experiment was to demonstrate that concepts used in rehabilitation and movement re-education can be translated into testable hypotheses and can serve to guide the development of experimental paradigms. It was not meant to prove a concept or idea, but rather as way of reaching out to members of the experimental community to demonstrate the potential utility of certain clinical concepts. The intention was to conduct a preliminary study that related these ideas to contemporary movement science and rehabilitation medicine.

Hypothesis

The hypothesis is two-fold:

(1) Constraints on movement exploration lead to a change in postural strategy.

(2) A change in postural strategy can generalize to activities that rely on, or incorporate, that pattern.

Using objective, observer, and subjective measures, the study looked at how various experimental interventions affected the subject's movement, asking the following questions: What is the subject's postural strategy and stability before participating in the experimental conditions? Did the subject move as a rigid rod at the ankles? Did the subject present a multi-segment motion, with movement at the hip joints? How did these change after each intervention?

The effect of constraints was tested by looking at changes in performance at the post-test. The expectation was that the subject's postural strategy may change, particularly that his or her balance would improve and that the amount of relative movement would increase, in other words, that he or she will move in a multi-segmented fashion, rather than as a rigid rod. In this experiment, this change would be operationalized as a shift from an ankle strategy to a hip strategy. Besides using the data from the SMART Balance Master equipment (described below), the videotapes of the subject's participation in the experiment were reviewed by experts in movement observation and rehabilitation to assess changes in balance strategy.

METHOD

<u>Subjects</u>: Subjects were selected and scheduled by the Physical Therapy Department at St. Agnes Hospital in Catonsville, Maryland (as was the equipment for the objective measures). The twelve subjects were drawn from hospital staff. The subjects consisted of four men and eight women. Ten were Caucasians and two were Afro-American. The ages ranged from 20 to 49 years old. Subjects were selected by one of the members of the physical therapy department; the only selection criterion specified was that they had no current movement limitations or pathology, as determined by direct questioning by the physical therapist who arranged for them to participate.

<u>Apparatus</u>: Postural strategy was assessed using a SMART Balance Master®, a standardized clinical equipment for computerized dynamic posturography (NeuroCom, 1994a; NeuroCom, 1994b). The SMART Balance Master is manufactured by NeuroCom International, Inc. for use in evaluating balance disorders (Cyr, 1992; Horak, Shumway-Cook, Crowe, & Blach, 1988; Keim, 1993; Nashner, 1993; Shepard and Telian, 1994), as well as other applications, including neurological assessment (Hamid, Hughs, and Kinny, 1991) and sensorimotor training (NeuroCom, 1994b). A photograph of the equipment is provided in Figure 2.

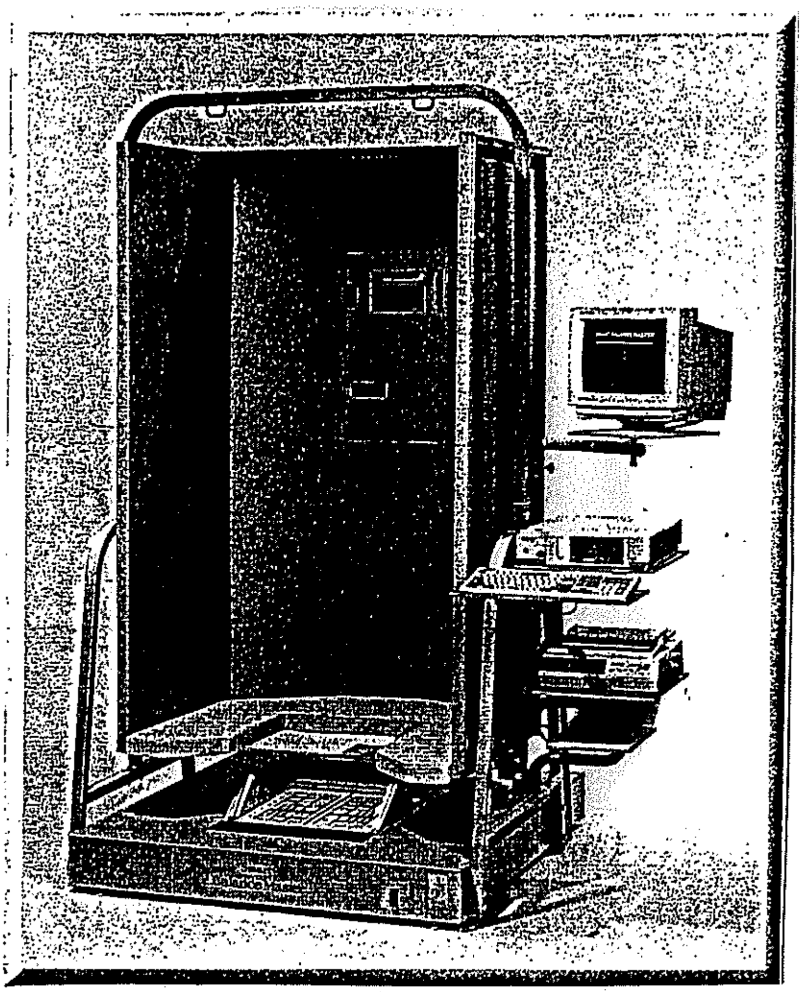


Figure 2. SMART Balance Master. (Photograph courtesy of NeuroCom International, Inc. Clackamas, Or.)

The SMART Balance Master contains three major mechanical and electrical subsystems (NeuroCom, 1994a):

1) A platform base that contains a dual forceplate, force transducers, and servomotors.
2) An electrical controller, which includes force transducer amplifiers, force plate and visual surround servo-controls, platform computer interface, and power supplies.
3) A system computer, which controls the tests, acquires and stores data, gives servo commands, and analyzes and displays test results.

The subject stands on the platform while strapped into a safety harness to prevent any possible injury. The base and the screen can move, both independently and together. The support surface and screen tilt forward and back, following the subject's postural sway. Unlike other equipment, the SMART Balance Master does not produce sudden jolting perturbations (NeuroCom, 1987). The subject is required to stand with his or her feet parallel and in one of three placement sites, depending on the subject's height.

The base incorporates a force platform to record the movement of the center of pressure, measuring the subject's ability to keep balance and tracking the responses to various perturbations. The information gathered by the force platform can be used to make the visual surround, the support surface, or both directly follow the person's forward and back postural sway. The specifications for the equipment are as follows (NeuroCom, 1994a):[14]

Components:

- Moveable dual forceplate, 18" x 18".
- Moveable visual surround.
- Overhead bar.
- Patient harness.
- 486 DX IBM compatible computer.
- 4 MB RAM.
- 1.4 MB, 3.5" removable drive.
- 170 Mb hard disk drive.
- System software.
- HP DeskJet printer.
- Handheld trackball (mouse).

Performance characteristics:

The dual forceplate and visual surround are controlled by direct servomotors that rotate independently about a lateral axis passing through the ankle joints.

- Force plate rotation +/-10°, maximum velocity 50°/sec.
- Visual surround rotation +/-10°, maximum velocity 20°/sec.

Electrical Characteristics:

115 volt/60 Hz or 230 volt/50 Hz.
Designed to meet UL544.

By mixing the conditions and comparing the subject's performance with eyes open and closed, the SMART Balance Master allows the testing of the contributions of various sensory systems to equilibrium (Cyr, Moore, & Moller, 1988; Nashner & McCollum,

[14]For further specifications, see NeuroCom (1994a) and Williams (1991).

1985). Postural sway is recorded for twenty seconds under each of six different sensory conditions:

1) Normal vision and fixed support surface.

2) Absent vision and fixed support.

3) Sway-referenced vision and fixed support.

4) Normal vision and sway-referenced support.

5) Absent vision and sway-referenced support.

6) Sway-referenced vision and sway-referenced support.

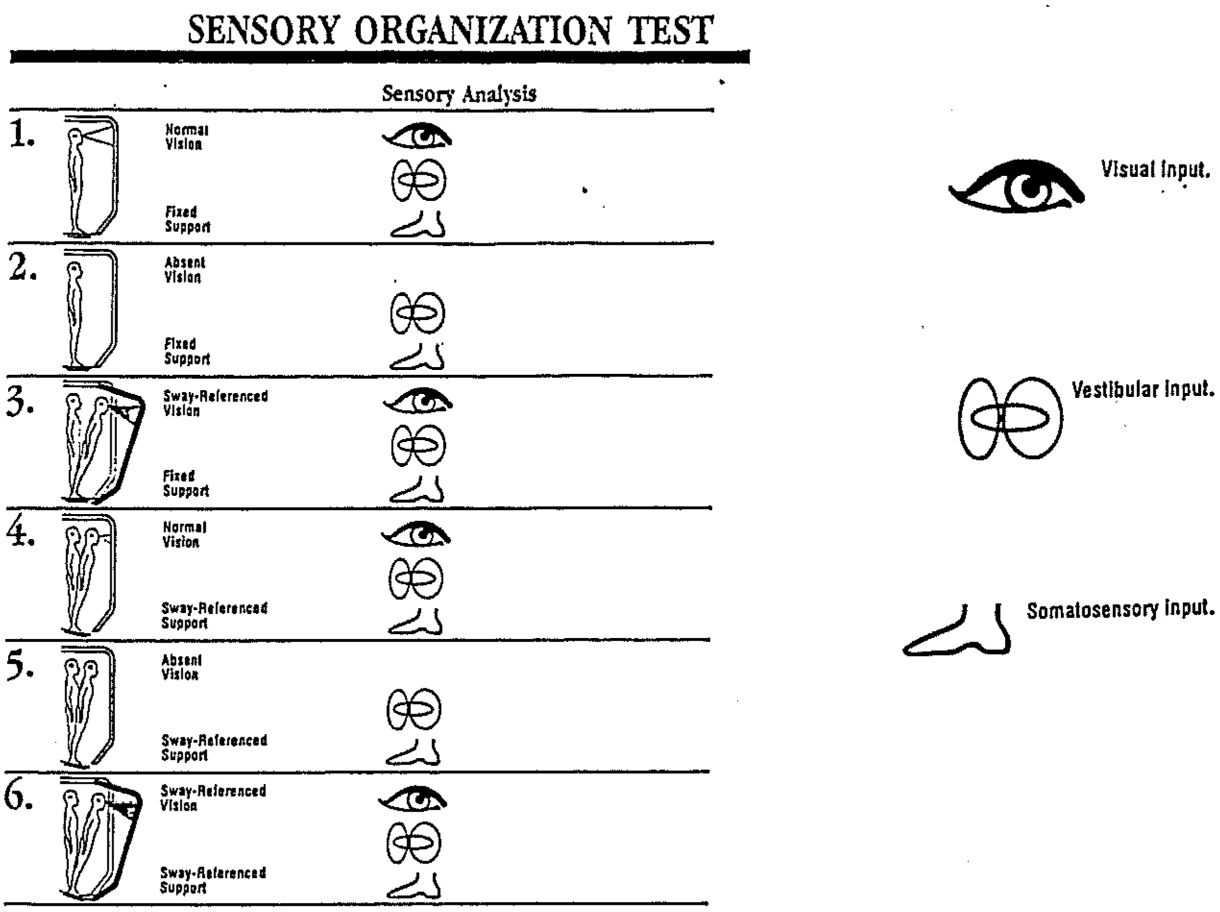
Table 1
Physical Characteristics of SMART Balance Master

	Width	Depth	Height
Assembled dimensions:	69″	60″	94″
Base	49″	60″	6″
Dual forceplate	18″	18″	–
Visual Surround	42″	36″	74″
Maximum subject height	–	–	80″

The six conditions[15] are graphically represented in Figure 3 below. The left column graphically illustrates whether the subject eyes are open or closed (with a representation of the visual field or a blindfold, respectively) and whether the force platform is moving

[15]NeuroCom refers to these six tests as the "sensory organization test." The *SMART Balance Master* also can conduct a movement coordination test to examine a subject's ability to make corrective movements to regain equilibrium when exposed to perturbations of the support surface.

or still. The conditions are described in words as well. The second column shows the sensory systems tested in each condition.



<u>Figure 3.</u> Description of SMART Balance Master sensory tests. (Illustration from "The *SMART and Pro*: *Pro* and SMART Balance Master® Systems" by NeuroCom, 1994, Clackamas: NeuroCom. Copyright 1994 by NeuroCom. Reprinted by permission.)

Because normal subjects do not change their postural strategies over time, computerized dynamic posturography provides reliable, repeatable measures of balance and postural strategies (Black, Pabski, Reschke, Calkins, & Shupert, 1993; Paloski, *et al.*, 1992; Paloski, Reschke, Harm, & Black, *in press*). The comparison of the results obtained under different conditions offers a way of evaluating the relative contribution of kinesthetic, vestibular, and visual senses (Cyr, *et al.*, 1988; NeuroCom, 1987). For example, by comparing the results of having eyes open and closed when the support surface is still, the contribution of the somatosensory perception can be assessed. Comparing moving surface with stable surface, the use of visual information can be evaluated. If, when comparing eyes closed on a moving surface with eyes open on a stable surface, sway increases without vision and with disturbed kinesthetics, then there may be a problem with the vestibular system. A comparison of the two eyes open and moving surface tests with the two eyes closed conditions informs us about the use of visual information.

<u>Procedure:</u> The experimental manipulation consisted of each subject participating in two of four experimental conditions. Besides the control condition, which consisted of talking to the experimenter for five minutes about issues not related to the task, each of the experimental manipulations added different constraints to the subject's motion:

1) *Physical constraint:* The subject stands with one leg crossed in front of the other and his/her head held still in space by the experimenter. The subject shifted weight from one leg to the other a half dozen times. This was performed first with one leg crossed in front and then the other. (Given the small size of the SMART Balance Master platform area, there is not enough room for the experimenter and subject to stand within its confines. Therefore this condition is performed outside the apparatus, with the subject and experimenter standing in front of the SMART Balance Master, not in it.)

2) *Visual constraint:* The subject fixed his/her gaze on an object affixed to the wall approximately twenty feet away while performing the weight shift in the crossed leg conditions.[16] (In order for the experimenter to ascertain that the subject kept his or her focus fixed, this condition was performed outside the SMART Balance Master equipment.)

3) *Instructional constraint:* The subject was instructed to attend to certain aspects of his/her kinesthetic experience during a sixteen minute movement lesson. (*See* Appendix Two for a transcript of the verbal instructions.) So that each subject would listen to the same instruction, the lesson was on audio tape and the subjects used a portable tape recorder and a headset to listen to the instructions.

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[16]The object gazed was located at eye-level on an otherwise empty wall.

In order to counter any effect that could be due to the order in which subjects performed each condition, the order in which they went through the process was randomized, as shown in Table 2 below.

Table 2
Order of Experimental Interventions

Subject	First intervention	Second intervention
One	Visual constraint	Physical constraint
Two	Visual constraint	Movement lesson
Three	Visual constraint	Conversation
Four	Movement lesson	Visual constraint
Five	Movement lesson	Physical constraint
Six	Movement lesson	Conversation
Seven	Physical constraint	Conversation
Eight	Physical constraint	Movement lesson
Nine	Physical constraint	Visual constraint
Ten	Conversation	Physical constraint
Eleven	Conversation	Movement lesson
Twelve	Conversation	Visual constraint

Data collection: The subject's balance on the SMART Balance Master was assessed before and after each intervention. In order to take into account any learning effect on the device, the subjects went through the initial test sequence twice.[17] The second iteration

[17]Clinical experience has consistently demonstrated that after the second trial there are no improvements in the subject's performance on the *SMART Balance Master* (L. Horn, personal communication, April 21, 1994).

will serve as the basis for comparison in the quantitative data. Three sets of scores were obtained for each of the twelve subjects, one for the pre-test and one after each of the (two) interventions they experienced. Subjects were instructed to stand comfortably on the SMART Balance Master platform with their arms hanging at their side while the suite of six tests was performed. Each test lasted for twenty seconds; the suite of tests was performed consecutively and in the same order each time. The SMART Balance Master recorded the movement of the subject's center of pressure and the amount of horizontal force generated by the subject's balancing actions.

The scores are output provided by the SMART Balance Master. The SMART Balance Master yields data about postural strategy (in other words, the data can be interpreted as the amount of hip motion relative to ankle motion) and about stability, the relative magnitude of sway. Strategy scores are reported on a continuum from 0 to 100, where 100 is a total ankle strategy and 0 is a total hip strategy. These numbers are based on the relative magnitude of shear force exerted on the platform; they tend to reflect abrupt or jerky upper body movements. Stability scores are reported on a scale from 0 to 100, where 100 is perfect stability (equated with the absence of any postural sway)[18] and 0 is a fall. These scores are based on the amount of movement of the center of pressure. Each set of scores on the SMART Balance Master consisted of the six sensory conditions described above, so there was one trial per condition per session per subject.

Balance also was assessed by independent expert observers. Observers One and Two are Feldenkrais practitioners with eleven years of clinical experience and with certification in Laban Movement Analysis, a movement analysis system developed for choreographic notation and movement description (Bartenieff, Davis, & Paulay, 1970; Dell, 1970; Hutchinson, 1977; Laban, 1950; Laban, 1956; Laban, 1960; Laban, 1966; Laban & Lawrence, 1947). Observers Three and Four are Feldenkrais practitioners, too; Observer Three has six years of clinical experience and Observer Four has four years of clinical experience. Observer Four is also a physical therapist with ten years of clinical experience. Observers One, Two, and Three work as instructors in Feldenkrais professional training programs.

During the experiment, subjects were asked to weight-shift right and left while standing with feet parallel and arms hanging at their sides. (The subjects performed this task standing in the SMART Balance Master, facing the screen as they would during the objective measures.) This test was performed both before and after each condition. Each subject's performance of the weight-shifting task was recorded by a video camera placed directly behind the SMART Balance Master, therefore, the video recorded the back view of these test movements.

The expert observers watched the video tapes of the pre- and post-tests, which they scored for changes in the quality and pattern of motion. Two observers (One and Two

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[18]Given that standing is a dynamic activity, a perfect stability score of 100 would be impossible for a human being to achieve. It is an abstract limit that can be approached but never reached. (A stable

first, then Three and Four) watched the videos of the subjects together in the chronological order in which the subjects were run. They only saw the sections of the tapes that included the behavioral test; they did not watch the SMART Balance Master tests or the interventions.

For the quality score, the experts were asked to mark any increases in smoothness as an improvement and any increases in jerkiness and unevenness as a decrement. They were asked to differentiate between small and large decrements or improvements. For the pattern score, the evaluators were asked to note any change in the relative movement between body segments, particularly in the relationship between the head, shoulder girdle, pelvis, and ankles. They were asked to differentiate between small and large changes along the spectrum from stiff to flexible. The scoring forms were set up as shown in Figure 4 below.

The qualitative difference scores (presented in Tables 26 and 27) are based on the observations provided by Observers One and Two.

Quality of motion:

Large decrement   small decrement   no change   small improvement   large improvement

|--------------------|--------------------|--------------------|--------------------|
-2   -1   0   1   2

Pattern of motion:

---

inanimate object would register 100 in the stability category.)

Much stiffer	slightly stiffer	no change	slightly more flexible	much more flexible
-2	-1	0	1	2

Figure 4. Sample Observer scoring sheet.

Finally, the subjects were interviewed after their participation in the experiment and asked the following questions:

1) "What did you notice about the effect of each intervention?"
2) "Which interventions, if any, had an impact on your way of moving and ability to balance?"
3) "If there was a change, to what would you attribute it?"

These interviews were videotaped for future analysis.

RESULTS

The results from the SMART Balance Master tests (as obtained by the procedures explained in the data collection section above) are presented in both tabular and graphic form. Tables 6 through 11 present the stability and strategy scores, as produced by the SMART Balance Master system. Figures 6 through 8 present this data graphically with each graph depicting one sensory condition following the first, second, and third test runs, respectively. These graphs follow the conventions used by the SMART Balance Master system. To facilitate the interpretation of the graphs, the results of the sensory tests are presented with the fixed support conditions arranged on the left and the sway-referenced support conditions on the right. To make comparison of fixed and sway-referenced conditions easier, the test results are also matched up so that the visual conditions are related horizontally. That is to say, eyes open, eyes closed and sway-referenced conditions presented side-by-side. This arrangement is demonstrated in Figure 5.

The difference scores are presented in data matrices in a way that facilitates inspection of effects.[19] The matrices are arranged so there is a column for each

[19]Difference scores are used because they relate most directly to the hypotheses: (a) The hypotheses were about changes irrespective of the baseline from which change occurred.
(b) The data from different conditions were matched samples required statistical tests on difference scores.
(c) Transformation of the raw scores to minimize ceiling effects would lead to a new scale, a relation between postural stability/strategy and force-platform parameters, that has not been used in biomechanics and motor control and, thus, would be difficult or impossible to interpret.

intervention (physical constraint, visual constraint, movement lesson, conversation) and for the "dependent variables" (stability and strategy or quality and pattern). One set of matrices, Tables 12-17, presents the quantitative data, and another set, Tables 26-27, presents the qualitative data. Each column presents the difference between pre- and post-intervention scores. Subjects and sensory-test conditions are in rows in the matrix of quantitative data. Each subject, observer, and pairwise comparison are in rows in the matrix of qualitative data. By scanning down a column you can see the relative amount of positive numbers, negative numbers and zeros (the basis for a statistical "sign test"). You can also see if the positive numbers are larger than the negative numbers (the basis for a statistical signed-rank or "Wilcoxon" test).

Each set of quantitative data graphs, Figures 6 though 8, compares one of the "experimental" interventions (P, V, or M) to the "control" condition (C). Each set contains six plots of difference scores for stability versus strategy, arranged by sensory test condition. Each plot of stability versus strategy contains six difference scores for the "experimental" intervention and six difference scores for the control. The symbols for the plotted data are sufficiently different so that you can readily see if there are any differences between the two conditions. To further facilitate comparison, the control condition scores are always represented as filled diamonds.

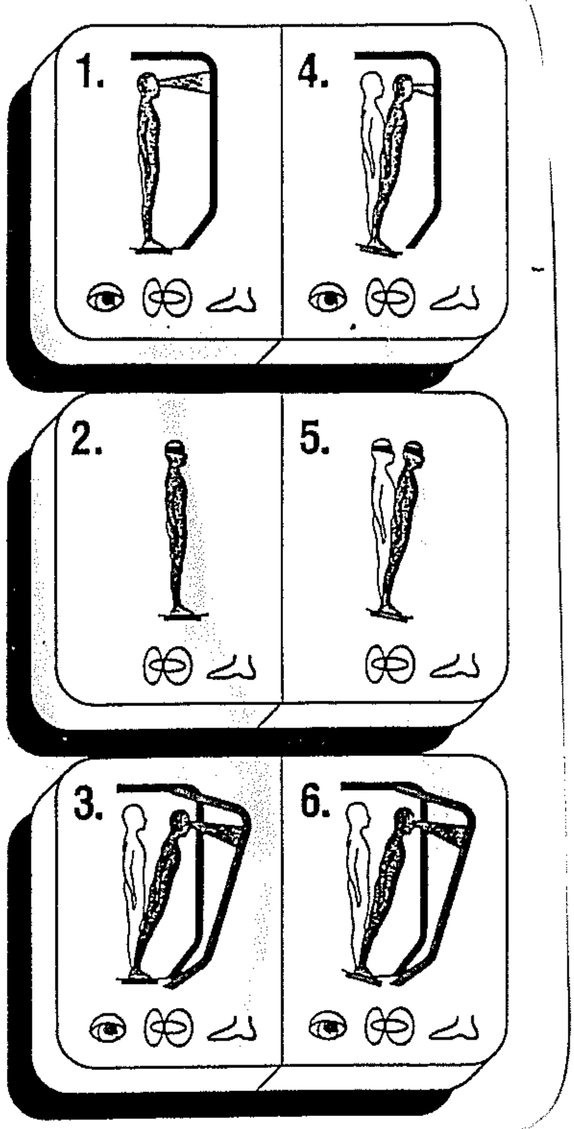

Figure 5. Arrangement of SMART Balance Master sensory tests results. (Illustration from "For your patients with imbalance and postural instability" by NeuroCom, 1987, Clackamas: NeuroCom. Copyright 1987 by NeuroCom. Reprinted by permission.)

A Wilcoxon Signed-Ranked Test for matched pairs (Darlington & Carlson, 1987) was performed on the difference between the pre- and post test scores, referred to in the quantitative data tables. This statistical analysis is a non-parametric test of the null hypothesis that difference scores are distributed symmetrically around "0." As demonstrated in Tables 18-21 below, there were no overall significant effects of the interventions on the quantitative data at $p > .01$. At $p > .05$, there is one significant result noted for each of the interventions; none of the conversation control tests show any significant effects.

The observer data are reported in Tables 22-25. The scores of the first observations, which compared the first post-test with the pre-test, and the second observations, which compared the second post-test with the first, are presented in separate columns. The quality and pattern data are each presented in separate columns. The qualitative data show overall improvement for all interventions, as shown in Table 3.

Table 3
<u>Significance of Qualitative Data.</u>

	Mean	T-score	DF	Significance[20]
Quality 2-1	.6818	5.59	10	$p < .001$
Quality 3-2	.5750	5.13	9	$p < .001$
Pattern 2-1	.5909	2.95	10	$p = .007$
Pattern 3-2	.7000	6.00	9	$p < .001$

The qualitative difference for Observer One and Two data are summarized, in Tables 26 and 27, in a manner similar to that described for the quantitative data. As with the quantitative data, each column contains six difference scores for the experimental intervention and six scores for the control condition.

The Cronbach Alpha Test was used to evaluate interrater reliability (Carmines and Zeller, 1979; MacLennan, 1993). Table 4 compares the alpha scores for quality and pattern parameters for the first and second post-tests. Table 5 compares the observers' alpha scores for each post-test according to each evaluation criteria. The overall alpha's for the observers were as follows: Observer One = .5206, Observer Two = .4180, Observer Three = .2461, and Observer Four = .4134. The overall reliability score for all the observers was .6065.

Table 4
Interrater Reliability Alpha Scores

	Quality	Pattern
Post-test 1	.6759	.8584
Post-test 2	.4567	.1497

Table 5
Comparison of Observer Reliability Scores

	Post-test 1		Post-test 2	
Corrected item-Total Correlation	Quality	Pattern	Quality	Pattern
Observer One	.6355	.8204	.2486	.1716
Observer Two	.3594	.7466	.6547	.0522
Observer Three	.1765	.6476	.0000	.0439
Observer Four	.7058	.6851	.3889	.1976

The general results of the subjective reports are reported in Table 28. In the interviews, the subjects reported that most interventions had little or no effect on the subject's postural strategies. The exception to this was the movement lesson, which *all*

[20]One-tailed significance test.

subjects report as having a positive effect on their balance (*see* Table 28). During the interview process, subjects who participated in the lesson had a lot to say while those who participated in the other interventions made few comments. Those who participated in the lesson said the following kinds of things, all of which are direct quotations (excerpted from the subject's responses to interview questions, which are reported in Appendix Three):

Excerpts from Subject Interviews

Subject 2

When asked what was noticed during the test movement after the lesson: "I felt like I had a little more movement in my pelvis. I started to lock my knees but then I was able to relax and try to move someplace else."

When asked to what this difference could be attributed: "Trying to feel the difference between how I was shifting my weight with my whole body as opposed to keeping my head still and move my pelvis around. "

Subject 4

When asked what changed overall after the lesson: "I felt like I was moving a little more comfortably at the end. . . I found it difficult, I mean, doing so many things because I was trying, like, to be aware, like, is my pelvis moving and am I moving as one? And when I shifted my weight I was trying to think about it."

Subject 5

When asked to describe to what the changes could be attributed: "You become, after the lesson, you just become more observant inwardly, you know. You're able to know and to pay attention to what's going on, especially with your pelvis. I paid a lot of attention to what my hip was really doing. Before I never paid any attention to, you know, whether my hip was moving. I was just trying, you know, I was just trying to move my legs."
When asked what caused the changes: "My body awareness. Me paying attention to the feedback mechanisms that were always going to my brain. Never paid attention to them before."

Subject 6

When asked what changed: "I learned to pay attention to my body. . . I used my pelvis."

Subject 8

When asked what about doing the movement lesson accounted for the changes noticed: "Definitely keeping the head still while moving the pelvis and thinking about the movement."

Subject 11

When asked what made the movement better after the lesson: "(The lesson) made me more aware of what parts of my body I use to keep my balance."

SMART Balance Master Data

In Tables 6-11, each table summarizes the results for one sensory condition. As explained in the data collection section above, these data represent the stability and strategy scores for each subject. The sensory conditions are:

EO—eyes open and fixed support.
EC—eyes closed and fixed support.
SV—sway-referenced vision and fixed support.
EO/SS—eyes open and sway-referenced support.
EC/SS—eyes closed and sway-referenced support.
SV/SS—sway-referenced vision and sway-referenced support.

The third column, order, refers to the order in which the subject proceeded through the experimental interventions. The initials represent:

N—Nothing, the initial conditions.
V—Visual constraint.
P—Postural constraint.
M—Movement lesson.
C—Control condition (conversation with experimenter).

Table 6
<u>E0 scores (eyes open and fixed support surface)</u>

Subject	Condition	Order	Stability 1–EO	Stability 2–EO	Stability 3–EO	Strategy 1–EO	Strategy 2–EO	Strategy 3–EO
1	1	N-V-P	97	96	96	98	99	98
2	1	N-V-M	94	94	95	99	99	99
3	1	N-V-C	93	94	89	99	98	98
4	1	N-M-V	92	88	90	99	99	98
5	1	N-M-P	97	94	95	99	99	99
6	1	N-M-C	95	96	94	97	99	99
7	1	N-P-C	95	97	96	99	99	99
8	1	N-P-M	96	97	96	99	99	99
9	1	N-P-V	94	95	94	99	99	99
10	1	N-C-P	97	97	96	99	99	98
11	1	N-C-M	96	90	94	99	99	99
12	1	N-C-V	91	88	94	99	99	99

Table 7
<u>EC scores (eyes closed and fixed support surface)</u>

Subject	Condition	Order	Stability 1–EC	Stability 2–EC	Stability 3–EC	Strategy 1–EC	Strategy 2–EC	Strategy 3–EC
1	2	N-V-P	90	92	93	96	97	96
2	2	N-V-M	95	94	93	99	99	99
3	2	N-V-C	90	95	87	99	99	98
4	2	N-M-V	94	94	93	99	99	99
5	2	N-M-P	92	90	86	99	95	99
6	2	N-M-C	91	93	94	99	99	99
7	2	N-P-C	90	93	88	99	99	97
8	2	N-P-M	91	92	93	99	99	99
9	2	N-P-V	90	88	86	95	93	95
10	2	N-C-P	95	95	90	99	99	96
11	2	N-C-M	92	88	87	99	99	98
12	2	N-C-V	91	92	89	98	99	99

Table 8
SV scores (sway-referenced vision and fixed support surface)

Subject	Condition	Order	Stability 1--SV	Stability 2--SV	Stability 3--SV	Strategy 1--SV	Strategy 2--SV	Strategy 3--SV
1	3	N-V-P	87	76	86	95	93	95
2	3	N-V-M	92	97	95	99	99	99
3	3	N-V-C	90	88	92	99	98	97
4	3	N-M-V	94	89	91	99	99	97
5	3	N-M-P	94	92	85	98	98	96
6	3	N-M-C	94	89	96	98	98	99
7	3	N-P-C	93	92	90	99	99	99
8	3	N-P-M	97	94	96	98	99	99
9	3	N-P-V	94	90	92	99	98	99
10	3	N-C-P	89	89	90	96	96	98
11	3	N-C-M	96	95	89	99	99	98
12	3	N-C-V	92	93	89	99	98	99

Table 9
E0/SS scores (eyes open and sway-referenced support surface)

Subject	Condition	Order	Stability 1--EO/SS	Stability 2--EO/SS	Stability 3--EO/SS	Strategy 1--EO/SS	Strategy 2--EO/SS	Strategy 3--EO/SS
1	4	N-V-P	69	60	57	82	84	82
2	4	N-V-M	86	92	91	80	92	93
3	4	N-V-C	85	88	96	86	87	93
4	4	N-M-V	89	74	82	88	88	90
5	4	N-M-P	78	70	35	85	83	72
6	4	N-M-C	63	74	93	84	89	91
7	4	N-P-C	84	83	73	86	89	86
8	4	N-P-M	91	97	90	87	95	88
9	4	N-P-V	83	84	87	87	81	91
10	4	N-C-P	72	72	88	78	78	94
11	4	N-C-M	81	91	77	86	91	83
12	4	N-C-V	78	85	88	88	91	89

Table 10
EC/SS scores (eyes closed and sway-referenced support)

Subject	Condition	Order	Stability 1–EC/SS	Stability 2–EC/SS	Stability 3–EC/SS	Strategy 1–EC/SS	Strategy 2–EC/SS	Strategy 3–EC/SS
1	5	N-V-P	68	55	54	84	84	83
2	5	N-V-M	71	79	81	81	82	85
3	5	N-V-C	63	85	60	80	89	75
4	5	N-M-V	80	62	86	79	86	89
5	5	N-M-P	61	42	44	53	61	71
6	5	N-M-C	46	65	75	87	88	88
7	5	N-P-C	69	82	64	66	86	83
8	5	N-P-M	58	73	78	78	77	80
9	5	N-P-V	70	72	79	73	67	74
10	5	N-C-P	73	73	83	84	84	84
11	5	N-C-M	65	60	55	86	82	86
12	5	N-C-V	55	68	79	85	80	86

Table 11
SV/SS scores (sway-referenced vision and sway-referenced support scores)

Subject	Condition	Order	Stability 1–SV/SS	Stability 2–SV/SS	Stability 3–SV/SS	Strategy 1–SV/SS	Strategy 2–SV/SS	Strategy 3–SV/SS
1	6	N-V-P	52	46	54	76	72	83
2	6	N-V-M	72	64	73	79	80	85
3	6	N-V-C	70	75	79	79	83	86
4	6	N-M-V	58	63	70	81	84	89
5	6	N-M-P	43	35	22	79	68	59
6	6	N-M-C	48	59	43	88	85	88
7	6	N-P-C	57	41	55	83	80	80
8	6	N-P-M	60	66	60	71	80	81
9	6	N-P-V	74	74	62	76	77	79
10	6	N-C-P	87	87	73	82	82	85
11	6	N-C-M	72	72	46	86	91	85
12	6	N-C-V	54	83	66	86	89	85

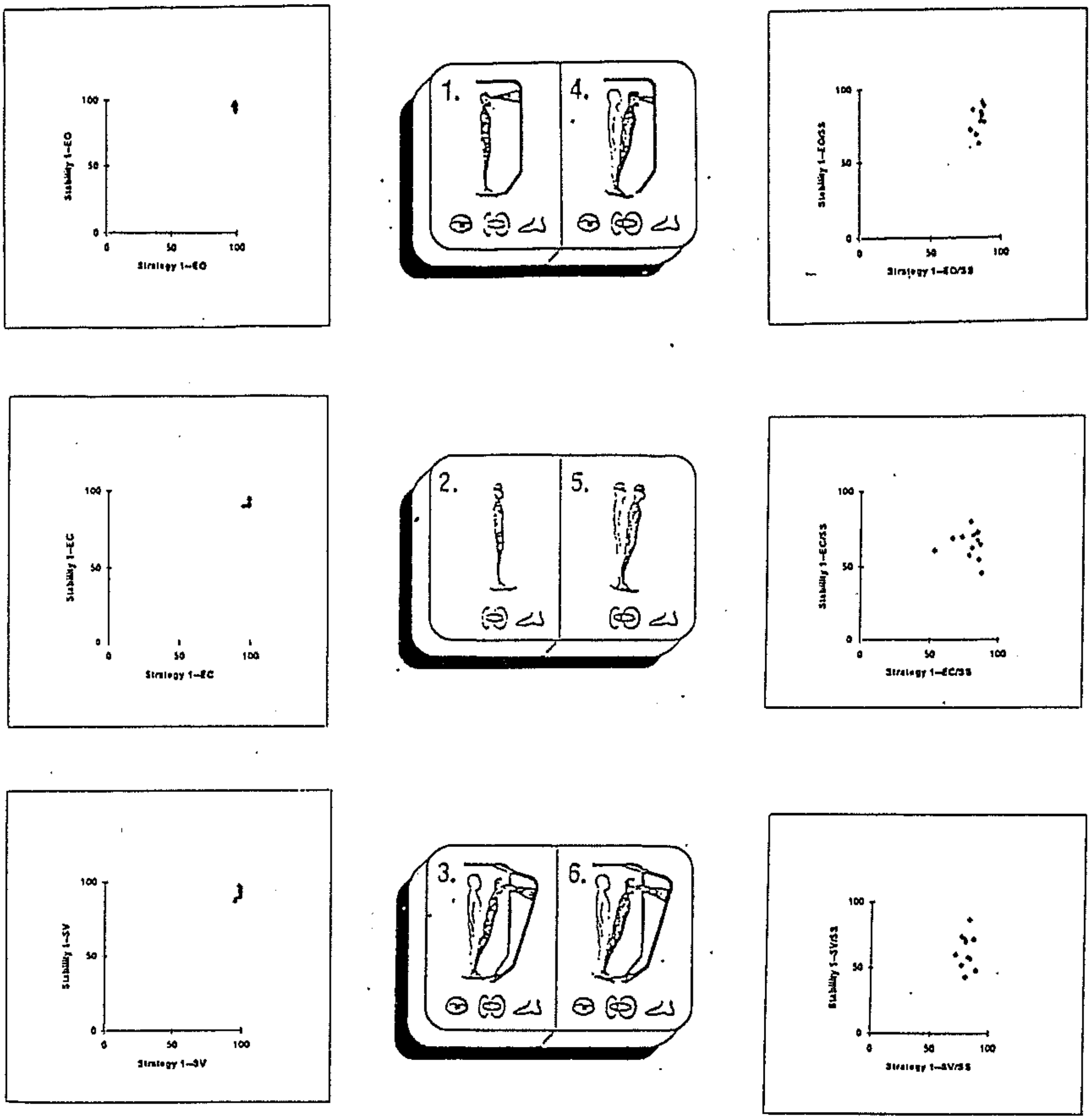

Figure 6. Graphs of each test condition, first test cycle. (Illustration from "On balance, no system is better than EquiTest" by NeuroCom, 1987, Clackamas: NeuroCom. Copyright 1987 by NeuroCom. Reprinted by permission.)

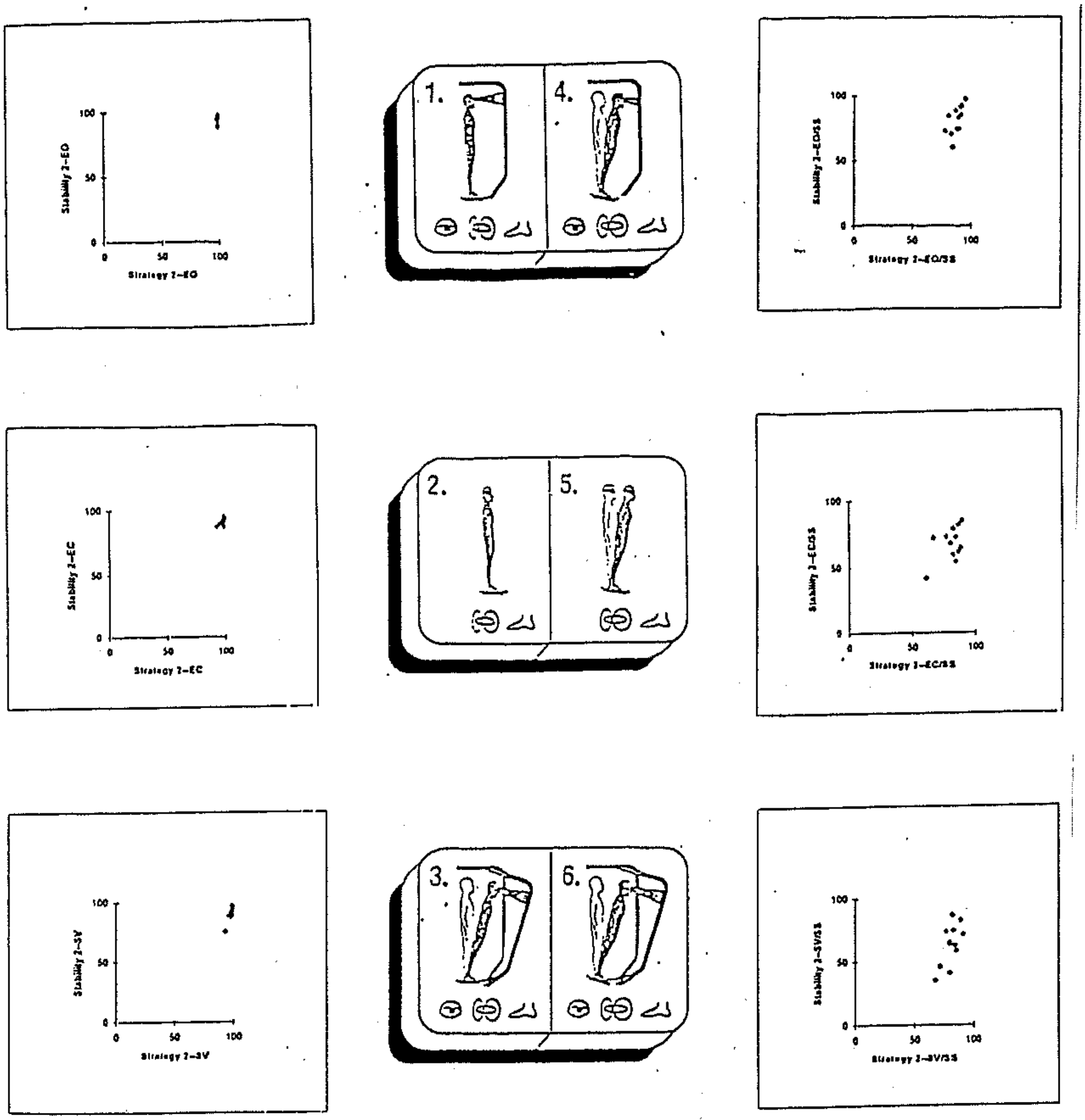

Figure 7. Graphs of each test condition, second test cycle. (Illustration from "On balance, no system is better than EquiTest" by NeuroCom, 1987, Clackamas: NeuroCom. Copyright 1987 by NeuroCom. Reprinted by permission.)

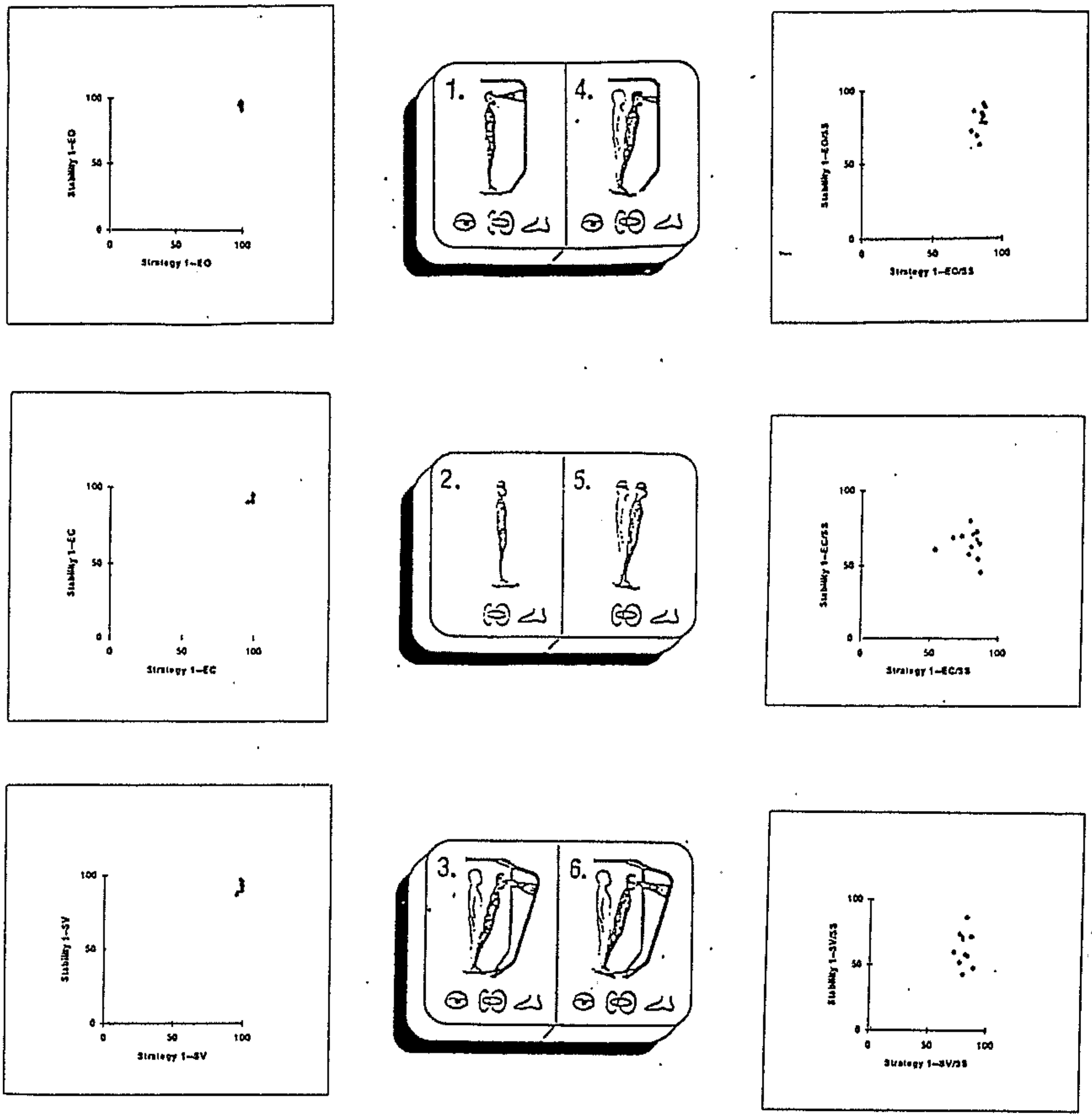

Figure 8. Graphs of each test condition, third test cycle. (Illustration from "On balance, no system is better than EquiTest" by NeuroCom, 1987, Clackamas: NeuroCom. Copyright 1987 by NeuroCom. Reprinted by permission.)

Table 12
EO difference scores

			Stability				Strategy			
Subject	Test	Order	Visual constraint	Movement lesson	Position constraint	Convers. control	Visual constraint	Movemen t lesson	Position constraint	Convers. control
1	1	N-V-P	-1		0		1		-1	
2	1	N-V-M	0	1			0	0		
3	1	N-V-C	1			-5	-1			0
4	1	N-M-V	2	-4			-1	0		
5	1	N-M-P		-3	1			0	0	
6	1	N-M-C		1		-2		2		0
7	1	N-P-C			2	-1			0	0
8	1	N-P-M		-1	1			0	0	
9	1	N-P-V	-1		1		0		0	
10	1	N-C-P			-1	0			-1	0
11	1	N-C-M		4		6		0		0
12	1	N-C-V	6			-3		0		0

Table 13
EC difference scores

1	2	N-V-P	2		1		1		-1	
2	2	N-V-M	-1	-1			0	0		
3	2	N-V-C	5			-8	0			-1
4	2	N-M-V	-1	0			0	0		
5	2	N-M-P		-2	-4			-4	4	
6	2	N-M-C		2		1		0		0
7	2	N-P-C			3	-5			0	-2
8	2	N-P-M		1	1			0	0	
9	2	N-P-V	-2		-2		2		-2	
10	2	N-C-P			-5	0			-3	0
11	2	N-C-M		-1		-4		-1		0
12	2	N-C-V	-3			1	0			1

Table 14
SV difference scores

			Stability				Strategy			
Subject	Test	Order	Visual constraint	Movement lesson	Position constraint	Convers. control	Visual constraint	Movemen t lesson	Position constraint	Convers. control
1	3	N-V-P	-11		10		-2		2	
2	3	N-V-M	5	-2			0	0		
3	3	N-V-C	-2			4	-1			-1
4	3	N-M-V	2	-5			-2	0		
5	3	N-M-P		-2	-7			0	-2	
6	3	N-M-C		-5		7		0		1
7	3	N-P-C			-1	-2			0	0
8	3	N-P-M		2	-3			0	1	
9	3	N-P-V	2		-4		1		-1	
10	3	N-C-P			1	0			2	0
11	3	N-C-M		-6		-1		-1		0
12	3	N-C-V	-4			1	1			-1

Table 15
EO/SS difference scores

1	4	N-V-P	-9		-3		2		-2	
2	4	N-V-M	6	-1			12	1		
3	4	N-V-C	3			8	1			6
4	4	N-M-V	8	-15			2	0		
5	4	N-M-P		-8	-35			-2	-11	
6	4	N-M-C		11		19		5		2
7	4	N-P-C			-1	-10			3	-3
8	4	N-P-M		-7	6			-7	8	
9	4	N-P-V	3		1		10		-6	
10	4	N-C-P			16	0			16	0
11	4	N-C-M		14		10		-8		5
12	4	N-C-V	3			7	-2			3

Table 16
EC/SS difference scores

			Stability				Strategy			
Subject	Test	Order	Visual constraint	Movement lesson	Position constraint	Convers. control	Visual constraint	Movement lesson	Position constraint	Convers. control
1	5	N-V-P	-13		-1		0		-1	
2	5	N-V-M	8	2			1	3		
3	5	N-V-C	22			-25	9			-14
4	5	N-M-V	24	-18			3	7		
5	5	N-M-P		-19	2			8	10	
6	5	N-M-C		19		10		1		0
7	5	N-P-C			13	-18			20	-3
8	5	N-P-M		5	15			3	-1	
9	5	N-P-V	7		2		7		-6	
10	5	N-C-P			10	0			0	0
11	5	N-C-M		-5		-5		4		-4
12	5	N-C-V	11			13	6			-5

Table 17
EV/SS difference scores

1	6	N-V-P	-6		8		-4		11	
2	6	N-V-M	-8	9			1	5		
3	6	N-V-C	5			4	4			3
4	6	N-M-V	7	5			5	3		
5	6	N-M-P		-8	-13			-11	-9	
6	6	N-M-C		11		-16		-3		3
7	6	N-P-C			-16	14			3	0
8	6	N-P-M		-6	6			1	9	
9	6	N-P-V	-12		0		2		1	
10	6	N-C-P			-14	0			3	0
11	6	N-C-M		-26		0		-6		5
12	6	N-C-V	-17			29	-4			3

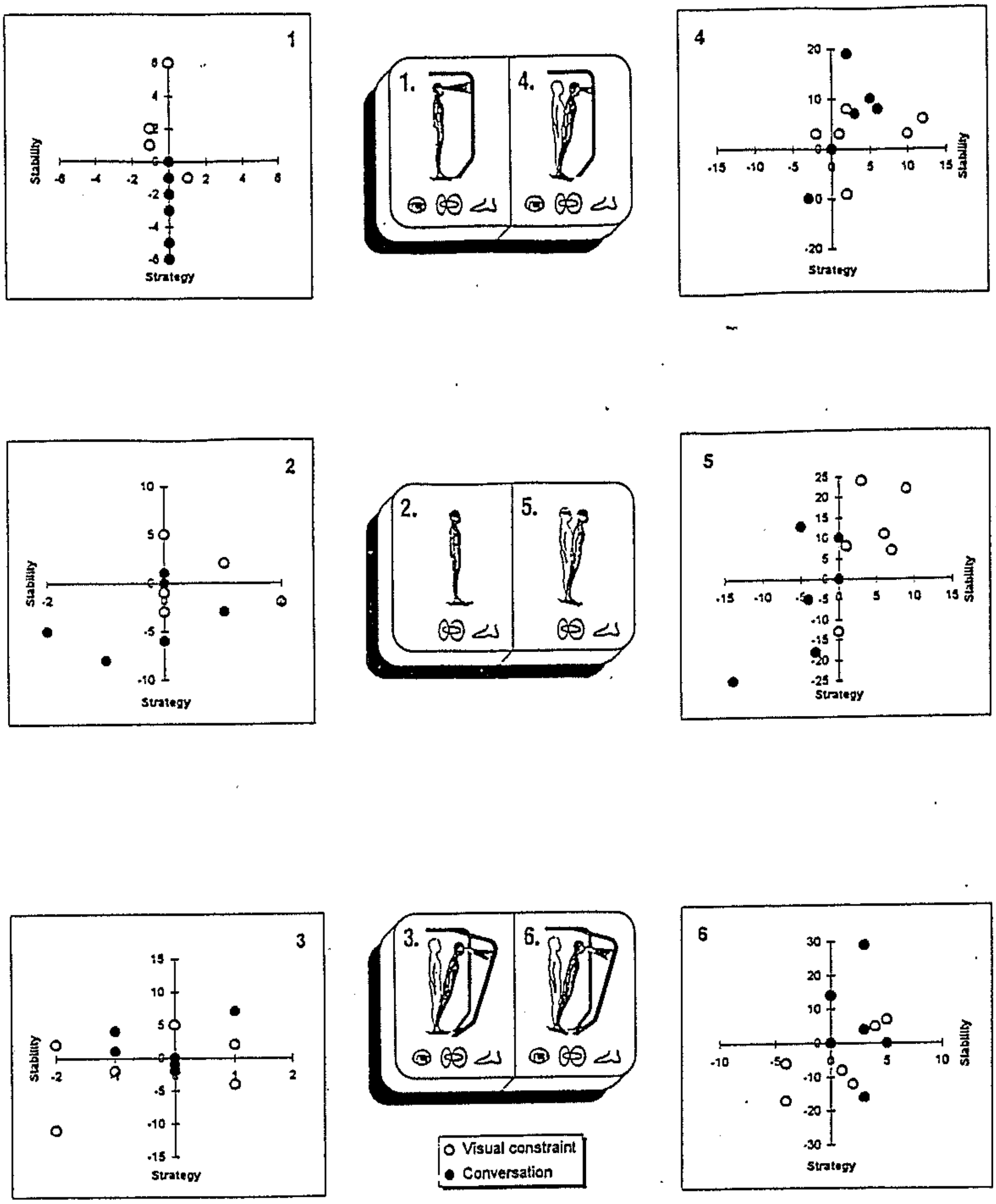

Figure 9. Difference graphs of visual constraint versus control. (Illustration from "On balance, no system is better than EquiTest" by NeuroCom, 1987, Clackamas: NeuroCom. Copyright 1987 by NeuroCom. Reprinted by permission.)

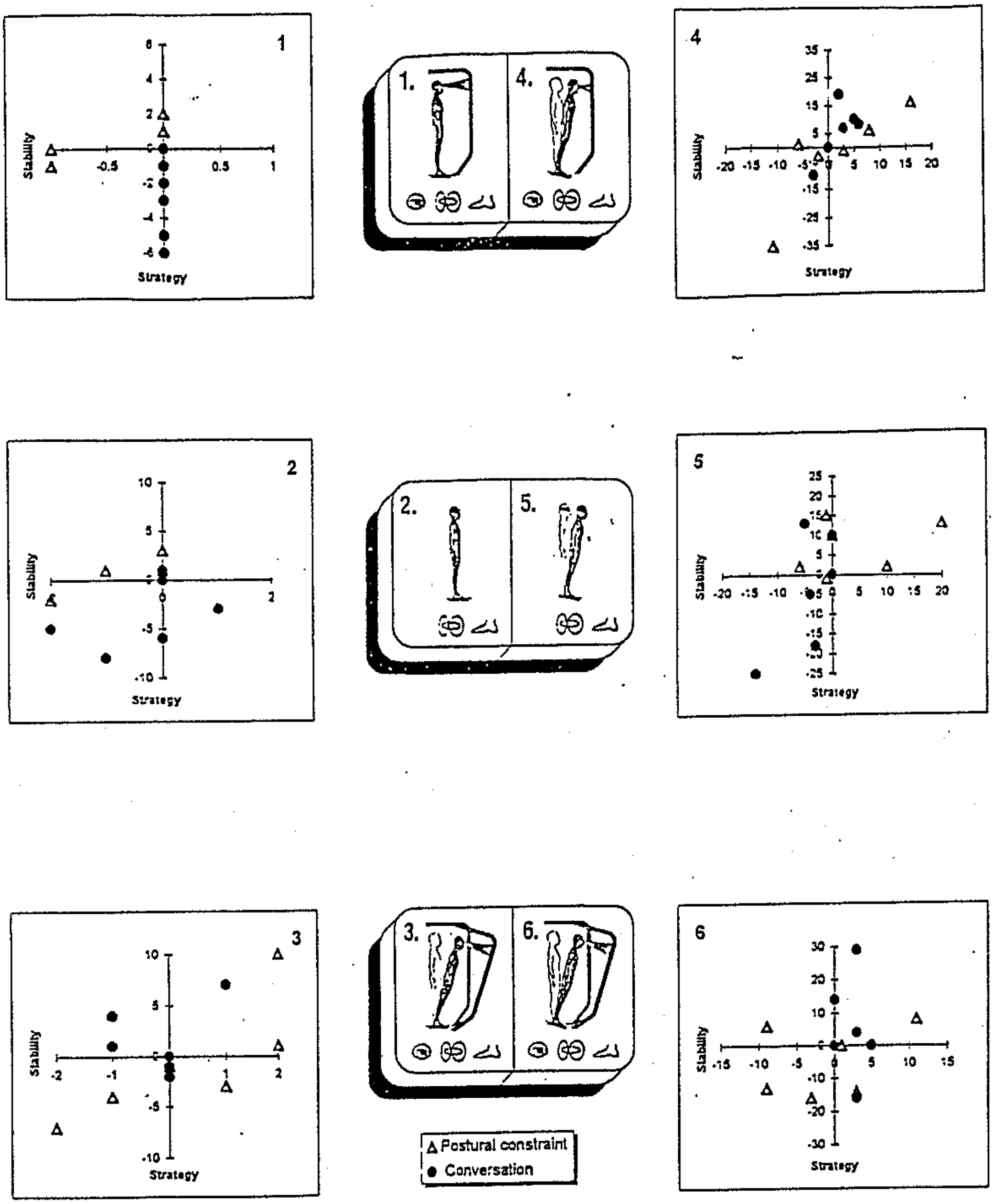

Figure 10. Difference graphs of postural constraint versus control. (Illustration from "On balance, no system is better than EquiTest" by NeuroCom, 1987, Clackamas: NeuroCom. Copyright 1987 by NeuroCom. Reprinted by permission.)

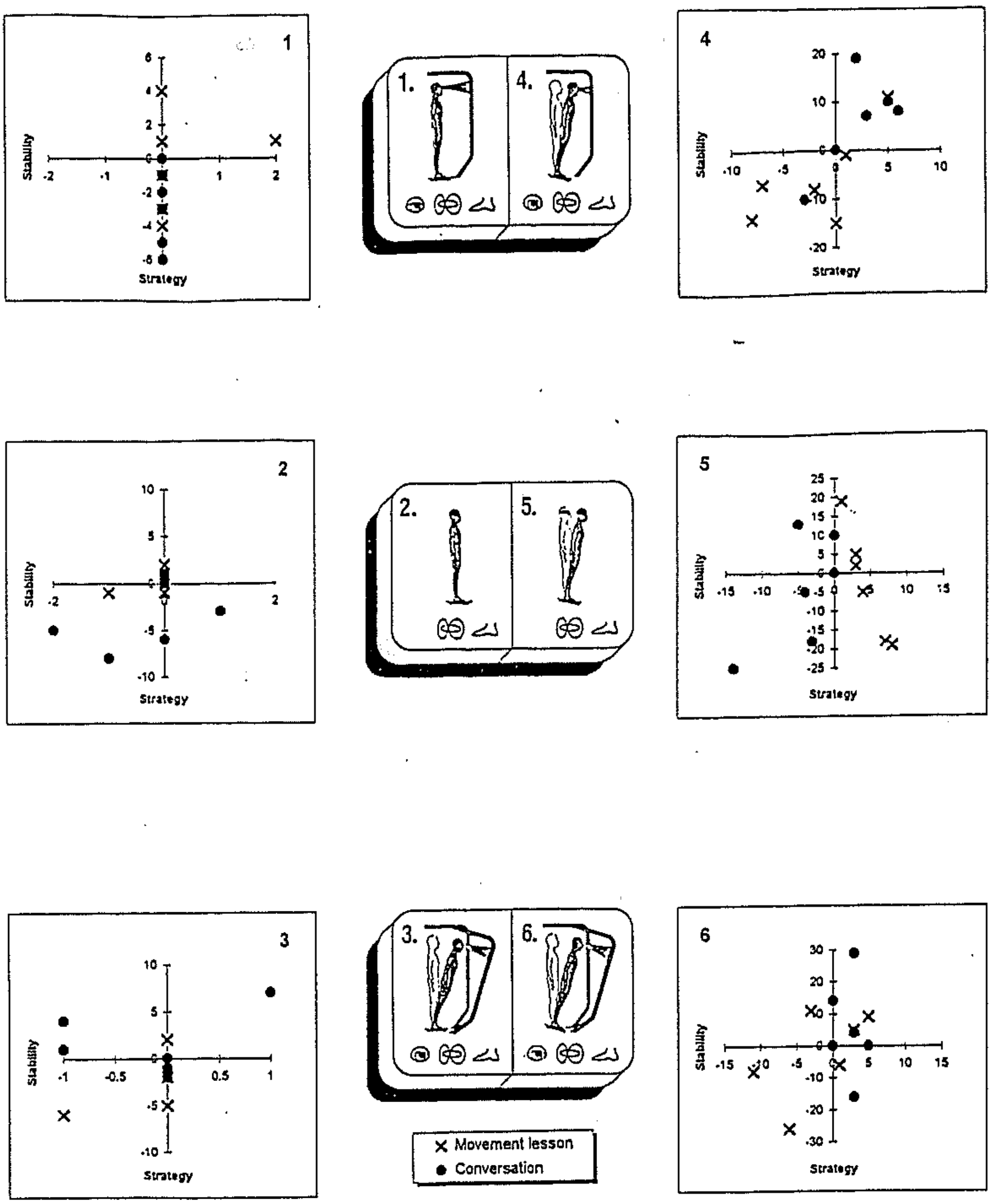

Figure 11. Difference graphs of movement lesson versus control. (Illustration from "On balance, no system is better than EquiTest" by NeuroCom, 1987, Clackamas: NeuroCom. Copyright 1987 by NeuroCom. Reprinted by permission.)

Table 18

Wilcoxon Signed Rank Test: Visual Constraint

Sensory Test	Stability		Strategy	
	Z	2-tailed P	Z	2-tailed P
EO	-.9439	.3452	-.5345	.5930
EC	-.2097	.8339	-1.3416	.1797
SV	-.3145	.7532	-.9439	.3452
EO/SS	-.9435	.3454	-1.5724	.1159
EC/SS	-1.3628	.7532	-.2.0226	.0431
SV/SS	-1.3628	.1730	-.5241	.6002

Table 19

Wilcoxon Signed Rank Test: Postural Constraint

Sensory Test	Stability		Strategy	
	Z	2-tailed P	Z	2-tailed P
EO	-1,3484	.1775	-1.3416	.1797
EC	-.7338	.4631	-.3651	.7150
SV	-.6290	.5294	-.5394	.5896
EO/SS	.0000	1.0000	-.3145	.7532
EC/SS	-1.9917	.0464	-.4045	.6858
SV/SS	-1.2136	.2249	-1.2579	.2084

Table 20

Wilcoxon Signed Rank Test: Movement Lesson

Sensory Test	Stability		Strategy	
	Z	2-tailed P	Z	2-tailed P
EO	-.2097	.8339	-1.0000	.3173
EC	-.2697	.7874	-1.3416	.1797
SV	-1.7821	.0747	-1.0000	.3173
EO/SS	-.3145	.7532	-.9439	.3452
EC/SS	-.3145	.7532	-2.2014	.0277
SV/SS	-.1048	.9165	-.6290	.5294

Table 21

Wilcoxon Signed Rank Test: Conversation Control

Sensory Test	Stability		Strategy	
	Z	2-tailed P	Z	2-tailed P
EO	-.6742	.5002	.0000	1.0000
EC	-1.2136	.2249	-.8018	.4227
SV	-.8090	.4185	-.5345	.5930
EO/SS	-1.0787	.2807	-1.3484	.1775
EC/SS	-.6742	.5002	-1.8257	.0679
SV/SS	-7303	.4652	-1.8257	.0679

Observer Evaluations

Tables 22, 23, 24, and 25 present the raw observer data[21] and Tables 26 and 27 present the difference data (for Observers One and Two, respectively).

Table 22
<u>Observer One data</u>

Subject	Order	Quality 2-1	Pattern 2-1	Quality 3-2	Pattern 3-2
1	N-V-P	1	-1	1	-1
2	N-V-M	1	2	-1	1
3	N-V-C	0	0	0	1
4	N-M-V	0	0	1	1
5	N-M-P	1	2	-1	0
6	N-M-C	1	1	xxx	xxx
7	N-P-C	-1	0	0	0
8	N-P-M	0	0	xxx	xxx
9	N-P-V	xxx	xxx	1	0
10	N-C-P	0	1	0	0
11	N-C-M	0	0	1	2
12	N-C-V	0	0	-1	0

Table 23
<u>Observer Two data</u>

Subject	Order	Quality 2-1	Pattern 2-1	Quality 3-2	Pattern 3-2
1	N-V-P	1	-1	1	2
2	N-V-M	2	2	0	1
3	N-V-C	1	0	0	1
4	N-M-V	0	0	0	1
5	N-M-P	1	2	0	-1
6	N-M-C	1	1	xxx	xxx
7	N-P-C	1	-1	0	0
8	N-P-M	0	0	xxx	xxx
9	N-P-V	xxx	xxx	1	0
10	N-C-P	1	1	0	0

[21]The "xxx" represents places where because of equipment problems or experimenter error the test was not performed and, therefore, no score could be reported.

11	N-C-M	0	1	1	1
12	N-C-V	1	1	0	0

Table 24
Observer Three data

Subject	Order	Quality 2-1	Pattern 2-1	Quality 3-2	Pattern 3-2
1	N-V-P	1	1	1	1
2	N-V-M	1	1	1	1
3	N-V-C	0	0	0	0
4	N-M-V	1	0	1	1
5	N-M-P	1	2	2	2
6	N-M-C	1	1	xxx	xxx
7	N-P-C	1	0	1	1
8	N-P-M	1	0	xxx	xxx
9	N-P-V	xxx	xxx	1	1
10	N-C-P	1	0	1	1
11	N-C-M	1	0	1	2
12	N-C-V	1	0	1	1

Table 25
Observer Four data

Subject	Order	Quality 2-1	Pattern 2-1	Quality 3-2	Pattern 3-2
1	N-V-P	1	1	1	1
2	N-V-M	1	1	1	1
3	N-V-C	0	0	0	0
4	N-M-V	1	1	1	1
5	N-M-P	2	2	1	1
6	N-M-C	1	1	xxx	xxx
7	N-P-C	0	1	1	1
8	N-P-M	0	1	xxx	xxx
9	N-P-V	xxx	xxx	1	1
10	N-C-P	1	1	1	1
11	N-C-M	0	0	1	1
12	N-C-V	1	1	1	0

Table 26
Qualitative difference scores—Observer One

Observer 1			Quality				Pattern			
Subject	Order	Comparison	Position constraint	Converse. control	Visual constraint	Movement lesson	Position constraint	Converse. control	Visual constraint	Movement lesson
1	N-V-P	2-1			1				-1	
2	N-V-M	2-1			1				2	
3	N-V-C	2-1			0				0	
4	N-M-V	2-1				0				0
5	N-M-P	2-1				1				2
6	N-M-C	2-1				1				1
7	N-P-C	2-1	-1				0			
8	N-P-M	2-1	0				0			
9	N-P-V	2-1								
10	N-C-P	2-1		0				1		
11	N-C-M	2-1		0				0		
12	N-C-V	2-1		0				0		

1	N-V-P	3-2	1				-1			
2	N-V-M	3-2				-1				1
3	N-V-C	3-2		0				1		
4	N-M-V	3-2			1				1	
5	N-M-P	3-2	-1				0			
6	N-M-C	3-2								
7	N-P-C	3-2		0				0		
8	N-P-M	3-2								
9	N-P-V	3-2			1				0	
10	N-C-P	3-2	0				0			
11	N-C-M	3-2				1				2
12	N-C-V	3-2			-1				0	

Table 27
Qualitative difference score—Observer Two

Observer 2			Quality				Pattern			
Subject	Order	Comparison	Position constraint	Converse. control	Visual constraint	Movement lesson	Position constraint	Converse. control	Visual constraint	Movement lesson
1	N-V-P	2-1			1				-1	
2	N-V-M	2-1			2				2	
3	N-V-C	2-1			1				0	
4	N-M-V	2-1				0				0
5	N-M-P	2-1				1				2
6	N-M-C	2-1				1				1
7	N-P-C	2-1	1				-1			
8	N-P-M	2-1	0				0			
9	N-P-V	2-1								
10	N-C-P	2-1		1				1		
11	N-C-M	2-1		0				1		
12	N-C-V	2-1		1				1		
1	N-V-P	3-2	1					2		
2	N-V-M	3-2				0				1
3	N-V-C	3-2		0					1	
4	N-M-V	3-2			0		1			
5	N-M-P	3-2	0					-1		
6	N-M-C	3-2								
7	N-P-C	3-2		0					0	
8	N-P-M	3-2								
9	N-P-V	3-2			1		0			
10	N-C-P	3-2	0					0		
11	N-C-M	3-2				1				1
12	N-C-V	3-2			0		0			

Subjective Reports

Following their participation in the experiment, the subjects were interviewed. Following each intervention in which the subjects participated, they were asked if they noticed any improvement in balance during either the weight shift task or the SMART Balance Master tests. The results of this part of the interview process are presented in the following table;[22] their answers to other questions are discussed in the Results section and presented in Appendix Three.

Table 28
Subjective report summary

Subject	First intervention	Change noted?	Second intervention	Change noted?
One	Visual constraint	No	Physical constraint	No
Two	Visual constraint	No	Movement lesson	Yes
Three	Visual constraint	xxx	Conversation	xxx
Four	Movement lesson	Yes	Visual constraint	No
Five	Movement lesson	Yes	Physical constraint	No
Six	Movement lesson	Yes	Conversation	No
Seven	Physical constraint	No	Conversation	No
Eight	Physical constraint	No	Movement lesson	Yes
Nine	Physical constraint	Yes	Visual constraint	Yes
Ten	Conversation	No	Physical constraint	Yes
Eleven	Conversation	No	Movement lesson	Yes
Twelve	Conversation	No	Visual constraint	No

[22] The "xxx" represents places where because of equipment problems or experimenter error the test was not performed and, therefore, no score could be reported.

DISCUSSION

This experiment did not have the results expected. It was assumed that the postural strategy of subjects who participated in the movement lesson would shift towards a hip strategy and that their stability scores would improve. If anything, the effects are the opposite of what I expected: less "stability" and more "ankle strategy" for the interventions compared to the "conversation" control.

While initially surprising, this outcome made some sense after considering the results. These results may mean that the interventions affected the dynamics of the subject's movements but the subjects did not know how to incorporate those changes into their action. In other words, the interventions made the subjects less stable and less sure, which they responded to by further constraining their freedom of movement and relying upon an ankle strategy more. This may mean that initially changes in dynamics are difficult to incorporate into motion and therefore they are somehow resisted. This finding is consistent with the theoretical claim that individuals learning a new skill freeze degrees of freedom, which means that the movement lesson did successfully teach a new postural strategy.

The initial test SMART Balance Master test was repeated twice based on the assumption that this repetition would eliminate any learning effect, as has been demonstrated with a clinical population with balance problems. It may be that normal subjects have such stable balance strategies that the intervention had little or no effect. In other words, a ceiling effect was shown. Individuals with balance problems may show different responses, therefore the experiment should be repeated with them.

It may have also been the case that the close, parallel stance imposed on the subjects by the SMART Balance Master equipment structure and standardized procedures were so different from the subjects' normal standing position and from the position used in the interventions that it interfered with their balance. Since a narrow base of support is inherently more unstable that a wide one, the change in stance is another variable that may have led subjects to adopt a less flexible postural strategy. Another problem might have been that both the SMART Balance Master test and the weight shifting task (videotaped for the observers) were conducted in a parallel stance, unlike the experimental conditions, which used the cross-legged stance. This means that a change in balance strategy would have required transfer of learning from one position to the other. As suggested by the preponderance of research experience in transfer of learning (Carr & Shepherd, 1987; Gordon, 1987), different results might have been obtained if the test movements were done in the same position as the interventions.

There are at least three reasons why the results of the observer studies proved unreliable: 1) The test might better have involved weight-shifting in the cross-legged rather than parallel stance; then transfer would not have been an issue. 2) The camera angle, which looked directly at the subject's backside, was not ideal. Shooting at an obtuse angle would have provided a different view of the subject and perhaps revealed more than a straight-on back view. 3) The directions given to the observers probably skewed their expectation to anticipate that changes would be observed. Also, one of the observers had some idea about which interventions were done by which subjects and this could have influenced the scoring.

The individual difference commented on repeatedly by the observers may also account for the difficulty in finding significant results. Both the quantitative and qualitative methods necessarily required an analysis that reduced the description of the subjects' complex behavior to a few abstract variables. Perhaps another experimental approach, such as three-dimensional motion analysis, would have taking these differences into account.

The experimental evidence showed that the measurement methods relied upon could not detect difference between the conditions. Yet these measurements are rather gross compared to the nuanced perceptions that movement teachers and therapists rely upon regularly. Empirical evidence gained from clinical experience suggests that there are clear differences between the conditions, differences in movability that might be detected with manual contact and exploratory movement. The kinds of variables investigated in an experimental study are nowhere near as complex and multidimensional as the strategies and techniques used in movement re-education, as detailed in Chapter Four and the Epilogue. This presents a challenge for the future in terms of finding ways of measuring what therapists notice and do, on the one hand, and finding ways of enriching what scientists investigate, on the other hand.[23]

The interviews proved fascinating on several counts. Several subjects confirmed the importance of vision in ordinary movement, noting that eyes-closed condition was the most difficult. Every subject who participated in the movement lesson reported the lesson led to an improvement in balance. Most demonstrated this change in the non-verbal behavior during the interview process, first moving in an undifferentiated way and then shifting to moving in a multi-segmented way. None of the subjects who participated in the movement lesson reported noticing any changes from the other interventions, though some who did not do the lesson reported that other interventions, particularly the physical constraint, improved their balance. This may mean the movement lesson had such a powerful kinesthetic effect that it masked any changes from other interventions.

What is most fascinating is the incredible individual differences that underlie the statistics. It is quite clear from the video tapes of the pre- and post-tests and of the interviews that each subject responded to the interventions differently, especially the movement lesson. Some of the subjects demonstrated a considerable change in movement ability and talked about significant changes in their body awareness. Others

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[23]Rating scales have been found to be reliable measures of certain aspects of human movement, *see* for example Sprague, Korach, van Emmerick, & Newell (1993). This study clearly demonstrates that human beings are able to reliably report on specific aspects of human movement and that these reports can be correlated with data from kinematic studies.

barely noticed any change. One subject had extreme difficulty maintaining her balance during the initial SMART Balance Master test and was the only person to hold on to the safety straps between trials. This subject was the only one to complain of feeling awkward and uncomfortable. Another talked about noticing how it was difficult to stand with one leg crossed in front without falling to the side but that the other crossing was not problematic. (In fact, she engaged the experimenter in lengthy discussion to figure out why this was the case.) Two subjects reported having slight back discomfort during the movement lesson, though neither complained of any lasting discomfort. These differences speak to the background and experience of each of the subjects, suggesting that future projects based on a more in-depth interview process would prove interesting and useful. It is interesting to consider what correlations could be made between kinesthetic self-perception and response to the interventions. Are some people pre-disposed to finding benefit in this approach and others not? What differentiates them?

Appendix Two

The following is the text of the movement lesson from which the material on the audio tapes was derived (Goldfarb, 1992a):

Notice how you are standing.

How is your right foot making contact with the floor?

Where is the most contact? On the heel? The ball of the foot?

Where is the least contact?

Is there more contact on the outside of your right foot? Or the inside?

How is your left foot making contact with the floor?

Where is the most contact? Where is the least contact?

Is there more contact on the outside of your left foot? Or the inside?

Is your weight evenly distributed over both feet?

If not, on which foot do you have more weight?

How do you know?

Can you sense any differences between your right and left legs, buttocks, or back?

Cross your right leg in front of your left leg and place it on the floor to the left of your left foot.

Shift your weight from your left leg to your right.

How does your right leg accept the weight?

From where did you initiate this motion? How did you accomplish it?

Shift your weight to your left foot.

Are your thighs pressing against each other or are your knees locked together?

Repeat the movement of shifting your weight from your left foot to your right and back, many times.

Can you breathe while shifting your weight?

Make this movement slow and easy.

Stop, bring your legs back to parallel, and rest, standing.

Once again, cross your right leg in front of your left leg and place it on the floor to the left of your left foot.

Shift your weight from your left leg to your right.

Slowly, shift your weight to the front of your right foot and then shift back your whole foot.

Repeat this movement many times, making it smooth and continuous.

What happens with your right foot when your weight shifts forward?

Does your whole body move forward as one piece or do you move just your pelvis?

Can you try it both ways?

Pause for a few moments.

Return to the position with your right leg crossed in front of, and to the left of, your left leg.

Shift your weight onto your right foot.

Slowly, shift your weight to the back of your right foot and then return to supporting your weight over your whole right foot.

Repeat this movement several times, gently and smoothly.

Does your whole body move forward or just your pelvis?

Can you try it both ways?

Now shift your weight forward and back on your right foot.

Do you notice how the rest of yourself is moving?

Stop, uncross your legs, and notice how your weight is distributed on your feet.

Rest, standing or sitting.

Again, cross your right leg in front of your left leg and place it on the floor to the left of your left foot.

Slowly shift your weight from your left leg to your right and back.

Notice how you do this movement: Are your knees pressing together or are your legs moving separately from one another?

Repeat the movement many times, keeping your thighs pressed together.

How does this effect the motion of ankles, hips, and back?

Pause.

Return to the previous position and motion.

Continue the movement of shifting your weight between your right and left feet, but now without pressing your thighs together.

How does your movement change?

Is your body moving as a solid piece? Or are you moving in a differentiated fashion?

Does your head move right and left? Forward and back?

Can you find a way to do this movement so that your head in one place and your body moves underneath?

Think of a juggler balancing a spinning plate on top of stick: the plate stays more or less in one place in space and the juggler moves the stick underneath to keep the plate balanced.

Think of your head as the plate and your pelvis as the base of the stick, so that your pelvis is doing the majority of the movement and your head is remaining relatively still.

Stop, lie down and rest.

Return to standing.

Notice how your contact is distributed over your feet now.

Cross your left leg in front of your right leg and place it on the floor to the right of your right foot.

Shift your weight from the back of your right foot to your whole foot, and back, many times.

Pause for a moment.

Shift your weight from the front of your right foot to your whole foot, and back, many times.

Increase the range of your movement, shifting your weight from the back of your right foot to the front of your right foot and then back many times, gently and slowly.

Notice how the rest of yourself is participating in the action.

Continue by moving your body a whole piece and notice how your head moves.

Now continue the movement, minimizing the movement of your head and finding a way to allow your pelvis and spine to move freely.

Stop and rest.

Again, cross your left leg in front of your right leg and place it on the floor to the right of your right foot.

Shift your weight onto your left leg.

Keeping your weight over your left leg, gently shift it from the back of your left foot to your whole foot, and back, many times.

Pause.

Shift your weight from the front of your left foot to your whole foot, and back, many times.

Increase the range of your movement, slowly shifting your weight from the back of your left foot to the front of your left foot and back many times.

Can you do this by moving your body as a whole piece?

Continue shifting your weight, but minimize the movement of your head by allowing your pelvis and spine to move freely.

Stop and rest.

Cross your left leg in front of your right leg, placing it to the right of and in front of your right foot.

Shift your weight from your right foot and leg to your left foot and leg, and back.

Find a way to do this so that your head stays relatively still and your pelvis moves.

Repeat the movement many times, allowing your breathing to continue without interruption.

Pause for a moment.

Cross your left leg in front of your right leg, placing your left foot to the right, and in front, of your right foot.

Shift your weight from the front of your leg foot to the back of your left foot, then to the back of your leg foot, and then to the front of your right foot.

Continue, moving your weight around the bottom of your feet in this clockwise circular pattern.

Pause.

Return to this movement, changing the direction of your movement to shift your weight in a counter-clockwise fashion.

Stop. Uncross your legs and notice how you are standing now.

How is your right foot making contact with the floor?

Where is the most contact? On the heel? The ball of the foot?

Where is the least contact?

Is there more contact on the outside of your right foot? Or the inside?

How is your left foot making contact with the floor?

Where is the most contact? Where is the least contact?

Is there more contact on the outside of your left foot? Or the inside?

Is your weight evenly distributed over both feet?

If not, on which foot do you have more weight?

How do you know?

Can you sense any differences between your right and left legs, buttocks, or back?

Shift your weight right and left, noticing how you move now.

Appendix Three

The following is the transcription of the interviews with each subject. Answers to questions about whether they noticed any changes following each intervention are reported in Table 28 above; here only comments about their participation in the experiment are reported. Since many subjects did not notice any change and, therefore, had no answer to the questions they were asked, only those times that subjects made comments or reported on their observations are reported here:

<u>Subject 1</u>

When asked what was noticed during the test movement after the interventions: "I felt some improvement in my lateral weight shift after you held my head."

<u>Subject 2</u>

When asked what was noticed during the initial tests: "I felt like I tended to lock my knees and stay pretty rigid."

When asked what was noticed during the test movement after the lesson: "I felt like I had a little more movement in my pelvis. I started to lock my knees but then I was able to relax and try to move someplace else."

When asked to what this difference could be attributed: "Trying to feel the difference between how I was shifting my weight with my whole body as opposed to keeping my head still and move my pelvis around. "

<u>Subject 3</u>

[Due to equipment problems, no interview data is available for this subject.]

Subject 4

General comments, when asked to reflect on experiment: "I was thinking about things I should be doing to be more aware, such as realizing what my knees were doing or noticing my breathing. The lesson gave me stuff to think about, helped me relax. My back got sore during lesson, but it didn't last."

When asked what changed overall after the lesson: "I felt like I was moving a little more comfortably at the end. . . I found it difficult, I mean, doing so many things because I was trying, like, to be aware, like, is my pelvis moving and am I moving as one? And when I shifted my weight I was trying to think about it."

Subject 5

When asked to describe to what the changes could be attributed: "You become, after the lesson, you just become more observant inwardly, you know. You're able to know and to pay attention to what's going on, especially with your pelvis. I paid a lot of attention to what my hip was really doing. Before I never paid any attention to, you know, whether my hip was moving. I was just trying, you know, I was just trying to move my legs."

When asked what caused the changes: "My body awareness. Me paying attention to the feedback mechanisms that were always going to my brain. Never paid attention to them before."

Subject 6

General comments about the SMART Balance Master *test:* "It was like, awkward, the first time I did it. First time I did it I didn't know what my body actually does."

When asked what changed: "I learned to pay attention to my body. When screen moved, I used my pelvis."

When asked made those changes: "Being aware."

Unsolicited comment about lesson: "I felt some low back soreness immediately after lesson."

Subject 7

When asked about the process: "It (the SMART Balance Master test) most difficult with eyes closed."

Subject 8

When asked what about doing the movement lesson accounted for the changes noticed:

"Definitely keeping the head still while moving the pelvis and thinking about the movement."

Subject 9

When asked about the process: "The eyes closed test was hardest. . . I felt that I warmed up with repeated tests and that I could cue in better."

Subject 10

When asked about the process: "The test without vision was harder."

When asked whether any changes were brought about by the interventions: "Weight shifting from side to side with my head held brought my awareness to where my lower back was in space and I was able to use that as an extra compensating factor."

When asked what could explain the change in movement noticed: "Just the awareness that I could use those joints to compensate for my center of balance."

Subject 11

When asked for general comments: "Doing the test with my eyes closed was difficult. . . Another thing, when I crossed my right over my left that was fine but when I did it the other way I kept falling to my right."

When asked if balancing improved: "The first few times I was concentrating, the last time I thought, I'll just do whatever. When you told me to sway at the beginning, I tried to do it without moving my head when the floor moved."

When asked what made the movement better after the lesson: "(The lesson) made me more aware of what parts of my body I use to keep my balance."

Subject 12

When asked for general comments: "I swayed more than I would have anticipated. . . mostly with my eyes closed."

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NeuroCom International, Inc. (1994b). *Smart and Pro: The Pro and SMART Balance Master Systems.* Clackamas, OR: NeuroCom, International, Inc.

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Riccio, G. E., & Stoffregen, T. A. (1988). Affordances as constraints on the control of stance. *Human Movement Science,* **7**, 265-300.

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von Foerster, H. (1984). On constructing a reality. In *Observing systems* (2nd ed.) (pp. 233-309). Seaside, CA: Intersystems Press.

von Holst, E., & Mittelstaedt, H. (1980). The reafference principle. In C. R. Gallistel (Ed.): *The organization of action* (pp. 176-209). Hillsdale, NJ: Lawrence Erlbaum Associates.

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Witkin, H. A., & Wapner, S. (1950). Visual factors in the maintenance of upright posture. *American Journal of Psychology*, **63**, 31-50.

Curriculum Vitae

LAWRENCE WM. GOLDFARB, MS

Born:	31 July 1958 in Paris, France
Citizenship:	French & American, by birth

Employment

4/92-present	Program Administrator and Educational Co-Director, Strasbourg International Feldenkrais Training; Strasbourg, France
1/91-5/93	Visiting Lecturer, Department of Kinesiology, University of Illinois; Champaign-Urbana, IL
4/90-8/90	Adjunct Therapist, Apex Physical Therapy Center; San Francisco, CA
2/87-8/89	Adjunct Therapist, Marin Spine & Orthopedic Center; Kentfield, CA
7/87-9/88	Adjunct Therapist, Physical Therapy Department, Calif. College of Podiatric Medicine; San Francisco, CA
6/87-12/90	Feldenkrais Teacher, Tamalpais Community Education District; Mill Valley, CA
1/86-7/86	Adjunct Consulting Specialist, Santa Cruz Spinal Care Center; Santa Cruz, CA
5/85-4/88	Feldenkrais practitioner, Fleming Physical Therapy Clinic; Santa Cruz, CA
9/83-8/86	Faculty, Twin Lakes College; Santa Cruz, CA
9/83-present	Private Feldenkrais practice Santa Cruz, Mill Valley & San Francisco, CA and then in Champaign, IL
9/82-present	Founder, Mind In Motion, an international movement and education consulting firm (*for courses, see below*)
9/81-6/83	Instructor, Office of Physical Education & Recreation, University of California at Santa Cruz; Santa Cruz, CA
5/81-12/84	Neurolinguistic Programming (NLP) trainer, leading courses in the US, Canada & Europe
12/78-1/80	Job Counselor, Hospitality House; San Francisco, CA

Academic Education

1/91-present	Kinesiology Department, Ph.D. candidate (January 1995 graduation), University of Illinois at Urbana-Champaign
8/84-8/90	Cybernetic Systems, Masters of Science, San Jose State University, Thesis title: *Articulating Changes;* San Jose, CA
9/80-6/84	Psychobiology, Bachelor of Arts, University of California at Santa Cruz, Thesis Title: *Sensory Syntax;* Santa Cruz, CA
9/76-5/78	Biology and Psychology undergraduate, Amherst College; Amherst, MA
9/72-6/76	G. Ray Bodley High School; Fulton, NY

Academic Honors

5/86	Distinction in MS Comprehensive Exam, San Jose State University
6/84	Honors in Psychobiology Thesis, University of California at Santa Cruz
7/81	President Undergraduate Fellowship, highest University of California system-wide award
12/80	Chancellor's Award, University of California at Santa Cruz
6/76	High School Diploma with Honors, G. Ray Bodley High School; Fulton, NY.
5/76	Regents Scholarship, New York State Regents

Professional Certification

11/94	Feldenkrais Trainer, Training Accreditation Board
5/90	Assistant Feldenkrais Trainer, Training Accreditation Board
8/83	Feldenkrais Practitioner, Feldenkrais Institute
5/80	NLP Master Practitioner, Division of Training & Research
8/84	NLP Practitioner, Division of Training & Research

Professional Training

8/10-88	Texts in Cybernetics; Felton, CA
2-88	Functional Orthopedics I, myofascial course with Gregg Johnson and staff of the Institute of Physical Art, San Francisco, CA
6/85	Ergonomic Analysis, Center for Ergonomics, University of Michigan at Ann Arbor; Ann Arbor, Michigan
10/84-12/90	Extended study with Heinz von Foerster in Cybernetics and learning; Pescadero, CA
10/84	Alexander Technique for Feldenkrais Teachers, course with Marjorie Barstow; Lincoln, Nebraska
8/84-present	Ongoing Advanced training in the Feldenkrais Method with Anat Baniel, Elizabeth Beringer, Carl Ginsburg, Dennis Leri, Myriam Pfeffer, Mark Reese, & Gaby Yaron.
3/83	Ericksonian Hypnosis, course with Steve Gilligan; Berkeley, California
3/82	NLP Trainer's Training with Richard Bandler & John Grinder, Division of Training & Research, Not Ltd.; Santa Cruz, California
2/82	Hypnosis & NLP workshop, Richard Bandler & David Dobson, Division of Training & Research, Not Ltd.; Santa Cruz, California
10/81	Metaphor workshop with David Gordon, Division of Training & Research, Not Ltd.; Santa Cruz, California
8/81	NLP Master Practitioner Training with Robert Dilts, John Grinder and Richard Bandler, University of California at Santa Cruz; Santa Cruz, CA
12/80-8/83	Feldenkrais Professional Training Program with Moshe Feldenkrais and assistants; Coto Sports Research Center (Winter '80/81) in El Toro, CA and Hampshire College (Summer '81, '82 & '83) in Amherst, MA
10/80	Strategies for Change with Robert Dilts, Division of Training & Research, Not Ltd.; Santa Cruz, CA
7/80	NLP Practitioner Training with John Grinder, Judith Delozier, Richard Bandler, Leslie Cameron-Bandler, Robert Dilts and David Gordon, University of California at Santa Cruz; Santa Cruz, CA
9/79-11/79	Clinical Hypnosis Training with Steve Gilligan and Paul Carter, META Institute; San Francisco, CA
3/79-6/79	Massage Practitioner Training, California Institute for Massage; San Francisco, CA
4/79	Contact Improvisation with Nancy Stark Smith, Project Artaud; San Francisco, CA

1/79	Contact Improvisation & Skinner Releasing Technique with Mangrove, Project Artaud; San Francisco, CA
4/78	Gestalt Therapy training with Marty Fromm, New England Center; Amherst, MA
1/78-6/78	Bioenergetics Training group with Paul Cohen, New England Center; Amherst, MA
9/77-6/78	Clinical Transactional Analysis Training group with Ed and Nan Gurowitz, Vermont Institute for Transactional Analysis; Burlington, VT
9/77-5/78	Peer Counselor Training, Room-to-Move/School of Psychology, University of Massachusetts at Amherst; Amherst, MA
7/77-8/77	Gestalt and Transactional Analysis Training with the staff of the New England Center; Amherst, MA
9/76-6/77	Group Facilitator Training, Intergroup Relations Committee, Amherst College; Amherst, MA
7/76-8/76	Mime training, Rochester Mime Theatre; Rochester, New York

Courses, lectures and workshops

Please note: The following list does not include the nearly one hundred in-service presentations and lectures provided to clinics, hospitals & universities over the years.

1994

A Course of Change; Munich, Germany
A Course of Change; Champaign, IL
A Course of Change; Champaign, IL
Assistant Trainer; Feldenkrais Professional Training; Bronxville, NY
Assistant Trainer; Feldenkrais Professional Training; Montreal, QC
Assistant Trainer; Feldenkrais Professional Training; Strasbourg, France
Assistant Trainer; Feldenkrais Professional Training; Strasbourg, France
Assistant Trainer; Feldenkrais Professional Training; Strasbourg, France
Assistant Trainer; Feldenkrais Professional Training; Strasbourg, France
Back Into Action; Chicago, IL
Back Into Action; Chicago, IL
Back Into Action; New York, NY
Introduction to Feldenkrais in Pediatric Care; Washington, DC
On Your Feet; Baltimore, MD

On Your Feet; Minneapolis, MN
Pushing, Pulling & Lifting; Bern, Switzerland
Pushing, Pulling & Lifting; Honolulu, HI
Pushing, Pulling & Lifting; Los Angeles, CA
Putting It All Together, Champaign, IL
Science is catching up with us: Will we be ready? (Feldenkrais Guild Conference); Berkeley, CA
Sitting: Platform for Change; Los Angeles, CA
Upward Mobility; Innsbruck, Austria

1993

Assistant Trainer; Feldenkrais Professional Training; Bronxville, NY
Assistant Trainer; Feldenkrais Professional Training; Chicago, IL
Assistant Trainer; Feldenkrais Professional Training; Paris, France
Assistant Trainer; Feldenkrais Professional Training; Strasbourg, France
Assistant Trainer; Feldenkrais Professional Training; Strasbourg, France
Breaking Habits; Graz, Austria
Evolving Movement; Innsbruck, Austria
Foundations of Learning; Innsbruck, Austria
Inside Touch, Feldenkrais Advanced Training; Champaign, IL
Inside Touch, Feldenkrais Advanced Training; Munich, Germany
Introduction to Feldenkrais in Pediatric Care; Minneapolis, MN
Introduction to Feldenkrais in Pediatric Care; Great Neck, NY
Introduction to the Strasbourg Training; Strasbourg, France
Pushing, Pulling & Lifting; Los Angeles, CA
Pushing, Pulling & Lifting; Chicago, IL
On Your Feet; Burlington, IA
Upward Mobility; Baltimore, MD
Upward Mobility; Milwaukee, WI
Why Robots Fall Down, American Society for Cybernetics, Philadelphia, PA

1992

Advancing Teaching Methods; Chicago, IL
Assistant Trainer; Feldenkrais Professional Training; Chicago, IL
Assistant Trainer; Feldenkrais Professional Training; Los Angeles, CA
Assistant Trainer; Feldenkrais Professional Training; Vienna, Austria
Back Into Action; Boston, MA
Back Into Action; Honolulu, HI
Back Into Action; Lafayette, LA
Back Into Action; Sonoma, CA
Breaking Habits; Anandale, VA
Bridging the Gap, Feldenkrais Advanced Training; Champaign, IL
Evolving Movement; Innsbruck, Austria
Introduction to Feldenkrais in Pediatric Care; Cleveland, OH
Introduction to Feldenkrais in Pediatric Care; Innsbruck, Austria
On Your Feet; Dallas, TX
On Your Feet; New York, NY
On Your Feet; Milwaukee, IL
On Your Feet; Munich, Germany
Pushing, Pulling, & Lifting; Baltimore, MD
Pushing, Pulling, & Lifting; Big Sur, CA
Sitting: Platform for Change; Tampa, FL

1991

Assistant Trainer; Feldenkrais Professional Training; Los Angeles, CA
Assistant Trainer; Feldenkrais Professional Training; Sonoma, CA
Back Into Action; Baton Rouge, LA
Back Into Action; Nashua, NH
Back Into Action; Chicago, IL
Back Into Action; Bay Shore, NY
Breaking Habits; Holland, MI
Breaking Habits; Honolulu, HI
Feldenkrais at Work; Vienna, Austria
Introduction to Feldenkrais in Pediatric Care; Dallas, TX
On Your Feet; Dubuque, IA
On Your Feet; Innsbruck, Austria
Pushing, Pulling and Lifting; Dallas, TX
Pushing, Pulling and Lifting; Innsbruck, Austria
Pushing, Pulling and Lifting; Newington, VA
Pushing, Pulling and Lifting; Vienna, Austria
Tutorial: Training the Feldenkrais Teacher's Intuition; Champaign, IL
Upward Mobility; Clearwater, FL

Use of Feldenkrais in the Management of Arthritis; Los Angeles, CA
With Instrument in Hand: Feldenkrais for Musicians; Honolulu, HI

1990

A Healthy Back: Reclaiming Flexibility; San Francisco, CA
A Healthy Back: Reclaiming Flexibility; Paris, France
Assistant Trainer, Feldenkrais Professional Training; Rohnert Park, CA
Assistant Trainer, Feldenkrais Professional Training; Paris, France
Back Into Action; Vienna, Austria
Bay Area Movement Symposium: Keynote; Orinda, CA
Bridging the Gap; Los Angeles, CA
Bridging the Gap; Paris, France
Breaking Habits; Baton Rouge, LA
Breaking Habits; Cleveland, OH
Breaking Habits; Urbana, IL
In-Residence, Unit One Program, University of IL; Champaign-Urbana, IL
Moving in the World of Objects; Vienna, Austria
On Your Feet; Austin, TX
On Your Feet; Rochester, NY
On Your Feet; Manassas, VA
Pushing, Pulling and Lifting; Chicago, IL
Pushing, Pulling and Lifting; Tampa, FL
Pushing, Pulling and Lifting; Kensington, MD
Untold Stories; Orinda, CA

1989

An Introduction to the Cybernetics of Movement, Somathematics; San Diego & Rohnert Park, CA
Articulating Changes; San Francisco, CA
Articulating Changes, The Frankfurter Ring; Frankfurt, West Germany
Articulating Changes, Hungarian Association for Humanistic Psychology; Budapest, Hungary
Back Into Action; Rochester, NY
Back Into Action; Los Angeles, CA
Back Into Action; Austin, TX
Back Into Action; Chevy Chase, MD
Educating the Forgotten Senses, American Society for Cybernetics; Virginia Beach, VA
Feldenkrais and the Dance, Siobhan Davis & Co.; London, England
In-Residence with Bebe Miller and Co., Jacob's Pillow; Lee, MA
On Your Feet; Berkeley, CA
On Your Feet; Chicago, IL

On Your Feet; Los Angeles, CA
On Your Feet; Rehabilitation Institute of Chicago, Chicago, IL
On Your Feet; San Francisco, CA
On Your Feet, Tampa, FL
Moving Gently Forward, Arthritis Foundation; Los Angeles, CA
The Fine Art of Sitting; San Francisco, CA
The Kinesthetic Dimension; Brussels, Belgium
Working with Others, Remembering Ourselves, Bay Area Body Therapy Guild; San Francisco, CA
With a Cello in Hand, Vienna Conservatory; Vienna, Austria

1988

Back Into Action; Los Angeles, CA
Back Into Action; Milwaukee, MN
Back Into Action; Palo Alto, CA
Back Into Action; Dallas, TX
Back Into Action; Atlanta, GA
Back Into Action; Somerset, NJ
Back Into Action; Manassas, VA
Back Into Action; Tampa, FL
Breaking Habits, Mind In Motion; San Francisco, CA
Mind In Motion, Gordon Conference on Cybernetics; Santa Barbara, CA
Moving In the World of Objects; Corte Madera, CA
Sensory-Motor Learning, American Society for Cybernetics Conference; Victoria, BC
Untold Stories, University of Georgia; Athens, GA

1987

Biofeedback without Machines, San Francisco State University; San Francisco, CA
The Dimensional Framework; San Francisco, CA

1986

Back Into Action; Denver, CO
Back Into Action; Santa Cruz, CA
At The Wheel, Santa Cruz Metropolitan Transit District; Santa Cruz, CA
At The Wheel, Santa Cruz Metropolitan Transit District; Santa Cruz, CA
At The Wheel, Santa Cruz Metropolitan Transit District; Santa Cruz, CA
At The Wheel, Santa Cruz Metropolitan Transit District; Santa Cruz, CA

At The Wheel, Santa Cruz Metropolitan Transit District; Santa Cruz, CA
Ergonomics and Feldenkrais, Feldenkrais Conference; Pingree Park, CO
Evolving Movement, Open Eyes; Santa Cruz, CA
Introduction to NLP; San Rafael, CA
Language is a Movement Phenomenon, Language and Learning Conference, Dominican College; San Rafael, CA
Lifting Safely, University of California; Santa Cruz, CA
Movement for Actors, University of California; Santa Cruz, CA
Preventing Back Injury, University of California; Santa Cruz, CA
Sitting Comfortably, University of California; Santa Cruz, CA

1984

At The Wheel, Santa Cruz Metropolitan Transit District; Santa Cruz, CA
At The Wheel, Santa Cruz Metropolitan Transit District; Santa Cruz, CA
At The Wheel, Santa Cruz Metropolitan Transit District; Santa Cruz, CA
Beyond Preaching to the Converted; Feldenkrais Conference; Santa Cruz, CA
Evolving Movement; Santa Cruz, CA
The Function of Pleasure; Santa Cruz, CA
The Function of Pleasure; Nelson, BC
Introduction to NLP; Lincoln, NE
Lifting Safely, Food & Nutrition Services; Santa Cruz, CA
Lifting Safely, Food & Nutrition Services; Santa Cruz, CA
Lifting Safely, Food & Nutrition Services; Santa Cruz, CA
Movement Analysis, Twin Lakes College; Santa Cruz, CA
Movement Analysis, NLP training; Santa Cruz, CA
On Your Feet, Santa Cruz Community Credit Union; Santa Cruz, CA
Summer Dance Workshop, Cabrillo College; Aptos, CA
Team-Building, Santa Cruz County; Santa Cruz, CA

1983

Efficient Movement, Twin Lakes College; Santa Cruz, CA
Evolving Movement; LeMoyne College, NY
Evolving Movement; Santa Cruz, CA
Evolving Movement, YMCA; Syracuse
Language Creates a Direction for Experience; Nelson, BC
Mind In Motion; Boulder, CO
Mind In Motion; Santa Cruz, CA
Mind In Motion; New York, NY
Sitting Comfortably, Santa Cruz County; Santa Cruz, CA

1982

The Bodywise Approach; Amherst, MA
The Bodywise Approach; Santa Cruz, CA
Evolving Movement; Syracuse, NY
Introduction to NLP; Amherst, MA
Introduction to NLP; Paris, France
Introduction to NLP; London, England
Movement for Performers; In-residence at Syracuse University; Syracuse, NY

1981

Introduction to NLP; Amherst, MA
Introduction to NLP; Farmington, CT
Introduction to NLP; Salt Lake City, UT
Introduction to NLP; Santa Cruz, CA

Publications

Accidentally on purpose (1994) *Telekinesis*
Accidentally on purpose, part II. (1994) *Telekinesis*
A moving conversation. (1987) *Continuing the Conversation*
Another voice. (1990) *The Feldenkrais Journal*
Articulating changes. (1990) Berkeley: Feldenkrais Resources
Begin at the beginning. (1992) *The Feldenkrais Journal of England*
Begin at the beginning. (1993) *The Newsletter of the Australian Feldenkrais Guild*
Begin at the beginning. (1994) *Feldenkrais Forum (German translation)*
Begin at the beginning. (1994) *In Touch*
Back into Action. (1994) Tucson: Therapy Skill Builders
Ecoset: A conceptual tool for generating and evaluating ecological hypothesis (*in press*) *Bioscience.* (Co-written with Brock Bernstein)
Emily's new crutches. (1991) *The Feldenkrais Journal*
Emotion as action. (1988) *The Feldenkrais Journal*
Emotion as action. (1990) *Bulletin de Liaison de L'Association des Practiciens de la Methode Feldenkrais* (French translation)
Felden-WHAT? (*in press*) *Bulletin de Liaison de L'Association des Practiciens de la Methode Feldenkrais* (French translation)
Felden-WHAT? (1993) *In Touch*
Following the chain of motion. (1993) *The Feldenkrais Journal of England*
Following the chain of motion. (1994) *In Touch*
Following the chain of motion. (1994) *Feldenkrais Forum (German translation)*

Letter from the Editor. (1992) *The Feldenkrais Journal*
Tools for making research more relevant to policy: Report to the occupational research division of employee services of Southern California Edison Co. (1993) Ojai: EcoAnalysis (Co-author with Brock Bernstein and EcoAnalysis staff.)
The pattern makes the problem. (1993) *Telekinesis*
The teacher learns. (1994) *Telekinesis*
The three C's. (1992) *Lifeline*
The three C's. (1993) *Telekinesis*
Why robots fall down. (*in press*) *The Feldenkrais Journal*
Why robots fall down. (*in press*) *Bulletin de Liaison de L'Association des Practiciens de la Methode Feldenkrais* (French translation)

Professional Affiliations and Activities

Association des Practiciens de la Methode Feldenkrais.
American Society for Cybernetics.
Feldenkrais Guild.
- Board of Directors, 1984-86.
- Chair, Education Committee, 1984-86.
- Coordinator, International Conference 1984.
- Editor, *Horizons*, 1991-92.
- Editor, *Keep In Touch*, 1987.
- Editorial Board, *The Feldenkrais Journal*, 1987-89, 1993.
- Co-Editor, *The Feldenkrais Journal*, 1990-91.
- Editor, *The Feldenkrais Journal*, 1991-92.

Pacific Institute for Cybernetics (1984-86).
- Co-founder.
- Chair, Conference Committee, 1986.

Preventative Medicine Research Group (1982-84).
- Co-founder.
- Chair 1983-84.
- Co-chair, Santa Cruz Stress Awareness Week 1984.

Society for Practical Epistemology (1980-86).