

Investigations into Bodily Motion and Space through Centripetal Force

by

Irene E. Brisson

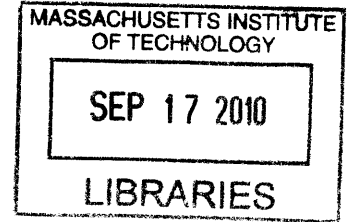
Submitted to the Department of Architecture
in partial fulfillment of the
requirements for the degree of

Bachelors of Science in Art and Design
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Abstract

The human body interacts with spatial and solid forms constantly: adapting, negotiating, and interacting. In the context of dance, set and costume design this interdependency between motion and form is given precedent whereas in architectural design, the form of space and structure is given priority over human bodies and their motions. Dance and performance artists have used designed objects to extend the spatial consequence of the body and its motions outside of the limb-defined kinesphere; artists have created sets and installations that serve as tools, as well as obstacles, for the body to negotiate.

Experimentation with weighted cloth and rope extensions explored the limits and effects of the centripetal force resulting for the orbital motion of the object on the central body. This system serves both to extend the rotation of the body further out into space and to amplify the wobble of the spinning body.

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The questioning process that is this thesis came out of a general sense that architecture could have a lot more to do with the body and its near constant states of motion than it does and vice versa. At some level architects and students are perpetually discussing bodies and the space they occupy and how they occupy it; rather, how they move in it, but somehow it is essentially detached. While environmental determinism would be a stretch, discussions do tend towards framing bodies' interactions with architecture in terms of the architecture is like this and so the body will do that. What happens if designers think first of the body inside and then the architectural space around instead of vice versa? Blown-up, frozen negatives of the body in motion are not likely to be the only solution, perhaps there are solutions that truly consider space at the two scales: body and architecture, simultaneously in a dependent and enriching way.

The human body interacts with spatial and solid forms constantly: adapting, negotiating, and interacting. In the context of dance, set and costume design this interdependency between motion and form is given precedent whereas in architectural design, the form of space and structure is given priority over human bodies and their motions. Dance and performance artists have used designed objects to extend the spatial consequence of the body and its motions outside of the limb-defined kinesphere; artists have created sets and installations that serve as tools, as well as obstacles, for the body to negotiate. This thesis proposes a series of objects, which exist between the scales of body and architecture, to amplify and modify human movement into an architectural scale where human movement creates and defines spaces larger than it.

This space, and scale, so crucial to motion and architecture is less specific than it could be. Webster's Dictionary's first definition is: "a limited extent in one, two, or three dimensions," the fourth definition is "a boundless three-dimensional extent in which objects and events occur and have relative position and direction." So space is boundless and limited; it exists between, inside things but also outside and entirely divorced from things. Boundless space is not really of our body scale though. Boundless space comes up more at the scale of the very small and the very large. At the astrophysical scale there is space, "empty" space for light years with little to no matter present at all. From the

opposite end of the spectrum, at the atomic scale distances have shrunk from light years to nanometers but the ratios of space or distance versus the size of masses continues to be extremely large. Perhaps the perspective of a proton is not so different from that of galaxy. This type of space, this ratio of mass and void is, due to the nature of our senses, generally outside untrained intuition. These spaces are at extreme edges of a scaling system centered, egotistically and quite logically around ourselves. Humans are between 10^{-1} m. and 10^2 m. The observable universe is around 10^{26} m and the hydrogen atom is at 10^{-10} m. While humans exist and can be measured against these scales, we have little to no direct sensory information about scales more than three or four in either direction from ourselves. Our sense of space is dictated by the sensitivity of our senses and the scale of our bodies.

Scales other than that of our bodies must be mediated by representation and interpretation by others and ourselves, through the methods and machines which we create, determined by the way they have been made. Even more generally, what one cannot directly perceive is understood differently from that which is directly perceived or experienced. Much like a certain video that can be found in grade school classrooms and freshman lectures at MIT that describes orders of magnitude, scale begins focused on a human or two. From that reference point the video zooms out to the projected fringes of the universe and zooms back in to the human and further to the scale of a proposed quantum soup and, finally zooms out again to a couple in a park. There is scale, and it begins and ends in relation to the human body. Space both larger and smaller can be viewed and grasped in reference to our innate sense of our own bodies and their size, shape and space.

Designing objects that delineate space for human bodies to occupy, architecture very nearly deals with this scale, except that it involves space not just for one body in one state, but for multiple bodies and multiple states. The designer's work lies perhaps between our base size, around one meter, twelve square feet, to four or five orders of magnitude greater, 120,000 to 1.2 million square feet. Of course, architectural scale is not based on absolute orders of magnitude. Rather, design functions constantly in relative scales to represent spaces much larger than ourselves at our size and smaller. The designer reduces spaces at the scale of multiple bodies, down to the scale of his hands to draw and model. As such, spaces are built for bodies, but spaces are, in a way, designed for cardboard figures, mouse cursors, our fingers or our hands. While circulation and occupation are frequent issues of consideration, the role of people and their bodies in spaces is simplified, generally, to standing upright, sitting with knees bent at right angles, leaning against walls and walking. Perhaps a shift in representation could lead to more danceable spaces, spaces where the wide potentials of fully functioning bodies are present in the design process, rather than static, vertical occupation.

Architectural notation already has a deep relationship to the body, and especially it's orientation as bodies and building, of course, both have to cooperate with gravity. Plan and section, parallel and perpendicular to ground are of course the basic planes for beginning to document motion. Even beyond the conventions of documentation, the basic units of architecture in the United States, at least retain a vestige of a system of measurement originating in the body. While perhaps feet and yards and inches are awkward, seemingly senseless and arguably inferior to the metric system, this shadowy reflection of measurement based on the dimensions of the body is arguably a link

between ourselves and the somewhat arbitrary units assigned to physical quantities. While once builders measured material and distances with their forearms (which interestingly enough are generally almost the same length as one's foot), their thumbs, their stride, etc. we now use standardized units that could have come out of average bodily dimensions. The body as measuring tool has never left though; in myriad examples of building, craft, and daily life people still use their height, width, speed, reach and more to approximate the magnitude of their surroundings. The major difference though is that where our bodies and their inherent units used to be the units, however vague, bodily dimensions are now used as references to approximate now exact, arguably exactly arbitrary, units.

Measuring with our bodies one can quickly recognize that there are particular proportions between our various body parts and long ago people began trying to find the relationships between our various lengths and create some coherent and whole logic of proportions and geometry. Perhaps the most famous old image of this thought is the da Vinci man inscribed in his height-defined square and leg length-defined circle. At best it is an ideal idea of a perfectly proportioned body, but it is a compact graphic summarizing our size, our proportions and the spatial extents of our influence. One can reach this far and that's really it if one is to maintain an ideal vertical posture. Of course human motion is hugely complex and da Vinci's man only begins to describe motion in the one plane that passes through the shoulders and hips. What happens forward and behind is an even further boggling situation which famously Rudolf Von Laban approached as he began developing a notation system for movement, particularly dance. He developed an icosahedron that described the extent of the limbs reach in three dimensions. He could

then precisely notate the mechanical motions of the body and shifts in occupation of a series of planes. Similarly, Trisha Brown developed for herself a cube with twenty seven points to capture and communicate her improvisations, as well as experiment with different processes of generating motion by assigning external information to sequences of points that the body would then be asked to occupy. Of course dance, and all movement, involves much subtle differentiation of the body which geometrical plans and sections of movement will not catch so his notation system grew to include various symbols for effort, shape, and more qualitative elements. William Forsythe has among other explorations in dance proposed the deformation of this cage. Wherein Laban's isocahedron the center of gravity and initial point of motion is at the center, Forsythe has explored the possibilities of each of the twelve vertices being axis of motion.

The potential for further exploration of the geometry of the space of and resulting from the body is clearly deep, but another line of thought could be how can these systems entirely centered on and emanating from the human body can be extended out of our scale to assist an understanding of larger spaces through on our intuitive understanding of our bodies and our personal sphere. For example, every point of the Laban cube, if the axis of the body maintains the same upright, vertical, cannot be equally occupied by each part of the body. The right hand high corner cannot be occupied by left hand the same way as it is occupied by the right; the left hand will of course fall closer to the center of the body on the same axis. Also, certain sequences of points can not be physically completed due to the simple physical fact that mass at our scale cannot pass through other mass, such as and arm penetrating another arm. So another layer of information in defining the body must be added, but these same restrictions do not apply if for example

if one proposes that the length of each equal vertice increases from around four feet to forty feet and the occupying entity is not one body but rather six, each with their own personal icosahedron, moving through this large icosahedron. If bodies are removed entirely for a period of sculptural experimentation and the occupant becomes concrete, intersections are in fact necessary. If each limb is extended with rope or some flexible material then intersections of width are still not feasible, but intersections can occur through twists and folds and a whole new set of trajectories and intersections within the, now unprioritized by sidedness, points of the icosahedron.

Possibly since humans began fashioning tools, people have been creating objects which increase the range of human effect on the world outside the individual: increasing the force we can exert by manipulating mechanical systems, increasing the speed with which we can move, increasing the distance we can reach with our bodies or in time. Particularly in theater, dance and performance art there has been both need and fascination with extending the body for both functional and aesthetic reasons. In ancient Greek drama actors for many reasons, wore cothurnus, shoes with elevating blocks attached, to increase their height and visibility to the audience as well as wearing large masks that served to both increase the legibility of facial expression and with a cone inset into the mouthpiece served to amplify their voices to reach audience members in the large outdoor amphitheaters. (Laver 16) Fastforwarding a few millennia, Loie Fuller, an early American modern dancer, patented her creation of huge, hundreds of square feet, silk skirts and dresses which she manipulated by both moving her body and using her arms to move rods encased in the fabric to activate the outer reaches of her garments. As such

her garments allowed her to literally fill an entire stage and create large complex shapes and spaces directly resulting from her movement.

Another artist who worked extensively with body extending objects was Rebecca Horn who made what she referred to as body extensions discuss different points about the body, motion, functionality and protection. (Horn, 2) In particular her series of wing-like objects including the body fan and feather arms coverings served both to expand the body outward, but also allowed her to fold them in and enclose herself. Other objects like her unicorn head-piece and head extension refer to the surrounding space as vertical and horizontal rods, respectively, project the body's posture into space. The head extension is hinged so that it dips down and up against the inclination of the hand, resulting in an amplification of changes in the body's alignment. These objects, for example, the Greek costume and Horn's unicorn head extension statically extend the size of the human body. On the other hand, Horn's body fan and Fuller's skirt and rod contraptions extend the body but in a more dynamic and responsive fashion that depends both on physical attachment and the action of forces.

Similar to the force relationships of these dynamic body extensions are objects that purposefully change the way the body does or can move by transmitting or changing forces. For example, a piece of body-jewelry by Alexander McQueen is a square frame attached just above the knees and elbows. It causes the wearer to walk much like a puppet with the rotation and lift of the shoulders dominated by the raising of the thighs and vice versa as a constant distance is maintained by the tension and compression in the frame tubing. (Evans, 144) In a simple tension situation, Elizabeth Streb has created a duet for two attached by harness and a long, elastic cord. A maximum distance cannot be

passed by the dancers and there is a range before this maximum distance wherein there is tension in the cord and their movements, especially their directionality and momentum affect the other. At a less wearable scale there are many interesting interventions in dance that are ambiguously set designs which are inextricably linked with the choreography. Particularly, the early work of Trisha Brown is fascinating for the harnesses and pulleys that allowed her and her dancers to stubbornly function perpendicular or in reverse of gravity's effect. (Goldberg, 162) In a wall walking piece performed in a loft on faux classical columns wrapped with part of the dancers sling and cable dancers were in a careful balance of force with their respective columns. The columns were incorporated into the apparently gravity defying, yet gravity dependent, situation. Also manipulating the directionality of gravity, Paula Josa Jones created a live performance piece from a video collaboration with Ellen Sebring, *Tilt*. By placing set and structured phrases on a see-saw platform with the ability to both tilt from end to end but also swing in the horizontal plane the dance evolved in response to the continuously changing relationship to gravity and acceleration. The precarious state of balance in continual flux provided inherent physical drama.

Milan Kundera's novelette, *Slowness*, tells, essentially, two stories of seduction in possibly the same French chateau separated by a couple hundred years of "progress." While he discusses cerebral notions of pleasure, conquest, and memory, he does so in very physical terms. Stillness, silence, speed, sensuality, roundness recur and bring with them their physical connotations. Kundera particularly makes a direct link between physical and mental or emotional experience making the statement that, "The degree of slowness is directly proportional to the intensity of memory; the degree of speed is

directly proportional to the speed of forgetting.” (Kundera, 39) He uses the example of a man walking down the street who will slow as he tries to remember something, and then speed up when trying to forget. He proposes that this reflects on the nature of society today, where ever increasing speed seems to be a high priority. Is society forgetting because of its speed, or is it speeding to forget something? The nature of speed has also shifted in the last century; physical speed used to be much more closely related to our own bodies. A runner, a hiker, even a horseback rider is physically conscious of the force and effort in his speed. In a car or plane the body is increasingly disconnected from the difference in velocity and effort between its and the ground’s frames of reference. Arguably detached speed loses some of the sensual response but also takes the body beyond the boundaries of self-propelled speeds and out of control in varying senses. Kundera speaks of a speeding driver when he writes that, “He is caught in a fragment of time cut off from both past and the future; he is wrenched from the continuity of time; he is outside time; in other words, he is in a state of ecstasy.” (Kundera, 2) This equation of speed and timelessness and ecstasy can be applied not just to man in the seat of mechanical speed but also to self-generated speed. Here is the departure point from Kundera’s writing into my proposal to use centripetal force to amplify the not only the body’s extent, but its motions’ affect on both foreign objects and itself.

Centripetal force is actually the acceleration of an object traveling on a circular path as a result of the constant change in direction of the tangent velocity that is perpendicular at each point to the radius of the circle. Centripetal force is, therefore, an axial force through the material that keeps the object in motion fixed to the center axis. The force is equal to the inward directed acceleration which is equal to mv^2/r , the mass of

the orbiting object times the square of its tangential velocity divided by the radius of the circle. Given $F_c = mv^2/r$, moving the variable of the radius to the other side of the equation ($F_c r = mv^2$) shows that the greater the radius, the less force is necessary to maintain a faster speed. Also, in the case of body rotating, which has mass around the theoretically small axis, the angular momentum ($\omega r = v^2/r$) of a point close to the central axis, like the hip, is extremely large though the velocity and force are small. Therefore, if an object is extended from the spinning body, the speed increases quickly to conserve angular momentum as the magnitude of the radius increases. Force by the body at the axis of rotation, through radial extension, allows a small amount of effort to become a much larger force along the arc of the path of the orbiting object.

The nature of centripetal force and circular acceleration gives rise to effects at all scales but particularly has tangible results at the human scale where forces of gravity and electrical attraction and repulsion are fairly uniform. Utilizing this tool for amplifying speed and motion creates speed that generates increased speed and increased force, which can be used with momentum and continuing exertion, to generate even greater force. One can become a whirling dervish; occupy a state of detached ecstasy as the body coasts on the momentum of the force it has generated. From the center of this frame it is an experience perhaps of ecstasy, Kundera's futureless, pastless state. From outside this frame of reference it is unclear what it is, but it is wholly different. The observer does not have the constant feedback of the system requiring more energy and feeding energy back in, and most importantly the observer does not feel the speed. Arguably, the approximately stable state where the orbiting object is levitating and spinning body is relatively centered and still. Rather what the observer is most aware of are the changes in

state: when the centripetal force approaches the gravitation force and the orbiting object begins to travel in the air, when the wobble of the body around the axis becomes noticeable, when the whole system threatens to and, inevitably, collapses. These boundaries are crossed at some points regardless of the absolute energy or speed of the system, but one could argue that the faster and more ecstatic the spin, the less penetrable it is by an outside viewer, except at the boundaries; whereas, a slower system where momentum is particularly being taken advantage of by the body to hover around the boundary condition of gravities force is a more dramatic situation to those in the outer frame of reference.

The first experiments utilized a medicine ball functioning at the distance of the outstretched arm. This allowed for a more direct relationship with the centripetal force as all forces were contained within the body. Spinning with the weight stretch out resulted in a sensation of greater speed than with it held close to the body, though from an exterior reference point the opposite is true. Following these base point experiments I began developing a sheet-like object that could be weighted at various lengths and widths to create multiple point systems simultaneously. The first major variable to be dealt with was determining the limits of length and weight that could function in equilibrium with forces exerted by my particular body. A maximum length turned out to be between eight and nine feet, depending on the weight attached to the sheet. With a garment calibrated to the dimensions and strengths of my body, I videotaped a series of trials spinning in different directions, which the body in more and less arched and contracted positions. This was in an attempt to manipulate the sheet to function as less of a linear radius with parallel weights and as multiple independent linear systems that would create dynamic

turbulence in the continuous fabric. At times there was turbulence, and fascinating shapes, and pockets of space, but the system was too closely held to itself to allow for clear understanding of the confluence of its subsystems.

The next iteration of a centripetal force-activated extension was a simplification of the sheet into its linear subsystems. Using ropes with weights at the end, beginning with one orbiting, then two, and finally three, it was much simpler to calibrate length and weight, especially since weight was approximately centered on a point rather than distributed through the fabric. The simplest case of this extension, one string or rope, one weight at the end of that string, held at one point can be easily modeled in theory. As the rotation of the body increases the angular velocity of the weight increases, the tangential velocity of the weight increases in direct proportion and the tension in the string, equal to the centripetal force, increases as the square of the velocity. As the centripetal force approaches the same absolute value as the gravitational force on the weight, it rises from the ground approaching a perpendicular line to the axis of rotation. This single rope, weight, and hold system is theoretically simple, except that instead of a perfectly still vertical axis at the center there is a human body which, while normally stable through continuous approximation its balance point and constant adjustments for imbalance, is never still. In general these adjustments are imperceptible but everyday situations like congestion, hearing and vision impairment, inebriation, fatigue, and increased speed draw attention to this ever adjusting balance point.

Increasing the system to two ropes, there arise a multitude of different choices with regards to connection between the two which impose parameters on their possible paths. At three, of course, they increase again, exponentially with the addition of each

new rope and weight, but the system begins a richer field for improvisation and manipulation on the part of the central body which can by adjusting the axis of rotation, through movement of his body, adjustment of hold points ahead of time or in the process of the spin, and changes in speed, create complex constellations and levels of dominance out of and within the subsystems.

Perhaps the essence of this exploration comes back to the simple and common, particularly in dance, notion of fall and recovery. To be sure it is particularly about amplification of bodily motion and its forces through a larger and weighted prosthesis. Initially the intention was to use this tool literally amplify the bodies motion into a larger space, but the much more interesting and dynamic effect of these experiments was the amplification of the rotation of the body, and particularly the error, the wiggle. Using centripetal force, at a larger scale than that of our self length and weight, increases the intensity of the shifts between stable and unstable, fall and recovery.

In the context of dance, as balance and control and coordination are practiced intensely this notion is readily apparent and goes by all manner of euphemisms: being on one's leg, on/off balance, centered, pulled up, activated core, kinesthetic awareness, fall and recovery. Doris Humphrey when preparing her thoughts on the art of choreography emphasized that the core of dance is fall and recovery and the suspense and relief inherent in the passage between the two.

In a way classical ballet has always dealt with this; there is a reason brilliant male allegro is breathtaking, because he flies through the air and of course must thus land. With the development of modern dance around the turn of the twentieth century fall and recovery became increasingly indulged. Wigman was performing contorted violent solos

throwing her body this way and that; Duncan was skipping lightly, running, collapsing her torso. Even Balanchine the great neoclassicist was indulging in this simple and crucial contrast. The moment between falling footsteps could be expanded into long moments on the edge of toe shoe hovering before the fall. Suzanne Farrell became one of his famous ballerinas not because of beautiful feet or incredible extensions for her sheer brashness in attacking every movement to the extreme, taking it as far as it could be taken before really and truly falling. And now we have Streb throwing herself and her dancers off 26' high trusses and trampolines, throwing themselves against the ground. British group DV8 performs similar stunts, for example with a dancer climbing a ladder and falling for successively higher rungs onto a colleague who breaks the fall with his own body. The risk inherent to the notion of fall and recovery can be endlessly modified, increased, decreased, emphasized, deemphasized and achieved with endless methods. The most fascinating methods for myself, prove to be those which are wholly related to, and interactive with the body and its forces.

I argue that our intuitive understanding of the universe, and all those things that are part of it, is based in the scale and potential of the human body and that in some form, all things outside of ourselves, must be represented at our own scale for comprehension. Thus while there are distinct and identifiable patterns and textures of images of objects at varying scales there is also a certain similarity in dispersion and branching and clustering, and maybe images of cracked earth aren't so different from images of molecular structures and old dry skin. It could be argued that the motion of the human body and the space it occupies is a reasonable way to model and understand larger spaces, larger motions. That the acceleration due to the circular spin of the earth produces gravity is not

particularly comprehensible, while a force diagram proves it to be true can we actually intuitively understand it without putting a fist out and spinning and feeling the force on our body from the same circular acceleration? Methods of representing, symbolizing, and idealizing physical systems is absolutely crucial to our understanding and being able to manipulate our physical environment, but equally crucial is constant, conscious return, especially in design, to the actuality of these systems acting in and upon our bodies and the potential for our bodies to interact with the environment through the same systems.

“What fascinated her was her own truth about herself... She wanted to amplify her self, make it blaze, turn it into light.” (Kundera, 48)

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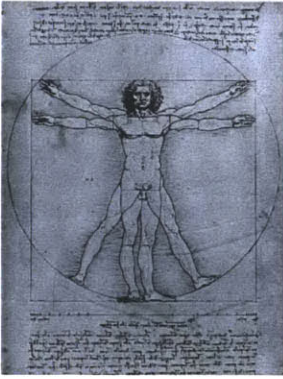
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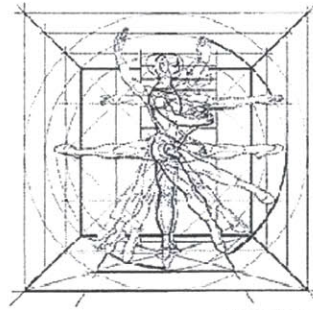
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Kinesphere
Illustration: Kaiserworks

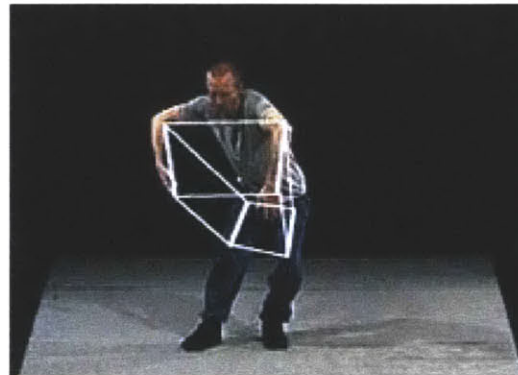
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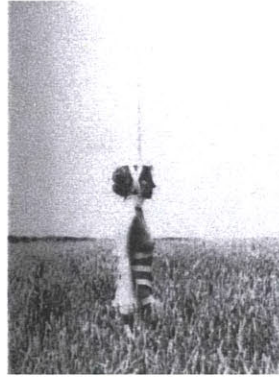
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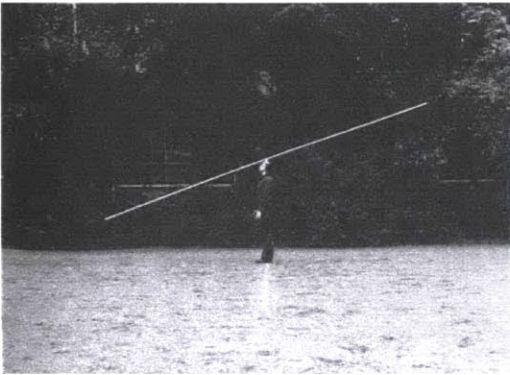
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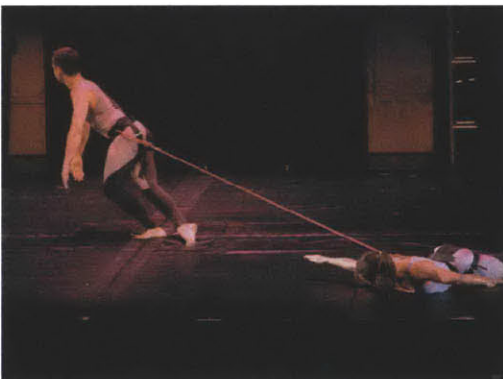
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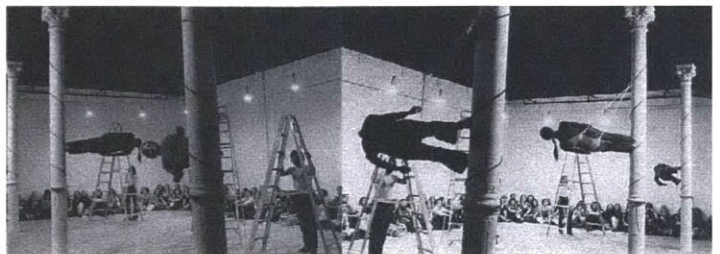
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Centripetal Force: Sketches



Summary of forces at work in orbital motion: centripetal force and acceleration inward, radially; centrifugal force outward, radially; tangential velocity.



Transition between circular motion and linear motion. Lowering bodily center of gravity for greater balance.



Variation in orbits as limbs extend and contract.



Description of proportional relationships between radius and circumference and speed.





Rotational Extnsion: Three

