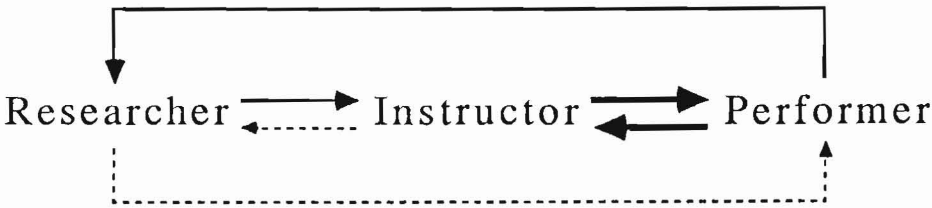
THE VALUE VISUAL VARIABLES IN BIOMECHANICAL ANALYSIS

Jackie L. Hudson

In the preface of Sports Biomechanics, Terauds, Barthels, Kreighbaum, Mann, and Crakes (1984) wrote "... of the dedication of the INternational Society of Biomechanics in Sport to bridge the gap between the sports biomechanics researcher and teh practitioner. It requires a special understanding of the needs of the athlete, needs of the coach, and needs of the biomechanics researcher. The sports biomechanics researcher must go to the practitioner" (p.v.). Following from these statements, the purposes of this paper are to examine the inter-relationship among the athlete, the coach, and the biomechanics researcher and to raise some issues with regard to the message about technique that the researcher delivers to the practitioner.

Some biomechanics researchers study technique as it relates to the etiology of injury while others study technique as it relates to the improvement of skill. Although the latter type of research undergirds this paper, many of the issues brought forth should have implications for the improvement of movement, whether the focus is on modification of a high-risk pattern of movement or on remediation of an inefficient pattern of movement. In either case, the ultimate user of our information is a performer. And, even though many performers are resourceful in creating their own opportunities to improve movement through trial and error, it is probably that greater gains in proficiency can occur through the intervention of an instructor. Of course, the instructor may be formally designated as coach or teacher or informally designated as parent or friend. Regardless of the designation, the instructor should be the intermediary in a process that is based on solid research.

Figure 1 depicts some of the relationships with respect to the flow of information among the researcher, the instructor, and the performer. In the long loop, information flows from the performer to the researcher to the instructor to the performer. That is, the performer, through a movement, informs a researcher, who after much effort informs an instructor, who then informs a performer of suggestions for an improvement in movement.



In the short loop of performer-instructor-performer, the performer informs the instructor by executing a movement, and the instructor, using the relevant knowledge base, evaluaates the response and suggests corrections. The intermediate loop traces from performer to researcher (and, perhaps, instructor) to performer. Thus, the researcher is informed by the performer, and after evaluating the performance, offers suggestiongs for change; the researcher may consult with the instructor before or during the delivery of information or not at all. Of the three loops depicted, the intermediate loop is the least common.

The short loop has tremendous potential for improvement of movement because many iterations can be made in a short period of time, the instructor can accumulate both short term data bases over a day and long term data bases over a season for use in evaluation, and one instructor can assist many performers in the same block of time. The success of the short loop is predicated on the ability of the instructor to extract relevant information from the performance and to provide appropriate suggestions as to change. From the visual perception research of Scully (1986) and others, it appears that much of the extraction of relevant information is in visual terms.

The long loop can be closed or open. In the closed loop the performers who contribute samples of movement are also the benficiaries of the suggestions for change. This closed loop profits the proverbial "n of 10" subjects. In an open loop, the initial and final performers are different; thus, if the "n of 10" subjects inform one researcher who informs 100 indstructors who each inform 100 performers, then the original "n of 10" performers can inform 10 thousand performers. And, much of the exchange of information in this loop of ten thousand and eleven people is in visual terms. Does it not behoove the researcher to consider the value of visual variables?

What is the value of visual variables? The answer depends on one's definition of "value." From Funk and Wagnalls (1963) there are five definitions of value that have relevance for biomechanics. Accordingly, let us consider each of these five definitions and raise some questions about the value of visual variables in biomechanical analysis.

Value 1. Exact meaning. What exactly is meant by the term "visual variable" in biomechanics?

> Visual 1. Pertaining to, resulting from, or serving the sense of sight. 2 Perceptible by sight; visible.
> Visible 1. Perceivable to the eye; capable of being seen. 2. Apparent; observable; evident. 3. At hand; available; manifest. 4. Constructed so that certain parts can be seen by the user.
> Variable 1. A quantity susceptible of fluctuating in value or magnitude under different conditions.

If variables are those aspects of movement that are subject to change, then visual variables are those changeable aspects of movement that are perceivable by the eye. Even naive observers are adept at perceiving information about human movement such as time, change in time, linear and angular position, change in position, speed, and perhaps, acceleration. However, experienced observers are more proficient than naive observers at using this kinematic information to evaluate performance (Scully, 1986). Thus, it is argued that for these mechanical units of position and time to be useful to the instructor, they may need to be reorganized into other visual variables that have more meaning in the context of human movement. For example, if there are a few, generic, visual dimensions of movement that are useful in distinguishing more from less skilled performance across a plethora of activities, then these visual dimensions should be a reasonable focus for observation.

Before discussing some generic dimensions of movement, let us consider three phases of temporal observation and three foci for spatial observation. The three temporal phases of movement are preliminary, propulsive and post-propulsive. The preliminary or preparatory phase can be illustrated by a softball batter who has maneuvered the bat into position to begin the forward swing. Because this preparatory phase is usally less vigorous than the propulsive phase, it is easy to overlook in a biomechanical analysis. The propulsive or primary phase of movement in batting would consist of the forward swing until contact with the ball. Even with photographic images, one may detect a bit of blurring in the bat and ball; the speed of movement can make this primary phase of movement difficult to observe. The post-propulsive or follow-through phase of movement in batting would be the remainder of the forward swing. One might assume that the propulsive phase was vigorous due to a certain robustness of the follow-through.

In observing the performer, there are three foci for spatial analysis. Ranging from telescopic to microscopic, these foci are somatic, sectional and segmental. The somatic or whole body level of analysis could be depicted by an airborne diver in the tuck position. In this case, the whole body would be rotating as a unit about the center of mass. In a sectional analysis, one would concentrate on one entire appendage or section of the body. The entire arm and racket may appear to be operating as one unit in a tennis ground stroke. For activities that are near-maximal and ballistic, such as a baseball throw for maximum speed or distance, a segmental analysis may be necessary to observe the sequential movements.

Returning to the visual dimensions of movement, it is argued that there are at least six generic dimensions that combine the aforementioned mechanical units (i.e., elements of position and time) into more useful variables for distinguishing less from more skilled movement. The visual variables which comprise the first dimension are the number and nature of segments involved in a movement. For example, a major league pitcher would appear to be involving all possible segments in a near-maximal effort while throwing a fastball. Conversely, the catcher, who remains in a squat position, amy use fewer segments and submaximal effort in returning the ball to the pitcher. From a review of motor development literature (Roberton & Halverson, 1984), the following hypothese about the number and nature of segments can be drawn: 1) novice performers tend to reduce the number of active segments by "freezing out" some degrees of freedom; 2) as the acquisition of skill progresses, more segments become active, especially in the sagittal plane; and 3) ultimately, some segments that had been moving sagittally begin to move in a transverse plane. Also, in tasks that are submaximal and/or dependent on accuracy for success, it is common to observe a retroversion in the number and nature of segmental movements from a transverse action to sagittal action or, perhaps, in action.

The second visible dimension of movement is balance. The variables of interest are line of gravity and base of support. In some cases it is desirable to maintain a line of gravity within the base of support. This can be demonstrated by a figure skater who is spinning on the ice. At other times it is desirable to move the line of gravity outside the base of support to get a certain amount of mobility. An example of this is the speed skating start.

The third visible dimension of movement is range of motion. Variables related to the initial and terminal positions of movement are the basis of this dimension. In the golf drive, it is desirable for the club to swing through a wide range of motion from the preliminary to post-propulsive phases. However, in a bseball bunt, it is desirable for the bat to move through a small range of motion.

The fourth dimension is related to range of motion and pertains to projectile and striking skills: extension at release, also known as lever length at contact. It is customary for a bsketball player to be fully extended when releasing a shot. In hammering a tack, a shortened lever length is common.

The fifth dimension is related to range of motion: a reduction in the moment of inertia, or compactness, prior to impact. We expect a skilled tennis player to demonstrate the "back scratch" position in the serve; doing so reduces the moment of inertia and enables more racket head speed at impact.

The final visual dimension, coordination of segments, is composed of the variables of sequencing and timing of segments. This dimension is more difficult to detect with the naked eye or still photographs. In some movement patterns, the segments initiate and terminate the propulsive phase simultaneously. In other movement patterns larger segments precede smaller segments in a temporally progressive and sequential manner during the propulsive phase of movement. The extent of simultaneity may be related to the nature of the task (e.g., maximal, ballistic, precise, discrete, etc.) and/or to the nature of the individual (e.g., experienced, well-conditioned, fatigued, etc.)

There are surely other useful visual variables and dimensions in addition to those discussed here; but, many others have been eliminated intentionally. In as much as acceleration is likely to fluctuate rapidly and greatly, seeing acceleration and then deducing force or torque from it seems virtually impossible. For this reason force, torque, and other mechanical variables that are derived form force, torque, and/or acceleration (e.g. stored elastic energy) are considered to be invisible variables.

Value 2: math. The quantity, magnitude or number an algebraic symbol or expression is supposed to denote.

How finely must these variables be measured? Mus these variables be quantified at all? This is the qualitative versus quantitative issue and seems to be related to two factors: The first is the medium on which the information is recorded. The medium can range from the brain in the case of naked eye observation to still photographs, to unshuttered video, to shuttered video, to high speed film. The amount of data that can be perceived, and correspondingly measured, is a function of the complexity, clarity, and decay of the display. Because of the evanescent nature of mental images of movement, the measurement of movement by the naked eye must be, of necessity, qualitative. Also, unshuttered video images may be too indistinct to permit quantification. And, if only one still photograph of a movement is recorded, then the variables based on a change of position or time cannot be quantitated. For the other media, there is the option of expressing the same information qualitatively or quantitatively. In making the choice between qualitative and quantitative measurement when the media allow both options, it seems appropriate to use the least sophisticated analysis which will answer the question at hand. Related to this conclusion is the second factor in the qualitative versus quantitative debate: the necessity of sophisticated analysis. In all probability, as the skillfulness of the performer is increased, the need for refined quantitative analysis will also be increased.

Value 3. The desirability or worth of a thin; intrinsic worth; utility.

Are these variables "useful" in describing, understanding, or modifying movement? First, let us address the description question as it relates to the researcher. If the purpose of an investigation is merely to describe movement, then the visual or kinematic variables are inadequate in providing complete information: it is also necessary to obtain kinetic variables. Yes, it is possible to do a "descriptive" study using "causative" variables — just look at the literature. But why are we conducting descriptive studies? Do we assume that by describing the detialed characteristics of an elite performance, we have defined the prototype of success that should be modeled by all less skillful performers? If so, can we assume that children are just scaled down adults? Can we assume that even among elite, professional athletes there is a stereotypical pattern of movement given the sometimes striking physical dissimilarities within this population? There is, however, one useful function of visual variables in descriptive investigations: it is possible to verify and validate the biomechanical assertions in the teching and coaching literature because the assertions usually are based on visual perception.

Just as mere description is limiting to the researcher, it is limiting also to the instructor. Yet, the introduction of new skills could be made with visual variables, particularly those that have been verified and validated through biomechanical analysis. And, feedback on the process of moving, if given in descriptive, visual terms by the instructor, should be useful to the perfomer.

If the purpose of a study is to understand movement, then the visual variables are rather weak because they do not show causation. However, for the instructor, it does not seem to be necessary to know what causes a large range of motion if it can be shown that more skillful performers display a large range of motion. So, for describing movement as well as understanding which components of movement are associated with skillful performance, both kinematic and kinetic variables have value.

If the intent of research or instruction is to modify movement (and this implies evaluation and prescription in addition to description), then the visual variables are of value because these variables are communicable to the performer. It is necessary to put the suggestions for change in a language/symbol system that is comprehendible by the performer regardless of age or experience. Because these terms are "descriptive" it is likely that they can be spoken to the performer and they can be "shown" to the performer because they are visible. The extent that these need sophistication of communication is likely to be commensurate with the availability of sophisticated instrumentation. In other words, if a minor aspect of a brief phase of a movement is to be changed, it is likely that the person responsible for modifying the movement would have high speed film or video and that the subject would be able to detect nuances from a stop-action replay. However, gross changes in many patterns in many people (the typical instructional setting) must be done by many teachers daily. The typical teacher has neither the time nor the equipment to do anything but qualitative, naked eye observation as a prelude to evaluation; hence, these visual variables represent the repertoire of remediation for the typical teacher.

Value 4. The rate at which a commodity is potentially exchangeable for others; a fair return in service, goods, etc.; worth in money; market price; also, the ratio of utility to price; a bargain.

How much information do visual variables return in exchange for the price of obtaining them? How does the price of visual variables compare to other variables? If a researcher purchased a two-dimensional high-speed film system, amortized the cost over 5 years, shot 20 rolls of film per year, and hired a student to digitize 10 points per frame; the price would be a penny a point. If a researcher purchased a two-dimensional shuttered video analysis system instead of the high speed cine system, the cost at the end of five years would be exactly the same. A three-dimensional high-speed film system would cost almost 2 cents per point and a three-dimensional, shuttered, automatic video system would cost about $10,000 less than the 3-D cine. A top quality force plate costs about the same as a 2-D shuttered video analysis sytem, about twice as much as a high speed film system and about 20 times the price of an unshuttered video camera. This seems like a considerable amount of money to pay for invisible variables. Of course, there are uses for invisible variables other than reporting to instructors.

What is the price for naked eye analysis? Recently, the state of Indiana ruled that the value of a life of an unmarried, childless woman in her thirties was $25,000. At that rate, visual variables are quite a bargain!

Value 5. Attributed or assumed valuation; esteem or regard.

Why do we not regard the visual variables as highly as other variables (e.g., the force variables)? Through the years many researchers have sensed an implicity valuing of kinetic variables over kinematic variables. Explicit confirmation of this valuation can be found in one of our primary journals: According to the editorial policy of the International Journal of Sports Biomechanics, (1988) "articles appropriate for the Journal are limited to the study of forces acting on the performer and the consequences of these forces as they pertain to sport and exercise" (p. 102).

Other evidence to support the higher valuation given to kinetic variables can be inferred from a series of papers written by Hay and colleagues. In their quest to identify the factors related to skill in jumping, these researchers developed and tested several models. The first model (Hay, Dapena, Wilson, Andrews, and Woodworth, 1976) was based on kinematic variables; however, subsequent models (Hay, Wilson, and Dapena, 1978; Hay, Vaughan, and Woodworth, 1981; Hay and Reid, 1988) have been based on kinetic variables. These latter versions require information about joint forces or torques for several segments and time intervals. It is interesting to note that despite the elegance and success of their models, Hay and coworkers have concluded that there remains a need "to develop methods to translate the findings of our work into terms which are meaningful to the practitioner for whose use they are ultimately intended" (Hay et. al., 1981, p. 520).

For the researcher who values the kinetic variables and acknowledges their inadequacy in communicating to the instructor, a compromise procedure has been described by Miller (1982). This method involves the superimposition of stick figure tracings onto force records. Although the efficacy of this method has not been reported, it appears that its greatest benefit may accrue to elite level coaches.

Whether visual variables are studied in conjunction with or in exclusion of invisible variables, it seems that the exploration of the visual variables could be a worthwhile area of investigation for researchers who wish to "bridge the gap" to the instructor. Specifically, there seems to be a need to identify the variables that matter in distinguishing more skillful from less skillful movement. Special consideration should be given to variables which are especially acute at certain stages of skill development. Also, researchers need to involve instructors in the development of methods for measuring the variables that matter. Procedures which maximize clinical convenience and prescriptive potency should be sought. This work might include the search for visual correlates to the invisible variables that matter. With the help of our colleagues in motor development/learning/control and pedagogy, we need to discern which of the variables that matter are manipulable and how best to do so. Finally, we need to synthesize this information into simple, generic taxonomies. These taxonomies should enhance our transmission of information to instructors as well as prepare us to analyze novel activities as they are developed.

As it stands now, without a knowledge base of visual variables including spatial and temporal foci, we have little useful information to provide to the instructor. In effect, we do not know what, where, or when to observe. Eventually, it should not matter that our view of the action is lofty or low but only that when we look we know what we are looking for. So, as we strive to "bridge the gap," perhaps we can be more considerate of the "eye" of the instructor.

References

Funk & Wagnalls standard college dictionary, text edition. (1963). New York: Harcourt, Brace & World.

Hay, J.G., Dapena, J., Wilson, B.D., Andrews, J.G. & Woodworth, G.G. (1978) An analysis of joint contribution to the performance of a gross motor skill. In A Asmussen & K. Jorgensen (Eds.), *Biomechanics* VI-B (pp. 64-70). Baltimore: University Park Press.

Hay, J.G. & Reid, J.G. (1988). *Anatomy, Mechanics, and Human Motion* (2n ed.). Englewood Cliffs, NJ: Prentice Hall.

Hay J.G., Vaughan, C.L. & Woodworth, G. G. (1981). Technique and performance: Identifying the limiting factors. In A. Morecki, K. Kedzior & A. Wit (Eds), *Biomechanics* VII-B (pp. 511-520). Baltimore: University Park Press.

Hay J. G., Wilson, B.D., & Dapena, J. (1976). Identification of the l imiting factors in the performance of a baisc human movement. In P. Komi (Ed.), *Biomechanics* V-B (pp. 13-19). Baltimore: University Park Press. International Journal of Sport Biomechanics. (1988). Editorial Policy. International Journal of Sport Biomechanics, 4, 102.

Miller, D.I. (1982). What the biomechanics researcher tells the diving coach and what the coach tells the researcher. In J. Terauds (Ed.), *Biomechanics in sports* (pp. 31-36). Del Mar, CA; Academis Publishers.

Roberton, M.A. & Halverson, L.E. (1984). *Developing Chidlren: Their Changing Movement*. Philadelphia: Lea & Febiger.

Scully, D.M. (1986). Visual perception of technical execution and aesthetic quality in biological motion. *Human Movement*

Science, 5, 185-206.
Terauds, J. Barthels, K., Kreighbaum, E., Mann, R. and Crakes, J. (Eds.) (1984) *Sports Biomechanics* (p.v.). Del Mar, CA: Academis Publishers.