Kinematic Specification of Dynamics as an Informational Basis for Person-and-Action Perception: Expectation, Gender Recognition, and Deceptive Intention

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SUMMARY

The widespread conviction that perceiving another person must rest on ambiguous and fakeable information is challenged. Arguing from biomechanical necessities inherent in maintaining balance and coping with reactive impulses, we show that the detailed kinematic pattern is specific to an acting person’s anatomical makeup and to the working of his or her motor control system. In this way information is potentially available about gender, identity, expectations, intentions, and what the person is in fact doing. We invoke the lawfulness of human movement, as elucidated by recent advances in motor control theory, to demonstrate the virtual impossibility of performing truly deceptive movements and to argue in general terms for the specification power inherent in human kinematics.

The outcome of the analysis is subsumed under a principle of *kinematic specification of dynamics* (KSD), which states that movements specify the causal factors of events. Generally, a linked multiple degrees-of-freedom system does not exhibit substitutability; a change in one of its “input” factors cannot substitute for, or cancel, the multivariable effects of a change in another factor.

Six explorative experiments are reported. Displaying humans in action with Johansson’s (1973) patch-light technique, we show that (a) the influence of an invisible thrown object on the kinematics of the thrower enable observers to perceive the length of throw; (b) the lead-in movements of a person lifting a box allow perception of what weight the lifter expects; (c) a person lifting a box cannot deceive observers about the weight of the box, only convey the deceptive intention; (d) gender of adults and children in complex activity is recognizable to about 75% of presentations; (e) gender recognition rises to about 85% correct when the observed persons are not self-conscious about gender; (f) real gender and expressed (acted) gender are simultaneously, but independently, perceived; and (g) observer instructions to judge only “gender” yields results that erroneously indicate a deception effect.

We conclude that the experiments have demonstrated the considerable effectiveness of kinematic information in enabling perception of persons and action. Judgments of good precision were often obtained. Some perceived properties were relatively subtle states of the seen person. True conditions were perceived despite deceptive endeavors. The KSD principle therefore appears an appropriate conceptual guide, and the patch-light technique a useful empirical method, for the study of social knowing.

The concluding discussion argues that person perception has a dual nature in that true person properties and communicative or deceptive expressions are co-specified in the kinematic pattern. Hence, they constitute *alternative foci* for perception, and attention can switch freely between them in normal social interaction. Extensive parallels exist between this view of person perception and Gibson’s (1979) treatment of pictures and picture perception.

Furthermore, we argue that the student of social knowing has much to gain from recent advances in motor control theory, and we raise the possibility that “hidden” person properties might be conceptually linked with characteristics and states of a person’s motor system whereby aspects of personality and emotion would be kinematically specified.

Finally, we argue that the complexity of kinematic information might present a principled
obstacle for a theory of indirect knowing (and a practical obstacle for the scientist) but not for a direct theory wherein perception is considered a natural system of sensitivity relative to which "complexity" has no a priori meaning.

Recently, it has been suggested that perceptual modes of social knowing should be reintroduced so as to challenge the predominance of cognitive, information-processing approaches (Baron, 1980, 1981; Lowe & Kas-sin, 1980; Newton, 1976, 1980). In particular, Baron (1980, 1981) and Knowles and Smith (1982) have advocated an extension of the ecological approach to perception and action, originated by J. J. Gibson (1950, 1966, 1979), into the field of social knowing.

Central to the ecological approach is that perception is the pickup of useful information. The process is considered direct in the sense of not entailing inference or similar constructive operations on insufficient input data. The possibility of perceiving something in this way rests on the availability of information to specify it in the domains of sensitivity of the perceiver. Hence, the viability of the ecological approach hinges on whether a good case can be made for the existence of such information. (An advanced explication of the philosophical rationale for the ecological approach has been provided recently by Turvey, Shaw, Reed, & Mace, 1981, following Fodor and Pylyshyn's, 1981, attack on the notion of direct perception.)

Gibson took the search for potential information in earnest. In his first book (Gibson, 1950) he forcefully advanced new types of information about the spatial layout of the environment (e.g., texture gradients and motion perspective) and thereby drastically changed the outlook for perception research. Later he laid out a framework for analysis of visual information under the rubric of ecological optics (Gibson, 1961, 1979).

A similar concern for the informational basis of social knowing is lacking, however. Thus Lowe and Kassin (1980) found it "surprising that so little attention has been given to the fundamental question of what aspects of behavior, situation, or person serve as the raw data for attribution" (p. 536). This neglect might have been partly programmatic in origin. Variously, the process of social knowing has been deemed independent of what is processed (Bruner & Tagiuri, 1954), or the information has been taken to be purely conventional; hence the "expression" of social conditions has been considered a matter of learning just as much as the interpretation thereof has (Birdwhistell, 1970/1973). A slurring of the distinction between perceptual and intellectual functioning is also involved. As pointed out by Knowles and Smith (1982) in a critical review:

social psychologists rarely employ such a distinction in their work. This probably results from the great interest that social psychologists have shown in what people say about perceptual events rather than what they select to attend to as the units of analysis. The consequence of this interest is that we know very little about the information on which social perception is grounded. (p. 56; italics added)

As a further consequence, social perception has been treated as an exclusively cognitive process. To quote Knowles and Smith (1982) again:

Traditional approaches to social perception have adopted an information processing perspective whereby the structure or organization necessary for meaningful percepts is supplied by higher-order processes within the head of the observer. (p. 54)
One finds social perception investigated as if it were analogous to a multiple choice examination. Given certain "cues" from a complex stimulus array, what kind of a perceptual decision, or judgment, does the individual report? (p. 54)

It follows that the relevance of this research might be limited to a very narrow sector of social interaction. Opposing the traditional approach, Baron (1981) cautioned:

One should not begin by denigrating the value of stimulus information but rather with attempting to see how far we can get with unelaborated stimulation before it appears necessary to appeal to higher order cognitive processes. . . . [Therefore,] analyses of social knowing should begin by specifying the possible stimulus-based informational supports for a given social judgment. (pp. 62, 64)

Likewise, Knowles and Smith (1982) argued for the adoption of an ecological perspective which will necessitate a revision both of our conception of the stimulus for social perception, and of the role of the perceiver of social events. An ecological perspective emphasizes the temporally and spatially extended patterns of stimulation isolated by an active, information-seeking perceiver who interacts with a structured environment by selectively attending to certain aspects of stimulation. Rather than an a priori assignment to the function of cue or clue, information immediately obtained through observation is assessed in terms of its specificity to the environmental source of stimulation and its perception. To the extent that the patterns of obtained stimulation are considered adequate to account for social percepts, the role of elaborate intervening cognitive processes is reduced. (pp. 54–55)

Not much has been done so far to exhibit the informational support for social perception. And the route typically taken (see Baron, 1980, and Knowles & Smith, 1982, for reviews) has been to search empirically for features of situations or displays that de facto determine the observers' impressions. A consideration of why certain features are informative is lacking. That is, what laws and principles could establish correspondence between informative structures and that which they are informative about? We will use the term firmness of informational basis to refer to the scope of applicability and stability of these laws and principles (cf. the discussion by Turvey et al., 1981). For example, information based on the laws of mechanics, biomechanics, motor control, and principles that can be derived from these would have a very firm basis. Conversely, the information available in conventional gestures would have a soft basis. Because these issues have not been considered, we are left with the impression that "behavioral cues" are as loose and ambiguous as, say, conventional gestures and verbal expression.

A major block to progress in this field is the widespread conviction that available information is inherently ambiguous—the doctrine of "intractable nonspecificity" (Turvey & Shaw, 1979). The nonsocial side of this stronghold of the cognitive approach has been successfully attacked through geometrical proofs for the existence of both exterospecific and propriospecific information in the optic array to a moving observer (e.g. Lee, 1974). In a similar way, it will be necessary to show that there exists, to a considerable extent, a firm informational basis also for social perception.

Although dear in principle, the notion of input nonspecificity must be a practical hinderance for the cognitivist. After all, the nature and outcome of inferential processes cannot be indifferent to the quality of available input. We think, therefore, that our pursuit of person-and-action information will be of relevance also to those who are determined to remain within the cognitive camp.

In this article a principle of kinematic specification of dynamics (KSD), which has been developed in earlier studies concerning the perception of inanimate events (Runeson, 1977/1983), will be presented. We show how it can be extended to matters of social knowing, satisfying some of the demand for a firm informational basis. The principle is applied to perception of another person's expectations, intentions, actual actions, gender, and deceptive intentions. Six experiments, exploring the human ability to perceive such properties from displays of the kinematic patterns of humans in action, are reported. The concluding discussion concerns expression and true conditions as alternative foci in person perception, the relevance of motor control theory in the study of social knowing, and the burden put by kinematic information on the visual system.

Kinematic Specification of Dynamics

The science of mechanics distinguishes kinematics, motion described as such, from dynamics, which is motion explained in terms of what causes and constrains it. The difference can be captured in terms of the fundamental
dimensions, mass, length, and time. Thus, kinematics is fundamentally built from length and time whereas dynamics is built from length, time, and mass. Basic variables in kinematics, then, are displacement, velocity, and acceleration but any variable used to describe change in geometrical configurations over time (e.g., angular velocity) belongs to the kinematic domain. Likewise, basic dynamic variables are mass, force, work, and momentum, but all properties of objects and events that are causally involved in determining the course of movements belong to the domain of dynamics in the wide sense. Science and technology thus make use of a host of dynamic variables: friction, elasticity, viscosity, shear strength, and so on. Of important note, when we consider animate motion we may also count, for instance, intentions and emotions as dynamic properties.

Using the kinematics versus dynamics distinction in this way we have previously challenged the traditional approach to "motion perception" by suggesting that perception of events is predominantly in terms of dynamic rather than kinematic properties (Runeson, 1977/1983; see also Runeson & Frykholm, 1981). Put simply, we tend to perceive causal aspects of events, not movements as such.

In addition to phenomenological support (e.g., Bassili, 1976; Johansson, 1973, 1976; Maas, 1971a, 1971b; Michotte, 1963), the claim about dynamics perception rests on an appreciation of the biological advantage of perceiving dynamics because of the relevance of dynamic properties to what can be expected from, or done with, objects, animals, and events. In other words, what the environment affords (Gibson, 1979, chap. 8; Michaels & Carello, 1981, chap. 3) is to a large extent constituted by dynamic properties.

What information could be available for perceiving dynamics? The science of mechanics typically provides equations for how given dynamic (kinetic) conditions determine the kinematics of events. For our purpose it will be necessary to reverse the analysis and, given the kinematics, try to solve for dynamic factors. Hence, we attempt to do inverse dynamics, adopting the term from the action/robotics literature in which it refers to calculation of joint torques required to produce desired movements (Hollerbach, 1982; Raibert, 1978; Saltzman, 1979). Our analysis differs, though, in focusing not so much on torques and forces but rather on mass distribution, elasticity, damping, and functional linkages. Furthermore, we explore the possibility that psychological states of a person can be similarly treated. To the extent that such reversals are possible, kinematics can be said to specify dynamics and hence contain the sort of information sought for.

The reader should be warned at this point that although the scientific analysis of available information must necessarily begin with description of kinematics and continue with the solving of equations until the desired properties are isolated, there is no suggestion that perception proceeds in a similar two-step and computational fashion. In the concluding discussion we instead argue that if, by inverse dynamics, information about dynamics can be shown to be available in kinematics, it opens the way for systems with direct sensitivity to the informational invariants.

Determining object properties from their motions is not uncommon as a textbook exercise problem (e.g., Kleppner & Kolenkow, 1973). For very simple events such as plain constant motion, the equations often lose specificity when reversed. With some increase in complexity the situation is different, however. Thus, Runeson (1977/1983) was able to show that damping and mass ratio are specified in the kinematics of linear collisions. Furthermore, it has been shown that these dynamic factors can be visually perceived (Todd & Warren, 1982; Runeson, Note 1).

Kinematic Information in Human Events

To bring the KSD principle to bear on social knowing, it must be applied to animate motion, which because of the mechanical complexity of the body does not yield easily to analysis. The observation that increased com-

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1 By letting \( M \) stand for mass, \( L \) for length, and \( T \) for time, the dimensional structure of the relevant variables can be revealed. Hence, displacement has the structure \( L, velocity LT^{-1}, \) and acceleration \( LT^{-2}. \) For basic dynamic variables we have force \( MLT^{-2}, \) work \( ML^2T^{-2}, \) power \( ML^2T^{-3}, \) and momentum \( MLT^{-1}. \) Shaw (see Mace, 1983) has used this kind of notation to explicate the nature of our work on the KSD principle and related work by Warren (1982) on perception and action in stair climbing.
plexity leads to better specification of dynamics (Runeson, 1977/1983) is encouraging, but to our knowledge a formal proof for such a rule is not available. In a later section we use principles from modern motor control theory to approach the KSD principle in general terms. First, however, we must analyze some specific possibilities for person perception through kinematic information.

A first example is borrowed from our previous study (Runeson & Frykholm, 1981) in which it was shown that observers could perceive the weight of a box by watching another person lifting and carrying it. The accuracy of the observers' weight judgments were close to what they achieved when lifting the box themselves. Accuracy was only moderately degraded when only the main joints of the actor (i.e., the person lifting the box) and the corners of the box were visible as bright patches on a video screen. This technique, introduced by Johansson (1973), provides a method for isolating the contribution of kinematic information. Generally, it was concluded that the variation of the weight of the box introduces specific changes in the kinematic pattern of the actor–box system and that human observers have the necessary kind of perceptual sensitivity to pick up this kind of information.

Although the successful outcome of the experiments allows positive conclusions about both availability of information and its use in perception, it remains to specify the nature of the information. Runeson and Frykholm (1981) discussed the static case of a standing person holding the box laterally supported against the abdomen. To maintain good balance without undue ankle strain, the person must lean backward in proportion to the weight of the box. Thus, we have an example of how an informative variation in the (here static) configuration of a person is enforced by universal laws of mechanics.

Continuing the example, we move from considering the person as a rigid body to taking the characteristics of human anatomy into account. The person holding the box tilts the trunk backwards while pushing the pelvis forward. In this way the vertebral column is put more in line with the resultant load, reducing strain on the back extensors. Thus, the angle between trunk and legs varies with the weight of the box and we have another potentially informative property enforced by laws of biomechanics.

Still, our weightlifter has not moved. As soon as he or she does, however, he or she will have to deal not only with the weight of the box (i.e., the pull of gravity on its mass) but also with the reactive or inertial forces that arise when the box is subjected to acceleration. Whenever motion starts, stops, or changes speed or direction, acceleration is involved. The inertial forces are proportional to mass and acceleration, and furthermore the direction of the inertial force varies with the direction of acceleration. It follows that as soon as one starts doing something with the box temporal and directional variation occurs in the load presented by the box on the actor. To maintain balance and prevent injury and inconvenience the actor has to compensate for these variations by continually adjusting for instance, backward lean and hip angle. A discussion of compensatory movements is provided by Saltzman (1979) who also suggested the terms instrumental and postural for the task-related and balance-maintaining aspects of movements, respectively. Thus, in addition to specification by static (i.e., average) postural parameters, the weight (mass) of the manipulated box is specified by the magnitude of postural adjustments relative to the acceleration of the box.

Plainly, when a certain acceleration of the box goes with small postural excursions, the box is light; when it goes with large excursions, the box is heavy. As a related example, consider the mechanical concept of center of mass (Kleppner & Kolenkow, 1973). The heavier the box, the more the actor–box system has its common center of mass displaced toward the box. When, for instance, the actor turns around with the box, the rotation will naturally be around a vertical axis through the center of mass, and the location of the axis will, therefore, be specific to the weight of the box.

\[2\] The term reactive forces subsumes three kinds of forces, inertial, centripetal, and Coriolis forces (e.g., Saltzman, 1979); the latter two pertain to rotation. Because rotation can be considered a special case of acceleration, and the present argument only requires general references to the reactive effects of subjecting masses to acceleration, these distinctions are not used; reactive and inertial will be used interchangeably.
For purposes of perception, kinematic information is superior because it consists of invariant relations within the display, whereas static information, such as backward lean, more often is dependent on external references. However, to produce discriminable effects the reactive forces must be large enough relative to static forces. It follows that action must exceed a certain degree of vigor (cf. the expression dynamic movements) and that in the example considered the range of weights to be discriminated must not extend too low relative to the weight of the actor (Runeson, 1977/1983).

Expectation

In the encounter between lifter and box it seems reasonable to expect that the kinematic pattern contains information not only about the box but also about the lifter. Because that would put us squarely in the field of person perception, let us consider what happens when a person first grabs the box and lifts it. If its weight is not known in advance, there is no way that he or she can adjust the posture properly, and the lift necessarily has to be preceded by a test phase. There is usually no way, however, to test the box other than to try to lift it. To do so the actor has to make tentative adjustments, and we may assume that any expectation he or she may have concerning the weight of the box determines postural adjustments.

Furthermore, when the actual weight differs from the expected, readjustments occur, and the amount of readjustment depends on, and hence specifies, the difference between expected and actual weight. Because the real weight is specified in other ways, we have information available about the actor's expectation.

It is instructive to observe at this point how a covert mental disposition becomes optically specified when it enters, as a dynamic factor, into interaction with mechanical and anatomical factors to generate the kinematics of an event. Thus, an expectation may be considered a dispositional property (cf. Turvey et al., 1981), a prototype example of which is magnetism. The latter typically becomes observable through the behavior (motion) of the magnetic object under certain conditions, such as when interacting with other magnetic objects.

Intention to Act

To be efficient, postural adjustments must often be undertaken before a new activity is begun. Hence, postural preadjustments, tuned to the intended action, are characteristic constituents of animal activity. They are particularly evident in a towering bipedal animal, like a human, in which the maintenance of balance is delicate.

Preadjustments also serve to prevent tissue damage as evidenced, for example, by the high incidence of back injuries among unprepared or unskilled young workers (Troup, 1979) and in jobs with unexpected loads (Andersson, 1979), such as when the load occasionally sticks to a swung shovel ("shoveler's fracture"; Rash & Burke, 1978, p. 241).

Any act that entails horizontal change of speed or direction of the center of mass must be preceded by a relocation of the feet relative to the vertical projection of the center of mass. Hence, to start walking, one normally swings one leg in the intended direction and waits for a fall to begin (Roberts, 1967, p. 171). A quicker alternative is to take a small step in the direction opposite to the intended path and lower the trunk. Only when a falling motion in the desired direction is underway can, and must, the locomotor movement begin.

In a similar way, pulling, pushing, and hitting with the hands, and the simple raising of an arm as well, produce reactive horizontal impulses that require postural preadjustments. Relying on electromyographic studies, Belen'kii, Gurfinkel', and Pal'tsev (1967) emphasize that the changes in the state of the segmental apparatus at different levels occurs at different times. Figuratively speaking it may be stated that when instructed to move his arm the subject in the standing position at first performs movements with his legs and trunk and only then with his arm. (p. 160)

Investigations of patients show that absence of anticipatory preparation for raising the arm leads to considerable initial disturbance and with disruption of the compensatory mechanism may even lead to complete loss of balance. (p. 158)

Another necessity in motor activity is that it be tailored to the layout of the environment and to what goes on there. In a strongly foveate animal (e.g., a human) it is necessary to direct
the eyes at the intended path of locomotion, for instance. Neurophysiological data demonstrate the fundamental nature of this coupling. For example, the well-known tonic neck reflex might serve "to orient the animal's limbs to the requirements of intention as expressed, perhaps, by gaze" (Easton, 1972, p. 593). Hence, the motor system reflexively gets prepared for locomotion in the direction of gaze.

At least in humans, however, the relation between gaze and locomotion is more complicated. Recent studies by Thomson (1980) show that one need not look steadily at the path of locomotion. After taking a good look, it is possible to walk with almost normal precision and even to steer around obstacles with eyes closed. Eight sec after the eyes close, however, this performance comes to a sharp end, and the walker stops or reverts to "blind" walking.

For the present purpose, we can surmise from Thomson's (1980) results that if a person has not been looking in a particular direction during the last 8 sec he or she will not be able to start moving with any vigor in that direction without first revealing his or her intention with the gaze. The same probably holds for other sorts of directed action. On the other hand, if the walker has taken a look, he or she may initiate quite well-guided action within a few seconds even with eyes closed—or looking in some other direction, which is more relevant here. In activities where force or efficiency are at a premium, however, head posture will be functionally linked with the rest of the motor apparatus and hence be a good intention indicator (see Easton, 1972, for examples).

Although postural preadjustments and gaze could provide only short-range prewarnings about a person's action intentions, they may nevertheless be of crucial importance in social activities such as steering one's way among other moving people in a crowded place and cooperative or antagonistic interaction.

**Sign Language**

Although based on conventional gestures, sign language is of related interest: In its use, intention is conveyed through movement at surprising levels (Bellugi & Studdert-Kennedy, 1980). In canonic form, signs are defined as postures and movements related to postures. However, in rapid signing, the canonical postures are seldom reached, movements between postures merge with movements integral to signs, and consecutive signs merge with each other (coarticulation) into a constant flux of motion. In addition there are individual variations, and signing may occur in a large or small space—even "whispering" in a very small space is possible. For such reasons it seems that for each sign the sign-language viewer would have to deal with a limitless variation of kinematic form.

Kinematic specification of dynamics has been advanced as a way out of this dilemma (Summerfield et al., 1980; Turvey, 1980). Behind the kinematic "surface" there might be a much less variable dynamic structure, and perception is more likely geared to that. Intentions are part of the dynamic structure that generates a person's movements, and the canonical forms of signs might therefore be present in the dynamic structure as a sequence of intentions held by the signer. Our ability to perceive dynamic properties (Runeson, 1977/1983) could thus enable the viewer to bypass the kinematic variability.

In fast movements, mechanical properties become dominant constraints on kinematic form because neuromuscular effects are too crude to interfere with the natural trajectories. In fact, it has been argued by several authors (Asatrayan & Fel'dman, 1965; Bizzi, Polit, & Morasso, 1976; Fel'dman, 1966; Kelso & Holt, 1980; Kelso, Holt, Kugler, & Turvey, 1980; Kugler, Kelso, & Turvey, 1980; Sakitt, 1980), for both theoretical and empirical reasons, that discrete movements (e.g., reaching) are fashioned as critically damped one-shot mass-spring oscillations. In principle, then, the entire trajectory of such a movement is predictable from observing only a part of it. In particular, the target position ("resting length") is specified. In signing, target position might be construed as the canonical posture.

To the learning sign-language viewer, shorter and shorter fragments of the movements toward the canonical postures will suffice to specify them perceptually. The signer can then switch to a new intended sign before the present one is completed. Each intention need be "held" only long enough for the ensuing kinematics to specify the target. We may then conceive of rapid signing as a sequence of dis-
crete sign intentions that on the kinematic surface is filtered by the inertia and damping properties of the limbs. Yet the kinematics retain specificity to the sequence of intentions by agency of the lawfulness of the movement apparatus and the KSD principle.

Identity and Gender

An individual person presumably has a unique composite of anatomical proportions, including both geometrical dimensions and distribution of mass between the members of the body (Bernstein, 1967, chap. 1). Because these dynamic properties extensively constrain how the person moves, the kinematic pattern of a person in action is likely to be specific to the individual—like a kinematic fingerprint. The possibility of recognizing people by the way they move might therefore obtain. Pioneering evidence has been produced by Cutting and Kozlowski (1977) who have shown, with Johansson’s (1973) patch-light technique, that recognition is possible from viewing the kinematics of walking friends. Frykholm (1983a, 1983b) has extended these findings by using methods that permit control of naming confusion. Hence, it was shown that better recognition was possible with extended and varied activity and that recognition learned by watching people perform one activity could transfer to displays of another activity. Furthermore, 11-year-olds were as good as adults in recognizing classmates. Remarkably, recognition performance was better when they were retested 3 years later with the same recordings. It was also shown that although false feedback led some observers to rename the actors, it did not interfere with consistency of recognition.

One source of anthropometric variation is gender. Gray’s Anatomy (Warwick & Williams, 1973) points to the “heavier build of the male above the waist, the female below it, differences in limb proportions, carrying angle of the forearm, muscularity and apparent length of the neck” (p. 204) as the more obvious gender differences. Although quantitative data are not very clear and there is overlap on many individual measures (Bernstein, 1967, chap. 1; Krogman, 1962, chap. 5), it seems that when the total configuration of gross anatomical proportions, including distribution of mass, is considered, men and women form distinct categories with few exceptions.

Cutting, Prollitt, and Kozlowski (1978) discussed geometrical gender differences (e.g., the relative width of hips and shoulders) and the consequent differences in the way men and women walk. They were able to show that artificially generated walking patterns are perceived as male or female depending on the values given to these geometrical proportions (Cutting, 1978).

In addition to geometrical dimensions, gender differences in the distribution of mass (Bernstein, 1967, pp. 12–14) also contribute to kinematic differences. When taken together, geometrical and inertial differences should, according to the KSD principle, lead to gender-specific kinematic patterns and offer a possibility for gender recognition.

A first empirical test of this possibility was provided by Kozlowski and Cutting (1977; Barclay, Cutting, & Kozlowski, 1978). Again using the patch-light technique, they found evidence of gender recognition in displays of natural walkers. When only static displays were presented (four snapshots from one step-cycle), gender judgments were random, however. From our argument above, this is to be expected because a kinematic display could contain information about both geometrical proportions and distributions of mass, whereas a static display could only contain information about (some of) the geometrical properties.

Deception

What happens when someone lifts an empty box but tries to make it look heavy or when a woman tries to act like a man? If we want to abandon the traditional account in terms of gestures and other optional cues and adopt the KSD principle as an informational basis, we must consider the nature of the human motor system a bit more in depth in order to evaluate the possibilities for deception. We will draw on recent insights in the field as presented by Bernstein (1967), Easton (1972), Greene (1972), Kugler et al. (1980), Michaels and Carello (1981, chap. 6), Saltzman (1979), Turvey (1977, 1980), Turvey, Shaw, and Mace (1978), and Saltzman and Kelso (Note 2). Our exposition is limited to a consideration of ideas that may help specifically in explicating the
KINEMATIC SPECIFICATION OF PERSON AND ACTION

KSD principle and its application to person-and-action perception. (For a representative view of the field, the reader should consult the above references.)

Evolutionary pressure has been on achievement, not on the kinematic detail of how we achieve. Therefore our motor system need not deal in movements as such—only in actions, defined as having functional specificity (Reed, 1982). A further insight is that there cannot be, as one used to believe, a motor program or a central controller instructing the myriad muscles in detail as to what they should do at each moment, simply because the magnitude of such a task would exhaust the capacity of any conceivable controlling device, brain or computer (Kugler & Turvey, 1979). This is what Bernstein (1967, chap. 4) calls the degrees-of-freedom problem.

Fortunately, there are other ways that a system can behave in a coordinated fashion and exhibit equifinality despite varying initial conditions and perturbations. Dynamics already knows of some such possibilities; a simple example is a damped mass-spring oscillator (e.g., Kugler et al., 1980).

In the emerging view, the responsibility for coordination and control of our movements is extensively deferred to relatively autonomous mechanisms at lower levels. The basic units are called coordinative structures (Easton, 1972), defined as “a group of muscles, often spanning several joints, constrained to act as a functional unit” (Michaels & Carello, 1981, p. 146; see Kelso, Southard, & Goodman, 1979a, 1979b, for empirical evidence). Turvey (1977) explained the workings of the system:

The executive charge is to control the modes of interaction of lower centers. (p. 218)

We assume, therefore, a repertoire of operations that modify and relate the coordinative structures so as to produce any and all acts. (p. 220)

When confronted with an event of a certain class the executive issues a standard set of instructions and leaves to relatively independent tuning systems the responsibility for achieving the appropriate variant. (pp. 245-246)

It follows that rather than being centrally computed, represented, and executed, the kinematic shape of our movements unfolds as a result of the interplay of multitudinous factors, of which only some are related to the operations of a central executive. Other factors include the relatively autonomous operations of lower level coordinative structures, certain properties of the environment, and, of importance, a variety of properties of our anatomical makeup.

Some of these factors may seem to present more of a burden than a benefit in the generation of coordinated movement, and one might wonder how efficient action could be possible on such premises. However, on appreciating the severity of the degrees-of-freedom problem (see Bernstein’s, 1967, pp. 126-127, suggestive example), one finds that mechanical constraints emerge as possible sources of relief. We must not think of our anatomy as arbitrarily concatenated. Rather, our geometrical proportions, the distribution of mass, the intricate connections of muscles and tendons across the joints, and the elasticity and damping of the tissues have been delicately tuned through evolution to provide adequate constraints. In the dynamic system thus established the options for motion have been reduced substantially toward those conducive to adaptive action. The remaining options are sufficiently few and appropriate to be coordinated and regulated by distributed neural intelligence.

Bernstein (1967) has been especially keen to point out the role of the inertial properties of the limbs. The reactive forces are exploited as natural pendular movements to economize on control and on energy as well. In skilled action, muscular force is used only to produce the minimally necessary deviations from the natural free movements (Bernstein, 1967, p. 109; Runeson, 1977/1983; Turvey et al., 1978). For example, in normal walking the muscles are silent during most of the forward swing phase of the leg (Mochon & McMahon, 1980).

The execution of genuinely deceptive movements would entail producing kinematic patterns that specify a model set of dynamic conditions, which does not in fact obtain (e.g., a different anatomical makeup or a different action). The only possibility would be if neuromuscular effects could delicately compensate for the mechanical differences between model and actual conditions so as to generate a kinematic pattern identical to what would ensue if the model conditions were true. For a number of reasons, the prospects for this are poor.

1. A deceptive movement would have a ki-
nematic trajectory that is unnatural to the actor or the activity. To produce it, the musculature would be called upon to supply forces specified as *detailed functions of time*. And it is precisely such point-by-point pushing of the limbs through given trajectories (Turvey, 1980) that the mechanical tuning of our anatomy has relieved the control system of. Hence, we are not likely to be able to wield this sort of central control.

To get a feel for the limitations of central motor control and the interdependence of movements throughout the body, Turvey (1977, p. 217) suggested we try to write the letter W while making circular movements with a foot. As a further illustration the reader is encouraged to try the following:

Sit at a table with the elbow resting on its surface and raise the arm to a roughly vertical position. Now flip the hand forward and back by flexing at the wrist. Observe the position of the wrist and how it changes when the hand is being rotated back and forth around the wrist joint. Try to keep the wrist stationary while moving the hand as before. You will probably find it remarkably difficult and a strange task indeed. Now hold an object, for example, a book, in the hand and move it freely back and forth as before. Again pay attention to the movements of the wrist and then try to reproduce those movements in spatiotemporal detail without the book.

To make the deception task slightly more realistic one could repeat the procedure without resting the elbow on the table and try to control the kinematics of both elbow and wrist. The difficulties experienced could not be due to lack of muscular strength. Rather, the necessary control facilities seem to be absent. The phenomenal strangeness of the wrist-monitoring task as contrasted with the naturalness of monitoring and controlling the fingertips suggests that through functional linkages across several joints the arm and the hand essentially operate as a unit devoted to doing work with the hand and the fingers. Hence, the movements of the wrist, the elbow, and the shoulder are incidental and subordinate to the dynamical requirements of the movements and the work done by the hand and the fingers. Thus we have an illustrative example both of the informative value of the unintentional kinematics of interpolated joints and of their resistance to volitional control.

2. As explained above, virtually all action involves compensatory movements throughout the body that serve to maintain an appropriately balanced posture and to handle reactive impulses. To fake these movements, without disrupting their instrumental function and without creating additional reactive effects, forces would often have to be exerted relative to the environment rather than between body segments (Runeson, 1977/1983). Usually, we have very few points of mechanical contact with the stable environment, most often located at the wrong end for deceptive purposes. Moreover, as soon as one or more joints are interpolated between a point of support and the point where it would be needed, the travel of reactive impulses will be revealed through elastic displacements due to the mass-spring-like character of the coordinative structures.

3. Departure from natural movements also entails departure from their inherent economy. More muscular force and energy would be required, which may not be available—in particular not for an extended period (Runeson, 1977/1983).

4. It might seem a possibility that “false” kinematic characteristics could be learned through extensive practice. What would have to be acquired through learning includes separate control over the kinematics of interpolated joints (e.g., wrists and elbows). Although the possibility of gaining some degree of control cannot be dismissed entirely, it is unlikely that such control could be upheld while one’s attention is engaged in doing actual work with the hands.

From this analysis it might at first seem that one would be unable to alter his or her movements at all. However, the actor retains several options. For instance, the speed of lifting a box can be varied to some extent, and the actor may choose to lift it more slowly in an attempt to make it look heavier than it is.

Recall, however, that the weight of the box is specified, not by its speed or acceleration, but by the relation between its acceleration and the actor’s postural adjustments. Even if the actor would manage to lift the box with a speed appropriate for a heavy box, the minuteness of postural adjustments would betray the deceptive intention. Thus, the informational effect of the actor’s altered movements will not be that a heavy box gets specified but only that the box is being lifted in a different,
perhaps awkward, manner. In other words, the
real weight of the box and the actor’s deceptive
intention are co-specified in the kinematic
pattern. Unnatural reactive effects would
spring up similarly if, for instance, a person
was successful in making arm movements like
the opposite sex.

The impossibility of simultaneous volitional
control of all parts of the body has been rec-
ognized in the deception literature (Zuckern-
man, DePaulo, & Rosenthal, 1981) as a reason
why the body leaks emotion. Ekman and Frie-
sen (1969, 1974) suggested that social pressure
is on control of the face rather than the body
and that the body therefore gives off better
cues to emotion than the face. Our analysis
would adjoin that the greater mass of the body
makes it relatively more constrained by me-
chanical factors and correspondingly less
amenable to swift and precise neuromuscular
control. Conversely, the reactive movements
produced by finger and face movements in
neighboring body segments are kinematically
attenuated because of the larger mass of the
latter, perhaps to the point of being visually
indiscriminable. Because reactive movements,
according to the KSD principle, are chief
sources of information about the actual dy-
namics of an activity, one obstacle to deceptive
action is rendered ineffective for fingers and
face. There remain, however, the constraints
provided by characteristics of the neuromus-
cular control system.

Admittedly, there are instances in which
hiding one’s personal characteristics, actions,
or intentions, or faking them, could have bio-
logical value. The preying predator would be
the prototypic example. The fundamental
constraints presented by mechanics and the
restrictive premises for central control must
have severely limited the evolution of abilities
to move deceptively, however. We may spec-
ulate that freezing responses sometimes serve
to hide an animal’s intentions rather than its
presence.

If there is a pressure to develop deceptive
abilities, there is also a concomitant pressure
on the prey-as-perceiver to develop abilities to
detect deception. In such cases there is likely
to be considerable perceptual resistance to de-
ception. In practice, successful deception re-
quires altering one’s movements only to the
extent that they become perceptually indistin-
guishable from the intended movements
(Runeson, 1977/1983). For this reason, the
upshot of our above analysis, the virtual im-
possibility of truly faking one’s movements, is
not equivalent to a claim that deceptive action
is bound to fail. Rather, it demonstrates that
detection of deception and perception of the
true condition need not be hindered by lack
of potential information. Hence, there is no
way that deception detection can be declared
a priori impossible, and empirical research is
the way to decide whether and when it actually
occurs.

As implied by the prey/predator example,
we must expect that our keenness on both
deceiving and deception detection will vary
extensively with what is being faked. Re-
searchers should therefore prefer realistic sit-
uations and be cautious in drawing conclusions
from one kind of study to other kinds of de-
ception. (Related concerns have been ex-
pressed by, for instance, Kraut & Poe, 1980.)

To sum up, let us note that although an
intention to act deceptively is a dynamic factor
in the sense that it can (will) influence a per-
son’s movements, it does not eliminate or
change the factor at which the deceptive in-
tention is directed—it adds a new dynamic
factor. The KSD principle entails that change
in one factor will not produce the same al-
terations of the kinematic pattern as a change
in another factor. In the above deliberations
on motor control we tried to show why this
must also apply to human action. Generally,
such lack of substitutability is characteristic
of nonlinear systems (Vidyasagar, 1978) and
systems with many dependent variables. We
should therefore expect that the kinematic
pattern will continue to specify the unchanged
factor and also the added deceptive intention.

Whether the “content” of the deceptive in-
tention will be recognizable is a different mat-
ter. For instance, one might just get the
impression that a lifter acts unnaturally. What
will be specified is what the actor does to alter
his or her movements. To apprehend the con-
tent of the actor’s intention, the observer must,
in some sense, share or recognize the actor’s
notion of how one moves with more or less
heavy boxes. This need not be a matter of
social convention, however. People may have
similar notions about it, deriving from how it feels to lift boxes—or how it looks. Even so, this kind of information will have a softer basis than the information specifying the actual weight of the box.

The KSD Principle Revisited

Our discussion of deception in the light of recent advances in motor control theory has led up to a point where we might say something more general about the KSD principle. Repeatedly our argument has taken the form:

1. Dynamic factor $a$ influences the kinematic shape of movement $M$.
2. Hence, the kinematics of $M$ specify $a$.

How can that logic be warranted?

First, let us note that the proper conclusion from motor control theory is not that our movement repertoire contains fewer items than we used to think. Rather, it is that the set of kinematically possible movements for a system with the large number of degrees of freedom of the human body is exceedingly large. It is relative to this grand set that a person's movement repertoire is a small selection.

A movement in the human movement repertoire identifies not a specific kinematic item but instead a subset of the grand set of possibilities, an "equivalence class" (Turvey, 1977, p. 226). For instance, the act of reaching for a cup, 1 m away on the table at which one is seated, can be satisfied by a very large number of kinematic trajectories of the hand, elbow, shoulder, trunk, and so on. If we restrict consideration to a particular type of cup located at a particular spot on the table and to a particular initial posture in a particular person, the set of kinematic possibilities is still very large. We may also choose a certain way of grasping the cup, a certain degree of hurriedness, a certain style of movement (e.g., sloppy or exact), and to a certain route between obstacles on the table. Each of these constraints divides the set of possible cup-reaching trajectories into smaller and smaller subsets, and we have now perhaps reached the point where the executive has nothing more to say about how the movement will be performed. Yet, we claim, because of the enormous size of the grand set, the selected subset is still large.

When the reaching movement is executed, only one member of the subset is realized, however. What is responsible for the final selection? We may answer that it unfolds through the dynamic effects of various properties of our anatomical makeup and of the autonomous workings of our neural motor control system (see Bernstein, 1967, p. 109, and Saltzman, 1979, for discussions of the various ways these redundant degrees of freedom get constrained). To the extent that the various subsets are hierarchically nonoverlapping, a particular kinematic pattern will specify all the factors responsible for its occurrence, and the KSD principle will hold universally.

This line of reasoning does not suffice to exclude the possibility that there could be overlaps between subsets. In such cases there would be some substitutability between factors and a corresponding lack of kinematic specification of them. The enormous size of the grand set suggests, however, that if overlaps occur, they will not be due to shortage of kinematic possibilities.

A second way to contemplate the KSD principle, one that may better help us gauge the likelihood of overlaps occurring for other reasons, is as follows. Although a large number of factors combine to generate the kinematic pattern, the latter also consists of variations in a large number of parameters. In other words, we have a large number of dependent variables (state variables), one for each degree of freedom. For each one there is, in principle, an equation of motion—a differential equation in which the variables are angular and torsional displacements at the joints, and the first two derivatives thereof. The constants of the equations (the independent variables) stand for anatomical and neural properties of the sort we want to reach. Displacement and its derivatives are available in observing the kinematic pattern. Inserting these values in the equations leaves us with a system of algebraic (i.e., non-differential) equations to be solved for the constants (cf. Raibert, 1978).

On the traditional account of motor control such an enterprise would not yield much because the equations would have to contain terms for muscular force as functions of time. Hence, the constants that we might want to solve for would be badly entangled among unknown force functions.

When the motor system is instead considered in terms of coordinative structures, in
particular when the damped mass-spring model (e.g., Kugler et al., 1980) is adopted, the prospects for the KSD principle are much brighter. In this view, the net force supplied by the muscles operating on one degree of freedom at a joint can be captured by three parameters: resting position, spring stiffness, and damping coefficient. The way that a movement of a limb from one position to another occurs is by a change of the resting position parameter upon which the limb finds itself displaced from its current equilibrium position and an acceleration toward the new position. The stiffness and damping parameters determine the magnitude of initial acceleration and deceleration as it approaches the new equilibrium position. With critical damping there will be neither oscillations nor over- or undershoot.

The mass-spring model is still in its infancy, and it is not clear how it will be integrated in a theory of extended activity. We surmise, however, that the three parameters stay constant as long as the current coordinative structure remains tuned for the same movement, after which a new set of parameters is installed, sometimes in conjunction with the activation of a new coordinative structure, and so forth. Whether or not there will be interspersed periods during which the motor system does not obey a mass-spring law (or another simple rule, e.g., ballistic swing; Mochon & McMahon, 1980), the periods during which the tuning of coordinative structures remains unaltered could be long but are not likely to be very short. This is because a too frequent change of tuning would be in conflict with the requisite economizing on available control capacity. Recalling Johansson's (1976) finding that it takes only a fraction of a second to identify a patch-light display as being a walking or running human, it seems that even though the motor system is repeatedly reparameterized as one engages in activity, there will usually be periods—of perceptually relevant lengths—during which the forces acting at each joint are not functions of time. In other words, during each of these periods a limb, perhaps the whole body, can be treated as a damped multilink mass-spring oscillating system without driving inputs.

Viewed in this way it would seem possible to describe the momentary state of the system in a set of generalized coordinates, one for each degree of freedom, and to write the equations of motion for it as Lagrange's equations, a powerful mathematical tool for analyzing complicated systems with many degrees of freedom (Meriam, 1975, Article 55). Because of the absence of explicitly time-dependent force terms, the set of equations will be mathematically autonomous.

In this system of equations there is a large number of constants to be solved for. They stand for the anatomical properties and the muscular effects. Each limb segment contributes three anatomical constants; mass, moment of inertia, and distance of its center of mass from the proximal joint (length, we assume here, is observable). The muscular effects contribute three constants for each degree of freedom of the proximal joint: resting angle, stiffness, and damping. Because each degree of freedom contributes one Lagrangian equation, the constants outnumber the equations by a factor of, say, 5.

The situation is not hopeless, however, if action can be observed over more than a minimal period of time (the time needed to obtain one reading on displacement and its derivatives). After the second such period a new set of values on the dependent variables will be available, and we have doubled the number of equations. In principle, we can therefore get as many equations as we want simply by observing the action long enough.

Will all these equations taken together suffice to solve for the constants? For a number of reasons the answer is not necessarily positive:

1. Each degree of freedom has a limited range of motion. Hence, the number of distinct readings on a dependent variable is limited.
2. Over a longer period, movement may be cyclic, in which case observations will be redundant.
3. If not cyclic, extended action will entail switching to new coordinative structures, which means that some of the muscular constants change (cf. Fowler, 1977).
4. Some constants may always enter the equations in fixed constellations. For instance, two constants may appear only as a ratio or difference. If so, they can not be disentangled. However, this need not always be a problem.

When we discussed recognition of gender and
identity, we were after anatomical proportions, and box weight was related to the weight of the lifter. It remains an intriguing, but speculative, possibility that the hard-to-discern constants appear in relations that correspond to perceptually relevant higher order invariants of person or action.

As it seems, we have a race between the specification power of the human kinematic pattern and the number of constants we want specified. Although we are inclined to bet the kinematic specification side will win out, it is still for intuitive reasons only. We believe, however, that the above arguments add to the intuitive support for the KSD principle and provide hints as to how a mathematical treatment of it could be constructed. Quite possibly, such a treatment might not come out completely in favor of either side. For instance, it might be that only some of the dynamic properties are specified kinematically. In a trivial sense this is bound to be true. Each atom of our body contributes to its mass distribution, and hence affects kinematics, but each one could not conceivably be specified. For each limb segment, specification of mass is most probably limited to certain aggregate parameters such as mass, center of mass, and moment of inertia. This holds for observation of gross action. Close observation of differential motions in the fleshy parts might specify finer aspects.

It would, of course, be of great heuristic value for the study of both social and nonsocial knowing if a formal proof for the KSD principle, along with a list of its necessary and sufficient conditions, could be provided. However, to serve as an informational basis for person perception it is not necessary that the KSD principle is universally true, only that it holds for an interestingly large number of person-and-action properties in a number of naturally occurring human actions and events.

Summary of Argument

Our discussion of the KSD principle in both general terms and as applied to specific person-and-action properties has indicated that the kinematic pattern of a person in action by mechanical, biological, and motor-control-related necessity is rich in information about both permanent and transient properties of the person and what he or she is in fact doing. Of particular interest is that, in principle, the kinematics of human action does not exhibit substitutability and can be expected to specify true properties despite deceptive or expressive endeavors. The KSD principle therefore warrants serious consideration as an informational basis for social knowing.

Some restrictions on the possible role of kinematic specification should be noted:

1. Facial expressions, gestures, styles, and so forth, are not rendered inefficient by kinematic specification. Kinematic specification should instead be viewed as an addition to the informational support for social knowing with particular value for perceiving true, as opposed to expressed, conditions.

2. Kinematic specification can be effective only in some activities, notably those in which the property in question is a sufficiently strong contributor to the unfolding movement. Vigorous whole-body movements will generally be more appropriate.

3. Perception requires not only potential information but also corresponding attunements of the perceptual system. Informational specificity is not to be equated with perceptual saliency (cf. fingerprint identification). Depending on property concerned and activity observed, person-and-action perception may range from the simple noting of the obvious to requiring the utmost of educated attention.

At this point we undertake a first round of explorative studies concerning the human ability to perceive the sort of properties discussed above. To test specifically the contribution of kinematic information, we used Johansson's (1973) patch-light technique.

Experiment 1: Action With Invisible Object

Johansson's (1973, 1976) studies with the patch-light technique demonstrated convincingly that the kinematic pattern was sufficient to allow perception of persons and what they were doing (walking, dancing, performing ath-

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3 The importance of a distinction between potentially available information, which is the only issue addressed by the KSD principle, and information actually picked up by an organism was recognized by Brunswik (1956) who used the terms cue-validity and cue-utilization in an analogous way.
letic exercises, etc.). Using computer-animated stick figures, Todd (1983) has identified variables in the kinematics of human locomotion that influence the identification of gait and the apparent naturalness of the displayed figure. Our weight-lifting study (Runeson & Frykholm, 1981) showed that the kinematic pattern could support not only recognition of broad categories of action but also fine quantitative judgments of a patch-light-equipped object acted upon. The present experiment was designed to probe whether an aspect of the activity itself could be perceived quantitatively even though the object acted upon was invisible.

The activity chosen was throwing a sandbag at a target placed at varying distances on the floor. Neither the bag nor the target was visible in the video recording, only the actor patch-lights, yet the observers were asked to judge the distance of the target. Hence, the experiment concerned the perceivability of an invisible source of influence on the human kinematic pattern. In this case the source was external and made invisible by technical means, thus forming a lead-in to studies of sources of influence that are invisible because they are internal to the person: expectations, intentions, and so on.

Method

Apparatus. A Sony 1/2 in. European AV-type video system was used. The camera was fitted with a 16-mm lens. A 1-kW halogen spotlight was placed adjacent to the camera lens, directed at the actor. During the experiment proper a 9-in. monitor was used with contrast turned up and intensity down so that the events were displayed as bright patches on a dark background.

Actors. One actor was a 34-year-old, well-trained, 183-cm-tall male, weighing 72 kg. The second actor was a girl, 14 years old, 158 cm tall, and weighing 49 kg.

Recording. The actors wore dark tight-fitting clothes with 20-mm-wide strips of retroreflective cloth-based tape wrapped around ankles, knees, wrists, and elbows, and 15-cm-long strips attached to hips, shoulders, and forehead. Small safety pins were used to fasten the reflectors to the clothes, and care was taken to position them level with the joints.

The sandbag was made of black cloth, 30 cm wide and 35 cm high. In the bag there were 2.5 kg of sand, confined to a loose clump by a sealed plastic bag. The actor held the bag around its "neck" with the thumb-and-forefinger side of the hand oriented toward the clump. This is the natural way to hold it when throwing with a hanging pendular movement of the arm. In this way, the center of mass of the sandbag was about 20 cm below the nearest part of the hand and a further 10 cm from the wrist reflector.

The recordings were made at a right-angle corridor intersection with the video camera backed about 5 m into one corridor and the throwing range extended into the corridor to the right, as seen from the camera. The image of the actor extended about 73% or 85% of the height of the screen and was centered in the display when throwing. The nearest target location was just outside the right edge of the display.

In each recorded act, the actor entered from the left with the bag in the right hand and walked up to a line marked on the floor. Standing with the left foot at the line, the other behind, the actor threw the bag trying to hit a target marker placed 1.75, 3.0, 4.25, 5.5, 6.75, or 8.0 m from the line. The arm was swung back and forth at least once before releasing the bag, and the actor remained standing for a few seconds until the video image was faded away.

Four times the bag hit the floor more than 50 cm off target, three of which occurred with the female actor who had difficulties reaching the two farthest targets. These acts were re-recorded until the 50-cm criterion was met.

Recording sequence. Each actor performed four blocks, each containing the six target distances in random order. In addition, 4.25 m was selected as a standard distance and was recorded four extra times. Two of these were at the beginning of the actor's sequence and the other two after the 8th and 16th normal act, respectively. A soundtrack was recorded, stating, "This was number X," after each act to be judged and, "This was a standard, 4.25 m," after each standard presentation.

Procedure. Fifteen psychology students served as observers. Three at a time they were seated about 4 m in front of the monitor in a moderately well-lit room. They were given a response sheet and instructed to judge the distance of the target in each throw, measured in meters from the actor's forward foot. They were not informed about the size or weight of the bag. To get acquainted with the task and the display, they were shown about seven acts from a randomly selected part of the tape with the sound turned off. Including a 15 sec pause, each act took about 25 sec, and the total time for the 48 judged acts and eight standards was 24 min.

Results

The averaged judgments and pooled within-observer standard deviations are presented in Figure 1 together with the average lengths of throw for the two actors.

Because of the small differences obtained between target distance and actual length, of throw, it is not possible to say whether the judgments agree better with one rather than the other, that is, whether it was possible to...
The trajectory of a thrown object is predictable from simple mechanics. It is necessary to know both velocity and direction of launching because the same target can be reached through a family of trajectories of varying heights. There is no obvious way that launching velocity and direction can be obtained from the display, however.

First, even if the arm–hand–bag were a rigid unit, it would not be clear where on the swing trajectory the bag was released. Also, the size of the bag was not known, and the velocity of its center of mass was therefore unknown throughout the swing. Second, examination of the recordings at normal brightness and contrast revealed that considerable rotation occurred at the elbow, wrist, and at the junction of hand and bag. Hence, we must consider the thrown mass as attached at the lower end of a four-link pendulum (upper arm, forearm, hand, and the “sling” part of the bag). The upper three links are forced (mass-spring-wise) whereas the fourth can swing freely. Only the motion of the upper two links are visibly indicated in the display through reflectors at their endpoints. A further complication is that the shoulders rotate during the swing. In fact, the whole body contributes to the throw. There is considerable kneeling in the middle of the swing, and the actor typically rises to the toes in the final thrust.

No simple informative variable seems to be available in the display. Rather, the information for length of throw must result from the reactive forces exerted through the lower two links on the upper links and on the whole body. Nothing short of an inclusive visual attunement to the kinematics-to-dynamics relations in human action might suffice to account for the results obtained.

Specifically, the present results are suggestive to our above discussion of sign language in showing how well the location of an unseen target can be specified through lead-in movements. It is also an extreme case of what Albert Michotte called “amodal perception” (Michotte & Burke, 1951/1962). In the “tunnel effect” (Burke, 1952) the trajectory of a moving object is seen also when it is briefly occluded in a tunnel. Here, however, the object itself is never visible.

Generally, the results are encouraging when we proceed to study perception of other person-and-action properties that are likely to be specified in the human kinematic pattern. If invisible external sources of influence on our movements are so well detected, internal sources ought to be detectable too.
Experiment 2: Expectation and Postural Preadjustment

To test whether the postural preadjustments of a person lifting a box can be perceptually effective, video recordings of such acts were made, but the display was extinguished from the moment the box began to leave the floor. The problem of genuinely manipulating the actor's weight expectation was circumvented by letting the actor know, and try, the true weight of the box before recording. The observers judged the weight of the box after seeing the lead-in motions only.

Method

The actors were fitted with reflectors as in Experiment 1. Reflectors were also attached to the corners of a 50 X 40 X 25 cm plywood box with good handgrips at the short ends (see Runeson & Frykholm, 1981, for details). There was no lid on the box, and the actor could see the sandbags loaded in it to vary its weight. Three weights were used, 3 kg (empty box), 13 kg, and 23 kg.

Actors. One male and one female, 180 and 172 cm tall, weighing 80 and 60 kg, respectively, participated as actors.

Recording. Although only the lead-in movements were to be used, complete acts were recorded. The box was placed on the floor, 1 m from a 74-cm-high table. The actor entered from the left, grabbed the box, lifted it up, stepped forward, and placed the box on the table. Before the recording sessions began, the actors were allowed to practice with the three box weights, and before each act they were told which weight (light, medium, heavy) would occur.

Recording was made in side view. A piece of reflective tape was stuck to the floor under the near edge of the box to appear as a bright patch in the display, indicating when the box began to leave the floor. Each weight was recorded five times with each actor.

Editing. An experimental tape was prepared for each actor with 14 acts in random order (one 3-kg act was left out for technical reasons). A soundtrack was added, stating the consecutive number of the acts. Frame-by-frame analysis of each act was done to locate the last frame before the indicator patch on the floor became visible. A white piece of splicing tape was stuck to the videotape opposite the indicator patch on the floor to serve as a cue for the interruption of the display.

Procedure. Twelve psychology students, 5 males and 7 females, aged 20-30, served as observers. Three at a time they were seated about 4 m in front of the monitor in a dimly lit room. All were shown the recordings of both actors, half of them in reversed order. To acquaint them with the task, they were first shown a few interrupted acts of the experimental tape. Before each actor sequence, the observers were shown three complete acts with the actor to follow and were told about the weight of the box in each case.

Interruption of the display was done manually. Because the index on the tape deck was close to the take-up reel, an experimenter could watch the movement of the white tape piece for about 2 sec before it got to the index and throw a switch interrupting the display with, in principle, zero reaction time. Three experimenters alternated on this task during each session to avoid fatigue effects.

Results

The distribution of judgments over box weights and actors are given in Table 1.

By assigning numbers (1–3) to judgments (light–heavy), "scores" were calculated and used to obtain each observer's ranking of the three box weights. Based on these, Friedman two-way analysis of variance by ranks (Siegel, 1956, chap. 7) showed that the results are significant for each of the actors (p < .001).

It can be concluded that watching the lead-in movements, including the preparatory postural adjustments, is sufficient to allow an observer to discriminate the weight of a box that a person is going to lift. The results are particularly accurate for the female actor: Three observers judged all 14 acts correctly, and two had only one error. As discussed by Runeson and Frykholm (1981), who found a similar difference between actors, a light and short person must make larger postural adjustments to a box of a given size and weight. In this experiment, therefore, the box weights should be easier to discriminate with the female actor.

Although the observers were instructed to judge the actual weight of the box, we can assume their judgments concerned the actors' expectations as well, because the box was not

<table>
<thead>
<tr>
<th>Judged weight</th>
<th>Box weight (in kg)</th>
</tr>
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<tbody>
<tr>
<td>Light</td>
<td>3</td>
</tr>
<tr>
<td>Medium</td>
<td>13</td>
</tr>
<tr>
<td>Heavy</td>
<td>23</td>
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<table>
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<tr>
<th>Male actor</th>
<th></th>
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<td>Light</td>
<td>18</td>
</tr>
<tr>
<td>Medium</td>
<td>23</td>
</tr>
<tr>
<td>Heavy</td>
<td>7</td>
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<table>
<thead>
<tr>
<th>Female actor</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>42</td>
</tr>
<tr>
<td>Medium</td>
<td>43</td>
</tr>
<tr>
<td>Heavy</td>
<td>0</td>
</tr>
</tbody>
</table>

Note. Each of 12 observers judged each actor–weight combination four (3 kg) or five (13 and 23 kg) times.
seen to move. The results provide an empirical underpinning for our theoretical analysis concerning the informational value of postural readjustments in perceiving certain expectations in another person.

Experiment 3: Lifted Weight and Deceptive Intention

Our third experiment concerned the possibility of deceiving an observer about the weight of a lifted box or, conversely, the ability of an observer to detect deception. The above discussion suggested that an observer might perceive not only the real weight of the box but also the actor's deceptive intention, that is, how heavy the box is meant to appear. This possibility prompts certain methodological precautions. If observers are asked simply to judge the weight of the box, they may be in doubt as to which weight should be judged: the intended or the real. In particular, if the real weight does not seem to vary from trial to trial but the intended weight does, as would be the case if only faked acts were presented, the observer might join the game and respond with judgments of intended weight. Hence, the result would erroneously indicate that deception had been effective. The present experiment was designed to present both true and faked acts. Furthermore, observers were given the dual task of judging both the real and, where they found it applicable, the intended weight of the box.

Method

The arrangements for recording were the same as in Experiment 2 except that the box was fitted with a lid that occluded its contents from the actor's view. Focal length of lens and camera-actor distance were chosen to make the height of the actor fill vertically about 70% of the video screen.

Actors. Three first-year psychology students, two females and one male, 167, 160, and 182 cm tall, weighing 54, 55, and 82 kg, respectively, participated as actors. None had any experience with acting or pantomime.

Recording. In addition to lifting the box and carrying it to a table, as in Experiment 2, the actor grabbed it again after a few seconds, turned around with it, and took it back the same way. The true acts, acts with real variation of the box weight, were recorded first. Three weights were used: 6.5, 11.5, and 19 kg. Each actor was recorded twice with weights 6.5, 11.5, or 19 kg. Before the recording of each faked act the actor practiced 12 times, alternating between the empty box and an identical box actually loaded with the intended weight. The recordings represent what students can do to deceive with a modest dose of practice.

Editing. An experimental tape was prepared, containing three blocks, one with each actor. Each block began with two true 11.5-kg acts, serving as standards. Then followed 12 acts (6 true and 6 faked) in random order, with 20-sec pauses interspersed. A soundtrack was added, telling after each act the weight of the box (if it was a standard) or the consecutive number of the acts to be judged.

Procedure. Six male and five female university students, aged 22-36 years, participated as observers. Observers were seated, one at a time, 1.5 m from the video monitor. They were told that in some of the acts the actor would try to make the box look heavier or lighter than it was. They were given a form to record their judgments. It had two columns: one for real-weight judgments and one for judgments of intended weight. They were instructed to give judgments of both real and intended weight when they thought the actor tried to deceive them and to give only real-weight judgments when they thought no deception was involved. They could ask for longer pauses when they wished.

Design. Experimental variables were true versus faked action and the three box weights. Auxiliary variables were actors and observers, forming a $2 \times 3 \times 3 \times 11$ factorial design with two replications.

Results

In the faked acts the deceptive intention was detected in 33%, 77%, and 83% of the light, medium, and heavy cases, respectively. The corresponding figures for false alarms in the true acts were 17%, 20%, and 23%. Quite naturally, the faking of a 6.5-kg box with a 4-kg box is close to not faking at all.

The quantitative judgments are summarized in Figure 2. Because the number of intended-weight judgments is very low in some conditions, two ways of computing means are shown. The “exclusive” values are means of the judgments actually given in the intended-weight column. The “inclusive” values were obtained by taking blanks to mean “intention no different from real weight” and inserting the corresponding real-weight judgments.

In the true acts the real-weight judgments rather faithfully followed the actual weight of the box, and the intended-weight judgments closely followed those of real weight. The depression at 19 kg is due to a few cases in which observers believed the actor tried to make the box look lighter than it was.

In the faked acts, in which there was really
Figure 2. Average judgments of real and intended weight in Experiment 3. (Excl. = exclusive; incl. = inclusive; intended/excl. = intention judgments actually given by observers; intended/incl. scores were obtained by inserting real-weight judgments where no intention judgments were given. At each plot point n = 66 except on the "exclusive" curves where n - values are given in the graphs.)

a difference between intention and reality, the judgments diverged accordingly. The actors' endeavors to fake the various weights resulted in only 2 kg of variation in judged real weight. Because the actual weight of the empty box was 4 kg, there was a substantial overall over-
estimation of its weight, however. It seems to have resulted from a tendency among several observers to use the standard (11.5 kg) as a default value when faking was in evidence.

If the KSD principle applies, there are two distinct "things" to see in the faked acts: real weight and the appearance intention (i.e., the intention to appear a certain way). If an intention is detected, it is likely to attract the observer's attention at the expense of real weight, in particular because a judgment of intended weight is then also required. Hence, information about real weight might be less well picked up, and the observer may not find reason to deviate much from the standard (see Experiment 5 for analogous results and discussion).

In conclusion, we have shown that our actors' attempts to fool the observers about the weight of the box had little if any of the intended effect. When substantial faking is involved, the observers distinguish clearly between real weight and the actors' appearance intentions.5

Experiment 4: Gender Recognition From Complex Activity

In Kozlowski and Cutting's (1977) experiment on gender recognition from the kinematic pattern of walking humans, 63% of the judgments were correct. Although statistically significant, it falls short of what one would normally mean by being able to tell the sex of a person. One reason why this result may underestimate the human capacity for perceiving gender from kinematic patterns could be that only side views of plain walking were displayed. Following the KSD principle, this may not have been a sufficiently vigorous activity to reveal the relevant differences in anatomical proportions. As suggested earlier (Runeson & Frykholm, 1981), gender recognition might improve when humans in more

5 Box-weight deception has been tried in one study without the dual-task precaution (McCrindle, Note 3). As we would surmise, the results indicated a deception effect (cf. Experiments 5 and 6).

Live performance box-weight deception has been tried in classroom settings with similar results. Within seconds of the appearance of the faking actor, considerable amusement arises in class.
complex activity are displayed. Experiment 4 was designed to test this claim.

Kozlowski and Cutting (1977) selected actors to be roughly equal in height and weight, presumably to rule out these factors as clues to gender. Deviant height or weight, toward the mean of the opposite sex, might covary with non-sex-typical body proportions, however, and the actors may therefore have been somewhat unrepresentative of their respective gender populations. Therefore no constraints on stature were applied in the present experiment. The possible role of height as a clue was attenuated by having actors perform at varying distances from the camera. Thus, the vertical extension of the image of the actor on the screen varied considerably.

Our procedure deviated further from that of Kozlowski and Cutting in obtaining only one judgment of each actor from each observer, thus eliminating the risk for a spuriously high judgment consistency that might occur if observers recognize actors from idiosyncratic gestures or irregularities in the placement of reflectors. To compensate, the number of actors was increased from 6 to 20, half of whom were adults and half were prepubescent youngsters.

**Method**

Apparatus and arrangement of reflectors were similar to Experiment 1. Only the actor was visible in the display.

**Actors.** Twenty actors were recorded (5 adult males, 5 adult females, 5 boys, and 5 girls). The adults were 20-45 years old. All children were 11-12 years old. Among both adults and children there was overlap in height between the sexes. None was unusually fat or thin.

**Recording.** Each actor was recorded once, performing the following action program:

Enter from the left, walk in a circle two or three times, sit down on a chair, rise and stand on the chair, jump down, walk toward the camera and sit down on the floor, run in a circle two or three times, lift a 5-kg wooden box from the floor, carry it to a table and put it down (side view of walking), grab it and carry it back to its original place, pick up a blackboard eraser from the floor and throw it away, and walk out of the picture to the left.

The action scheme was demonstrated and rehearsed before recording, and the actors knew about the gender-recognition purpose of the experiment.

The vertical extension of the image of the actor on the monitor screen varied between 30% and 80% of the screen height.

**Editing.** From the source tape an experimental tape was prepared containing the 20 acts in random order. Each act lasted about 30 sec, followed by a 30-sec pause.

**Procedure.** Twelve observers participated. Most of them were psychology students and staff members, 22-49 years old. The observers were seated, 2 to 4 at a time, 2-3 m from the monitor in a normally lit room. The task was explained to them, and a few of the acts (different acts for different observers) were shown as illustrative examples. They were told not to communicate with each other during the session nor to disclose any other reactions related to the task. Each observer was given a pencil and a form to record the judgments. They were told to guess if they were not sure. The experimental tape was used directly for half of the observers, with the second half of the tape shown first to the rest of the observers. They were not informed that the actors were both children and adults.

**Results**

Overall, 75% of the gender judgments were correct. For adult males, adult females, boys, and girls the figures were 83%, 67%, 63%, and 88%, respectively. All figures differed significantly from random (50%). The errors were to a large extent attributable to a few actors. One adult female was judged as male by 10 out of 12 observers, which is statistically significant in the reverse direction. One boy was judged as female by 8 observers. Three actors were correctly judged by all observers, and five by all but 1 observer.

The differences in results between the four age/gender groups might suggest that judgments were biased by the height of the actors, such that adult-height actors tended to be judged male and youngsters-height actors judged female. The observers were not informed about the age differences among actors nor did they always become aware of it during the experiment. However, a major portion of the differences are attributable to the two deviant actors, neither of whom differed clearly in height from their respective group peers. (Significantly misjudged actors were also found by Barclay et al., 1978, and Kozlowski and Cutting, 1977.) If a height-effect remains, it has raised the number of correct responses for adult male actors but lowered it for adult female actors, and vice versa for children. When the results are averaged over gender, effects of height should therefore tend to balance out.

At most, the height differences due to age groups should have tended to distract from gender-relevant differences, and we may conclude that patch-light displays of adults and prepubescent children in complex activity
permit observers to make at least 75% correct judgments of gender.

Experiment 5: Natural Action Versus Gender Emphasis and Deception

As in the case of deceptive box lifting, the KSD principle raises difficulties for gender deception. A person cannot change his or her anatomical makeup, and it is likely to remain specified despite deceptive endeavors. The possibility of perceiving also what the actor intends to look like probably depends on whether actor and observer share explicit or implicit notions about gender-typical movements—a likely condition because of the abundance of gender stereotypes.

To test the possibility of gender deception through altering one's movements, or the ability of observers to detect such intentions, precautions similar to Experiment 3 were observed. Thus, cases of natural action were included as well. Furthermore, two conditions of appearance intention were used: emphasizing own sex and acting like the opposite sex. Asking for judgments of both real and intended sex was also considered necessary.

Method

Apparatus and arrangement of reflectors were the same as in Experiment 4. A chair was placed in the middle of the action area. A 3-m-long, 45 X 45 mm wooden balancing beam was placed on the floor, giving a three-quarter view of the balancing actor in the left half of the display.

Recording. Each actor performed the following action program three times:

Enter from the left, walk in a circle twice, stand on the chair, jump down, pick up the chair and carry it about 2 m to the left, walk along the beam on the floor trying to maintain balance, and leave the area to the left.

The natural condition was recorded first. The actor was told that the purpose of the experiment was to test whether their particular actions could be recognized when displayed in the patch-light technique. This instruction served to prevent self-awareness regarding gender. The actions were demonstrated and rehearsed before the recording.

The second recording was for the emphatic condition. The gender-recognition purpose was revealed to the actor, and he or she was instructed to give a slight emphasis to movements characteristic of their own sex so as to simplify recognition yet not to reveal to the observers that they were being prodded. They were asked to practice a few times before recording.

Third, the deceptive condition was recorded. The instruction was to perform like the opposite sex, trying to deceive the observers without revealing the deceptive intention. Practice preceded recording.

Results

Real gender. The proportions of correct judgments are presented in Table 2.

Without replications and quantitative judgments, analysis of variance (ANOVA) required collapsing either the observer or the actor variable to form scores. Observers were considered the less interesting variable, and the proportion of correct judgments obtained among the 20 observers for each actor—intention combination were used as scores. Hence, a three-way partial hierarchical design (Kirk, 1968, pp. 229–236) with actors nested under gender and n = 1 was realized. Without replications, actors are necessarily treated as a random effect.

Tested in this way, only the intention effect was found significant (p < .05). According to

<table>
<thead>
<tr>
<th>Actor's appearance intention</th>
<th>Natural</th>
<th>Emphatic</th>
<th>Deceptive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>87</td>
<td>79</td>
<td>74</td>
</tr>
<tr>
<td>Female</td>
<td>84</td>
<td>56</td>
<td>77</td>
</tr>
<tr>
<td>M</td>
<td>85.5</td>
<td>67.5</td>
<td>75.5</td>
</tr>
</tbody>
</table>

Note. Total number of judgments = 600.
Tukey a posteriori tests, only the natural versus emphatic difference was significant. Error term for the intention effects was the actor–intention interaction. The size of this term was to a large extent due to large differences between actors in the emphatic condition. A rerun of the analysis with the emphatic condition omitted showed the natural versus deceptive difference to be significant (albeit only at $p < .10$). Arcsine transformation of data led to a similar outcome of the analysis.

The results clearly contest the opinion that a person can act so as to appear to be male or female at will. In fact, the more significant effect obtained is in the opposite direction.

The figure obtained for gender recognition in the natural condition (85.5%) is higher than in Experiment 4 and, to our knowledge, the highest obtained with the patch-light technique. With deceptive action, recognition is only moderately degraded. It remains at 75.5%, which is similar to the results of Experiment 4. Thus deception has not been very successful. Surprisingly, recognition drops in the emphatic condition. Rather than facilitating recognition, the actors' attempts to emphasize their own sex seem to have confused the observers.

As in Experiment 4, individual figures in Table 2 must not be uncritically equated with recognition performance. In particular, the differences between male and female actors may have arisen from response biases. For instance, when unnatural action was detected, judgments may have been influenced by notions such as, “A woman wouldn’t act exaggerated like that” or “When someone obviously acts like one sex, it must be someone of the opposite sex.”

Gender self-awareness. Although there were a number of differences between the arrangements of Experiment 4 and 5, we suggest that recognition in Experiment 4 was suboptimal, because the recordings were made under conditions more similar to the emphatic or deceptive conditions than to the natural condition in Experiment 5.

We may assume that most people cannot avoid becoming self-conscious in front of a camera, in particular when they know that gender will be the observers' focus of interest. In this predicament, some actors may take a favorable attitude to the experiment and to the possibility of telling men from women on the way they move. They will then pay some attention to what may be gender-typical aspects of their movements and are likely to accentuate these to some extent.

Alternatively, some actors may not believe that men and women move differently, or they may be unfavorably inclined toward studying gender differences. If so, they may try to act in a gender-neutral way or even bias their movements toward the presumed style of the opposite sex.

Both ways, the actors will be more self-conscious or embarrassed than in the neutral condition because they know the observers will be attending to the actor's person rather than to the actions performed. Thus, knowledge of the gender-recognition purpose will produce a generally awkward motion configuration and will tend to bias it in ways similar to either of the two unnatural conditions of Experiment 5, both of which led to degraded recognition.

A look at the data for individual actors lends support to the above interpretation. In Experiment 4, as in the experiments by Barclay et al. (1978) and Kozlowski and Cutting (1977), there were a few actors for which recognition was poorer than chance; that is, they were consistently misperceived. In Experiment 5, however, such cases occurred only in the emphatic condition in which one male and three female actors received recognition scores between 30% and 45%, whereas the remaining six remained at 80% or higher. In the natural and deceptive conditions, there were no such reversals, and recognition scores for the deviant own-sex actors were close to the group averages. Our data therefore suggest that the consistent gender misidentifications obtained in the previous experiments occurred not because some persons were gender atypical in their anatomical makeup or style but rather because they react to self-awareness about gender with confused or exaggerated action. In the deceptive condition they had a more distinct task to accomplish, which may have offset the effect of self-awareness.

According to the KSD principle, the adding of a dynamic factor does not cancel kinematic information about factors already present. In this case, it is unlikely that the addition of gender-appearance-intentions and/or general embarrassment has disrupted the gender-specific information that arises from differences
in anatomical makeup. It remains to be explained why intentional action had a degrading effect on real-gender recognition at all. As discussed in Experiment 3, it might be understood in KSD terms by noting that when dynamic factors are added, there will be more to see than in the neutral case. The additions might have a distracting effect, in particular because they may have higher attensity. Response biases may also have contributed to degradation of scores.

**Intended gender.** Although the inclusion of the natural condition in the experiment led to interesting results on recognition of real gender, it entails complications in the interpretation of the intended-gender judgments. For instance, when an observer has left a blank, it might be because he or she perceived the actor to move naturally, but alternatively, he or she might have perceived unnaturalness in the actor’s movements but could not decide which sex was intended thereby. Conversely, some observers may, despite instructions, have felt an urge to avoid blanks so as not to appear imperceptive.

In Table 3 is given the total distribution of judgments over the combined real and intended gender categories, from which a variety of comparisons can be derived. Overall, the occurrence of intention was reported in 60% of the unnatural scenes. Under the natural condition there were 45% false alarms, however. When detected, intentional acts were correct as to which sex was intended in 76% of the cases.

It seems that the occurrence of deceptive or emphatic gender intentions is somewhat harder to detect than real gender. It should be observed, however, that the outcome reflects not only the acuteness of the perceiver but also the actors’ compliance with the instructions and their acting skills.

**Relation between perception of real and intended gender.** To the extent that anatomical makeup, as specified by the kinematic pattern, is the perceptually efficient information for gender recognition, the KSD principle suggests that recognition of real gender and detection of appearance intentions should be independent of each other.

Because in a complex data set independence can only be demonstrated as absence of specific kinds of dependence, we need to consider predictions from an alternative view of gender recognition and deception. Thus, if gender recognition is based on features over which people do have volitional control, not only would deceptive intentions entrain judgments of real gender (which they do not, as shown above), but judgments of real and intended gender should also be closely related because they would have to be based on the same information.

In the conventional view, one would therefore expect a preponderance of converged judgments (e.g., male acting male) over diverged (e.g., male acting female) judgments. The KSD principle would not lead to such an expectation. As can be seen in Table 3, converged judgments are in fact substantially fewer

### Table 3

<table>
<thead>
<tr>
<th>Actual conditions</th>
<th>Natural male</th>
<th>Male acts female</th>
<th>Male acts male</th>
<th>Natural female</th>
<th>Female acts female</th>
<th>Female acts male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural males</td>
<td>61</td>
<td>14</td>
<td>12</td>
<td>4</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Male act male</td>
<td>38</td>
<td>36</td>
<td>5</td>
<td>6</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Male act female</td>
<td>31</td>
<td>6</td>
<td>37</td>
<td>7</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>Natural females</td>
<td>3</td>
<td>0</td>
<td>13</td>
<td>52</td>
<td>19</td>
<td>13</td>
</tr>
<tr>
<td>Female act female</td>
<td>13</td>
<td>0</td>
<td>31</td>
<td>29</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>Female act male</td>
<td>9</td>
<td>1</td>
<td>13</td>
<td>28</td>
<td>13</td>
<td>36</td>
</tr>
<tr>
<td>Total</td>
<td>155</td>
<td>57</td>
<td>111</td>
<td>126</td>
<td>58</td>
<td>93</td>
</tr>
</tbody>
</table>

**Note.** Number of judgments on each row = 100. Italicized figures are the fully correct judgments, that is, judgments that are correct on both real and intended gender.
than diverged ones; that is, the dependence is rather in the opposite direction from the conventional prediction.

It must be pointed out, however, that the above comparison is a bit shaky because we must allow for response biases or implicit notions of correlation held by the observers. Hence, if real and intended gender are perceptually distinct, an observer may attend to one of them more and let the judgment of the other be influenced by the first according to some implicit rule. For instance, as data suggest, when someone is seen to act female, observers may tend to think it is a male.

Because all combinations of real and intended gender occurred with equal frequencies in the experiment, the average accuracy of judgments is not affected by response biases. On the conventional view, the accuracy of real-gender and intention judgments should correlate positively because of their shared informational support. Conversely, if they are based on distinct information, as per the KSD principle, a person's anatomical makeup may be more or less gender typical, independent of his or her ability to convey appearance intentions. Hence, accuracies should not be positively correlated.

Despite wide variations in accuracy among observers (57% to 93% on real gender and 37% to 60% on intended; blanks considered correct responses to the natural cases), a correlation of only .29 (n = 20) obtains between accuracy scores on the two judged variables. Furthermore, this figure is likely to have been influenced by spurious sources of positive correlation in the form of variations between and within observers in perceptiveness, task motivation, and alertness.

The between-observers effect was removed by calculating a phi coefficient on the real and intended gender right/wrong contingency table (n = 30) for each observer. Together these 20 coefficients are significantly above zero (binomial sign test: p = .006; t-test: p < .05), but their arithmetic mean is down to .09 (Mdn = .10).

Within-observer effects do not seem to be removable in this kind of experimental design. If they were, the correlation figure is likely to drop further or even go negative. In any case, correlations as low as .09 or .29 could not be of theoretical significance.

To conclude, no support for a perceptual closeness of real gender and intention have been found in Experiment 5. The results are better understood by considering real gender and appearance intentions to be independently specified in the kinematic pattern and independently perceivable. Precisely because of this independence, observers are free to focus their attention on one or the other of these properties, and the accuracy of judgments will vary accordingly (i.e., zero or negative correlation). Overlaid on the perceptual outcomes there may be response biases, such as preference for divergent pairs.

**Experiment 6: Gender Deception With Unsuspecting Observers**

To ensure fair and sensitive tests of deception detection, the observers in Experiments 3 and 5 were informed about the possible occurrence of deception attempts and were asked to judge the true condition and the appearance intention separately. The results showed that real and expressed weight or gender can be perceived distinctly and that deception was not very effective. The present experiment was designed to test whether the precautions were in fact warranted, that is, whether gender judgments would be affected in consonance with the actors' appearance intentions in a conventional deception design with unsuspecting observers judging only "gender."

**Method**

The same video recordings as in Experiment 5 were used, and the experimental arrangements and procedure were also similar. A new judgment form with only one column, marked "Gender," was used, and the instructions were simply to judge the gender of each person appearing in the display.

**Observers.** To ensure an unsuspecting initial attitude, psychology students were not used. Nineteen observers, 19–38 years old, were instead recruited from a high school for adults.

**Results**

The proportions of correct judgments are presented in Table 4. Analogous with Experiment 5, an ANOVA showed the intention effect to be significant (p < .05). The recognition figure obtained in the natural condition agreed well with the results in Experiment 5, now with a different group of observers. The results
differed markedly in the unnatural conditions, however. In the emphatic condition, recognition was level with the natural condition, whereas it was markedly lower in the deceptive condition.

If considered alone, the results of the present experiment might well have been taken as evidence that deceptive action was efficient, not to reverse gender appearance, but to disrupt gender recognition substantially. When combined with the outcome of Experiment 5, a different interpretation is required. Because the results of the two experiments were similar in the natural condition, the present group of observers is not likely to have been composed of poorer or less alert perceivers. We suggest that the crucial difference between the two experiments resides in the ambiguity of the term gender when used alone: whether it refers to the actor’s person or style of action. The observers may have judged ‘‘maleness’’ versus ‘‘femaleness’’ rather than real gender. If so, the occurrence of emphatic action has tended to support the real-gender impressions; hence, it compensates for the general obscuring effect of intentional action evidenced in Experiment 5. Conversely, deceptive action has tended to compete with the real-gender impression, aggravating the obscuring effect.

Rather than demonstrating a deception effect, the results of Experiment 6 remain compatible with our above claim that real and acted gender are distinctly perceivable. Together, the two gender-deception experiments demonstrate that observers distinguish or combine impressions of real and acted gender depending on instructions and task. To be fair to our perceptual abilities, deception experiments should therefore alert the observers to the possible occurrence of deception, preferably by giving them a dual-judgment task.

### Concluding Discussion

The present experiments, together with other studies by, for instance, Cutting and coworkers (Barclay, Cutting, & Kozlowski, 1978; Cutting, 1978; Cutting & Kozlowski, 1977; Cutting, Proffitt, & Kozlowski, 1978; Kozlowski & Cutting, 1977), Johansson (1973, 1976) and ourselves (Frykholm, 1983a, 1983b; Runeson & Frykholm, 1981), have shown that kinematic displays could support perception of the following types of properties of a seen person:

1. What category of person it is (gender).
2. Who it is (identity).
3. What the person is actually doing (lifting a so-and-so heavy box, throwing something so-and-so far away).
4. What the person intends/expects to do (lift a so-and-so heavy box).
5. What his or her appearance-intentions are (deceptive or emphatic).

Of particular interest is (a) the relatively high quantitative orderliness with which certain action parameters are perceived, (b) the insusceptibility to faking, and (c) the remoteness from and seclusion within the actor of some of the properties perceived. It should also be pointed out that the immediacy with which the patch-light displays are perceived as humans in action, as reported by Johansson (1973, 1976), prevailed in the present experiments, too.

The patch-light technique does not exclude the possible contribution of optional gestures and styles of movement. For at least three reasons we do not think that such factors can explain the present results. First, chief agents of gesturing such as face and hands were not visible in the displays. Second, action with gender emphasis did not improve recognition, nor did deceptive action have a strong negative effect. Third, it would be strained to argue that people have acquired gestures to express length of throw or weight of a lifted box.

The present results, together with the generality of the KSD principle, should serve to establish kinematic specification as a prominent kind of information and the patch-light technique as a useful research method in the

### Table 4

**Percentage of Correct Judgments of Real Gender in Experiment 6**

<table>
<thead>
<tr>
<th>Actor’s gender</th>
<th>Intention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Natural</td>
</tr>
<tr>
<td>Male</td>
<td>88.4</td>
</tr>
<tr>
<td>Female</td>
<td>80.8</td>
</tr>
<tr>
<td><strong>M</strong></td>
<td><strong>84.6</strong></td>
</tr>
</tbody>
</table>

*Note. Total number of judgments = 570.*
Expression and Reality: The Duality of Person Perception

The three deception experiments have provided suggestive evidence that perceiving another person has two aspects: true properties of person and action, and intentional or communicative expressions. Our theoretical analysis has shown that distinct information for the two aspects can be available. The experimental results support the consequent hypothesis that they can be independently perceived.

We suggest that in normal social interaction we automatically shift attention between the two aspects depending on our purposes or the situation. In particular, the true conditions may often be obvious or indifferent and attention therefore lingering on the communicative expressions.

Thus, in addition to the severe mechanical and motor control obstacles to deceptive action, the duality of person perception provides another reason to suspect that professional actors might not be radically more adept at faking box weight or gender in front of observers eager to discern true from faked action. The skill of an actor is more probably on the communicative than on the deceptive side. Faking is part of the game at the theater—in pantomime it is the whole game—and the audience knows this from the outset.

Presumably, self-presentation is fashioned to have high saliency and easily apprehended meaning. Hence, it may dominate the impression obtained by the indifferent, inattentive, or inexperienced person. Task-specific experience does not seem to have been a prerequisite for deception detection in our experiments, however, because the observers are not likely to have had much experience with gender deception nor with box-weight faking. In the balance must be put that the actors, too, were inexperienced with these kinds of deception.

Our experiments have shown how misleading results can occur in a conventional deception design in which appropriate alerting and attention-directing instructions are lacking. Such instructions must be given with great care and perhaps be embodied in the kind of task given, because the observers know they are in an experiment and are prone to let the experimental setting define what passes for "reality" therein (cf. Mixon, 1974, p. 79). More generally, the independence of reality and expression perception, our liberal shifting of attention between them, and their prevalent concordance in real life may have supported a preoccupation with intentional expressions and deception, and a consequent belittlement of human abilities to perceive true conditions. Our development of the KSD principle and the empirical results may help to establish a more balanced perspective.

It is interesting to note how our studies have led us to a discussion of the nature of person perception that almost point for point parallels Gibson's (1979, chap. 15) discussion of an entirely different category of perceptual objects: pictures. After pointing out that pictures, too, are objects in our environment, Gibson (1979) wrote,

A picture, photographic or chirographic, is always a treated surface, and it is always seen in a context of other non-pictorial surfaces. Along with the invariants for the depicted layout of surfaces, there are invariants for the surface as such. . . . The information displayed is dual. The picture is both a scene and a surface, and the scene is paradoxically behind the surface. This duality of the information is the reason the observer is never quite sure how to answer the question, "What do you see?" For he can perfectly well answer that he sees a wall or a piece of paper. It is this duality in the optic array from a picture that makes the drawing a bad way to begin the study of perception. (p. 281)

If we allow ourselves to call the depicted scene the "expression" provided by the picture-as-object, we find that pictures have a dual nature analogous to that of people. Gibson (1979) also brought forth an empirical demonstration that illustrates, as did our Experiments 5 and 6, how misleading results can be obtained if dual questions are not posed to the observer:

I once took a good, sharp photograph of a lawn with trees and a paved walk and had it enlarged about twenty times so that it could be mounted on a six-foot panel. The observer stood at a point where the visual angle of the picture at his eye was the same as the visual angle of the array admitted to the camera. He was told to estimate distances in terms of the number of paces needed. To the question, "How far away from you is the elm tree?" he would visualize himself walking up to it and reply, "Thirty paces." But to the question, "How far away from you is the picture?" he
would pause and reply, "Oh, that's four paces." For the latter estimate he had to shift the operation of his visual system so as to pick up quite different invariants. The lawn in the picture was not connected with the floor of the room. . . . The duality of the information in the array is what causes the dual experience. (pp. 282–283)

Thus, our idea that expressive or deceptive movements do not obliterate the kinematic information about the true properties of a person is perfectly analogous to Gibson's conclusion that the geometrical pattern on a picture surface does not, even when the artist has done his best, disrupt optic array information about the surface as such. For both pictures and people, the expressive contents and the actual state of affairs are co-specified in the optic array. It follows that they are also potentially co-perceivable, although in practice they might more often serve as alternate perceptual foci.

People may differ from pictures in that their actual properties are sometimes hard to discern in the face of deceptive expression. As always stressed by Gibson (e.g., 1979), perception requires that the perceiver has learned to detect the relevant informational invariants, and we must expect that occasionally very well educated attention is necessary in order to see through deceptive self-presentation (Baron, 1981). Perhaps the analogy with deception is stronger if, instead of pictures, we consider camouflaged objects (e.g., vehicles painted such as to present some of the optic invariants of rocks, trees, and bushes). Here, indeed, the true properties of the objects are nontrivial to the observer. The analogy with person perception entails, then, that although deception might be effective under certain conditions (most notably, static situations), it becomes transparent for perception when the person or vehicle is observed in action.

Social Knowing Meets Motor Control Theory

We started out using simple rigid body mechanics, yet we were able to pry out a first few bits of information for lifted-weight perception. The second step was to bring in simple biomechanics, which uncovered information about "hidden properties" such as intentions and expectations. Third, we turned to motor control theory, which helped us evaluate the possibility of deceptive action and led to general considerations about the information available in the human kinematic pattern.

We take this progression as a prototype for work within an ecological approach to the understanding of person-and-action perception. Once we have abandoned the traditional central-control notion of animal motion, according to which the brain plays the piano, each key connected to a muscle, executing a score composed in complete freedom (cf. Turvey, 1980; Turvey et al., 1978), we can begin to unravel how perception is capitalizing on the lawfulness of human movement.

Realizing that the kinematic detail of human movement unfolds from constraints, the sources of which are the type of things we need to know about other people, we should be eager to partake of the progress in the field of motor control. While that discipline works out how constraints yield the kinematics of the movements, the student of social knowing has much to gain by following suit—trying to reverse the dynamics-to-kinematics relations and exploring what is potentially revealed about people in their movements. Below, we speculate about what might be expected along this route.

*Styles of Motor Activation as "Hidden" Person Properties*

We have seen that there are individual differences in one of the sources of constraints on movements: anatomical makeup. It would not be a very large step to say that there are also variations and differences in the physiological and neural mechanisms of motor control and coordination. Although the details vary, a recurrent theme in the motor control literature is that of a division of labor between separate systems for selection of action through setting up coordinative structures, tuning them to current conditions, and triggering action (e.g., Easton, 1972; Greene, 1972; Michaels & Carello, 1981, chap. 6; Roberts, 1967; Turvey, 1977, 1980). Coordinative structures are set up ("activated") in preparation for action and can be held for a long time. Quite plausibly, there are variations in people's readiness to act, generally, or in their inclination to take some types of action rather than others. Such variations might be understood in terms of coordinative structures and the
ways they get activated: how readily their different types get activated and which, if any, are prevalent when the person is, superficially, not preparing for any action.

Considered in this way, an action readiness is a state of organization set up throughout the motor system. It therefore constrains, in characteristic ways, all movements of a person. Even small posture-maintaining movements and responses to perturbations or surprises are likely to bear witness to the sort of action readiness prevalent in the person (cf. Bernstein, 1967, pp. 110–113; Michaels & Carello, 1981, p. 140).

General and specific action readiness, intra- and interindividual variations therein, and a person’s style of motor activation would seem to be highly relevant for social functioning. It seems an exciting possibility that conceptual links might be established between aspects of the motor system, as treated in modern motor control theory, and traditional concerns in person perception: intention, emotion, and personality. In this way, kinematic specification might have a bearing even on these, the most hidden properties of a person.

The idea that a person’s emotions are revealed and perceivable through his or her movements has been discussed by Heider (1958, pp. 42–43), Koffka (1935), and Köhler (1929, chap. 7). Hence Koffka (1935) wrote:

The movements of an irritated or a depressed person will be causally connected with his state of mind, and will on the other hand provide proximal stimuli for other persons who observe him. . . . Emotion might cause or influence action by mere release; in this case the form of action would be independent of the emotion which released these actions, depending only on the “motor-mechanisms” thus brought into play. But all along in our discussion of action we have found the concept of release quite inadequate to deal with the facts; everywhere we found actions not only released, but also guided or steered by forces residing in the total field. . . . If an emotional stress steers action, then the ensuing movements will, to some extent, mirror the emotions; characteristics of overt behaviour will map characteristics of the field in which this behaviour is started. (p. 658)

Although the role of emotions as causally involved in the unfolding of our movements would require further clarification, the KSD principle relieves the approach of a critical weakness not considered by Koffka, the ambiguity of the “proximal stimulus.” Armed with the KSD principle we can now say that to the extent that emotions influence movements, they are specified in the kinematic pattern by biomechanical necessity.

The above also has a bearing on the issue of direct versus indirect perception. Thus, Baron (1981) considered “hidden meaning” an important obstacle to direct perception and suggested that the various instances of social knowing can be ordered on a continuum from direct to indirect. He insisted, however, that cognitive mechanisms not be invoked too soon and mentioned the possibility that hidden person properties may turn out to be visible if higher order invariants and extended observation are considered. Our above speculations have pointed out how such a possibility may materialize and serve to extend direct knowing to central matters of social knowing.

Requirements on Perception—and on Perception Research

The extreme theoretical variability of human motion, the large number of degrees of freedom, is the origin of the enormous specification power characterizing the kinematic pattern of a human in action. A seemingly relevant objection against considering this potential food for perception is that the informational properties are likely to be exceedingly complex, thus presenting insuperable difficulties for a perceptual system.

As we have argued elsewhere (Runeson, 1977), such an objection might be relevant for the machine-vision designer and, indeed, for a theory of indirect knowing. Traditionally, one would argue that the movements are first registered as kinematics, stored in memory, and then operated on by an inferential process that, it is hoped, extracts the dynamic factors. If we have a hard time handling these matters intellectually, as at least we had in the information analysis above, problems of a related nature should also accrue to the storage and inference stages of indirect knowing.

It is not so with direct perception, however. As a natural system, perception is not subordinate to the same notion of “complexity” as the scientist qua thinker (Runeson, 1977; see also the discussion by Heil, 1981, on the common confusion of the complexity of descriptions with the complexity of the things described). Instead, natural systems often ex-
hibit "smart" solutions to seemingly complex tasks—the very reason, perhaps, that science is hard and difficult work (Runeson, 1977; see also Heil, 1981; Michaels & Carello, 1981; Turvey & Shaw, 1979). If the upshot of our information analysis, the specificity of the human kinematic pattern to a number of factors that are relevant items for person-and-action perception, is correct, we know that the information exists. If so, there is no warrant for postulating that extraction of this information must occur through inferential processes nor through applying dynamic equations to registered kinematic data and solving them for the dynamic constants. We must instead entertain the likely possibility that natural systems are solving the problem in a much more elegant and direct way than we would do intellectually (cf. Runeson & Lind, 1981). To avoid premature dedication to any particular idea about the nature of these smart solutions, we prefer simply to talk about perceptual sensitivity to informational invariants.

This is not to say that all information in the kinematic pattern of human action can be perceptually appreciated. Evolutionary pressure has been only on picking up useful information, and furthermore, evolution might have failed to yield solutions to some pick-up needs (i.e., what seems to us to be an animal’s needs). Analyses of available information does not, therefore, preempt the study of person-and-action perception. As we have tried to illustrate, information analysis should inspire and guide empirical work and provide conceptual tools for interpreting the results. Once information has been found and shown to be perceptually effective, the charge will be to study how perceptual systems are fashioned to exhibit the necessary sensitivity—whether we find the informational invariants simple or not.

To conclude, let us repeat that the perceivability of a certain person property through kinematic specification obtains only when the seen activity fulfills certain requirements, for example, when it is relatively vigorous. This is in nice concordance with the common wisdom that it is when the going gets rough that one really gets to know what another person is like. It also points out that the close dependence of perception on action, advanced by Gibson and the ecological approach, should concern not only the activity of the perceiver but also that of the person perceived.

Reference Notes

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