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CONTEXTUAL SPECIFICITY IN PERCEPTION AND ACTION

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The visually guided control of helicopter flight is a human achievement, and thus,understanding this skill is, in part, a psychological problem. The abilities of skilled pilots are impressive, and yet it is of concern that pilots' performance is less than ideal:They suffer from workload constraints, make occasional make errors, and are subject to such debilities as simulator sickness. Remedying such deficiencies is both an engineering and a psychological problem.

When studying the psychological aspects of this problem, it is desirable to simplify the problem as much as possible, and thereby sidestep as many intractable psychological issues as possible. Simply stated, we do not want to have to resolve such polemics as the mind-body problem in order to contribute to the design of more effective helicopter systems. On the other hand, the study of human behavior is a psychological endeavor and certain problems cannot be evaded.

In this paper I discusses four related issues that are of psychological significance in understanding the visually guided control of helicopter flight. First, I present a selected discussion of the nature of descriptive levels in analyzing human perception and performance. Here I will argue that the appropriate level of description for perception is kinematical, and for performance, it is procedural. Second, I argue that investigations into pilot performance cannot ignore the nature of pilots' phenomenal experience. The conscious control of actions is not based upon environmental states of affairs, nor upon the optical information that specifies them. Actions are coupled to perceptions. Third,I discuss the acquisition of skilled actions in the context of inherent misperceptions. Such skills may be error prone in some situations, but not in others. Finally, I discuss the contextual relativity of human errors.

Each of these four issues relates to a common theme: The control of action is mediated by phenomenal experience, the veracity of which is context specific.

LEVELS OF DESCRIPTION

How do we characterize what helicopter pilots are doing? One answer to this question is that pilots are controlling the dynamics of their craft. At one level of description it makes sense to describe pilots' behavior in these terms; however, at another it does not.

Within some control theory models, pilots are characterized as having perfect understandings of the dynamical properties of their flight environment. Given the nature of the variables under examination in these models, it does not matter that the achievement of such dynamical understandings makes no psychological sense. However,from the point of view of understanding task performance related to other pilot variables, more appropriate characterizations of human behavior are needed.

I argue that pilots can achieve only very simplistic understandings about dynamics, and that the appropriate level of description for perception is kinematical,and for control, it is procedural.

Dynamics Versus Kinematics

In Classical Mechanics, dynamical analyses relate to the action of bodies that move due to the application of forces. In nature, object motions are constrained by the law of least action, where action has the dimensions of energy x time. Kinematical analyses, on the other hand, deal only with pure object motions without consideration of mass, and thus, of energy. As a level of analyses, kinematics is far less restrictive than is dynamics: Most of the object motions that can be describe in kinematics are inconsistent with Newton's Laws.

Research has shown that people's understandings of dynamics is extremely simplistic and heuristical (Proffitt & Gilden, 1989). Moreover, the spontaneous dynamical intuitions of trained physicists differ very little from those of unsophisticated people. Physicists' expertise becomes evident only when they are permitted to symbolically represent the system under consideration. In this sense physicists have a dual awareness: One is immediate, appeals to phenomenal categories, and differs little from naive common sense; the other is deliberate, appeals to the symbolic categories of first principle representations (e.g. $F = ma$), and is far removed from common sense. I propose that helicopter pilots do not fly their crafts by controlling dynamics. Being people, pilots have neither the perceptual nor conceptual ability to penetrate their helicopter's dynamics during flight. Rather the problem of representing the control of helicopter flight is best stated in terms of a mapping between phenomenal variables. That is, pilots must relate the kinematical variables available in perceptual stimulation to appropriate control actions. The dynamics of the craft constrain the nature of this perception/action coupling; however, the pilot need not appreciate these dynamics in order to exploit them. In essence, pilots need to appreciate the dynamics of helicopters no better than children need to understand the dynamics of their bicycles. The rules that define skilled control of a particular mechanical system, need not embody any of the system's dynamics. These rules (transform functions) relate one class of kinematical variables, perceptions, to another, actions.

Declarative Versus Procedural Knowledge

There is a very old distinction between "knowing how" versus "knowing that" that has more recently come to be described as procedural versus declarative knowledge. Procedural knowledge consists of rules for regulating skilled behaviors; they are recipes for action, are evoked by specific situational variables, and are typically not accessible to awareness. Riding a bicycle or flying a helicopter depends upon procedural forms of knowledge. Declarative knowledge is explicit and entails a conscious conceptualization and articulation about some state of affairs.

Piloting a helicopter evokes procedural knowledge. These rules are not general because they are blind to the underlying dynamics of the vehicle. The dynamics of helicopter flight create an environment in which particular kinematical variables in perception and action are related in specific ways. Learning these relationships establishes procedures for producing desired kinematical outcomes.

PHENOMENA

Pilots fly helicopters by heeding and affecting phenomenal states of affairs. What are the relevant phenomena? During the NASA Workshop, my group picked slant perception as a phenomena to study.

This choice was motivated by the existence of a striking everyday phenomena that may jeopardize successful low altitude flying. When, for example, people drive in San Francisco, they cannot help but be struck by the incredibly steep inclines of some of the roads that they encounter. When asked to estimate the slopes of these hills,people provide erroneous estimates in the neighborhood of 45-75 deg (informally collected anecdotal evidence). In fact, the steepest road is no more than 15 deg. Evidence exists that this is a general finding (Ross, 1974). When approaching a large incline, such as a hill, people grossly overestimate its slant.

We decided to study the psychophysics of this phenomena by initially asking the question: What slant will be perceived for (1) various hill slants, (2) viewed at various altitudes, (3) by a moving observer who either approaches or moves laterally with respect to the hill (4) at different speeds. These, of course, are frequently encountered situations for helicopter pilots.

Our prediction was that slant will be greatly overestimated in all conditions and that this error will be greatest when the hill is approached head-on at low altitudes. Other more specific hypotheses were formulated for each of the other variables.

In addition to mapping out the psychophysics of slant perception across these variable, we hope to determine the visual variables that affect slant perception, and ultimately to develop a model for human slant perception. With regard to this latter goal, levels of description issues again emerge. In particular, we would like to know the geometrical space in which kinematic information is represented (see Lappin this volume).

From a geometrical perspective, the slant of a hill is fully specified to a moving observer; however, people seem not to appreciate well the optical information that is available. This implies that people have either (1) little sensitivity to the available information, or (2) that they possess the required sensitivities, but are unable to use it effectively when making slant judgments.

CONTROL

Given that people misperceive the slant of hills, why do they not evidence this misperception when walking up them? The answer to this question, and the related helicopter control issue, is that accurate perceptions of environmental state of affairs are not required for effective control of action within the situation. So long as perceptual attributes co-vary perfectly with environmental dimensions, control will not reflect on underlying misperceptions.

Consider how control behaviors are learned in a situation like flying a helicopter at low altitudes over a hill. Suppose that the novice pilot misperceives the slant of a hill to be 60 deg when, in fact, its inclination is 15 deg. In order to maintain the desired altitude relative to the hill, the pilot must learn to couple the appropriate control responses to what is perceived. To put the matter simply, he or she must learn to pull back on the stick by some amount, given that a hill of some perceived slant is approaching. Through learning, the pilot will come to couple the appropriate control responses to the misperception of slant. It does not matter that slant is misperceived, since control responses have been acquired in the context of this misperception, and the misperception co-varies with distal slant.

That fundamental misperceptions may not be evidenced in particular control contexts, does not imply that they will never result in pilot error. One working hypothesis for the overestimation of slant is a conjecture that the perceived horizon is displaced below its actual location. This concomitant to slant misperception might have no influence on flying over a hill, but might very well effect judgments of the height for obstacles encounter on the hill. Given that the perceived location of the horizon may serve as an important cue to whether an obstacle is above or below ones flight path, misperceiving slant may result in errors in some contexts but not in others.

ERRORS

The sorts of control errors that people make tend to be context specific. Accidents that occur in helicopter flight are known to be far more likely in certain situations than in others. Assuming a skilled operator, the contextual specificity of control errors derives not from a single cause but rather from at least three quite different sources.

Workload

Obviously, some situations require considerably more effort than do others. Some of these contexts present a greater diversity of task relevant information requiring attentional allocation and information integration. In other situations, the control behaviors are particularly arduous. And finally, some situations present especially difficult demands on both perceptual and control resources.

Degraded or Missing Information

As tasks move farther from those encountered in everyday experience, it becomes increasing likely that the information that is typically relied upon to perceive some environmental state of affairs may be reduced or absent. For example, optical flow rate specifies speed only if the observer knows his or her altitude. Thus, optical flow suffices in perceiving speed for a locomoting person accustomed to his or her own eye height, but not when that person is piloting an aircraft.

Misperceptions

As the above discussion on slant misperception noted, misperceptions may be inconsequential in some contexts, but not in others. Moreover, context can be defined in two quite different ways. First, context may be defined in terms of the environment: maintaining a constant altitude while flying over a hill versus deciding whether a tree is above or below one's flight path. Here the contexts have an external referent: hills and trees. On the other hand, contexts can be defined by differential task demands that arise in the same physical situation. Thus, for example, a pilot may successfully maintain a constant altitude while piloting his or her craft over a hill, thereby implying that the hill's slope was accurately perceived. However, if asked to estimate the slope of the hill verbally, or by adjusting a visual or manual slant indicator, that same individual will evidence a strong overestimation of slant.

It is tempting to ignore or disparage the significance of the explicit slant estimation error, since only the control of altitude has practical significance. I think that this would be a mistake. If we want to understand what a pilot is doing, we must take a psychological perspective, and thereby recognize that the visually guided control of action is mediated by phenomenal experience. Thus, an adequate account of visually guided control cannot simply attempt a mapping of environmental properties, as they are manifest in optical structure, onto control behaviors. Visual experience is formed by optical structure, but it is not equivalent to it. To assume otherwise is a futile attempt to sidestep the difficult issues inherent to the study of human behavior.

CONCLUSION

The dynamics of helicopter flight create an environment. In this environment, pilots learn to relate particular kinematical variables in perception and action. Learning consists of discovering how control procedures transform current phenomenal states into those desired in the future. These procedures cannot be general, since they were acquired without any first-principle understanding of the dynamics inherent in the context of their acquisition. In addition, control procedures are often acquired in the context of misperceptions. Yet, because of their contextual specificity, they may lead to errors in only a limited set of situations.

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