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Perception/Action: An Holistic Approach II

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Perception/Action: An Holistic Approach II

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Abstract

A general systems approach was used to study the emergent properties of the human perception/action system. Two task domains, the control of locomotion and the recognition of objects from dynamic occlusion, were used to study human performance. The locomotion task involved the control of altitude. Experimental results indicate that conflicting results from studies of altitude perception can be explained when global optical flow rate is considered. Optical analyses of the structure of flow fields, empirical results from human performance studies, and control theoretical analyses of the state space all converge to indicate that altitude and speed are not independent with respect to the problem of controlling locomotion in low altitude flight. In the dynamic occlusion task, the effects of time delays, visual noise, training, and instructions have been evaluated. The results tend to support the hypothesis that information was the critical determinant of performance in the dynamic occlusion task. Mode (active versus passive observer) was only important to the extent that it made additional information available to the observer. This conclusion is consistent with research on adaptation where the "reafference hypothesis," in which mode played an important role, is being replaced by the "information hypothesis."

Perception/Action: An Holistic Approach II

A fundamental role of the human component in complex systems (e.g., vehicular control, air traffic control, or process control) is to "close-the-loop." That is, the humans are included in the system because of their unique and adaptive abilities of perception, decision making, and motor control. Although there have been great advances in automated control systems, the adaptability and generality of the human have yet to be matched by automated sensing and control systems. This generality and adaptability of the human controllers that makes them attractive (if not essential in many cases) as components within complex systems poses a great challenge to basic researchers interested in modeling human performance, as well as for system designers who need to be able to integrate across human and electro-mechanical components to predict and evaluate system performance. The general goal of this research program is to develop a framework for studying humans as an adaptive, closed-loop controllers.

Traditionally, psychology has parsed the problem of human performance into problems of perception, cognition, and motor control. Research programs have evolved that focus on one or the other of these components in isolation from the others. For example, those who focus on perception often tightly constrain action (e.g., fixating the head with bite boards, using brief, tachistoscopic stimulus presentations, or using restricted response protocols such as key presses). Those who study motor control go to great lengths (e.g., deafferentation) to isolate motor control from perception. And those who study cognition select problems (e.g., tower of Hanoi, missionaries and cannibals, logic theorems) with minimal perceptual and motor demands.

Such strategies for studying perception and action have been successful in reducing complexity and allowing scientists to make inferences about the elementary cognitive processes that combine to control performance. However, these approaches miss the emergent properties that arise from the coupling of perception and action. Without an understanding of these emergent properties it may not be possible to integrate what we have learned about perception systems and action systems in isolation into a comprehensive and general theory of human performance (a theory capable of guiding decisions about interface design and training for complex systems such as high performance aircraft). Thus, it is important not to ignore these emergent properties of the closed-loop, perception-action system. An *active psychophysics* (Flach, 1990; Warren, 1988; Warren & McMillan, 1984) is needed to compliment the traditional work on passive psychophysics, perception, and motor performance.

A fundamental theme of our research program is that perception must be studied in the context of action. The importance of the coupling of perception and action for development of visually guided behaviors in cats was demonstrated in the classic study of Held and Hein (1963; See also Held, 1965).

In attacking the general problem of active psychophysics, our research has examined two classes of problems: the discrimination of objects using information available in dynamic occlusion and the control of locomotion. The first section of this report will discuss the problem of control of locomotion and the second section will discuss the problem of dynamic occlusion.

Perception and Control of Altitude

According to Haber (1987) jet fighter pilots simply fly into the ground in visual flight conditions with no evidence of mechanical or operational failure or medical emergency at a rate of about two crashes per month. For this reason, it is critical that we understand the information (or lack thereof) that pilots use to control locomotion. Our recent research has focused on the information in optic flow for the control of altitude. Several potential sources of information have been identified. These include splay, optical density, and depression angle (see Flach, Hagen, & Larish, 1992; or Flach & Warren, in press, for quantitative and graphic descriptions).

Recently, there has been some controversy about the relative effectiveness of these various sources of information. Research simulating fixed wing aircraft has consistently found splay to be the most effective source of information for altitude (Flach, Hagen, & Larish, 1992; Warren, 1988; Wolpert, 1988; Wolpert & Owen, 1985; Wolpert, Owen, & Warren, 1983). Research simulating rotary wing aircraft has consistently found depression angle to be the most effective source of information for altitude (Johnson, Bennett, O'Donnell & Phatak, 1988; Johnson, Tsang, Bennett, & Phatak, 1989).

In a recent study in our lab (Kelly, 1993; Kelly, Flach, Garness & Warren, 1993), we looked at global optical flow (GOF) rate as a possible intervening variable. The hypothesis was that when a vehicle is in hover or moving at very low forward speeds (low GOF rate), depression angle would be most informative. However, when a vehicle is moving forward at higher speeds (high GOF rate), then splay is most informative. To test this hypothesis, four flow textures (splay only (vert), depression angle only (horz), block, and dot [in principle grid and dot texture should contain both splay and depression information]) were crossed with four global optical flow rates (0, 0.25, 1, 4). Results showed an interaction as shown in Figure 1. Performance with splay only (vert), dot, and block textures was independent of GOF rate and had lower error rates than with depression (horz) texture. Performance was generally poor with horizontal texture and became worse at the highest flow rate. In no case, not even at the hover (0 GOF rate), condition was depression angle superior. Thus, we were unable to replicate the results of Johnson et al.

A second study has just been completed. In the previous study GOF rate was manipulated within subjects. In the second study, we tested subjects only in a hover condition. Under that condition we were able to replicate the results of

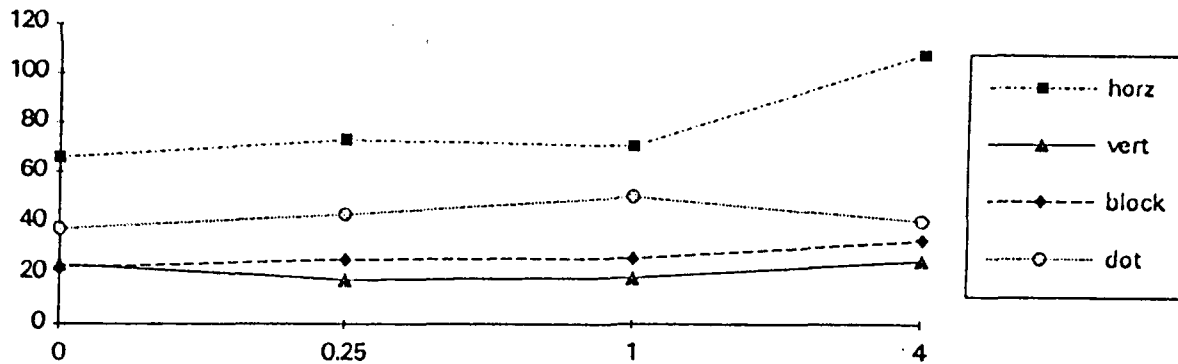


Figure 1. RMS Altitude error as a function of texture and global optical flow rate.

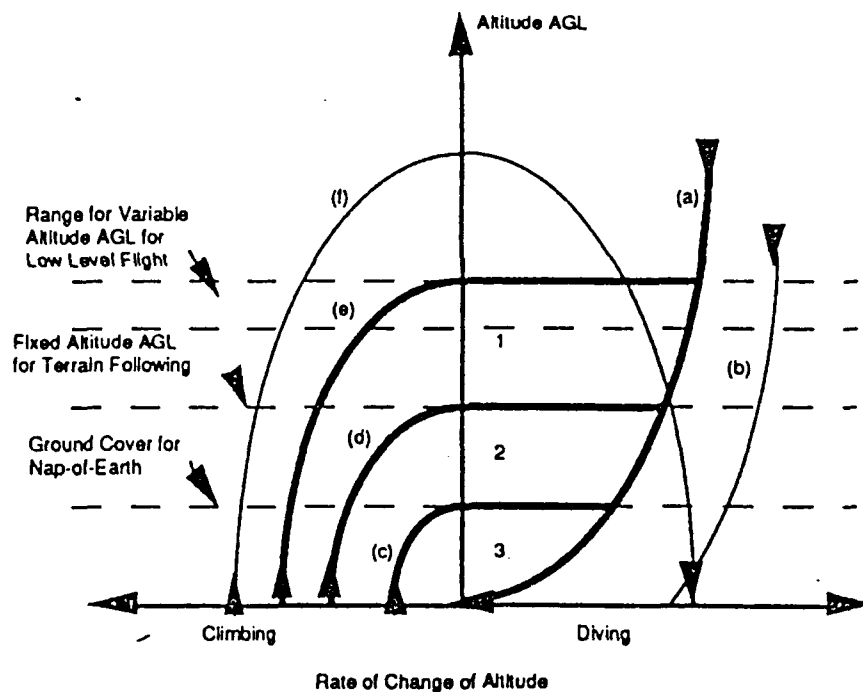


Figure 2. A state space representation showing altitude and rate of change of altitude. The curves in this diagram represent paths through the state space. The dark curves (a, c, d, & e) represent critical boundaries for different types of low level flight. The space outside of the areas bounded by these critical limits represent conditions where there is no control action that will avoid crashing into the ground or ceiling that delimits safe areas within the state space. Curves b and f are examples of paths where crashing into the ground or ceiling is unavoidable. The hypothesis is that safe flight requires that the pilot can perceive position with respect to these boundaries.

Johnson et al. We found that depression angle resulted in superior performance. Splay angle resulted in the poorest performance. These results suggest that splay is generally better (over a wide range of GOF rates), but that depression angle is better for the specific case of 0 GOF (hover). More importantly, this program of research indicates that altitude and speed may not be functionally independent sources of information. This same conclusion has been suggested from analytical analysis of the control or state space for vehicular control (Flach & Warren, in press). Figure 2 illustrates that critical boundaries for low altitude flight are generally specified as a joint function of altitude and rate of loss of altitude. This suggests that it will be important to examine higher order structures in optic flow that are invariant over variations in altitude and speed (e.g., tau or time-to-contact).

Dynamic Occlusion

The dynamic occlusion task required subjects to identify wire frame, three dimensional objects using the information made available from the temporal-spatial pattern of occlusion and disocclusion created as these objects are moved within a field of point lights. This task has been explained in a previous report to AFOSR (Flach 1992; see also Flach, Allen, Brickman, & Hutton, 1992). This task has been used to evaluate performance as a function of the mode by which the pattern of occlusion is generated. One dimension of mode is whether the subject is active or passive. Subjects have been run in yoked pairs. One subject in each pair was able to control the pattern of occlusion/disocclusion using a joystick control. This is the "active" subject. The second "passive" subject saw the same pattern of occlusion/disocclusion, but had no control of the motion of the object. Another dimension of mode is whether the pattern of occlusion/disocclusion is created by a subject who has the intention of identifying the object (subject generated information) or whether the pattern was generated in a stereotypical pattern by the computer (e.g., constant rotation at fixed velocity).

Previous research with the dynamic occlusion paradigm has indicated that under the yoked conditions in which the information (pattern of dynamic occlusion) was identical for active and passive observers, there was no difference in performance (Flach, 1992; Flach et al. 1992). Performance was equivalent for the two classes of observers. Further, an interaction with practice has been found for the other dimension of observation mode. Early in practice subjects perform better with computer generated information than with subject generated information. With practice, however, the performance of these two groups converged.

Over the last year, further experiments have examined the effects of noise, mode awareness, time delay, training, and shape in the dynamic occlusion paradigm.

Noise. In previous research, the only variation visible in the display was the result of motion of the object. When an edge of the object was positioned in front of a point light, the light disappeared, and when the edge moved from in front of the point light it reappeared. Noise was added to the display so that the points would appear and disappear at random intervals, independent of the position of the object. Thus, instead of being positioned in a field of steady point lights, the object was now positioned in a field of randomly blinking point lights. The rationale for this new dimension was the hypothesis that the correlation between intended actions and patterns of occlusion would allow the "active" subject to distinguish between signal (occlusions resulting from object motion) and noise (random blinking of point lights). In turn, it was thought that this would give the active subject an advantage in recognizing the objects.

Experiments conducted with noise found tentative support for our hypothesis. First, the experiments replicated previous results showing no effect of mode (active vs. passive) in no noise conditions. Performance levels were reduced when noise was introduced. When noise was manipulated within subjects a significant mode by noise interaction was obtained. Active and passive observers were equivalent when no noise was present, but subjects were better in the active mode, when noise was included (see Figure 3). A similar pattern was found in a second experiment in which noise was manipulated between subjects. However, the interaction was not statistically significant in the second experiment.

Mode Awareness. In all our previous experiments, the subjects have had explicit awareness of the mode in which they were operating. That is passive subjects, knew that they could not control the motion of the object and active subjects knew that they could control the object. Even if this were not made explicit by instructions --- when no noise was present, it would be easy for the subjects to quickly discover the constraints on their particular mode. However, the addition of noise in the display opens the possibility to manipulate awareness. An experiment was run in which all subjects were instructed that they had control over the object. In fact, however, they only had control on a randomly selected, half of the trials within a block. Thus, on half the trials one subject had control while the second subject was passive. On the other half, the roles were reversed. However, the key difference between previous studies was that the subjects believed that they had control on every trial. Thus, their actions were "superstitious" on half of the trials.

When subjects were run in this ambiguous mode condition, there was a substantial effect of mode, with "true" active subjects performing better than "superstitious" active subjects.

Time Delay. A critical parameter of any closed-loop control system is the time delay. Thus, it is likely that this will be an important factor to consider for evaluating the coupling of perception and action. We examined two levels of

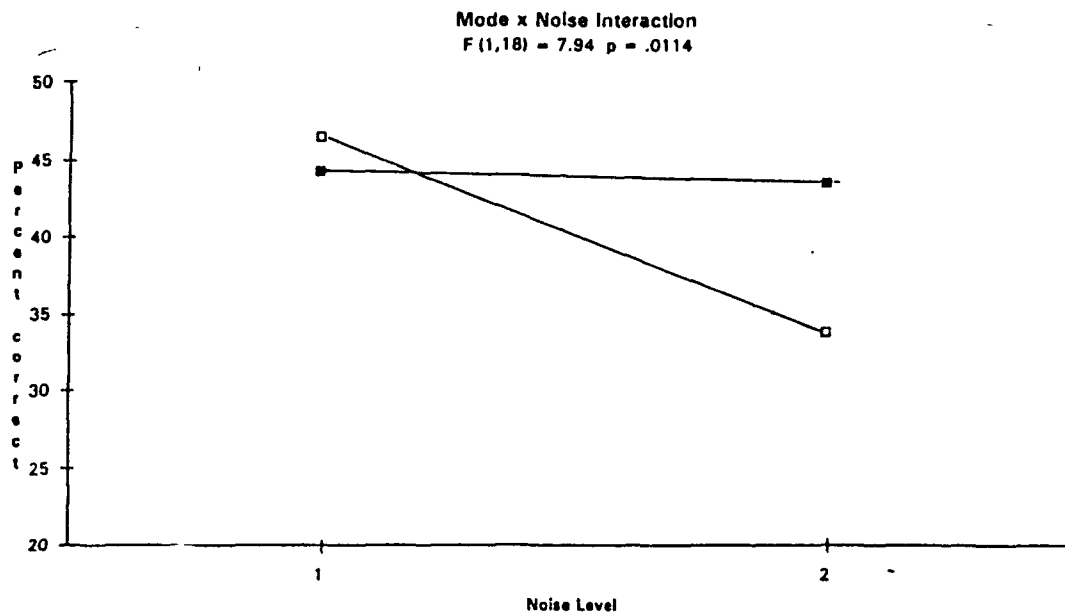


Figure 3. Interaction between noise and mode. For Noise = 1 no random blinking was present in the display. For Noise = 2 random blinking was present. Solid symbols represent Active subjects. Open symbols represent Passive subjects.

time delay (200 ms and 2 s) with or without noise. Results showed no effect of the differential delays. The noise, again, resulted in a significant decrement in performance. No interactions with mode (active vs. passive) were found. We have some tentative hypotheses about why time delay was not effective for this task. However, further studies are required.

Training. In earlier studies, an interaction was found between practice and the source of motion (subject generated vs. computer generated). Early in practice performance is best with the stereotypic patterns generated by the computer than with the exploratory motions generated by the subjects. Later in practice the performance for the two types of motion converges. One hypothesis for this pattern of results is that subjects are learning to use the joystick early in practice and are able to devote less attention to the task of identifying the object. Later, as they become more skilled at manipulating the object using the joystick, performance improves to a level equivalent to that obtained when the computer generates the motion. To test this hypothesis, a training manipulation was tested. Subjects were trained to move "visible" 3-d objects with the joystick prior to being tested in the dynamic occlusion task. However, the training to familiarize subjects with the mapping from the joystick to object motion did not change the pattern of results. Thus, the unfamiliar mapping of the stick to object motion does not appear to explain the early differences between subject generated and computer generated motions.

Shape. A final manipulation examined the shape of the objects used. In all the previous studies six 3-d shapes were used. These shapes may be discriminated based on gross features (e.g., short and fat versus tall and narrow). Thus, subjects may not be required to identify the shape per se, but merely discriminate between it and the other five objects based on these gross features. Perhaps if the distinctions between the objects were more subtle, then there may be some advantage for the active subject. To test this hypothesis a new object set was constructed. This set included squashed and stretched versions of the previous shapes. The result of changing the dimensions along different axes was to make it more difficult to discriminate among the shapes. Results showed that this manipulation made the task significantly more difficult. However, performance for active and passive observers remained equivalent with this new object set.

Summary. The results of the new manipulations are all consistent with an "information hypothesis" regarding the coupling of perception and action (Welch, 1986). This hypothesis suggests that mode per se (e.g., active vs. passive observer) is not the critical dimension. Rather, performance depends on the quality of information available to the observer. The active observer will perform better than the passive observer, if and only if, the active mode makes information available that is not available for the passive observer. In our paradigm this happens when background noise is present. The active observer has knowledge of the commanded motion and thus is better able to distinguish the signal (occlusion resulting from object motion) from noise (random blinking).

Also, when the mapping from the control stick to the object is "real" versus "superstitious," then there is an advantage for the active observer. In all other conditions that have been tested, performance was equivalent for active and passive observers.

General Conclusions

A common theme has emerged from both research paradigms (altitude control and dynamic occlusion). Both paradigms highlight the importance of information in linking perception and action. The ability to make discriminations of either altitude or object shape depends on the ability to differentiate variation within the optic array that are specific to the critical task dimension from other optical variations within the flow field. For the pick-up of altitude, variations from global optical flow make it difficult to judge altitude changes using horizontal texture (depression angle). This noise is minimal in the hover condition and increases with increasing optical flow rate. Thus, we see differences in subjects' ability to control altitude using horizontal texture as global optical flow rate is changed. In the dynamic occlusion task, differences were found between active and passive observers only when the mode provided differential access to information. This was seen in noise conditions where knowledge of the commanded motion was available to the active subject.

Publication Activity

Journal Articles and Book Chapters:

- Flach, J.M., Brickman, B.J., Hutton, R.J.B., & Allen, B.L. (In preparation). Mode or information: The coupling of perception and action in functional systems. For submission to *Psychological Review*.
- Flach, J.M. & Guisinger, M. (In preparation). Fitts' Law and dripping faucets: A new metaphor. For submission to *Psychological Review*.
- Flach, J.M., Kelly, L., Garness, S., Warren, R. & Stanard, T. (In preparation). Active control of altitude: Interactions of texture and global optical flow rate. For submission to *Journal of Experimental Psychology: Human Perception and Performance*.
- Flach, J.M. (In press). The ecology of human-machine systems: A personal history. In Flach, J.M., Hancock, P.A., Caird, J. & Vicente, K. (Eds.). *The ecology of human-machine systems I: A global perspective*. Hillsdale, NJ: Erlbaum.
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- Flach, J.M., Hagen, B.A., & Larish, J.F. (1992). Sources of information in optic flow for the regulation of altitude. *Perception & Psychophysics*, 51(6), 557-568.

Published Conference Proceedings:

- Kelly, L. Flach, J.M., Garness, S. & Warren, R. (1993). Altitude control: Effects of texture and global optical flow. *Proceedings of the Seventh International Symposium on Aviation Psychology*. Columbus, OH.
- Flach, J.M. & Bennett, K.B. (1992). Graphical interfaces to complex systems: Separating the wheat from the chaff. *Proceedings of the Human Factors Society 36th Annual Meeting*. Santa Monica, CA: Human Factors Society. (pp. 470-474).
- Flach, J.M. & Hancock, P.A. (1992). An ecological approach to human-machine systems. *Proceedings of the Human Factors Society 36th Annual Meeting*. Santa Monica, CA: Human Factors Society. (pp. 1056-1058).

Conference Presentations Publication of Abstract Only:

- Flach, J.M. (1993). Meaning: The lost dimension. *Proceedings of the Human Factors Society 37th Annual Meeting*. Santa Monica, CA: Human Factors Society. (Oct).
- Flach, J.M. (1993). A constraint-based global perspective on information for control. Presented at the *VIIIth International Conference on Event Perception and Action*. University of British Columbia, Vancouver, BC, Canada.
- Flach, J.M. (1992). Skill: Dancing with the environment. *NASPSA '92*. North American Society for the Psychology of Sport and Physical Activity. Pittsburg, PA. (June).
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Participating Professionals

Graduate Students	RA Support	Proposal Approved	Thesis Completed
Brad Allen	8-90 - 9-91	4-93	Exp. Nov 93
Bart Brickman	6-92 -	4-93	Exp. Nov 93
Sheila Garness	9-92 -	Exp Nov 93	
Mark Guisinger			
Robert Hutton	6-92 -	3-93	Oct 93
Leigh Kelly	9 -91 - 6-92	7-92	Oct 93
Amy Robison			
Terry Stanard	9 -93 -		

Theses

Kelly, L. (1993). *Altitude control and the interaction of global optical flow with ground texture type*. Psychology Department, Wright State University.

Hutton, R. (1993). *The role of activity in the perception of three dimensional objects from dynamic occlusion*. Psychology Department, Wright State University.

Undergraduate Students: Jeffrey Light (Jeff has begun work on an honors thesis in the laboratory that will be completed in Spring 1994)

Interactions

Other Support from Air Force Labs.

Perception and Control of Locomotion, AFOSR Augmentation Awards for Science and Engineering Research Training AASERT. 1993-1996, \$ 77,534.

Fusion Interfaces for Tactical Environments Laboratory, Armstrong Laboratory, WPAFB, Subcontract to Logicon, "Human Factors support in display evaluation" 1993 \$9874.78.

Presentations:

Flach, J.M. (1993). Beyond the servomechanism: Active Psychophysics. Invited presentation Risø National Laboratory, Kognitiv Systemsgruppe, Roskilde, Denmark. (Sept. 3)

Flach, J. M. (1993). Perception and action: A holistic approach. Presentation to the Center for Human Motor Research, Department of Movement Science

- Division of Kinesiology, University of Michigan, Ann Arbor, MI. (March 26th).

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- Flach, J.M. (1992). Perception/Action: A Holistic Approach. Presentation to the Human Movement Sciences Group, Psychology Department, The Free University, Amsterdam. (Dec).
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