1984 ANNUAL MANUAL ABSTRACT

DOES McRUER'S LAW HOLD FOR HEART RATE CONTROL VIA BIOFEEDBACK DISPLAY?

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Some persons can control their pulse rate; rapidly increasing or decreasing it with the aid of a biofeedback display. If the biofeedback display is modified to show the error between a command pulse-rate and the measured rate, a compensatory (error correcting) heart rate tracking control loop can be created. An exploratory experiment is described to measure the dynamic response characteristics of this control loop when subjected to step and quasi-random disturbances.

The control loop includes a beat-to-beat cardiotachmeter differenced with a forcing function from a quasi-random input generator; the resulting "error" pulse-rate is displayed as feedback. The subject acts to null the displayed pulse-rate error, thereby closing a compensatory control loop. McRuer's Law should hold for this case, as it has for most other compensatory manual control situations.*

In this preliminary experiment, a few subjects already skilled in voluntary pulse-rate control are being tested for heart-rate control response, using the STI Describing Function Analyzer. The DFA measures the response/input fourier coefficients at five input frequencies from which various closed-loop and opened-loop transfer functions can be computed. In a method similar to past human-operator tracking research, control-law properties are derived, such as: crossover frequency, stability margins, and closed-loop bandwidth. These are evaluated for a range of forcing functions and for step as well as random disturbances.

Heart rate variation has been proposed as one measure of task-induced mental workload. In that context, this research has application to:

- Developing the applied technology needed to properly evaluate heart-rate workload measures.
- Training subjects (drivers, pilots, N-plant operators) to cope with task-induced workload via psychophysiological feedback (e.g., anticipatory heart rate rise; incipient overload).
- Screening subjects as to sensitivity to heart rate variations and heart rate control ability, as they affect the above applications.

This presentation constitutes an early status report on the results to date.

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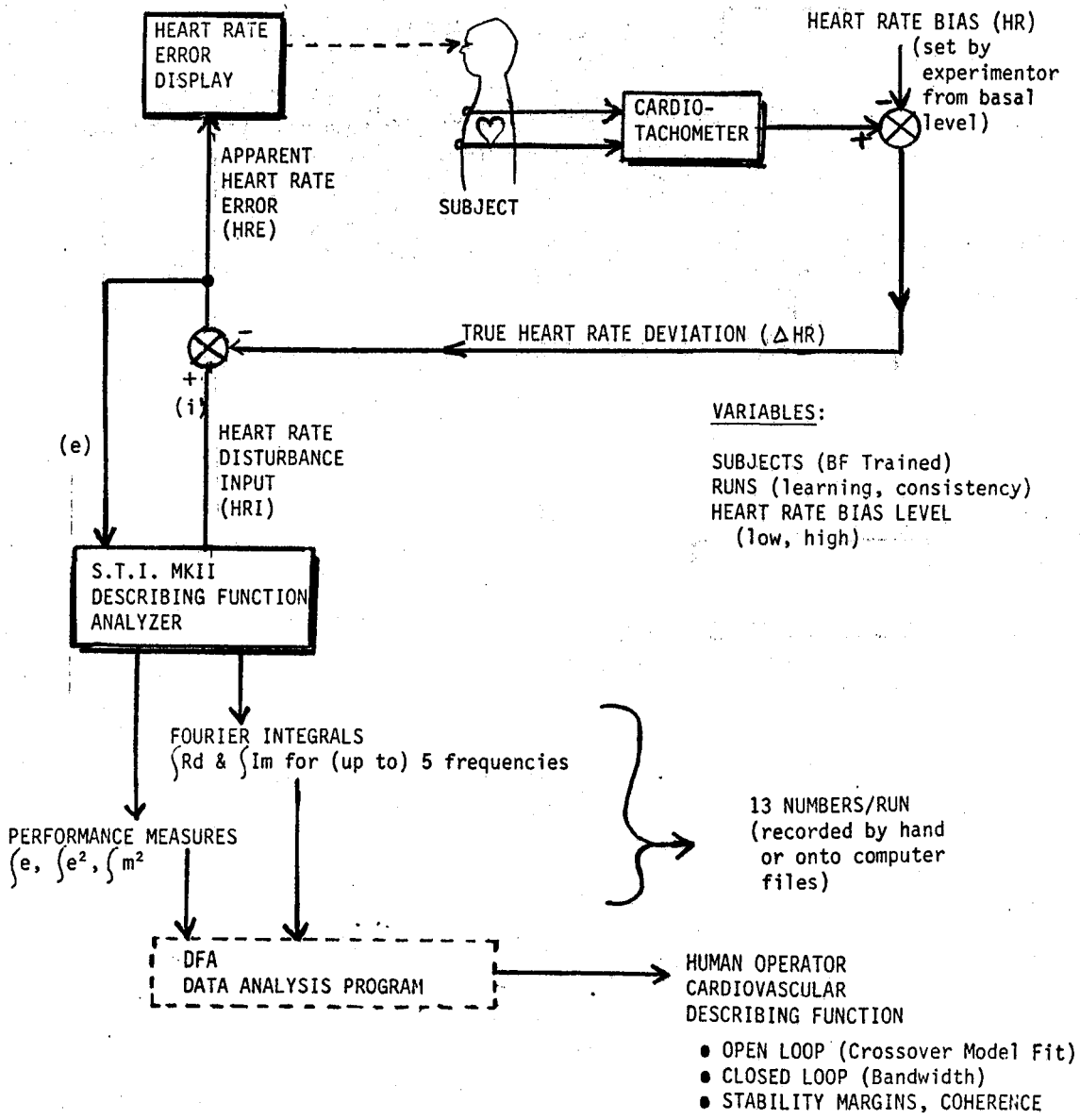
*McRuer's Law (sometimes called the Crossover Model for Operator Adaptation) states that the opened-loop frequency-response of a random-forcing-function compensatory man-machine control loop will be adjusted by the operator to resemble that of an integrator with time-delay in the "gain crossover" frequency range near unity magnitude-ratio.

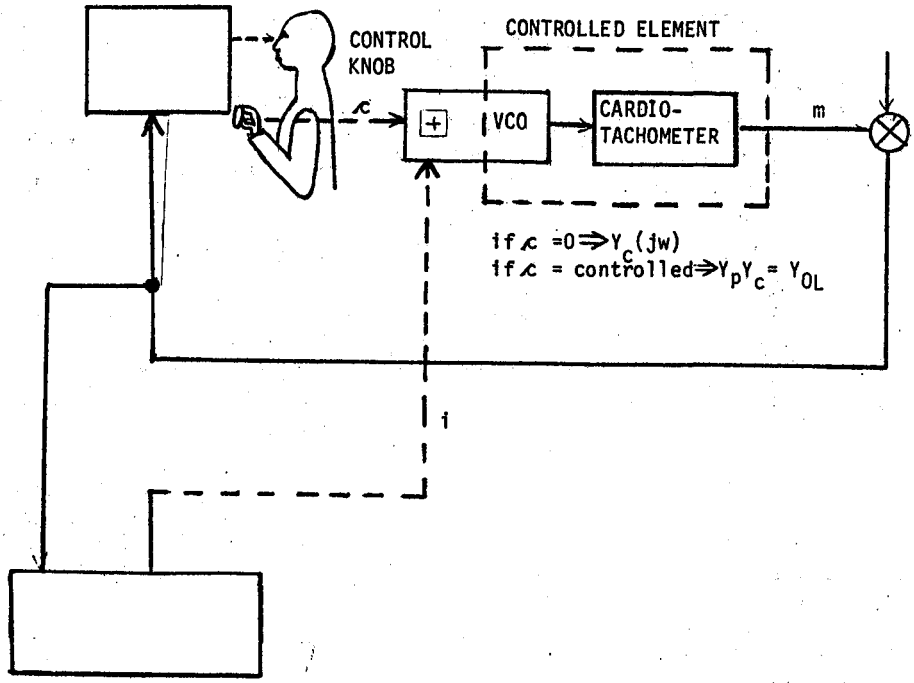
INTRODUCTION

- SOME PERSONS CAN CONTROL THEIR PULSE RATE AT WILL VIA BIOFEEDBACK.
- DISPLAY THE "ERROR" BETWEEN PULSE RATE AND A DISTURBANCE (FORCING FUNCTION) COMPENSATORY TRACKING.
- FOR COMPENSATORY TRACKING WITH AN UNPREDICTABLE FORCING FUNCTION, McRUER'S (CROSSOVER MODEL) LAW HOLDS.
- Q: DOES McRUER'S LAW HOLD TRUE FOR HEART RATE CONTROL VIA BIOFEEDBACK DISPLAY?

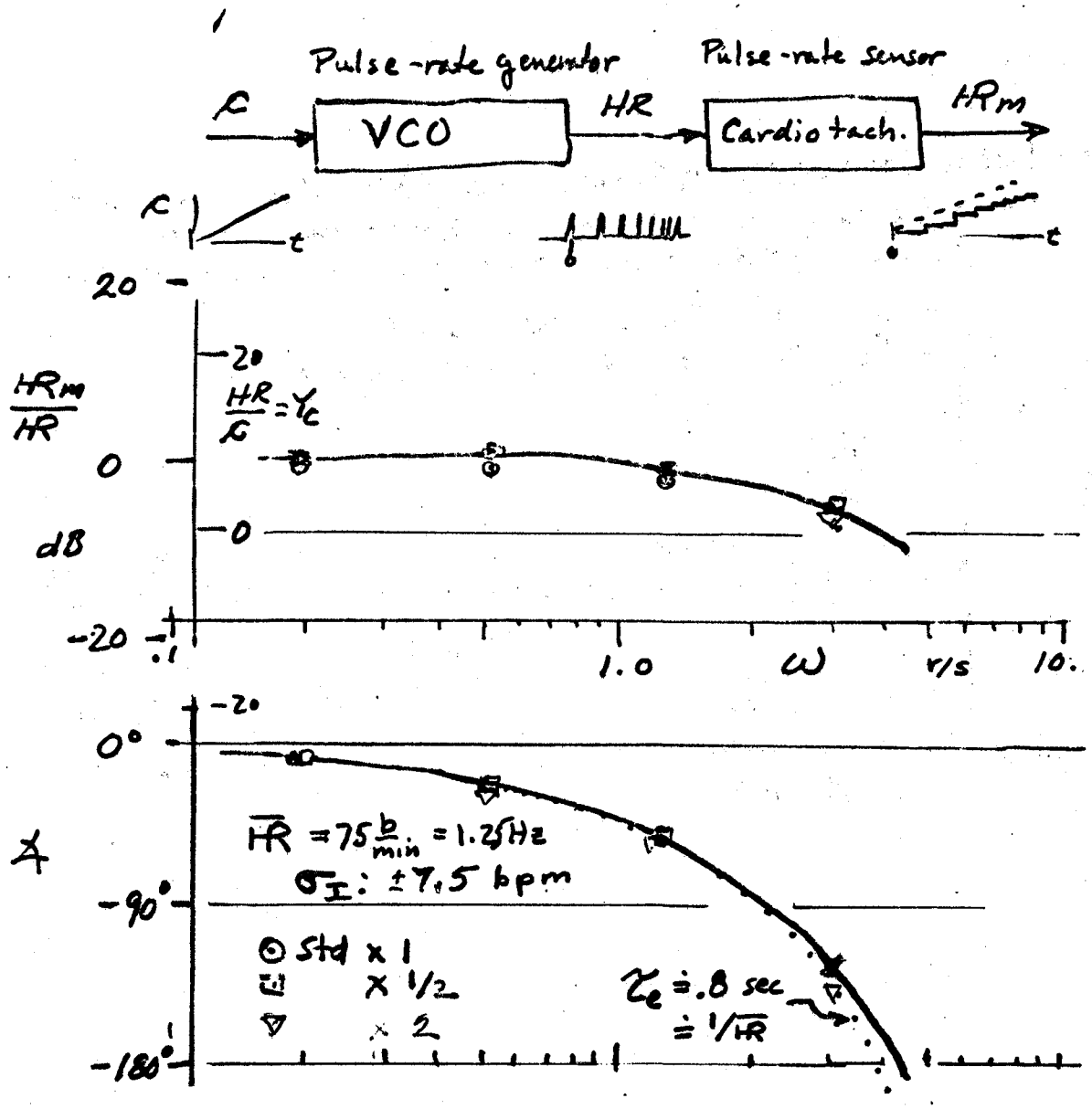
HEART RATE REGULATION USING BIOFEEDBACK -

SYSTEM DIAGRAM



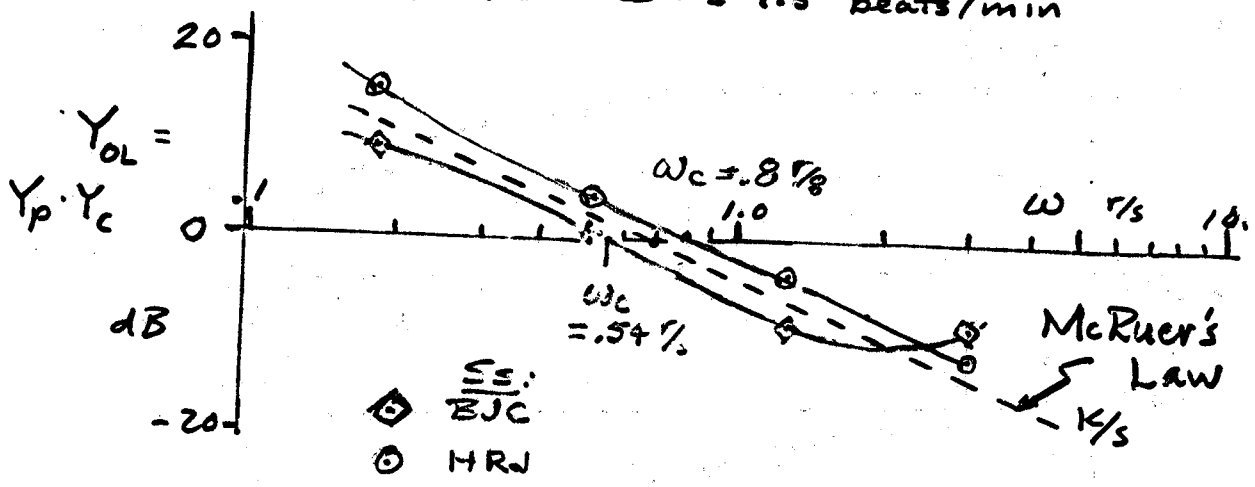

CONTROL
KNOB
CONTROLLED ELEMENT
VCO
CARDIO-
TACHOMETER
m
if α =0⇒$Y_c(jw)$
if α = controlled⇒$Y_p Y_c = Y_{OL}$
i

FREQUENCY RESPONSE OF CARDIOTACHOMETER CONTROLLED ELEMENT



OPEN LOOP DESCRIBING FUNCTIONS FOR COMPENSATORY TRACKING WITH A CARDIOTACHOMETER USING MANUAL CONTROL VIA A V.C.O.

Avg Pulse Rate : 75 beats/min
RMS Disturbance : ± 7.5 beats/min



STATUS:

- McRUER'S LAW DOES HOLD FOR MANUAL TRACKING WITH A CARDIOTACHOMETER.
- NEED SKILLED HEART RATE CONTROL SUBJECTS.

APPLICATIONS

- DEVELOPING THE APPLIED TECHNOLOGY NEEDED TO PROPERLY EVALUATE HEART RATE WORKLOAD MEASURES.

- TRAINING SUBJECTS (DRIVERS, PILOTS, N-PLANT OPERATORS) TO COPE WITH TASK-INDUCED WORKLOAD VIA PSYCHOPHYSIOLOGICAL FEEDBACK.

- SCREENING SUBJECTS AS TO SENSITIVITY TO HEART RATE VARIATIONS AND HEART RATE CONTROL ABILITY, AS THEY AFFECT THE ABOVE APPLICATIONS.

New Uses for Sensitivity Analysis: How Different Movement Tasks Effect Limb Model Parameter Sensitivity

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In general, sensitivity analysis is a heuristic technique for systematically evaluating how output "behaviors" are influenced by varying system "parameters". The basic method can play a major role not only directly by helping tune existing model parameters but also indirectly through the design of experiments that may allow certain parameters to be isolated and defined by certain behaviors.

The present work extends past eye and head model sensitivity efforts in a number of significant ways. First, original results for the newly developed eighth-order nonlinear limb antagonistic muscle model of elbow flexion and extension are presented. Second, a wider variety of sensitivity analysis techniques are used and a systematic protocol is established that shows how the different methods can be used efficiently to compliment one another for maximum insight into model sensitivity. Third, it is explicitly shown how the sensitivity of output behaviors to model parameters is a function of the controller input sequence, i.e. of the movement task. When the task is changed (for instance, from an input sequence that results in the usual "fast movement" task to a slower movement that may also involve external loading, etc.) the set of parameters with high sensitivity will in general also change. Such task-specific use of sensitivity analysis techniques identifies the set of parameters most important for a given task, and even suggests task-specific model reduction possibilities.