

Quantitative Analysis of Purposive Systems:

Some Spadework at the Foundations of Scientific Psychology

Course: Autonomous Machine Learning (9/30)

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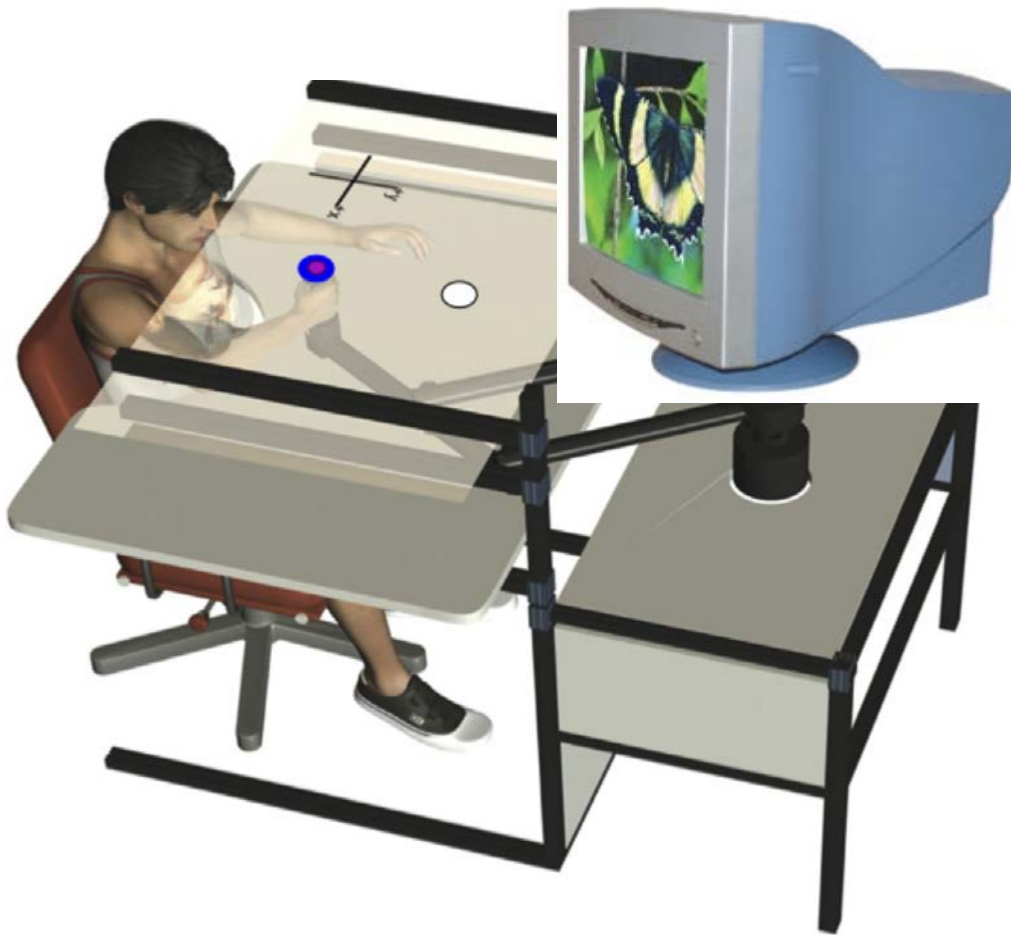
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Introduction

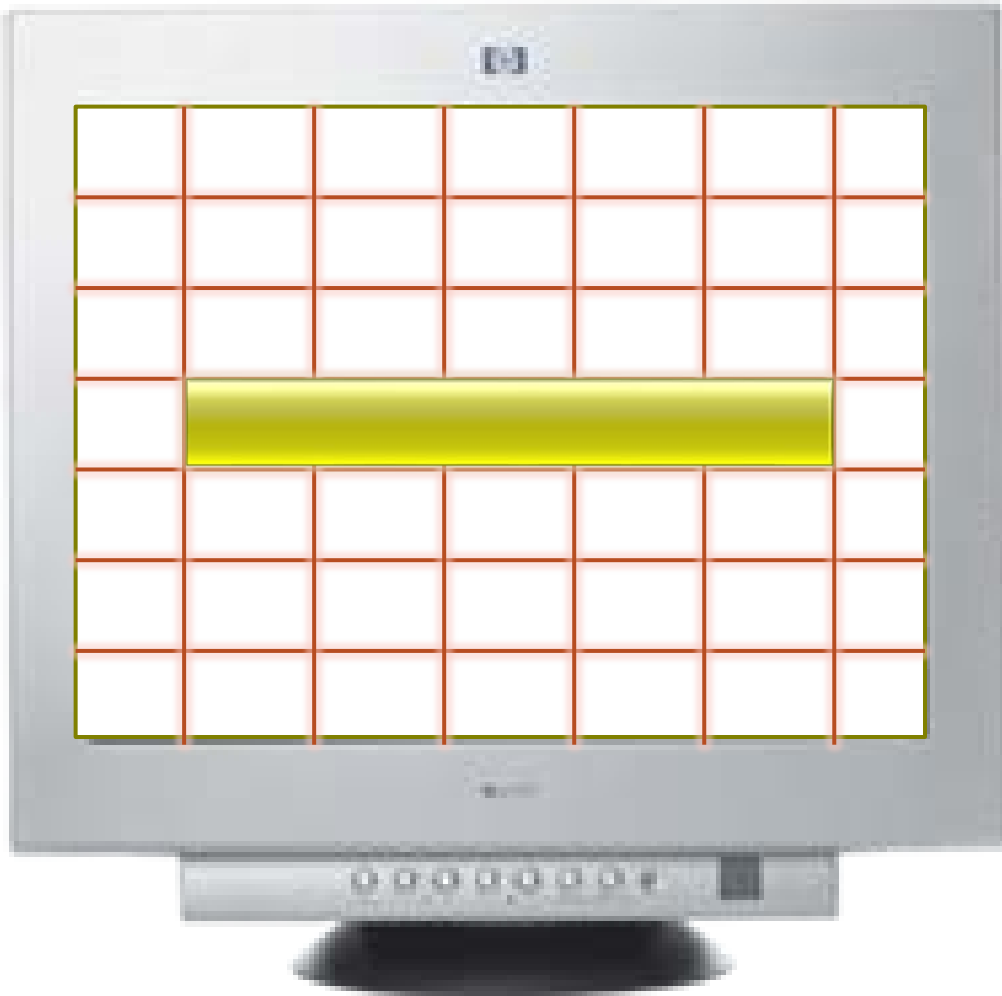
- Until this, we have learned that how the proposed Quasi-Static analysis can be introduced from mathematical & physical principles.
- And now, we will see the real evidence for this analysis from several series of human experiments.
- **So we want to verify that human is ideal Type N system.**

General Experimental Method



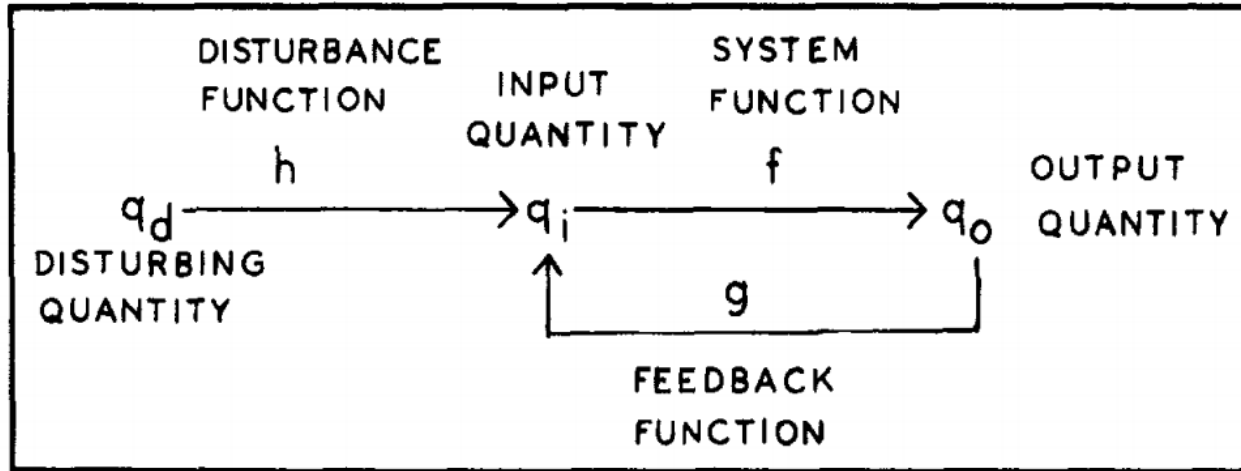
- A subject sits facing CRT monitor and holding a control stick.
- This stick can make positive or negative movements to a **cursor**.
- The subject is trained enough to perform some various 6 tasks.

Details of Experiments



- We call this yellow bar cursor.
- The y position of cursor is input value $\rightarrow q_i$
- The movement of control stick is output value $\rightarrow q_o$
- Some disturbing noise is given to the cursor $\rightarrow q_d$

Details of Experiments



- A typical experiment begins with $[q_d = 0]$ for a while.
- And All the experiment last for 60 sec after the random-number is varied.
- On first experiment, we will consider linear functions for h, f, g .

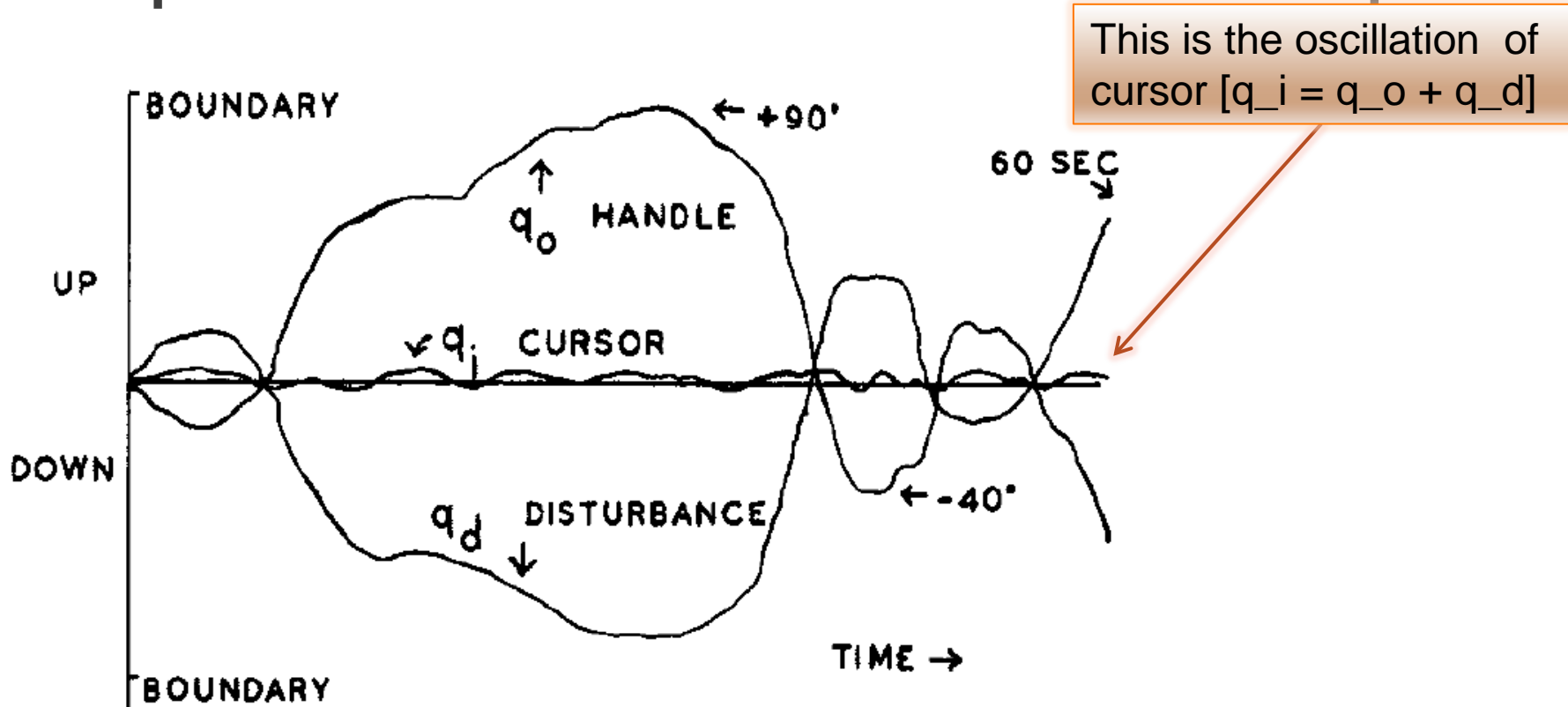
Disturbing Noise

- Inside the computer, there is a random-number routine.
- The random number is varying continuously but the frequency is limited to 0.2 Hz.
 - 0.2 Hz (=1 change per 5 seconds)
- The subject has no way to sense the magnitude of q_d directly.
- This type of noise is necessary, because the sine-wave disturbances were memorized by the subject.

Experiment 1: Basic Relationships

- The subject is requested to hold the cursor at center row($y=0$) while some random noise q_d is disturbing.
- And in this experiment, $q_i^* = 0$. This means the desired position of the cursor is set to zero.
- So the task is just trying to cancel the noise q_d .

Experiment 1: Basic Relationships



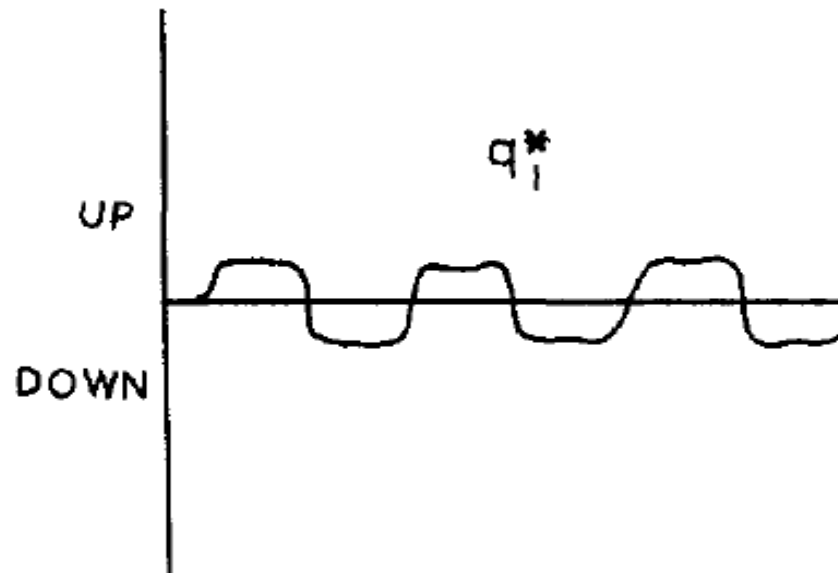
- The practiced subject result, $RMS(q_i) = 2\%$ of maximum scale.
- So we can say $\rightarrow q_o = -q_d$ (nearly)
- **It is a fact that the input is stabilized with output.**

Experiment 2: Unspecified q_1^*

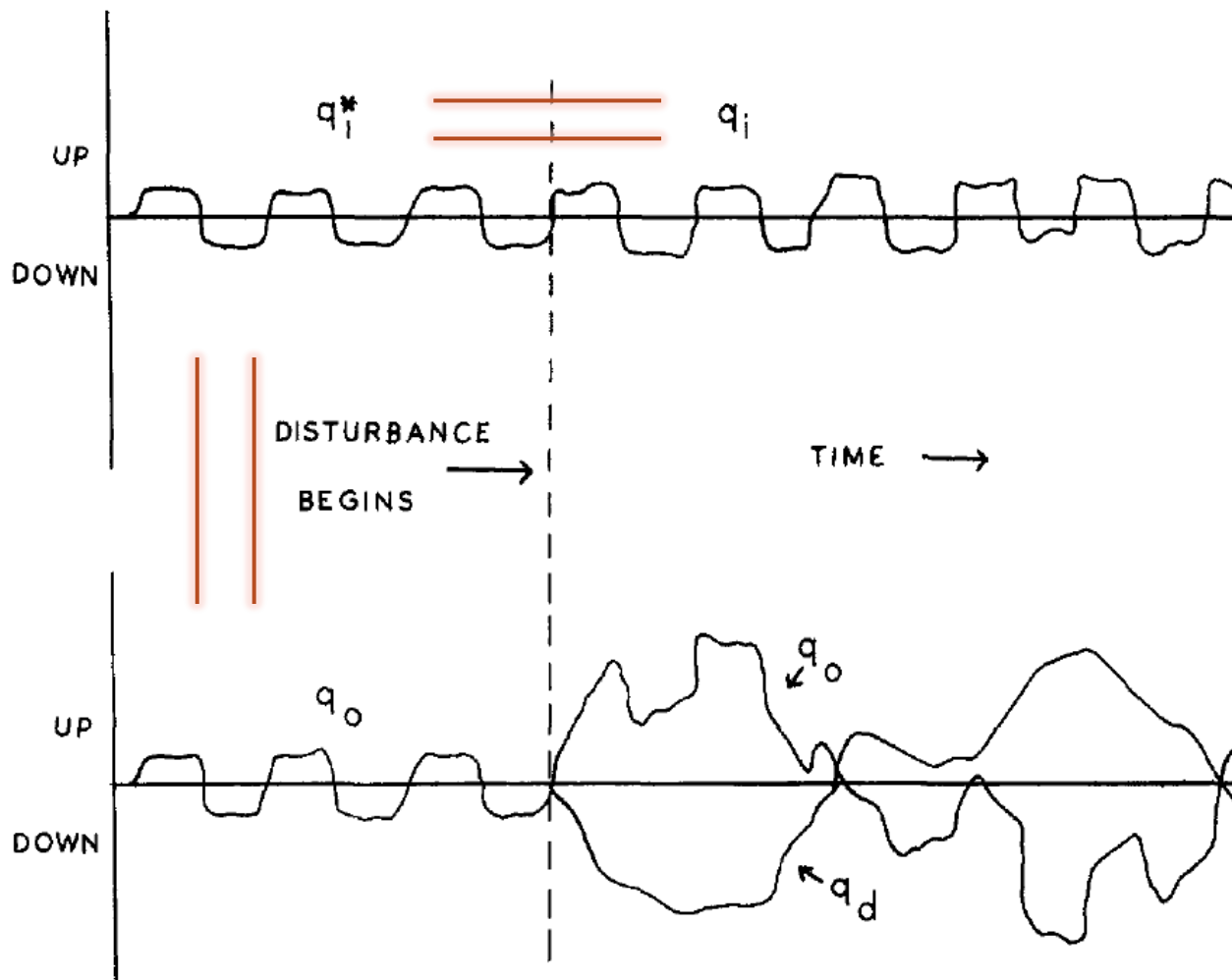
- The subject is now asked to hold the cursor in some other position($y = -2$ or $+1$).
- Of course at the first phase, there is no noise q_d , so the subject can recognize q_i^* (desired position).
- And the result is the same as experiment 1.
- **This shows that the subject determines q_i^* by oneself.**

Experiment 3: Change of Variable

- Now the subject is asked to make the cursor move in rhythmic pattern.
- As before we did, there is no noise in the first phase to recognize the q_i^* (desired pattern).



Experiment 3: Change of Variable



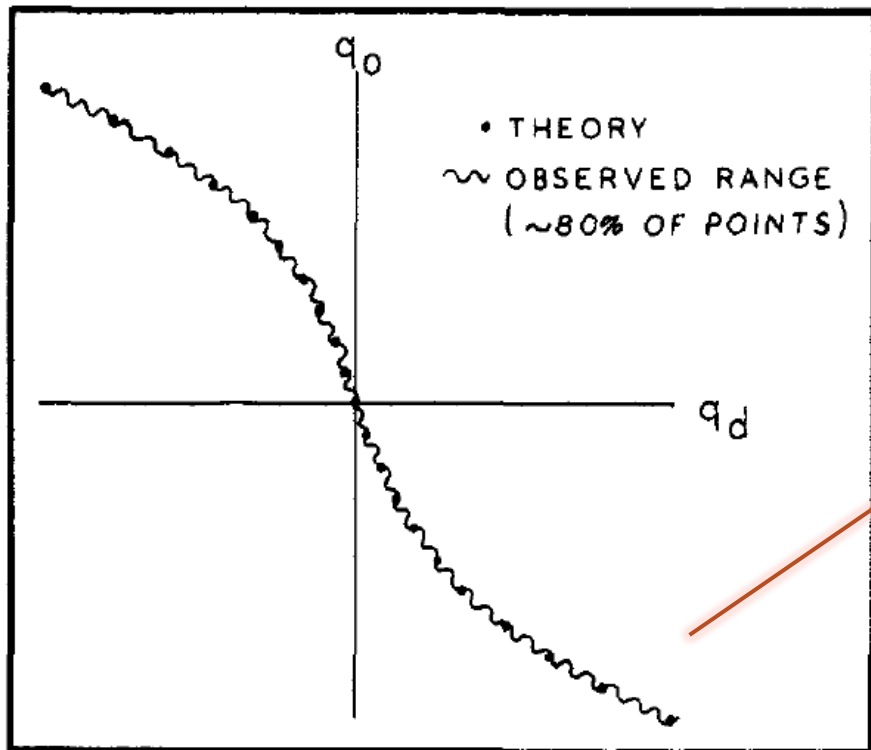
$$q_i = q_o + q_d$$

Experiment 3: Change of Variable

- Two major points are illustrated here.
- 1) More than one input quantity can be defined.
- 2) The regularities(=***behaviors***) are more likely to be associated with inputs rather than outputs.
- **Outputs reflect disturbances as well as the actions required to produce a given input pattern.**

Experiment 4: The Behavioral Illusion

- Like exp_1 again, the subject is asked to hold the cursor at center row ($y=0$).
- But here, the computer is programmed to insert a nonlinear function between actual handle position and the effect of the handle on cursor position.



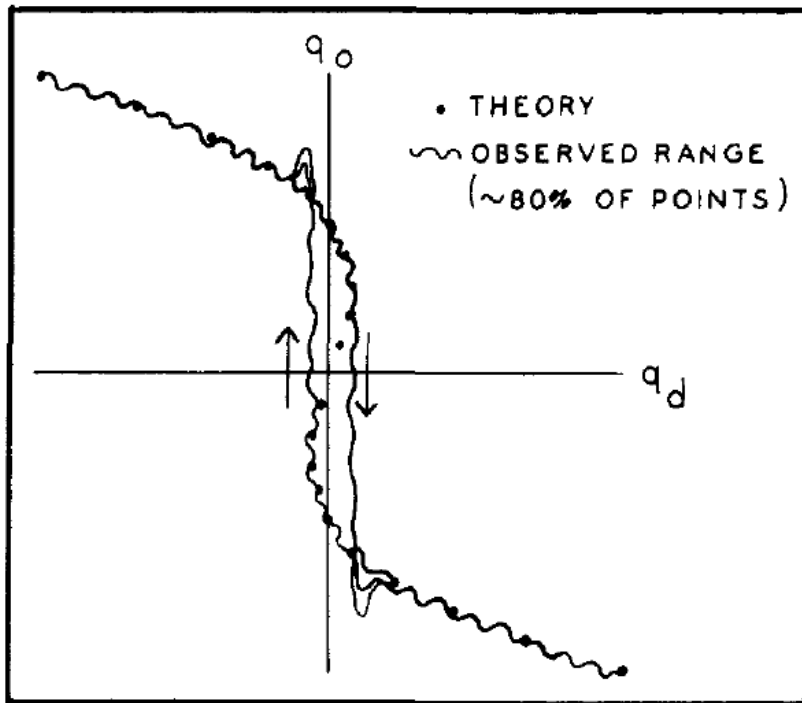
$$g(x) = Ax + Bx^3$$

$$Aq_o + Bq_o^3 = -q_d \text{ where } q_i^* = 0.$$

Experiment 4: The Behavioral Illusion

- The RMS error between q_i and q_i^* remains about 2% of maximum scale. And most subjects notice nothing different about this rerun of Experiment 1.

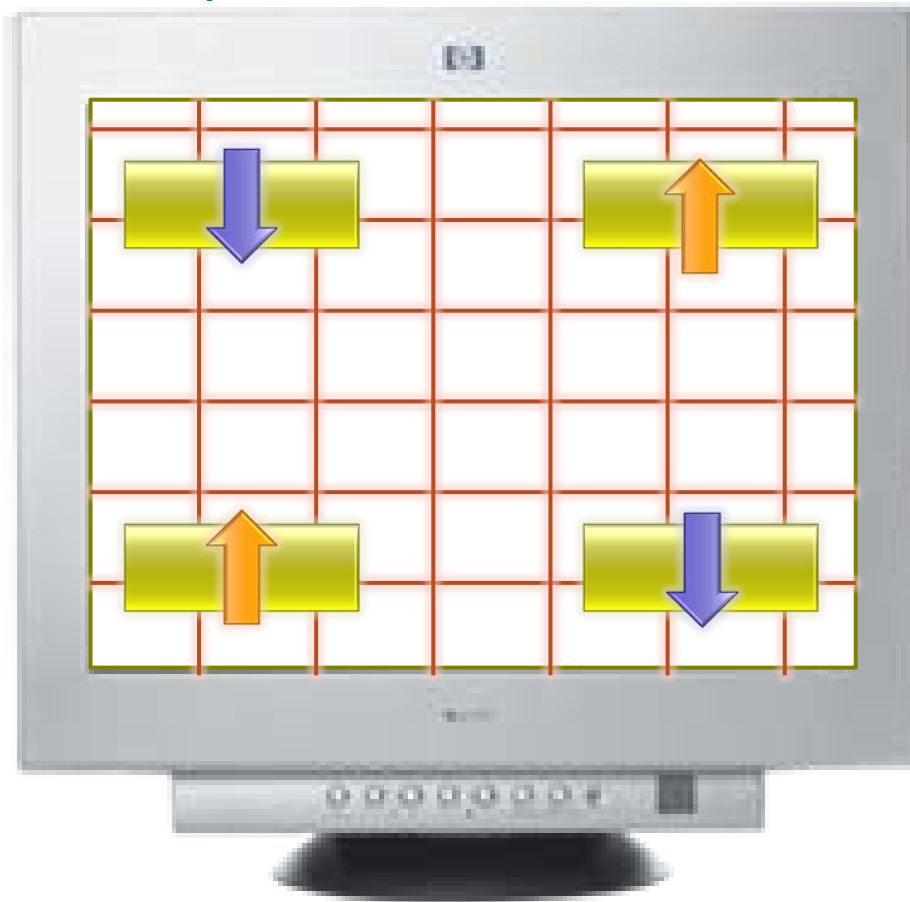
$$g(x) = Ax + Bx^3$$



- But when we change the coefficient of non-linear function for more extreme slope, most subjects do notice something different now.
- A few have complained that the handle is broken or that the computer is malfunctioning, but soon they can perform just as well as anyone else.

Experiment 5: Multiple Choice

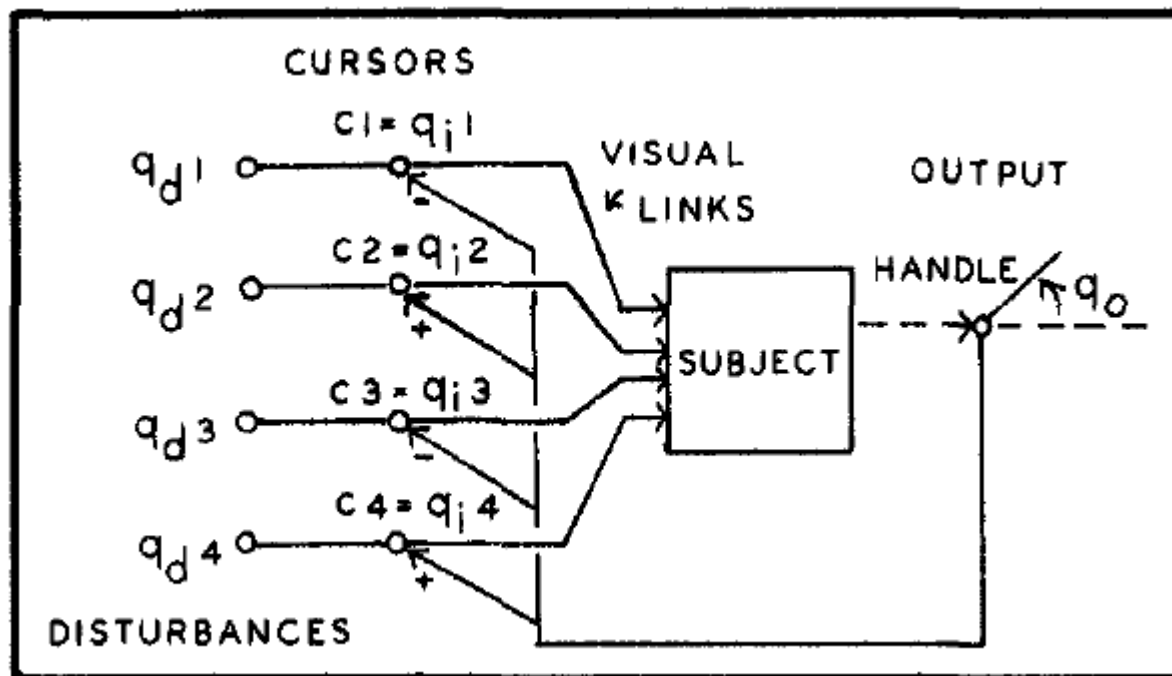
- Now the display shows four side-by-side cursors instead of one, each moving up and down in its own pattern with own independent random noise.



- The handle movement contributes equally to the all cursor.
- But the C1, C3 cursors are affected to the opposite direction.

Experiment 5: Multiple Choice

- Then the subject is asked to pick any one cursor and hold it as steady as possible.
- One of the four cursors remains at the position q_{1^*} determined with all disturbances set to zero, while the other three cursors wander unsystematically up and down.



Experiment 6: More-Abstract Controlled Quantities

- Under the same conditions as Experiment 5, the subject is asked to hold constant some other aspect of the display (not specified by the experimenter) rather than the position of one of the cursors.
- At this time, most subjects notice that the handle affects odd and even cursors oppositely.
- What determines which quantity will be controlled?
 - → What the person attends to becomes the controlled.

Conclusions

- For 3 decades, the control systems had a 4 big mistakes.
- But the control system is very promising view to build a quantitative analysis in cybernetics.
- We suggest a general control system which can explain the relationships between living organism and environment.
- And we show that this N type system is actually exists in human metal-behavior systems.

Thanks