King Saud University

College of Engineering

IE – 341: “Human Factors Engineering”

Spring – 2025 (2nd Sem. 1446H)

Chapter 10. Human Control of Systems Compatibility – Part I (Spatial Compatibility)

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Chapter Overview

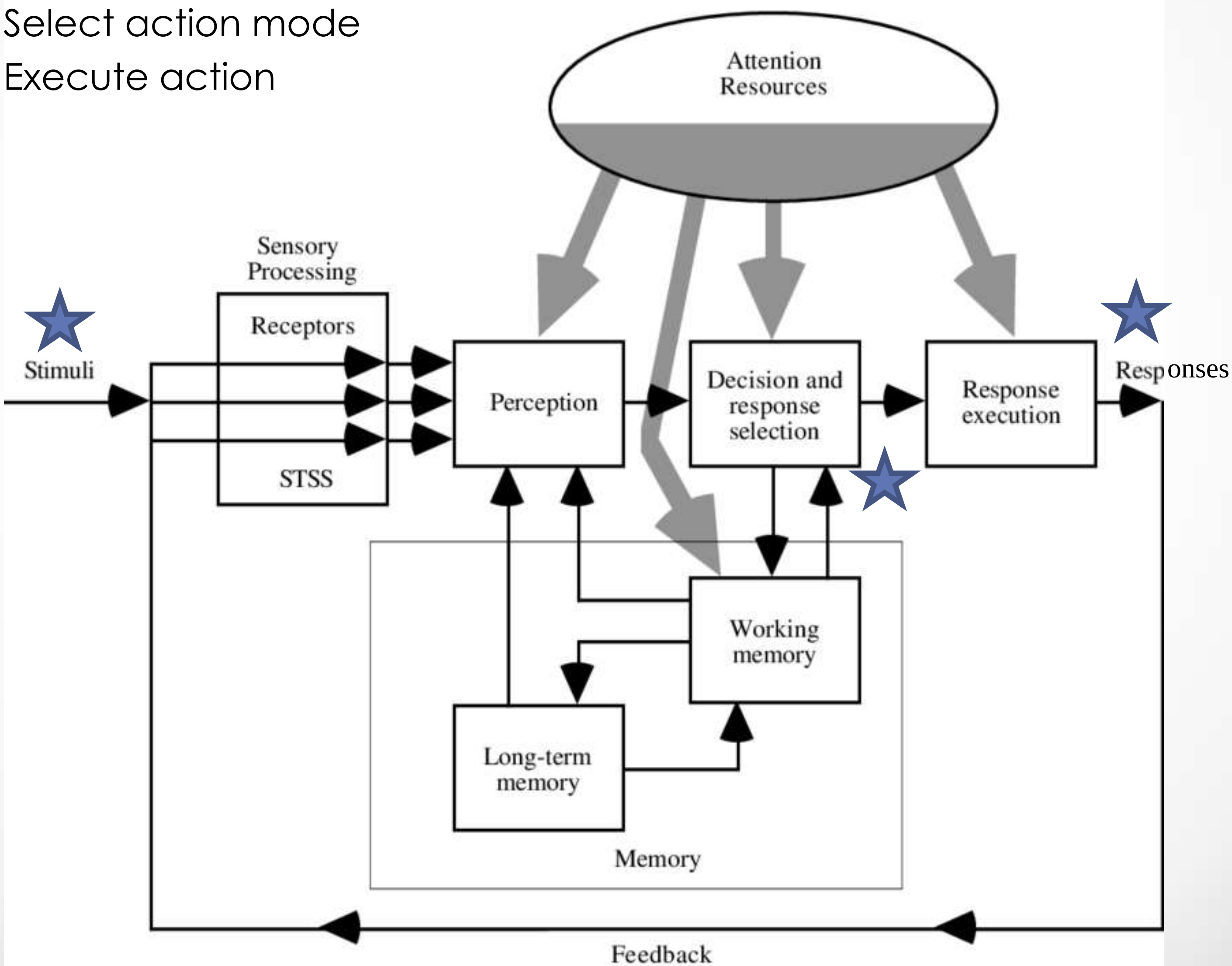
Information Processing and Compatibility

1. Information Display – Coding (Ch. 3)
2. Fitts' Law (Ch. 3, Ch. 9)
3. Hick Hyman Law (Ch. 3, Ch. 9)
4. Signal Detection Theory (Ch. 3)
5. Memory - Attention (Ch. 3)
6. Compatibility - Part 1 - Spatial Compatibility (Ch. 10)
7. Compatibility - Part 2 - Movement - Modality Compatibility (Ch. 10, Ch.3)

Contents

Introduction

- Human function in system control:
  - Receive information
  - Select action mode
  - Execute action

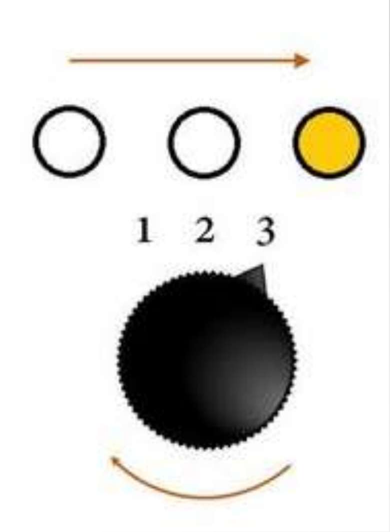


Cont. Introduction

- Human action:
  - Becomes control input to the system
  - Remember (Ch. 1) *output* of 1 system $\Rightarrow$ *input* to another system
  - Output of system: usually as feedback regarding effects of action
  - Then human function starts again (as listed above, and so forth)

- Human functions involved with system control:
  - Compatibility (discussed here; most important), also:
  - Tracking (not discussed here)
  - Supervisory control (not discussed here)

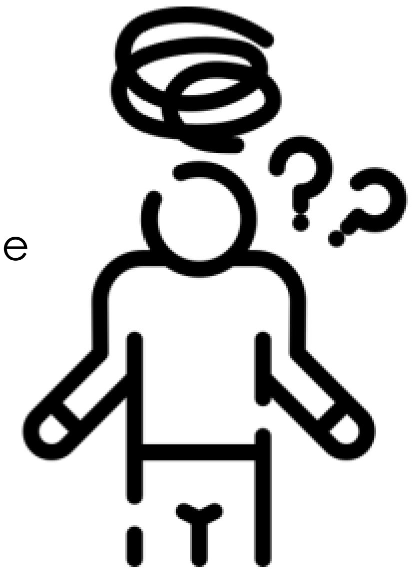
Cont. Introduction



- Compatibility:
  - Considers relation between controls and displays
  - Determines how easy and convenient people choose and perform correct actions given several alternatives
- Definition:
  - “degree to which relationships are consistent with human expectations”
- Types of compatibility
  - Conceptual, Spatial, Movement, and Modality (discussed in ch. 3)
  - Discuss here: spatial and movement i.t.o. relation between control & display
- Effect of compatibility:
  - Faster learning
  - Faster reaction/response time (RT)
  - Less errors
  - Higher user satisfaction

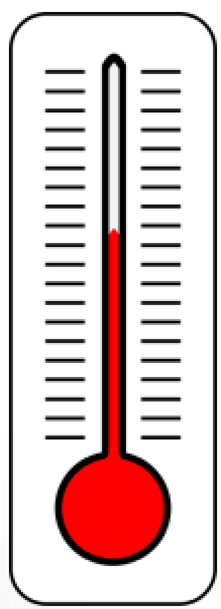
Cont. Introduction

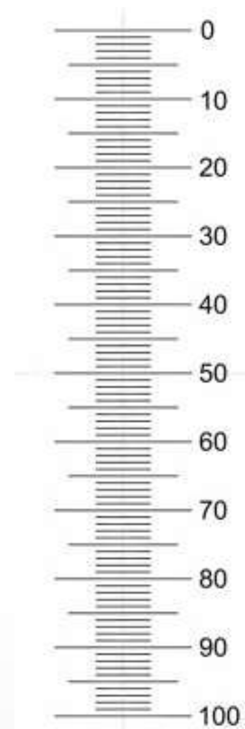
- Effect of non-compatibility:
  - People *can* get used to non-compatible (“out of sync”) systems, but:
  - There’s higher information processing burden on user (i.e. more thinking)
  - Under stress conditions:
    user may make compatible
    (i.e. natural) response
    ⇒ which (here) will be incorrect response
    ⇒ error or accident



Cont. Introduction

- Special considerations for compatibility relationships
  - Some are stronger than others
    - e.g. when shared by a larger group of population than others
  - Sometimes it is necessary to violate a compatibility relationship to make use of another one
    - e.g. study by *Bergum* (1981) for subject group:
      a) 93% expected upward movement of pointer ⇒ increase
      b) 71% (of same group) expected numbers to increase: top to bottom!





Spatial Compatibility

Spatial Compatibility

- Types of spatial compatibility
  A. *Physical similarities* of displays and controls
  B. *Physical arrangement* of displays and controls

A. Physical similarities of displays and controls

- o Involves design of displays/controls in order to have similar:
  - Physical features
  - Modes of operation

- Case 1: study by *Fitts and Seeger* (1953)
  - o Three displays / three controls (all combinations used) *(see next slide)*
  - o Displays: lights in various arrangements
  - o With light operation ⇒ subject moves stylus along corresponding channel to turn light off
  - o Each group of subjects attempted each of 9 possible combinations
  - o Performance measured as: RT, errors, information "H" lost (bits)
  - o Results:
    - Best performance: when stimulus panel resembled response panel
    - Best combinations (S_a-R_a, S_b-R_b, S_c-R_c)

Cont. Spatial Compatibility

Cont. A. Physical similarities of displays and controls

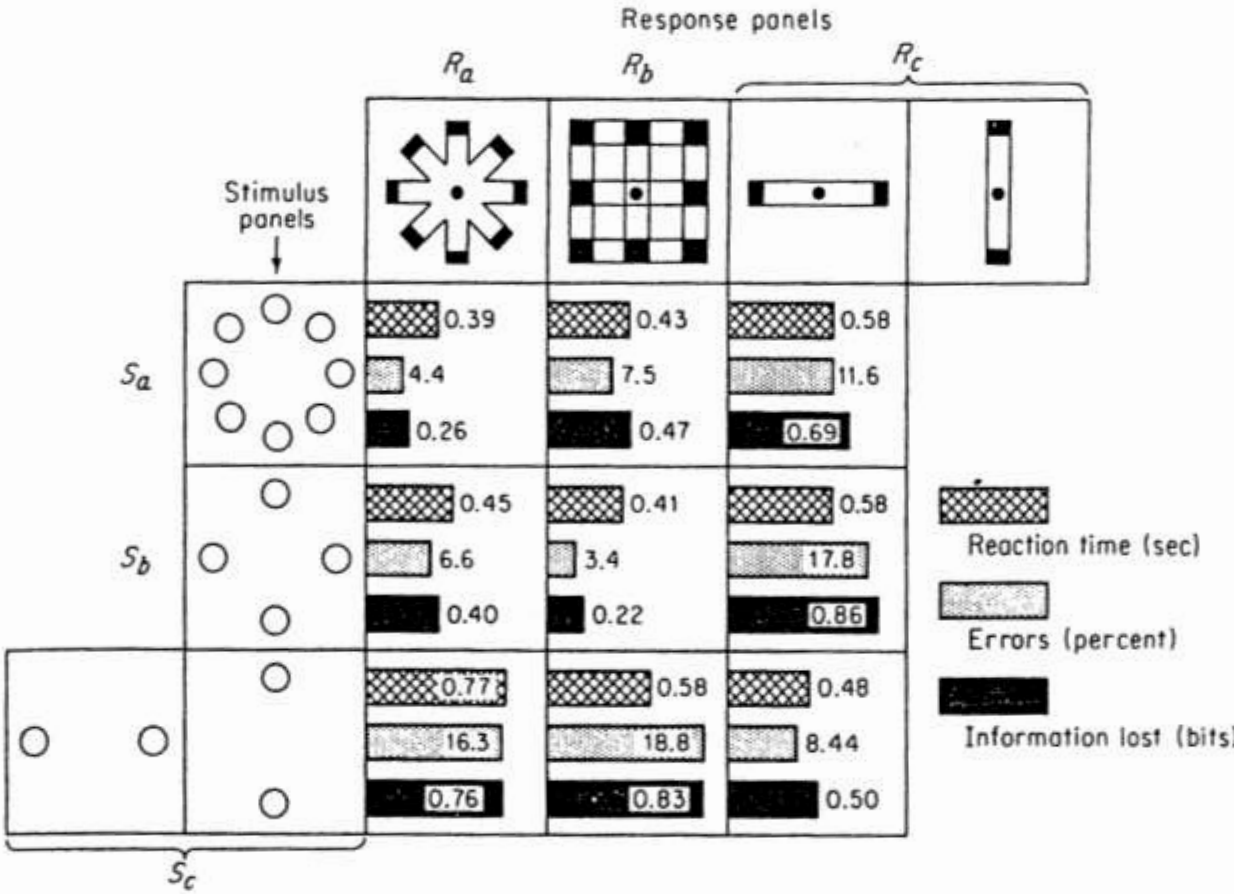
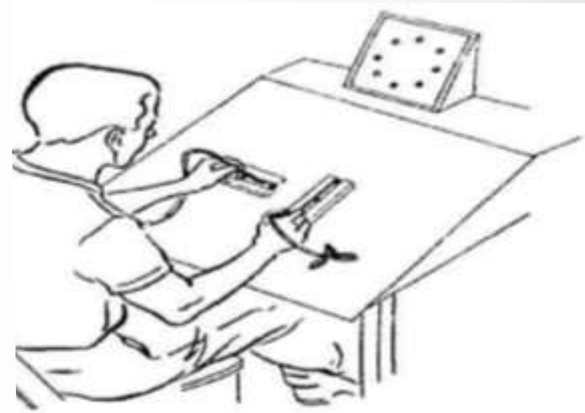
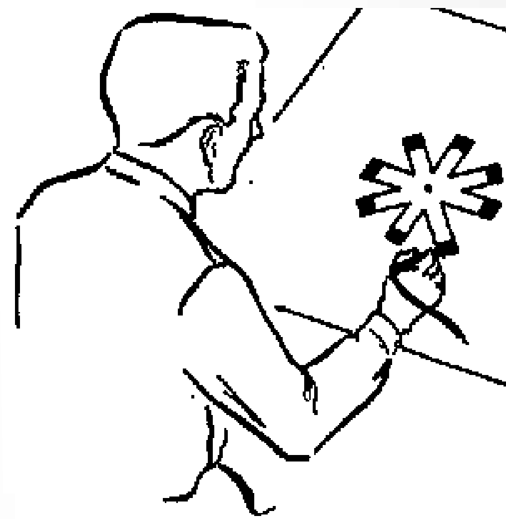


FIGURE 10-1.
Illustrations of signal (stimulus) panels and response panels used by Fitts and Seeger. The values in any one of the nine squares are the average performance measures for the combination of stimulus panel and response panel in question. The compatible combinations are S_a-R_a, S_b-R_b, and S_c-R_c, for which results are shown in the diagonal cells. (*Source: Fitts and Seeger, 1953.*)





Cont. Spatial Compatibility

Cont. A. Physical similarities of displays and controls

- Case 2: keyboard and screen (*Bayerl, et al, 1988*)
  - Keys on keyboard arranged as:
    - Rows on top or
    - Columns on one side *(see next slide)*
  - Meaning of keys depends on software (as screen label for each key)
  - Authors compared different screen vs. keyboard layouts, i.t.o:
    - Mean time to find and press keys (i.e. RT)
  - Result:
    - RT is smaller (i.e. higher compatibility) when labels (on screen) and keyboard configurations are physically similar

Cont. Spatial Compatibility

Cont. A. Physical similarities of displays and controls

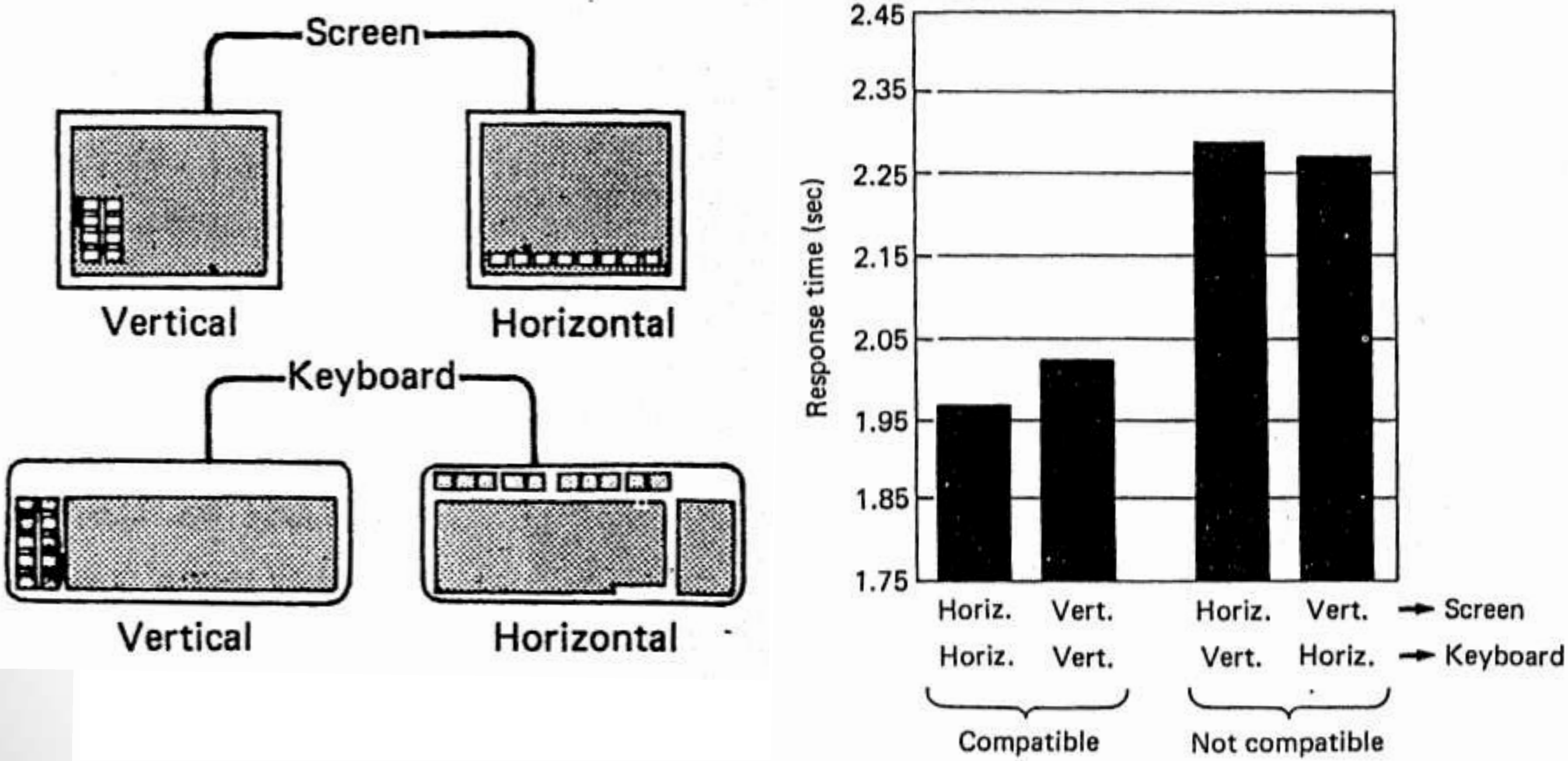


FIGURE 10-2.
Response times for selecting function keys as related to the arrangement of keys on the keyboard and the arrangement of labels on the screen: an example of spatial compatibility by physical similarity. (*Source: Adapted from Bayerl, Millen, and Lewis, 1988, Figs. 1 and 2. Reprinted with permission of the Human Factors Society, Inc. All rights reserved.*)

Cont. Spatial Compatibility

B. Physical arrangement of displays and controls
   - This involves applications of findings of first two experiments
   - Most famous: burner control arrangement on 4-burner stove

- Control-Burner arrangement experiments
  - Several studies conducted (*Chapanis, 1959; Ray, 1979*) (*see next slide*)
  - Subjects:
    - Presented with various arrangements of controls / burners
    - Asked to turn on specific burners
  - Number of errors recorded
  - Results:
    - Two studies similarly ranked various arrangements
    - Exercise: rank arrangements on following slide from best to worst

Cont. Spatial Compatibility

Cont. B. Physical arrangement of displays and controls

FIGURE 10-3.
Control-burner arrangements of a simulated stove used in experiments by Chapanis and Lindenbaum, and by Ray and Ray. (*Source: Adapted from Chapanis and Lindenbaum, 1959.*)

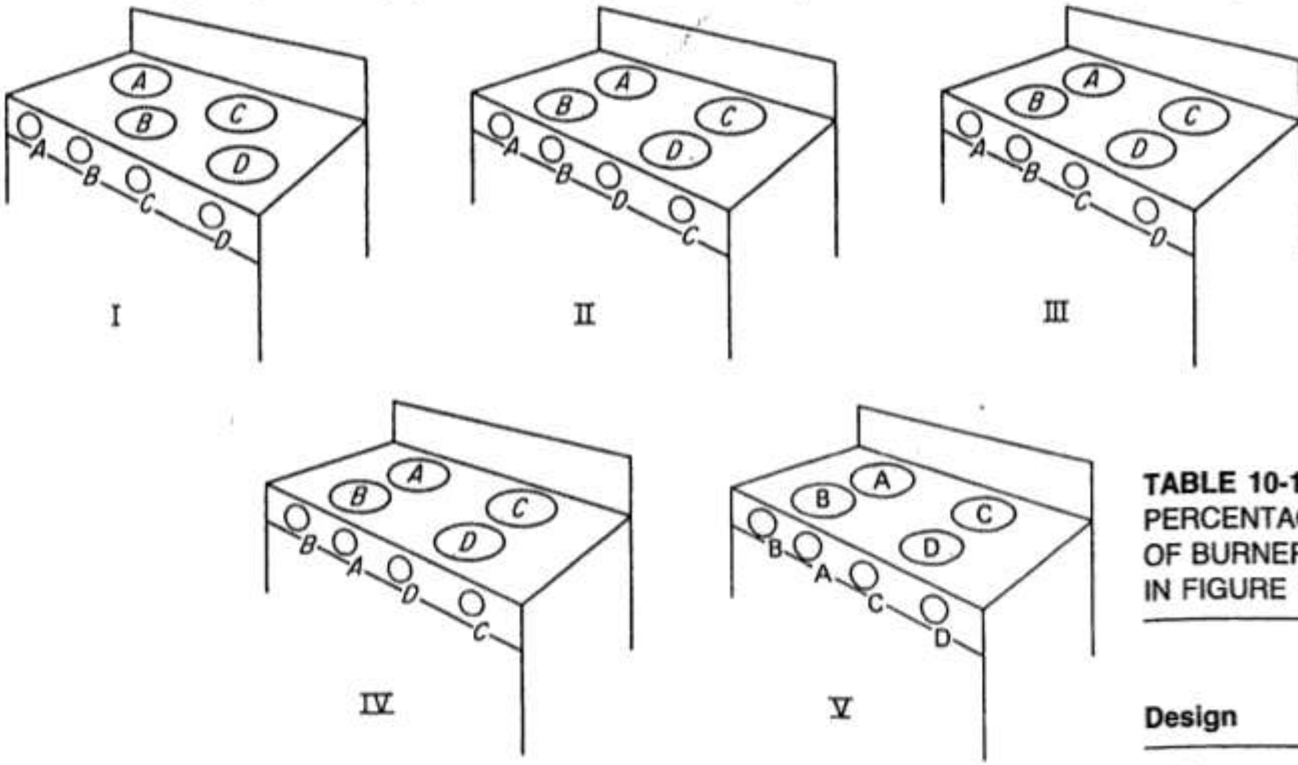


TABLE 10-1
PERCENTAGE OF ERRORS IN EXPERIMENTAL USE OF BURNER CONTROLS ON STOVES SHOWN IN FIGURE 10-3

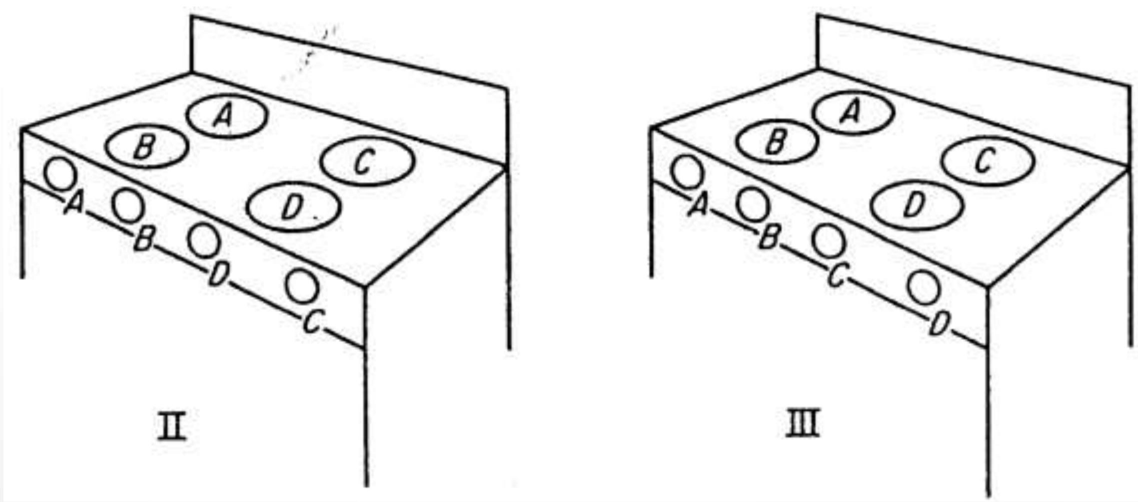
Design	Chapanis and Lindenbaum (1959)	Ray and Ray (1979)
I	0	Not tested
II	6	9
III	10	16
IV	11	19
V	Not tested	12

Source: Chapanis and Lindenbaum (1959) and Ray and Ray (1979).

Cont. Spatial Compatibility

Cont. B. Physical arrangement of displays and controls

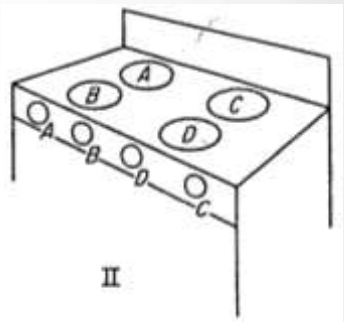
- Cont. Control-Burner arrangement experiments
  - Another experiment (*Shinar, 1978*):
  - Subjects asked to indicate burners* for unmarked controls ⇒
    - 31% chose arrangement III
    - 25% chose arrangement II (yet with less errors than III)
  - Conclusions:
    - People don't always choose options resulting in optimum performance
    - Better to use performance measures (vs. subjective measures) to decide on best display/control arrangements



Cont. Spatial Compatibility

Cont. B. Physical arrangement of displays and controls

- Cont. Control-Burner arrangement experiments
  - Another experiment (*Osborne, 1987*):
  - Added "sensor lines" to stove top (see next slide):
    - Lines are drawn from controls to corresponding displays
    - Senor lines: either partial or complete set
    - They used arrangement II (from first experiments)
  - Offset arrangement (from first experiments) also added for comparison
  - Which do you think gave: least RT, least errors?
  - Results: sensor lines ⇒ greatly reduced RT, almost eliminated errors

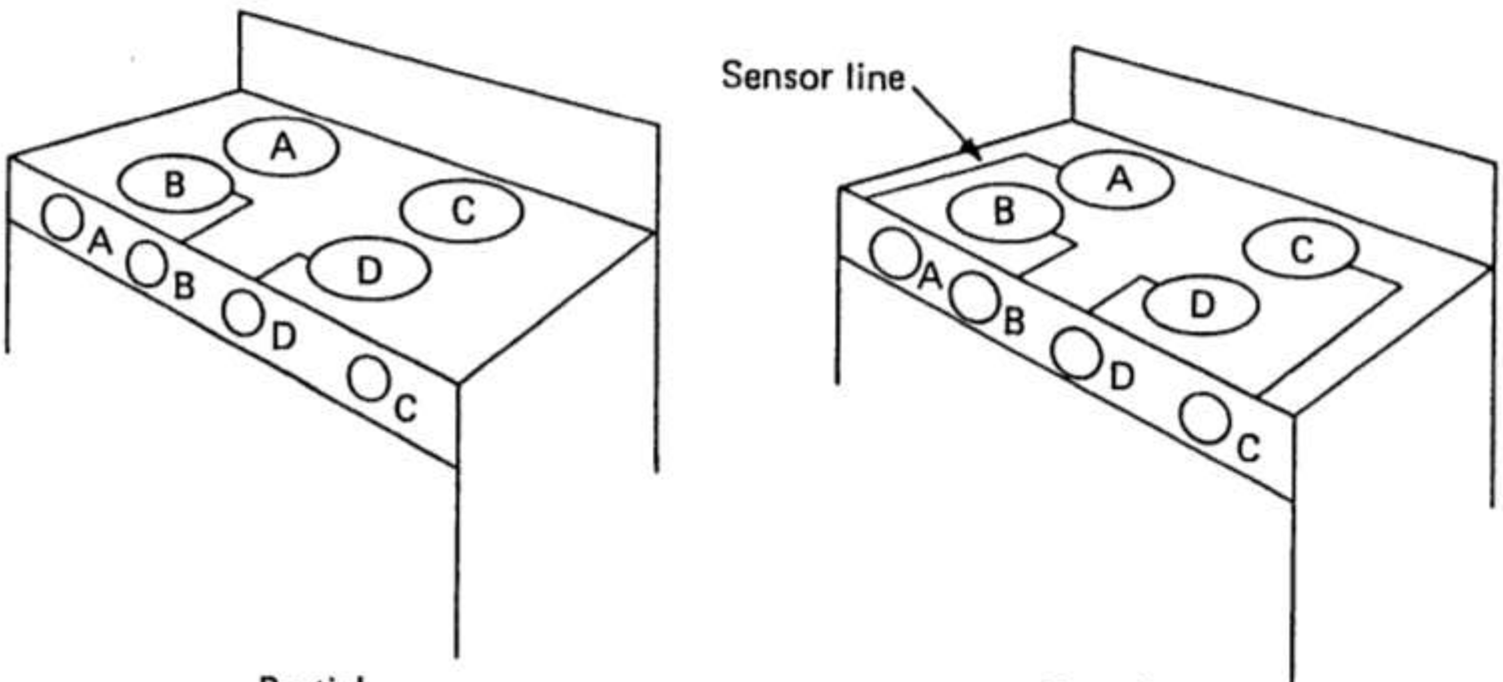


Arrangement	Response Time	Errors
Offset (I)	917 *ms*	0
Aligned (II) – complete sensor lines	980 *ms*	0
Aligned (II) – partial sensor lines	997 *ms*	0
Aligned (II) – no sensor lines	Most time*	6 – 9 %

Cont. Spatial Compatibility

Cont. B. Physical arrangement of displays and controls

FIGURE 10-4.
Stove tops showing use of a partial and complete set of sensor lines connecting burners with their respective controls. Use of sensor lines reduced response time and virtually eliminated control errors. (*Source: Adapted from Osborne and Ellingstad, 1987, Fig. 1. Reprinted with permission of the Human Factors Society, Inc.*)



Partial
(only B and D connected)

Complete

Cont. Spatial Compatibility

Cont. B. Physical arrangement of displays and controls

- Cont. Control-Burner arrangement experiments
  - Watch example in YouTube video:

  "Ergonomics and Design" (from start until 4:06)

  https://youtu.be/LAKlmdMHpdE?list=PLV-xlApuz3HbJ66G4pqxzdYO7o_3xZEi1

  Note the Stove example (@3:17)

  Q: which arrangement is used here, and why?

References

- ***Human Factors in Engineering and Design***. Mark S. Sanders, Ernest J. McCormick. 7th Ed. McGraw: New York, 1993. ISBN: 0-07-112826-3.