King Saud University

College of Engineering

IE – 341: “Human Factors Engineering”

Spring – 2024 (2^{nd} Sem. 1445H)

Human Capabilities

Part – A. Vision (Chapter 4)

Part 2 (b): Symbols – Codes

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Lesson Overview: Vision

Part 1:

- Process of Seeing (Vision)
- Visual Capabilities
  - Accommodation
  - Visual Acuity
  - Convergence
  - Color Discrimination
  - Adaptation
  - Perception
- Factors Affecting Visual Discrimination
  - Luminance Level
  - Contrast
  - Exposure Time
  - Target Motion
  - Age
  - Training

Cont. Lesson Overview: Vision

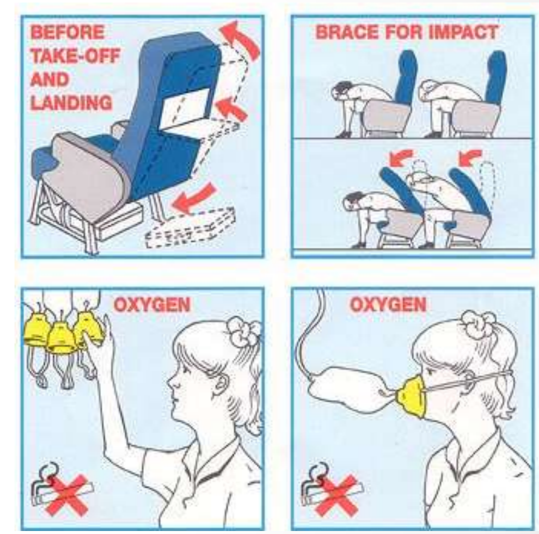
Part 2 (this part):

- Alphanumeric Displays
  - Characteristics
  - Typography
  - Typography Features
    - Hardcopy
    - Visual Display Terminals (VDT)
- Graphic Representations
- Symbols
- Codes

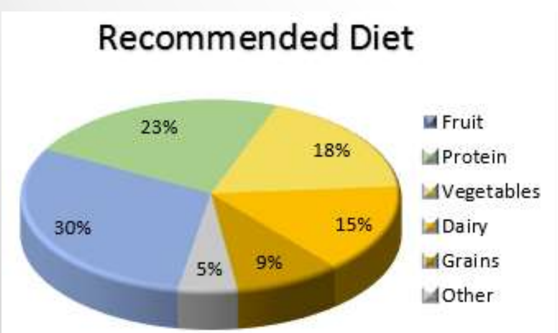
Graphic Representations

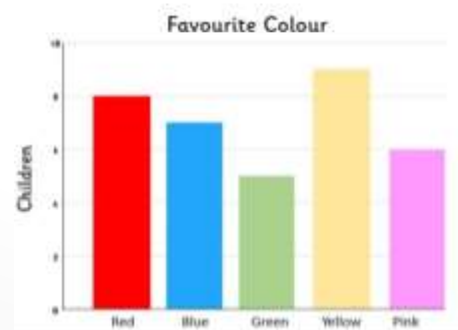
GRAPHIC REPRESENTATIONS

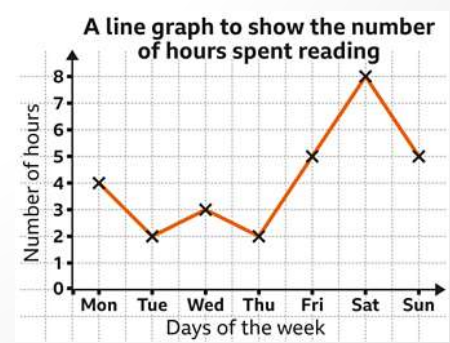
- Graphic Representations of Text
  - graphically representation:
    possible for text or numeric data
  - pictorial information: important for speed
  - text information: important for accuracy
  - instructional material should combine:
    - pictures + text =
      speed + accuracy + long-term retention



- Graphic Representations of Data
  - data graphs:
    - e.g. pie charts, bar charts, line graphs



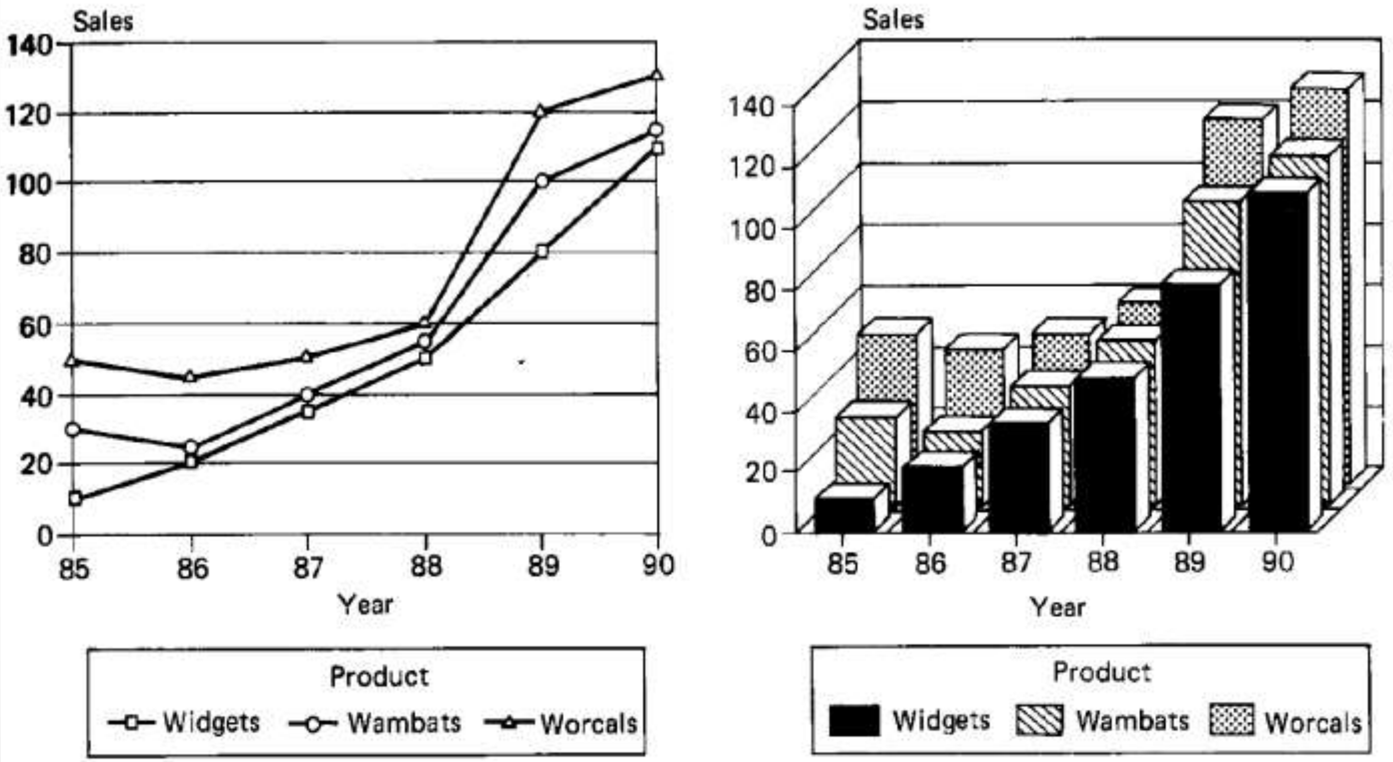




GRAPHIC REPRESENTATIONS

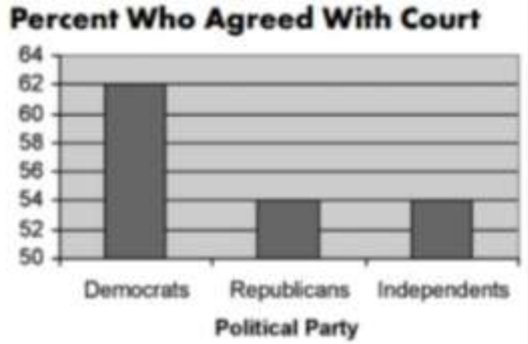
- Graphic Representations of Data (cont.)
  - data graphs (cont.):
    - 2-D graphs, 3-D graphs (as shown below for same data)
    - research: there is no one best format for representing numeric data
    - different formats may best show different types of information

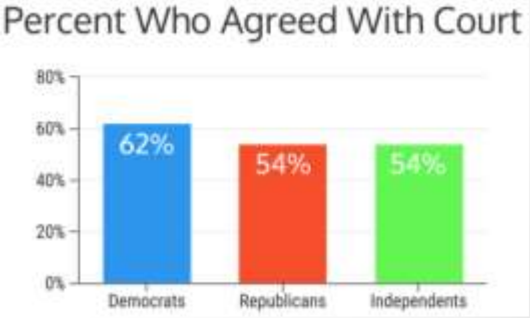
FIGURE 4-13
Illustrations of two graphic representations of data. Left, multiple-line graph; right, three-dimensional clustered bar chart. The data presented is the same in both representations.



GRAPHIC REPRESENTATIONS

- Graphic Representations of Data (cont.)
  - graph should be:
    - consistent with numerical data
    - properly, clearly labelled (all variables, units, etc.)
  - problem with some representations:
    - may distort data perception ⇒
    - leads to inaccurate interpretations of the data (next slide)
    - e.g. 1 and 2: graph may change perception for the differences between 2 variables (which one is better?)
    - e.g. 3 and 4: use of 3D blocks/volume (vs. 2D) gives exaggerated impression of increase among different conditions

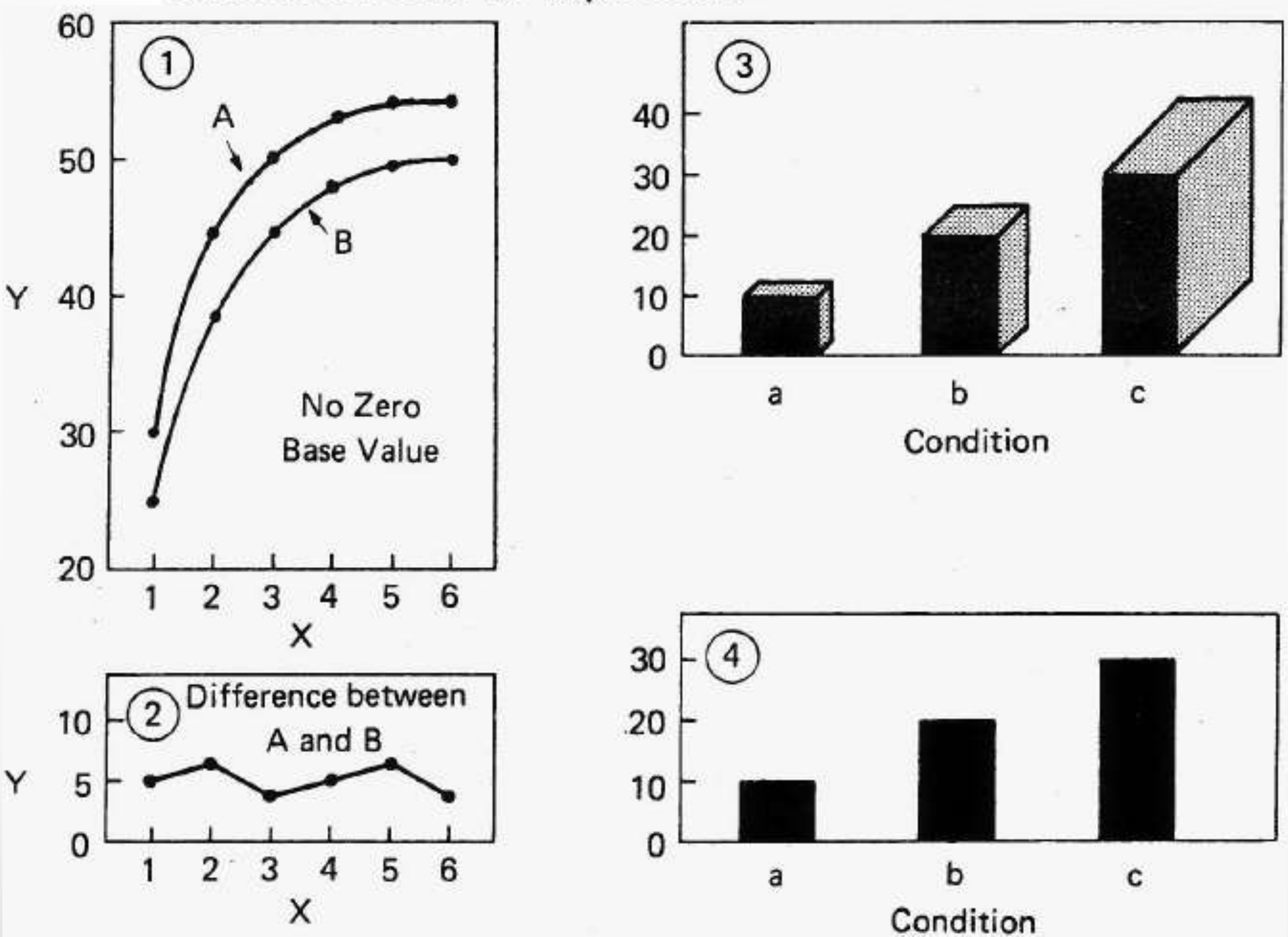




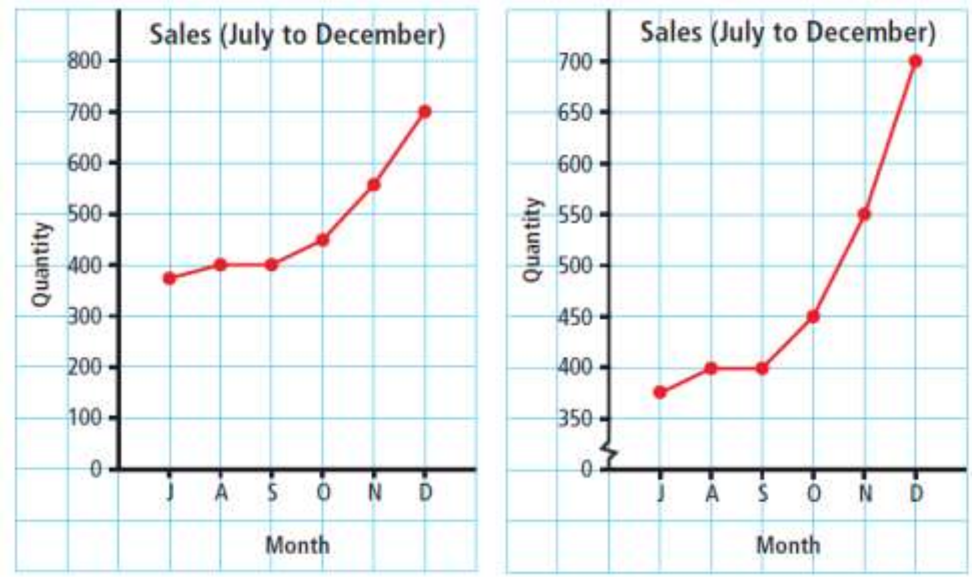
Effect of omitting the baseline
Source: "5 Ways Writers Use Misleading Graphs To Manipulate You"

GRAPHIC REPRESENTATIONS (cont.)

FIGURE 4-14 Examples of possible distortions in perceptions of data presented in graphics. Part 1 can suggest that the difference between *A* and *B* increases; however, part 2 shows that this is not the case. Part 3 can suggest disproportionate increases from condition *a* to *b* to *c*; part 4 corrects for such an impression.

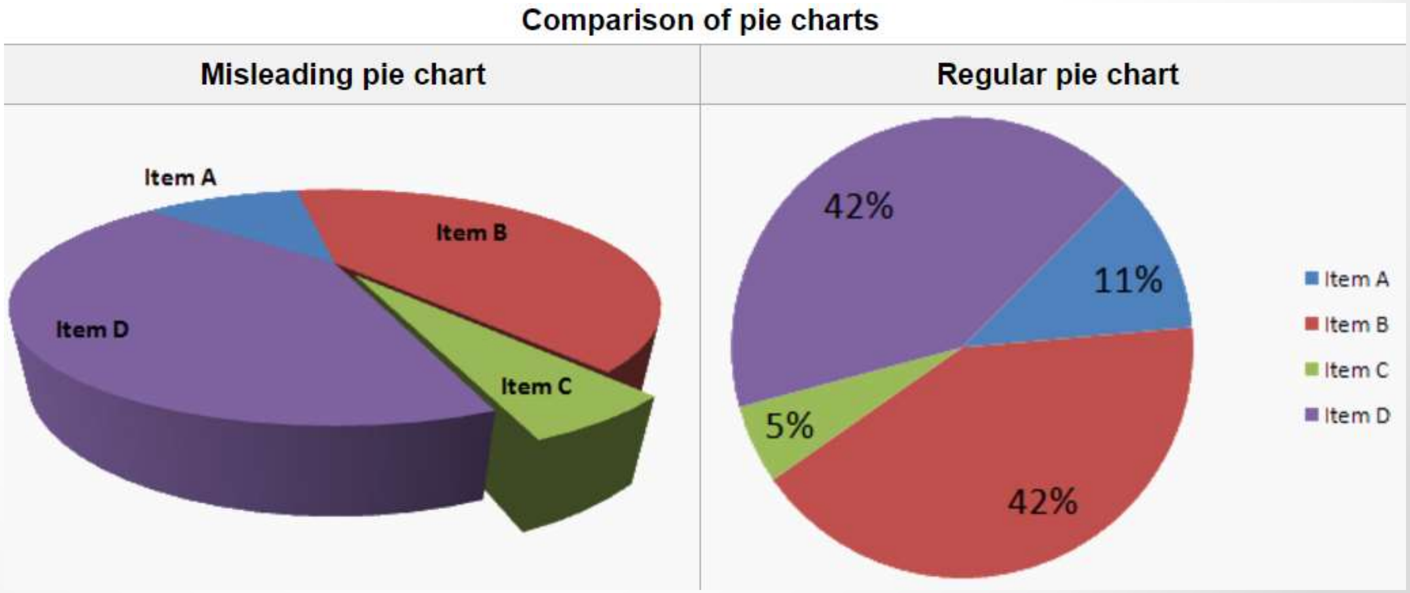


GRAPHIC REPRESENTATIONS (cont.)



Graph A

Graph B



Symbols

SYMBOLS

- Visual symbols should be very clear
  - e.g. men vs. women restroom sign

- Comparison of Symbolic & Verbal Signs
  - verbal sign may require “recoding” (i.e. interpretation)
    - e.g. sign saying “beware of camels”

  - symbols mostly do not require “recoding”
    - e.g. road sign showing camels crossing
    - ⇒ no recoding (i.e. immediate meaning)

  - note, some symbols require learning & recoding
  - *Ells* and *Dewar* (1979):
    - conducted study on traffic signs and symbols
    - subjects listened to a spoken traffic message
    - then shown traffic signs (symbolic sign or verbal sign)
    - then asked to say whether/not spoken message matched each sign
    - mean reaction time for correct response was less for symbols (next slide)

"two-way traffic“

SYMBOLS

- Comparison of Symbolic & Verbal Signs
  - *Cont. Ells* and *Dewar* (1979): see results below

"two-way traffic“

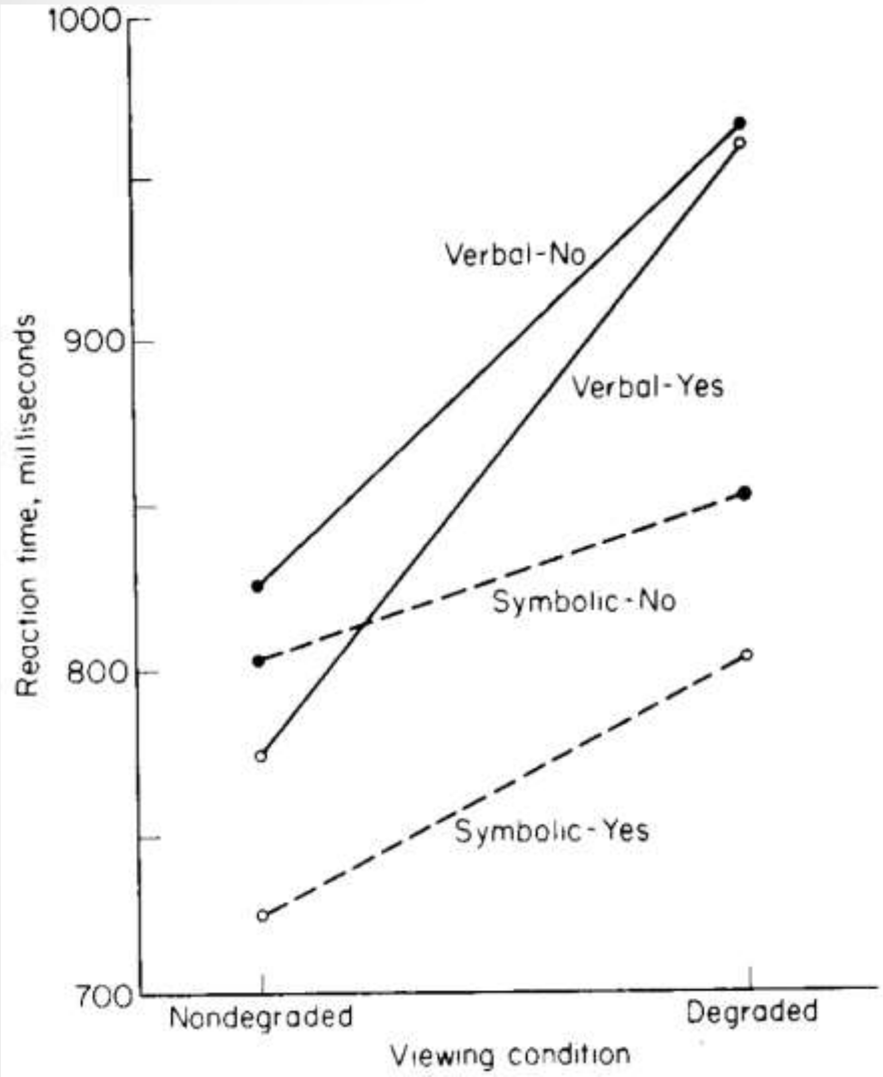
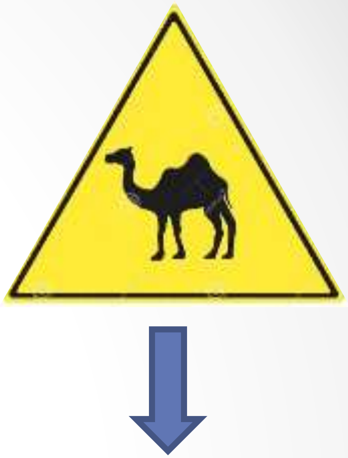


FIGURE 4-15
Mean reaction times of yes and no responses to symbolic and verbal traffic signs viewed under nondegraded and degraded viewing conditions. (*Source: Ellis and Deward, 1979, Fig. 1, p. 168.*)

SYMBOLS

- Objectives of Symbolic Coding Systems
  - symbolic coding system consists of:
    - *symbols*: that best represent their ***referents***
    - *referents:* concept that symbol represents
  - objective: strong association of symbol-referent
  - association depends on either:
    - any established association, "recognizability"
    - or ease of learning such an association
  - guidelines for using coding systems (discussed in Ch. 3):
    - Detectability
    - Discriminability
    - Compatibility
    - Meaningfulness
    - Standardization



"Beware of camels"

SYMBOLS

- Symbols:
  - either are used (or developed to be used) confidently
  - otherwise, they are tested experimentally for suitability
- Criteria for Selecting Coding symbols

1. **Recognition**: subjects presented with symbols and asked,
   - to write down
   - or say what each represents (see example)

SYMBOLS

- Criteria for Selecting Coding symbols (cont.)

2. Matching:

- symbols are presented to subjects along with a list of all referents represented
- subjects match each symbol with its referent
- ⇒ *confusion matrix* : indicating number of times each symbol is confused with every other one
- also num. of correct and incorrect matches
- also reaction time may be measured

3. Preferences and Opinions:
subjects are asked to express their preferences or opinions about experimental design of symbols

SYMBOLS

- Examples of Code Symbol Studies
  1. Mandatory-action symbols (1982)
     - e.g.: “recognition” testing of symbols + learning/training (see below)
     - shown to a group of newly arrived Vietnamese in Australia

FIGURE 4-16

Symbols of mandatory-action messages used in a study of recognition and recall of such symbols. The percentages below the symbols are the percentages of correct recognition, as follows: O = original test; R = recall 1 week later. (*Source: Adapted from Cairney and Siess, 1982, Fig. 1.*)

	1: Must use ear protection	2: Must use eye protection	3: Must use foot protection	4: Must use hand protection	5: Must use head protection	6: Must use breathing protection
O →	10%	20%	30%	50%	37%	13%
R →	73	96	100	97	97	97

SYMBOLS

- Examples of Code Symbol Studies (cont.)
  2. Comparison of exit symbols for visibility (1983):
     - example of symbol recognition/matching
     - here alternative designs were made/tested for the same referent
     - signs (18): viewed under difficult viewing conditions & brief time
     - note, some “no-exit” symbols: perceived as “exit”!

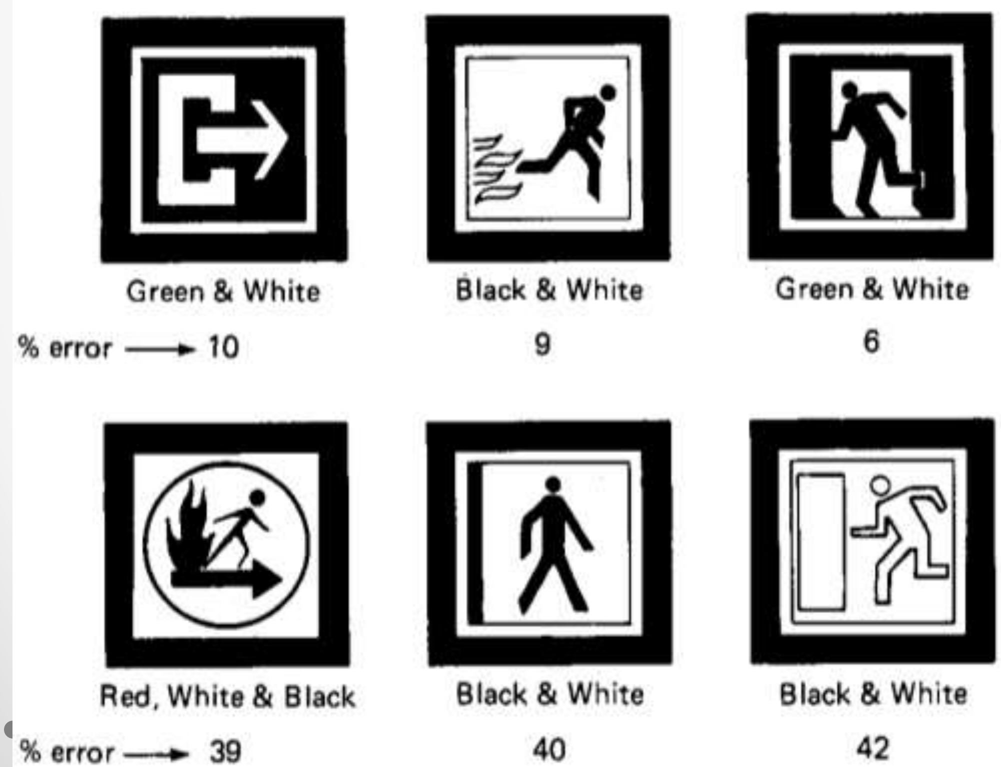


FIGURE 4-17
Examples of a few of the 18 exit signs used in a simulated emergency experiment, with percentages of errors in identifying them as exit signs. (*Source: Adapted from Collins and Lerner, 1983.*)

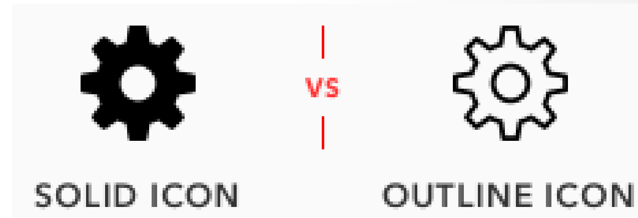
SYMBOLS (cont.)

- Examples of Code Symbol Studies (cont.)

2. Comparison of exit symbols for visibility (cont.):

o Generalizations about features of signs:

- **Filled figures:** superior to outline figures



- **Square or rectangular backgrounds**: better identified than circular figures

- **Simplified figures** (i.e. reduced number of symbol elements) are better than complex figures

SYMBOLS (cont.)

- Perceptual Principles of Symbolic Design

Easterby (1967, 1970) developed principles to enhance the use of symbols:

- **Figure to ground**: e.g. direction must be clear (e.g. CW or CCW)
- **Figure boundaries**: solid boundary better than outline boundary
- **Closure**: figure should generally be closed (i.e. continuous)
- **Simplicity**: include only necessary features
- **Unity**: include text and other details close to symbol

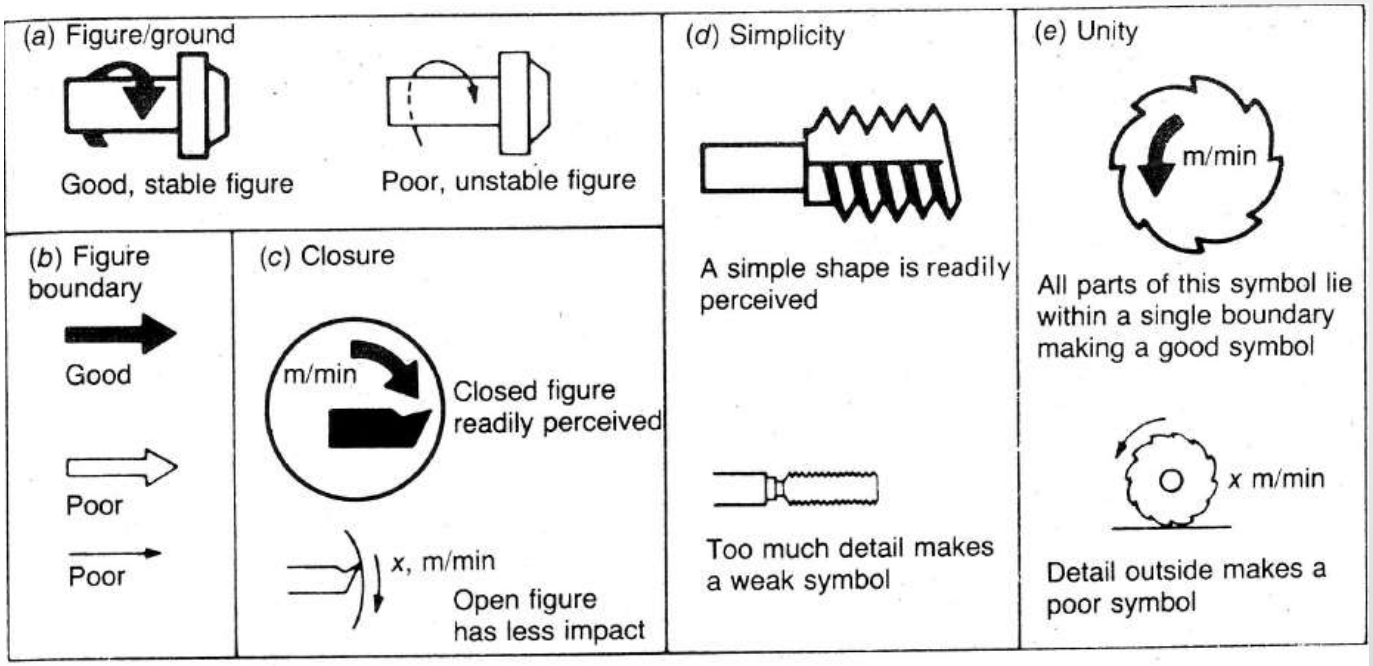


FIGURE 4-18
Examples of certain perceptual principles relevant to the design of visual code symbols. These particular examples relate to symbols used with machines. (*Source: Adapted from Easterby, 1970.*)

SYMBOLS (cont.)

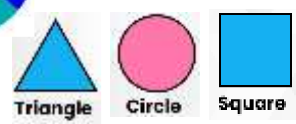
- Standardization of Symbolic Displays
  - symbols should be standardized (i.e. same symbol) if:
    - used for **same referent**
    - used by the **same people**
    - e.g. international road signs (below)

(*a*) Danger signs (*b*) Instruction signs (*c*) Information signs

FIGURE 4-19
Examples of a few international road signs. These are standardized across many countries, especially in Europe. Most of these signs are directly symbolic of their referents.

Codes

CODES

- Coding elements:
  - ***Referents***: items to be coded
  - ***Code***: sign/symbol used to indicate referent
  - ***Coding dimensions***: visual stimuli used, eg.:
    - colors 
    - geometric shapes 

    - sizes 
    - numbers 

    - letters
  - Codes could have:
    - single dimension
    - or more than one dimension (multidimensional)

CODES

- Single Coding Dimensions
  - experiments can be done to find best dimension
  - experiment by *Smith and Thomas (1964)*:
    - varied shapes, geometric forms, symbols, colors (below)
    - e.g. red, gun, circle, or B-52 in a large display of items
    - mean time/errors to count target class was measured
    - color showed greatest superiority (see next slide)

Aircraft shapes	C-54	C-47	F-100	F-102	B-52
Geometric forms	Triangle	Diamond	Semicircle	Circle	Star
Military symbols	Radar	Gun	Aircraft	Missile	Ship
Colors (Munsell notation)	Green (2 5 G 5/8)	Blue (5 BG 4/5)	White (5 Y 8/4)	Red (5 R 4/9)	Yellow (10 YR 6/10)

FIGURE 4-20
Four sets of codes used in a study by Smith and Thomas. The notations under the color labels are the Munsell color matches of the colors used.

CODES

- Single Coding Dimensions (cont.)
  - cont. Experiment by *Smith and Thomas*
    - results shown below: why is color the best code?

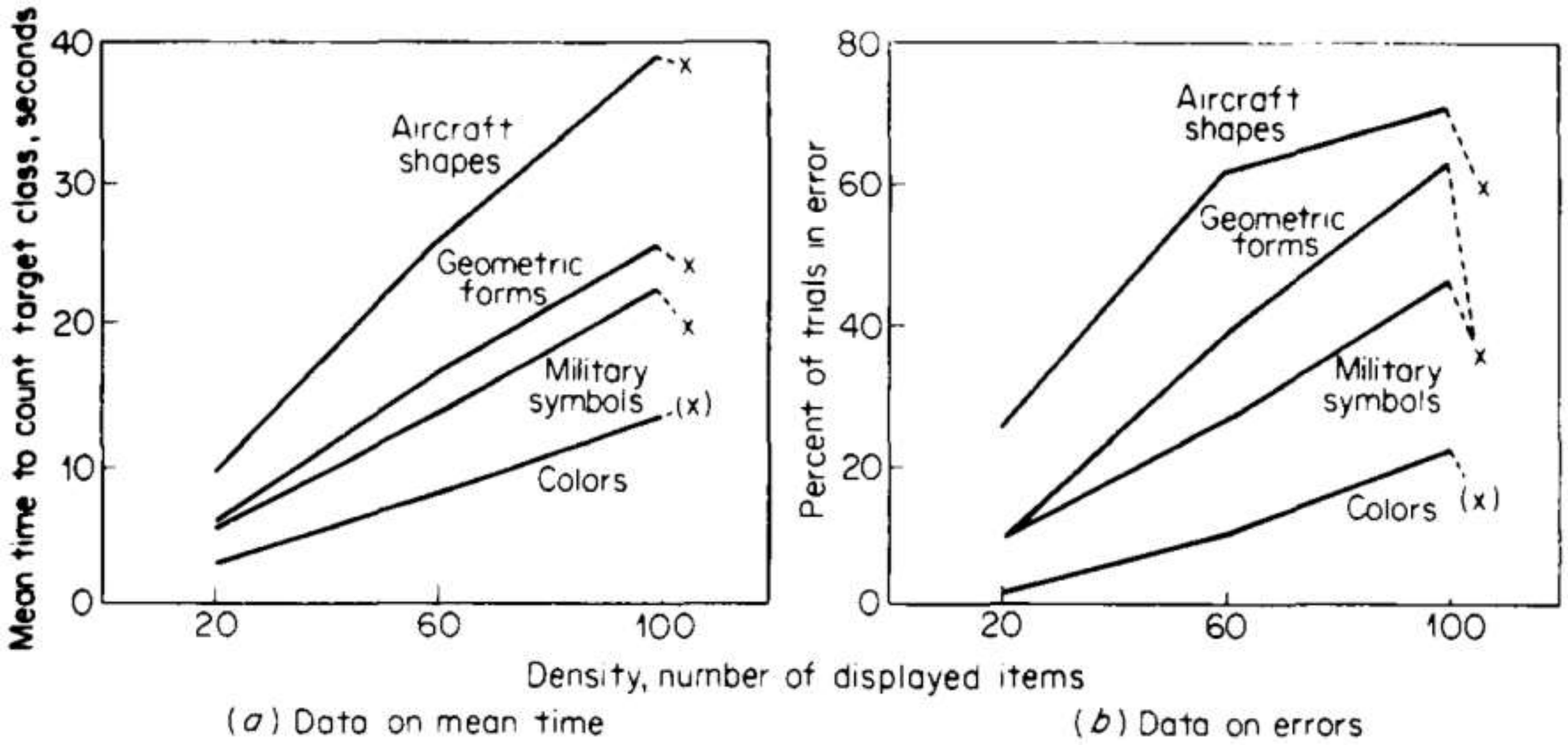


FIGURE 4-21
Mean time *a* and errors *b* in counting items of four classes of codes as a function of display density. The Xs indicate comparison data for displays of 100 items with color (or shape) held constant. (*Source: Smith and Thomas, 1964. Copyright © 1964 by the American Psychological Association and reprinted by permission.*)

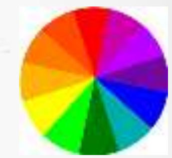
CODES (cont.)

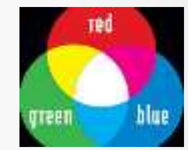
- Single Coding Dimensions (cont.)
  - different coding dimensions differ in relevance for various tasks and situations
  - table (right): guide to selecting appropriate visual code

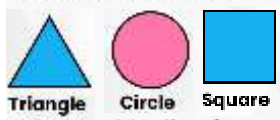
TABLE 4-5
SUMMARY OF CERTAIN VISUAL CODING METHODS

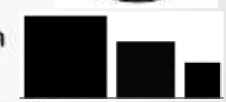
(Numbers refer to number of levels which can be discriminated on an absolute basis under optimum conditions.)

Alphanumeric	Single numerals, 10; single letters, 26; combinations, unlimited. Good; especially useful for identification; uses little space if there is good contrast. Certain items easily confused with each other.
Color (of surfaces)	Hues, 9; hue, saturation, and brightness combinations, 24 or more. Preferable limit, 9. Particularly good for searching and counting tasks. Affected by some lights; problem with color-defective individuals.*†
Color (of lights)	10. Preferable limit, 3. Limited space required. Good for qualitative reading.‡
Geometric shapes	15 or more. Preferable limit, 5. Generally useful coding system, particularly in symbolic representation; good for CRTs. Shapes used together need to be discriminable; some sets of shapes more difficult to discriminate than others.‡
Angle of inclination	24. Preferable limit, 12. Generally satisfactory for special purposes such as indicating direction, angle, or position on round instruments like clocks, CRTs, etc.§
Size of forms (such as squares)	5 or 6. Preferable limit, 3. Takes considerable space. Use only when specifically appropriate.
Visual number	6. Preferable limit, 4. Use only when specifically appropriate, such as to represent numbers of items. Takes considerable space; may be confused with other symbols.
Brightness of lights	3–4. Preferable limit, 2. Use only when specifically appropriate. Weaker signals may be masked.‡
Flash rate of lights	Preferable limit, 2. Limited applicability if receiver needs to differentiate flash rates. Flashing lights, however, have possible use in combination with controlled time intervals (as with lighthouse signals and naval communications) or to attract attention to specific areas.







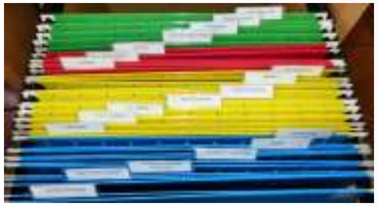


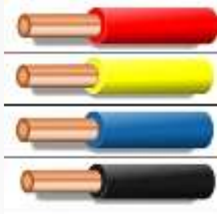
CODES (cont.)

- Color coding
  - color is a very useful visual code
  - Q: What is # of distinct colors that normal color vision person can differentiate (absolute basis)?
  - Jones (1962) found that the normal observer could identify 9 surface colors (different hues)
  - with training, people are able to identify around 24 colors or more *(Feallock, 1966)* (different hues, saturation, or lightness)
  - but when dealing with untrained people, it is wise to use a smaller number of colors

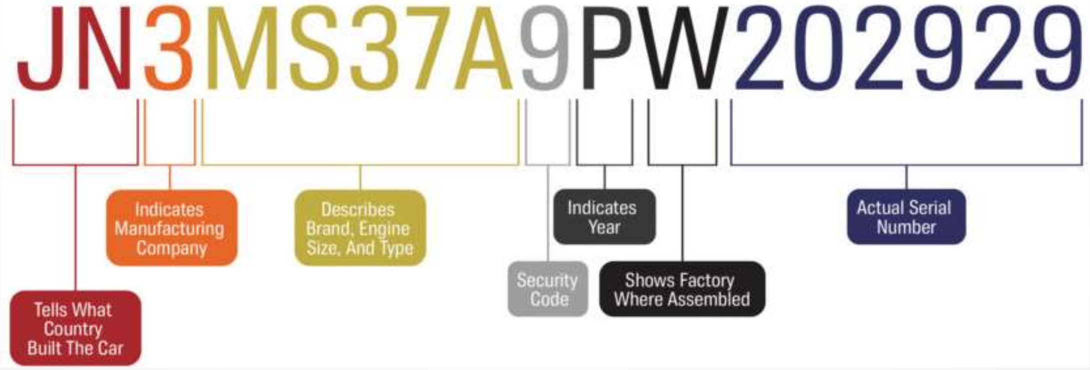
CODES (cont.)

- Color coding (cont.)
  - color coding is very useful in “searching”/ “spotting”, counting, locating (as compared to other dimensions), e.g.:
    - searching maps
    - items in a file
    - identifying color-coded wires





  - reason is the fact that colors "catch the eye“
  - note, color is not a universal “identification” code
  - e.g. study by Christ (*1975*) found (as result of 42 studies):
    - color codes: generally better for searching tasks (vs. other visual codes)
    - but letters/numerals were better for identification tasks (why?)



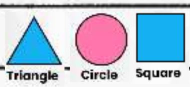
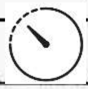
CODES (cont.)

- Multidimensional codes
  - Recommended (*Heglin, 1973*): no more than 2 dimensions be used together for rapid interpretation
  - certain combinations do not 'go well' together (see figure)
  - ⇒ not always more effective than single-dimension codes

ABC123

FIGURE 4-22

Potential combinations of coding systems for use in multidimension coding. (*Source: Adapted from Heglin, 1973, Tables VI-6, VI-22.*)

	Color	Numeral and letter	Shape	Size	Brightness	Location	Flash rate	Line length	Angular orientation
Color 		X	X	X	X	X	X	X	X
Numeral and letter	X			X		X	X		
Shape 	X			X	X		X		
Size	X	X	X		X		X		
Brightness 	X		X	X					
Location 	X	X						X	X
Flash rate	X	X	X	X					X
Line length	X					X			X
Angular orientation 	X					X	X	X	

References

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