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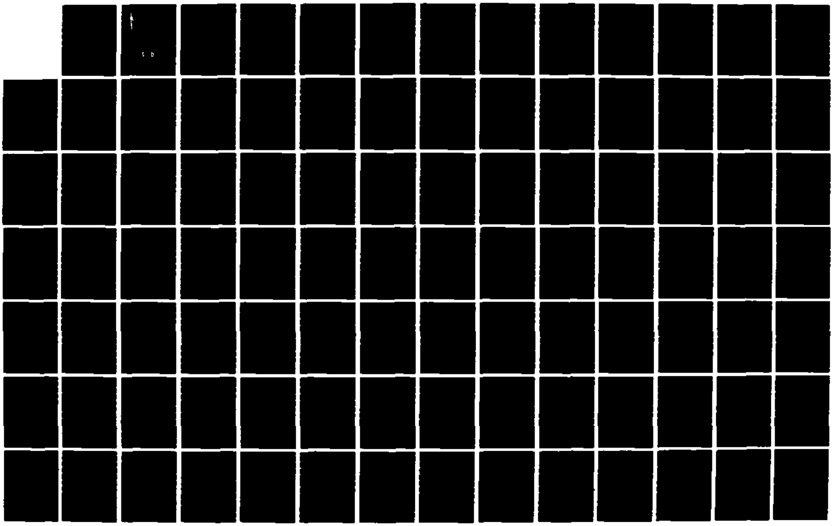

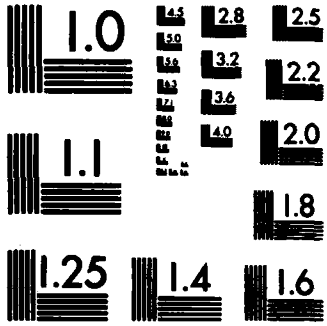

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

HUMAN FACTORS ENGINEERING

A Self-Paced Text
Lessons 11-15

Approved for Public Release:
Distribution Unlimited

Ruth Brogan
Jerry Hedge
Kevin McElory
Judah Katznelson

US ARMY HUMAN ENGINEERING LABORATORY

PACIFIC MISSILE TEST CENTER

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HUMAN FACTORS ENGINEERING

LESSON 11: STANDARDIZATION OF CONTROLS, OR WHICH WAY IS UP?

Welcome back to your course in Human Engineering. You're 25 percent smarter now and going strong! This lesson will begin a series of three presentation on controls. The reason why so much emphasis is placed on controls will become evident to you as you progress.

Turning for a second to Lt. Eager, you'll see how proper design of controls (or lack thereof) affected him. As you recall, when we last saw Eager, he was incensed by the fact that he could not communicate with his copilot. Almost irrational, he clinched his fists as if to convey physically his message to him. As the copilot reflexively reached for the ejection button to escape, he pushed the button (as one would think you should), but instead of ejecting the copilot, this action caused the aircraft to fall apart. You see, the button was designed so that your were required to pull it in order to eject and to push it in order to destruct the helicopter. Poor design!! It saved the copilot from an unnecessary trip, but it cost the government the price of the helicopter.

This little episode introduces you to the lesson topics--controls. As Eager and his copilot discussed what had happened, they realized that if a real emergency had occurred, and they had pushed the button without thinking, they would have been in deep trouble. So, they started thinking about the design of controls.

Earlier in this course you were introduced to the work of Paul Fitts. His studies showed that about 50 percent of the aircraft accidents he examined involved confusion of one control with another (e.g. confusing the controls for the landing gear and the flaps). In general, these confusions were caused by (1) lack of standard arrangements; (2) lack of uniform operating characteristics; (3) difficulty in distinguishing one control from another because of shape; and (4) use of habitual sequences of operation at inappropriate times.

Which of the following do you think is the best example of nonstandard arrangement of controls in a car:

(1) A high beam control button on the floor of the car. Go to Page 63.
(2) A horn activated by a lever located on the steering column. Go to Page 5.
(3) A brake pedal to the left of a clutch pedal. Go to Page 33.

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- -

From Page 12

(4) Most TV's we've seen have either push-button or rotary on-off switches. Return to Page 12.

- -

From Page 64

(3) Sorry. This answer is one way of establishing priority, but there are other factors to consider. Go back to Page 64.

- -

From Page 83

(2) If you'll remember, we stated earlier that all control devices possess some resistance. Return to Page 83.

- -

HUMAN FACTORS ENGINEERING

LESSON 13: CONTROL DYNAMICS

Well, well, well. Here you are, almost one-third of the way through this course, right? Congratulations! We're glad you're back for another lesson. This promises to be another fact-filled lesson...but enough of this chitchat.

In Lesson 11 you were exposed to a general discussion of control types and how they related to the function involved. Lesson 12 was then devoted to explaining ways to position these controls so as to enhance man-machine performance.

Now we would like to complete this discussion of controls by looking at the relationship between man and machine in terms of mixing control types on a panel to enhance performance. We also will consider the importance of other variables, such as making controls as compatible as possible, taking into account the distance of the control panel from the controller, and even evaluating the strength requirements for various controls.

However, before we begin this final lesson on controls, let's turn to another installment of our saga of I. M. Eager and his super choppers. As the last exciting episode ended, super helicopter (MOD 5) had been reduced to a pile of rubble on the edge of the runway, and I. M. Eager had demanded a new, improved version of the helicopter (which would make this version, MOD 6, five more than he had expected).

By this time, Eager had become used to waiting, so the wait for chopper #6 did not seem so long (and in fact, time passes amazingly quickly in dreams). Finally, the next helicopter did arrive, and because Eager remembered his helicopters of the past, he was on his guard; in fact, he learned that Human Factors Engineering played an important role in anthropometry, work space design, visual capabilities, visual and auditory displays, and standardization and placement of controls. At this point, he expected to find an additional area where human factors expertise had been neglected.

So, it was with trepidation that Eager and his copilot advanced toward the door. The copilot stepped up to the door and attempted to unlatch it, but due to the spring tension on the door, he was catapulated backwards 50 feet or more. While Eager found this scene highly amusing and laughed for some time, he also realized this to be one more headache. So--back to the drawing board and on with this lesson.

(Go on to the next page)

- -

From Page 3

Before we get started with any heavy-duty discussions, we want to make sure you've remembered to review the supplemental readings provided for you. It is important that you become familiar with these pages in the supplement before you continue with this lesson. If you don't, you may end up in Eager's position, and besides, several key questions in the following sections will require you to use the knowledge you've gained from the supplement. Now, away we go!

As mentioned before, we will be discussing some aspects of controls that deal with attempts to enhance man-machine interactions. This process focuses on dealing with size and shape of controls, distance of the controller from the controls, as well as the mixing of types of controls on a panel. While it's important to realize that while the principles of design are not limited to panels alone, panels serve as good examples. When talking about man-machine interactions, an important concept arises, and we discussed just this concept in Lesson 11. Now, tell us which of the following terms did we talk about in Lesson 11?

(1) Control-Display Ratio. Go to Page 53.
(2) Size and Distance Trade-offs. Go to Page 61.
(3) Stimulus-Response Compatibility. Go to Page 93.
(4) Strength Requirements. Go to Page 55.

From Page 8

(4) Very good, you are absolutely right. In essence, man-machine interface represents the human operator as an important link between the mechanical or electronic displays and controls of a machine.

Congratulations, you have now successfully completed another lesson in our human factors engineering course. However, before we say goodbye, why don't we check back in on I.M. Eager and see how his most recent headache is progressing.

(Go on to the next page)

From Page 4

If you'll remember, Eager's copilot had been sent tumbling backwards for some distance before coming to a stop. Eager, while somewhat amused, realized that once again changes would have to be made and time wasted awaiting these changes. Still, Eager is not quite so eager to send for another helicopter. After all, the men from B.A.R.F. are tired of taking the rap for Eager's helicopter failures, and besides, super helicopters aren't bought in 5 & 10 cent stores. To find out how he resolves this situation, tune in next time for ...'other senses.' Turn to Page 9 for Lesson 14.

From Page 59

(1) Right on, your are absolutely correct. All of these (and more) affect the operator's manual dexterity.

All right, the factual part of this lesson is over. However, you may be interested to hear how I. M. Eager resolves his design dilemna. Well, after the detonations had finished and the chopper looked like a pile of broken tinker toys, Eager gingerly stepped over the remains. Struggling, he managed to maintain his military bearing. The senior analyst was nowhere to be found (remember, he snuck away), and the copilot had long since run out of Eager's reach; so Eager turned smartly in the direction of B.A.R.F., snapped his fingers, and yelled, 'next!' After all, this is a dream. How else could you order a new helicopter by snapping your fingers? ... In any event, see you next lesson when you will learn about Eager's next version of his choppper, and, in addition, a lesson on control dynamics will be mentioned. Tune in for Lesson 13 ... Control Dynamics. Turn to Page 3 for Lesson 13.

From Page 1

(2) A standard location is on the steering column. While this may not be the case in all cars, it is an accepted standard. Return to Page 1.

From Page 33

(4) Right again. All three of these deviate from what you'd normally expect.

Examples of the other problems identified by Fitts will be covered later in this lesson. By your answers, you have indicated that you understand the importance of designing controls in standard ways. In summary, you use population stereotypes. You locate a control where 'everyone' expects it to be. You use directions of motion which are natural--for example, turning a wheel clockwise to go right or pushing a throttle forward to increase forward speed. Certain direction-of-motion relationships (such as turning a faucet clockwise to shut off water) have become traditional. The designer must avoid control relationships (either between controls and displays or between control and vehicle motion) which imply incorrect or unexpected directions of motion.

When designing a military system, for example, there are several questions that human engineering personnel must answer in regard to controls. The key questions are presented in the following checklist:

1. Have you chosen the best type of control?
2. Is the control the right size?
3. Are the operating force, extent of movement, and speed of movement correct?
4. Have you provided body support?
5. Is the direction of movement correct?
6. Are the control-display ratios correct?
7. Is the control correctly coded?
8. Have you considered environmental factors?

Before any further detailed study of control is possible, let's look at a definition and some major types of controls. A control is a device used to transmit a decision, via a force, from an operator to a piece of equipment. Light switches, steering wheels, brake pedals, and typewriter keys are all controls. While the concept of controls is a simple one, as Eager found out, the application of this concept in systems design is a little more complex.

There are several ways in which to categorize controls. For simplicity's sake, think of controls fitting into one of two broad functional categories: those involved with continuous adjustment and those concerned with discrete settings.

(Go on to the next page)

From Page 6

Controls whose function is continuous adjustment allow an operator to transmit information along a quantitative continuum, a qualitative continuum, or a representational continuum (e.g., hot, warm, cold). The key word is obviously 'continuum.' Which of the following are all examples of continuous adjustment controls?

(1) Dimmer-switch, radio tuner knob, high-beam switch in a car. Go to Page 22.
(2) Light-switch, brake pedal, gear shift. Go to Page 47.
(3) Thermostat, steering wheel, accelerator pedal. Go to Page 21.

From Page 25

(2) This factor quite definitely needs to be accounted for in the operation, but not in the design of equipment. Return to Page 25.

From Page 10

(1) You've confused methods of preventing accidental activation with methods of coding. Return to Page 10.

From Page 56

(1) Very good, we're glad to see you've begun to think of the various aspects of Human Factors Engineering in this way.

We hope that you have, indeed, begun to become more aware of the area of Human Factors Engineering, as well as more familiar with some of the key words used in this field. Throughout these 13 lessons you have been exposed to some words and phrases that are unique to this area of research. In fact, in the last paragraph, we presented the concept of man-machine interface. This term has been alluded to on a number of occasions in previous lessons. Based on what you have learned thus far, would you say that man-machine interface refers to:

(1) The necessity for man to always be present to correct problems that arise in machines. Go to Page 18.
(2) Man is the most important element in any system. Go to Page 27.
(3) The output of man's information processing abilities. Go to Page 48.
(4) A set of identifiable components (namely, man and machine) interacting in pursuit of a common goal. Go to Page 4.

From Page 78

(1) Sorry, but a better answer to the question is available. Return to Page 78.

From Page 88

(2) These aren't the only environmental effects which must be taken into account. Return to Page 88.

HUMAN FACTORS ENGINEERING

LESSON 14: OTHER SENSES

In the last three lessons you have review a great deal of information regarding the design of controls. Lesson 11 reviewed the various functions and types of controls as well as some coding practices. Lesson 12 was concerned mainly with rules for positioning controls, and Lesson 13 involved control dynamics--control-display ratios, S-R compatibility, and strength requirements. This lession will go into greater detail concerning coding practices and will introduce the use of senses other than vision and audition.

One reason for this increased scope is the experience of I. M. Eager. After reviewing all the information on controls, he was still not content that he knew everything about Human Factors Engineering. You see, Eager liked being a lieutenant and he figured that if he 'messed up' one more time, the general might see to it that he never wore his bars again--and Eager was not ready to be 'disbarred.' So...after his latest failure, he stopped at the Human Engineering Lab's library and did some research on controls and the senses.

Think back to Lesson 11. What is the main reason for coding?

(1) To make controls aesthetically pleasing. Go to Page 48.
(2) FED-STD-595. Go to Page 40.
(3) MIL-M-18012. Go to Page 16.
(4) To make controls easier to identify. Go to Page 10.

- -

From Page 12

(2) A regular wall light switch would be an example of a toggle switch; a light dimmer is not. Return to Page 12.

- -

From Page 9

(4) Absolutely correct. This is the only reason for coding.

You have been provided several documents which present information on coding. For example, you have used MIL-STD-1472 and MIL-HDBK-759. Throughout these documents you can find the statement that 'coding' is used to differentiate similar-looking but unrelated devices from one another. In addition, FED-STD-595 describes the colors used for coding. Normally, color should not be used as the sole or primary source of control coding; controls should be painted black or gray. However, if color coding is used, the following colors should be utilized: red, green, orange, yellow, and blue color coding is most effective when specific meanings can be attached to the colors.

Red is the basic color for identifying fire, danger, stop, and emergency.

Green is used to designate safety and first-aid equipment.

Orange designates dangerous moving parts of machines, starting switches, and starting buttons.

Yellow designates caution.

Blue also designates caution, generally limited to warning against starting or using equipment under repair.

Do you remember what other types of coding techniques can be used? Which of the following are accepted methods for coding?

(1) Recessing, location, orientation, and covering. Go to Page 7.
(2) Location, labeling, shape and size. Go to Page 58.
(3) Location, recessing, labeling, and shape. Go to Page 65.

- -

From Page 62

(4) Very good, you've realized that a number of these resistance forces come into play with any control movement; and since we already told you elastic resistance was involved, the rest was easy, right?

So far, so good. Several specific features of control systems still remain for us to cover bef re we can broaden the scope of our focus to concentrate on the human operator in relation to the nature of control systems. So, first let's begin by touching on the topic of feedback in relation to operation of controls.

The operation of controls provides feedback of two sorts, either intrinsic or extrinsic feedback. Intrinsic feedback to the operator results from the individual's ability of "sense" on his own what is occurring from the control action he has taken. For instance, the greater the tension on a spring-centered joy stick and the greater its displacement, the more clear-cut and dramatic the results will be. Now, do you feel like you have an idea of what type of feedback is provided by extrinsically-based feedback?

(1) Information that is obtained from some external source that indicates the consequences of the control action. Go to Page 50.
(2) Information that is sensed through the muscle structure and therefore indicates the consequences of the control action. Go to Page 46.
(3) Both of these answers are correct. Go to Page 51.

- -

From Page 90

(5) Understanding the work space requirements is important, but there are many other things you need to know, too. Return to Page 90.

- -

From Page 22

(4) Excellent. Even though there are descriptive labels, this control slides along a continuum and, therefore, is a continuous adjustment control. It is linear because it requires a horizontal (rather than circular) motion to operate it.

Since your have a fairly good handle on the general types of controls, it's time to become more specific. Table 11.1 in your supplement lists some of the more common types of controls. Later, we will examine the relative value of controls; for now, just look across the top of the table at the titles.

The first type listed in Table 11.1 (page 28 of your supplement) is a hand-operated push button, which is a discrete setting, linear control. This type of control is illustrated in MIL-STD-1472 in the section titled Controls.

Another frequently used control is the toggle switch which like push buttons are discrete, setting linear controls. Take a moment and look at this section which also provides standards for design for other types of controls.

Which of the following is a good example of a toggle switch?

(1) None of the answers presented here is correct. Go to Page 75.
(2) A wall light dimmer switch. Go to Page 9.
(3) A turn indicator on the steering column of a car. Go to Page 29.
(4) An on-off switch of most TV's. Go to Page 2.

From Page 58

(2) You're partially correct. You do need adequate space for labelling, but if the operator can't read labels because of poor lighting or illiteracy, your labels will be of no value. Return to Page 58.

From Page 89

(1) Standardization is important, but why is this type of control standard for this situation? Return to Page 89.

From Page 76

(2) You eventually may have to come to this, but it shouldn't be your first consideration. Return to Page 76.

From Page 98

(2) Both shape and size coding could be combined with labeling, but this combination is by no means a requirement. Return to Page 98.

From Page 69

(2) You're only partially correct. Return to Page 69.

From Page 56

(2) Now, that's not very nice. Although that could have been a motivating factor, it wasn't. Return to Page 56.

From Page 73

(1) You're only partially correct. Return to Page 73.

From Page 33

(3) With most thermostats, moving an indicator to the right will increase the temperature; therefore, this is an example of a design flaw, but then, so are the other answers given here. Return to Page 33.

From Page 9

(3) MIL-M-18012 delineates colors for immediate action controls in aircraft, but it's not the reason for the coding. Return to Page 9.

From Page 38

(2) Think back to what was said about continuous adjustment controls. With only 10 possible settings, you'd lose more than you'd gain by selecting a continuous adjustment type control. Return to Page 38.

From Page 56

(3) The importance of hierarchical arrangement was not central to our discussion. Return to Page 56.

From Page 98

(4) Size and shape are not the prime methods of coding, and if they were, they'd have been discussed long ago. (But don't underestimate the importance of these methods.) Return to Page 98.

From Page 69

(3) You're only partially correct. Return to Page 69.

From Page 73

(2) You're only partially correct. Return to Page 73.

From Page 70

(2) Outstanding, exactly right. In fact, this entire breakdown of Class "A," "B," and "C" controls depends on standardization.

Standardization is a concept which is central to all coding. You've seen that colors should be standardized (e.g., red equals emergency), and labeling should be standardized (e.g., labels above controls), etc. Figure 14.3 illustrates the Air Force's standardization of shape controls for USAF aircraft. This coding of controls is valuable because (1) they are standard across different aircraft types; (2) they are easily discriminated among one another (even with gloves on); (3) some have symbolic meaning (landing gear control is shaped like a wheel).

Another way to code by touch is through texture coding. In general, three surface characteristics can be used to achieve reasonable discrimination--smooth, fluted, and knurled. Figure 14.4 in the supplement illustrates the various textures.

A final means of coding is size coding. While size coding is not as valuable a method as is shape coding, there are instances where its use is appropriate. Can you think of any? Which of the examples listed below do you think is a valid answer to the question, "when should size coding be used?"

(1) When the equipment being designed is complex. Go to Page 30.
(2) When vision is the only sense which can be used to discriminate. Go to Page 23.
(3) When knobs must be placed atop one another. Go to Page 87.

From Page 8

(1) Man serves more than just an equipment repairman function. Return to Page 8.

From Page 43

(4) Very good. This, indeed, is a way to ensure that the controls are not accidentally engaged.

There are a variety of ways that you can protect controls from being inadvertently activated. We will talk about seven of them. First, you can recess the control device into the control panel. This will prevent the control from being accidentally hit. However, there is a disadvantage to this method (as there are to the others, also). In order to recess switches, knobs, etc., it will be necessary to have a deeper amount of panel space. This means that in a small area, the work area itself would have to be lessened so that the panel could be enlarged. To clarify this, think about a wall light switch. If the switch is recess, the wall will have to be that much thicker, or a barrier would have to be place around the switch, which, in turn, could adversely affect the individual's safety. Who wants to bump into a barrier on the wall as you walk by?

Second, the important controls could be located so that accidental activation is unlikely. For example, it might be a good idea to have the ejection control located away from other more often used control devices. A third method, orientation, suggests that the controls be placed along the axis which is least likely to encounter accidental forces. For example, if the user is more likely to be pushed forward or backward during acceleration and deceleration, then important controls can be placed so that a sideways movement is required to activate them.

Two other methods to prevent activation are locking and covering. If the controls are not often used, then locking the controls may be an acceptable method. This method would require the user to perform two manipulations before engaging the control. For instance, in a straight stick automobile, you really wouldn't want to engage inadvertently the reverse gears, especially if you're cruising at 55 mph. In most autos, it takes two sequential movements to activate reverse—a push in and down (or up), or perhaps a horizontal, then vertical movement. Anyway, you get the picture.

The method of covering the controls can also be used. Think of the protective covering currently being used on thermostats. These covers serve to prevent unnecessary manipulation of the thermostat setting and thus maintain the desired temperature within the environment.

(Go on to the next page)

From Page 19

There are two more methods which can be used to prevent accidental engagement of a control device. The resistance of the control can be increased so as to make accidental engagement unlikely, or operational sequencing can be used. In sequential operations the control affecting system output could be the last one in a series which, in turn, could only be engaged if all the previous steps had been correctly taken. Which of the following is an example of this type of method?

(1) An auto ignition. Go to Page 73.
(2) A combination lock. Go to Page 63.
(3) Thermostat. Go to Page 88.
(4) A recessed car door handle. Go to Page 94.

From Page 22

(3) You're only half right. Don't let the labels mislead you into thinking this control is discrete. Return to Page 22.

From Page 50

(1) Oh, come on, do you need to get your eyes checked? We said feedback, not flashback! Return to Page 50.

From Page 7

(3) Very good. All three of these controls allow the operator to vary his responses along a continuum. The other two answers include discrete controls.

Those controls listed above which were not continuous adjustment controls had one thing in common. They all provided the operator with a finite number of discrete settings from which to choose. Some had only two choices—on or off. This is sometimes referred to as an activation-type control since it is used to activate a system. The light switch and high-beam control are examples of activation controls. Other discrete setting controls allow for several response choices. Examples of these would be gear shifts in a car or a TV channel selector.

So, as a designer, one of the first things you must examine is the function of a control. You, obviously, do not want a continuous adjustment control to turn equipment on or off. On the other hand, a discrete setting type of control would be impractical for controlling the volume of loudness produced by your stereo equipment. After you've decided on the function of a control, selecting the exact control to use requires more detailed analysis.

As we get into more detail concerning the various types of controls, you'll need to refer to two of the documents which were issued to you at the beginning of the course. These are MIL-HDBK-759, "Human Factors Engineering Design for Army Materiel," and MIL-STD-1472, "Human Engineering Design Criteria for Military Systems, Equipment and Facilities." The illustrations and tables presented in these documents will assist you in understanding and implementing control design procedures.

The number of specific types of controls is large. As you become more involved in control design in your job and become more familiar with MIL-STD-1472 and MIL-HDBK-759, your knowledge of types of controls will expand. For now the following discussion of the more frequently used controls will provide you with the background necessary to understand better those areas of your job requiring human factor engineering knowledge.

(Go on to the next page)

From Page 21

You know that controls have two possible functions: continuous adjustment or discrete settings. In turn, there are two general types of controls: rotary controls and linear controls. Rotary type controls are those which require circular motions to operate. Examples are numerous--a channel selector on most TV's, a steering wheel, an overhead dimmer switch, etc. Linear controls are those which require noncircular motion to activate. Controls such as pedals, light switches, and keyboards are all examples of linear controls.

Before you continue, take a moment for review. Picture an automobile with an air-conditioner. On the dashboard is the control for this unit. There is a lever which slides horizontally to control the temperature of the air. It is labelled off, warm, cool, cold. Which of the following best describes this control:

(1) Discrete setting, rotary. Go to Page 36.
(2) Continuous adjustment, rotary. Go to Page 44.
(3) Discrete setting, linear. Go to Page 20.
(4) Continuous adjustment, linear. Go to Page 12.
(5) From the information presented, we cannot really answer this question. Go to Page 55.

From Page 7

(1) Two out of three are examples of continuous adjustment controls, but the high beam control can only be on or off and, thus, is a discrete control. Return to Page 7.

From Page 78

(2) Helmets might protect your head from the impact of initial acceleration, but they won't help you function against an accelerating force. Return to Page 78.

From Page 58

(1) You're right, but only partially. While labelling does no good if the operator can't read (unless you use common symbols), there are other factors listed, such as space dimensions and lighting, which argue against labelling as the coding technique for this situation. Return to Page 58.

From Page 18

(2) When vision is the only sense which can be used to discriminate, size coding may not be the best method of coding. Think about what you have learned in this lesson. Don't forget options such as color coding, labelling, etc. Return to Page 18.

From Page 98

(3) Both shape and size coding could be combined with color coding, but this combination is by no means a requirement. Return to Page 98.

From Page 70

(1) Color of controls is an important aspect in reducing confusion, but remember, we are discussing equipment often used in an environment providing little or no light. Return to Page 70.

From Page 36

(2) You're right. While there is little difference between the feet when you consider strength and speed, most people prefer to use the right foot, especially when the task is critical.

(3) The area for locating hand controls should be larger than that for foot controls because of the greater range of movement of the arm and hands relative to the feet.

(4) The most critical and important controls should be given priority and located closest to the operator.

Now, let us consider spacing between controls. There are several factors which must be considered in determining the proper spacing between controls in a given area. These are:'

(1) Whether the controls will be required to be used simultaneously or sequentially. For example, if there are two knobs which have to be used simultaneously by both hands, they will need to be spaced so that the operator has enough room for both hands. This would require a larger area between the knobs than if they had to be activated sequentially by one hand; then you would want to have a smaller area between the knobs. Other factors are:

(2) You also must take into account the size of the control and the amount of movement required.

(3) Of prime importance are the effects on the system's performance if an error, such as inadvertantly choosing the wrong control, is made.

What do you think the next consideration should be?

(1) The effects varying weather conditions may have on the operator. Go to Page 55.
(2) Whether the operator is taking any medication which might affect his performance. Go to Page 7.
(3) No other factors need to be taken into account. Go to Page 95.
(4) Any personal equipment, such as gloves, that might hinder the manipulation of the controls. Go to Page 88.

From Page 71

(1) This sound good, but what happens when both operators need to use the same controls? There is a better design than this one. Return to Page 71.

From Page 59

(2) Poor general safety and illumination don't affect the operator's manual dexerity, although they may cause errors in the worker's performance. Return to Page 59.

From Page 62

(2) Viscous resistance does not occur with spring-centered joy sticks; viscous is independent of displacement. Return to Page 62.

From Page 93

(3) One of these answers is correct. Return to Page 93.

From Page 8

(2) Man and machine both play important roles in system effectiveness. Return to Page 8.

From Page 90

(3) Knowing the requirments of the control task is important, but there are many other things you need to know as well. Return to Page 90.

- -

From Page 84

(3) We really don't have enough information to say that a toggle switch is required. Return to Page 84.

- -

From Page 91

(2) In the headward direction, 12 G's can only be tolerated for about 6 seconds or .1 minute. Return to Page 91.

- -

From Page 96

(1) It might be good to think this one through again before answering. Return to Page 96.

- -

From Page 12

(3) Very good, a turn indicator is a good example of a toggle switch.

A third type of control is the rotary switch. Page 67 of MIL-STD-1472 illustrates one type of rotary switch. This type of control, a discrete setting, rotary type, is described in paragraph 5.4.2.1.1. If you have a stereo receiver which can operate as a record player, AM-FM, or tape player, you've probably used a rotary switch. The control which allows you to select the modes of operation of your set is a rotary switch or rotary type control.

Knobs present another important type of control. What is referred to as 'knobs' in this table are really continuous adjustment rotary controls. Page 72 in MIL-STD-1472 illustrates several different knobs of this type. The dimmer switch is an excellent example of this type of knob. Paragraph 5.4.2.2 discusses this type of control.

Rotary switches are sometimes referred to as knobs, also. Remember, the main distinction between a rotary switch type knob and continuous adjustment rotary control knob is the function--one serves to implement discrete settings, the other continuous adjustments.

A crank is another continuous adjustment rotary control. Page 74 of MIL-STD-1472 illustrates this type of control and paragraph 5.4.2.2.2 describes it. You may not remember, but in days gone by, this type of control was used to start a car; you have probably seen this in old movies. Speaking of cars, have you ever had a flat tire? Well, if you have, you've had to use a jack to change it. The jack is controlled by either a crank or the next type of control--the lever.

Page 85 of MIL-STD-1472 presents data on the lever. Perhaps the best example of a lever is an on-the-floor stick shift in a car. This is a discrete lever. Levers, however, can also be continuous. Paragraph 5.4.3.2.1. describes such controls. The throttle used to control RPM's on many different types of machinery is a good example of a continuous adjustment type lever. The term 'joy stick' is often used to describe a lever-type control.

The handwheel is another familiar type of control. Page 75 of MIL-STD-1472 illustrates handwheels. The uses of handwheels are obvious to all of us who drive cars (or turn on water, for that matter). Paragraph 5.4.2.2.3 describes handwheels.

(Go on to the next page)

From Page 29

The final type of control you'll look at is the pedal. There are two type of pedals: leg-actuated and ankle-actuated. Do you think you can distinguish the different types? Give it a try. Which of the following is a leg-actuated pedal?

(1) Accelerator pedal. Go to Page 52.
(2) Brake pedal. Go to Page 90.
(3) Organ Pedal. Go to Page 76.
(4) All of these. Go to Page 96.

From Page 18

(1) Complex equipment might call for using size coding somewhere in your design, but you really have other options available to you which might be better, such as color coding, labelling, etc. Return to Page 18.

From Page 49

(1) Good going, you hit the nail right on the head. You can make controls easier to identify by placing them in a specific place (location), by coloring them, by making them large or small (size), by making them some specific shape, or by placing a label above or below the control.

Section on Controls in MIL-STD-1472, contains a table titled "Advantages and Disadvantages of Different Types of Coding," which describes some coding techniques and rules. When we discuss the senses in Lesson 14, a more detailed discussion of coding techniques will be presented. Right now, though, we've just about run out of time. Before we close, let's take another look at Eager.

Eager and his copilot walked away from the destroyed helicopter; they had been thoroughly embarrassed and decided not to let it happen again. While the helicopter pad was being cleared, they got out MIL-STD-1472 and MIL-HDBK-759 to see where they had gone wrong; there was a lot more to designing controls than they thought. There's a lot more for you, too. Turn to Page 42 to begin Lesson 12.

From Page 75

(1) An increase in hearing ability is unlikely to occur because of vibration. If you think about it, an increase in your visual abilities is also highly unlikely. Try reading while riding in a car. Return to Page 75.

From Page 43

(3) Sorry. The proper spacing of controls will help to prevent their accidental activation, but selecting an arbitrary distance of half an inch isn't necessarily the correct procedure. Return to Page 43.

From Page 84

(2) We really don't have enough information to say that a leg-actuated control is needed. Return to Page 84.

From Page 1

(3) That's right. Imagine the number of accidents that would occur when drivers reflexively pumped the clutch in an attempt to stop.

What about nonstandard operating characteristics? Which of the following do you think is an example of this design flaw?

(1) Turning the stem of a watch counterclockwise to wind it. Go to Page 51.
(2) Pushing a car's turn signal up to indicate a left turn. Go to Page 53.
(3) Turning a thermostat to the right to lower the temperature. Go to Page 15.
(4) All of the answers presented here are correct. Go to Page 6.

From Page 45

(2) Correct. Very good! If there are a large number of controls to be grouped, they should be arranged in rows from left to right, rather than columns from left to right. Again, you have taken advantage of that good ol' population stereotype. (However, if you're designing for users who read in columns, you may want to reconsider the answer.)

The third major factor to take into account when locating controls and displays is that of association. If the job requires an operator to use a large number of controls and/or displays, their location and arrangement should aid the operator in determining the following: (1) which controls are used with which display; (2) which equipment component each control affects; and (3) which equipment component each display describes.

So far in this lesson, you've learned methods for preventing the accidental activation of controls. Also, you were given three factors to consider when designing the location of controls and displays: priority, grouping, and control-display association. In addition, some general guidelines have been presented so you can use them when determining how to locate controls to their best advantage. To see how all these various guidelines fit together, consider the instrument panel and control devices on your automobile. You could say that the gas pedal, brake, and transmission shift are all priority items, as opposed to the radio, ashtray, and glove box. As such, they are placed within easy reach. Also, notice that the visual representations (displays) are either attached to their particular controls or placed close to them. In some cars, a windshield washer knob has a picture of a windshield being washed. The use of the location principles mentioned in this chapter has helped to make you more efficient in operating your automobile.

Now, we'd like to present to you some other considerations to keep in mind when designing and locating controls. So far, we've been concerned with the best physical arrangement of the controls; now we need to locate them so that the human can most effectively use them. As a general rule, the location of the controls should not require the human to expend his energy merely to maintain body position. Control movements are more easily performed if the limb is slightly flexed. This makes good sense, doesn't it? After all, wouldn't it be easier to do most control movements with a bent elbow rather than a straight arm?

(Turn to Page 39)

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From Page 75

(3) Usually your gross muscular coordination does remain. At least it remains long after your fine motor control has been adversely affected. You were half right, because there is a decrease in visual activity. Return to Page 75.

- -

From Page 33

(2) In most cases we've seen, pushing up will cause the right turn signal to flash; therefore, this is an example of a design flaw. But then, so are other answers given here. Return to Page 33.

- -

From Page 39

(3) You're right. Congratulations. In a true prone position, the operator's strength is reduced by about 30 percent. If, however, a slightly slanted position is used, then the operator may be able to exhibit a greater strength than when seated.

We will not go into a great deal more detail on specific factors to take into account when locating controls; MIL-STD-1472 and MIL-HDBK-759 provide further necessary information. Instead, we hope you have realized that you should test things out if information is not available to you from military standards or other sources mentioned in the previous lesson. For example, if you had designed a new control situation that had required a prone position (and you didn't know about the strength differences) you should have realized that a group of operators needed to be tested on the equipment in a prone, not sitting, position.

Without covering all the details, a few general considerations will be presented:

(1) If speed and accuracy are of importance, always require the use of the preferred or dominant limb of the operator.

(2) If possible, all foot controls should be operated from a seated position. Do you think there is a need to consider whether the person has a dominant right or left foot?

(1) No. Go to Page 82.
(2) Yes. Go to Page 25.
(3) I don't know. Go to Page 68.

From Page 22

(1) You're confused. Read over the functions and general types of control once again. Return to Page 22.

From Page 90

(1) Outstanding. It seems you're well on your way to understanding what Human Factors Engineering is all about.

It is important for you to gather data to answer all the following questions. What will be the function of the control? What will be controlled? What types of changes will be accomplished by using the control? What are the requirements of the control task? What is the range of the control? What precision is required, how much speed is needed? Tcw will the operator know which control to use? What feedback will he need--how will he know which control is set properly? Where will the control be located--in a large space or a confined space? What other controls will there be? What happens if this control is accidentally activated? To answer intelligently the question "What control is best?," you must first answer all these questions.

Once this background information has been gathered, the selection of the proper control can be made. The following general rules, coupled with specific data found in MIL-STD-1472 and MIL-HDBK-759, will assist in this selection.

1. Controls should be distributed so that no one limb of the operator is overburdened.
2. Select, locate, and orient controls so that their motion is element, equipment, or vehicle. (e.g. If you want the vehicle to move forward, design the control so that it, too, must be moved forward.) This concept is called stimulus-response (S-R) compatability.
3. Select multirotation controls (e.g., cranks) when precise settings are required over a wide range of adjustment. (Linear controls have a much more limited range.)
4. Select discrete setting controls (also referred to as detent controls), rather than continuous adjustment controls, when the settings are discrete positions or values only.
5. Continuous adjustment controls should be used when precise settings are required. However, remember that continuous adjustment controls do require more time and attention to achieve a proper setting.
6. When force and range of setting are a primary consideration, select the type of control recommended in MIL-HDBK-759, table titled "Recommended Manual Controls."
7. Select controls that can be easily identified.
8. Combine functionally related controls to reduce reaching movements, to aid in sequential or simultaneous operations, or to economize in panel space.

(Go on to the next page)

From Page 37

With these general rules in mind, answer the following questions.

You have a new copy machine which can reproduce an orginal at rates varying from 1 per second to 10 per second. What type of control would be best to use to set the speed?

(1) Multirotation. Go to Page 61.
(2) Continuous adjustment. Go to Page 16.
(3) Detent. Go to Page 84.

From Page 62

(3) These two resistances are not complementary. While viscous damping is independent of displacement, elastic resistance is not. Return to Page 62.

From Page 34

Needless to say, hand controls should not be operated from awkward positions, such as crouching or stooping, unless it is absolutely necessary to do so. Some equipment or situations may require that the human operator be in a prone position, for example, space vehicles. While this position allows hand controls to be operated with some effeciency, you must realize that the efficiency is not as high as when the operator is seated. In fact, the strength obtainable in a prone position is:

(1) About 30 percent of that obtainable when seated. Go to Page 47.
(2) About 10 percent of that obtainable when seated. Go to Page 68.
(3) About 70 percent of that obtainable when seated. Go to Page 36.
(4) About 50 percent of that obtainable when seated. Go to Page 72.

From Page 96

(3) You're wrong on this one. We've never heard of such an adjustment, but at least you're on the right track. Return to Page 96.

From Page 9

(2) FED-STD-595 identifies colors for use in coding, but it's not the reason for coding. Return to Page 9.

From Page 70

(4) What's being discussed involves somesthetic discrimination, but it's not the underlying factor discussed. Return to Page 70.

From Page 76

(1) Oh, this really isn't a realistic answer, is it? Return to Page 76.

From Page 71

(4) That's right. If there is adequate space, duplicate sets should be provided. Otherwise, the controls should be placed equidistant from each operator.

Here are some more rules on placing controls:

(2) If the controls are emergency ones, you should place them in easily accessible positions, but separated from the controls which are used during normal operations.

(3) Secondary controls and displays can have their locations determined by functional groupings.

(4) If controls are used to adjust or calibrate, and they are used infrequently, it may be advisable to place them outside of the primary work space areas. By so doing, you avoid cluttering the work place with low priority devices.

The next factor to be considered is that of grouping the controls. Controls can be grouped by two methods: functional grouping and sequential grouping. The functional grouping method requires that all controls and displays that are used for specific tasks or functions be placed together. With the sequential grouping method, all controls that are operated or all displays that are observed in sequence are grouped together.

We will give you some general guidelines to use in grouping displays and controls.

(1) Group displays so they facilitate check reading. If you look at Figure 12.1 on Page 29 of your supplement, you will see an example of such a grouping. Notice that a quick glance at the entire group of displays allows you to determine that one of the dials is out of the pattern.

(2) If you require the operator to use the controls sequentially, then place them from left to right if on a horizontal plane. If a horizontal sequence is not feasible, use a vertical arrangement and group them so they are activated from top to bottom. In other words, take advantage of natural stereotypic patterns of behavior.

(Turn to Page 45)

HUMAN FACTORS ENGINEERING

LESSON 12: POSITIONING OF CONTROLS, OR THE RIGHT PLACE AT THE RIGHT TIME

Hi, welcome back to your course on Human Factors Engineering. The last time we got together you heard about the confusing situation into which Lt. I. M. Eager and his copilot had fallen. If you remember, Eager had dreamed of designing the perfect helicopter, but in his dream various features of the craft had been improperly designed. Eager became enraged and, having no one else on whom to vent his anger, started advancing menacingly on his copilot. The copilot, justifiably fearing bodily harm, grabbed the ejection control. However, as you probably recall, the copilot pushed in when he should have pulled out. In so doing, because of poor control design, he activated not the ejection mechanism, but the self-destruct mechanism. Of all the helicopter's design features, this was one which worked perfectly...needless to say!

It was only at this point that Eager realized that he should have paid more attention to the design of the controls. Now it was too late. Much to the chagrin of the one proud senior analyst, now slinking away, a series of rapid detonations within the bounds of the engine were sounding off. Chopper MOD 5 was disassembling ... piece, by piece, by piece.

Now, we are sure that you see the importance of correctly positioning controls, especially after the misadventure of I. M. Eager and his perfect helicopter. This lesson will help you to design the position of control interacting with these devices. If you recall from your last lesson (sure you do), you learned about the functions of various controls; when to use a toggle switch instead of a rotary control, for instance. You also reviewed how to code the controls so as to maximize identifiability. In addition, your last lesson presented some general design recommendations.

In this lesson you will be concerned with four major areas dealing with the positioning of controls. First, accidental activation will be discussed. After all, you wouldn't want to activate inadvertantly the self-destruct button, would you? Next, you'll be presented some factors to consider when deciding when and how to locate the controls.

(Go on the the next page)

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From Page 42

Okay, let's begin this lesson with a question. Which of the following is a method of preventing accidental activation of control devices?

(1) All of these are ways of preventing controls from being accidentally activated. Go to Page 86.
(2) Placing a protective covering over the display panels. Go to Page 66.
(3) Locating controls so that they are at least one-half inch apart. Go to Page 32.
(4) Recessing the controls into the control panel. Go to Page 19.

From Page 87

(3) Very good, you've understood one of the key points of this lesson very well.

So, you've learned quite a bit in this lesson. Lt. I. M. Eager also learned quite a bit from his library visit and was ready to try to develop a useable helicopter once again. You'll see him next in Lesson 15, vibration and acceleration or "Take It Easy, I Have a Weak Stomach." Lesson 15 begins on Page 79.

From Page 22

(2) You're only half right. The function of this control is continuous adjustment, but it's not a rotary type. Return to Page 22.

From Page 81

(2) This answer applies to recommended comfort levels, not to safety limits. You should reread Section 5.8.4 in your copy of MIL-STD-1472. Return to Page 81.

From Page 93

(1) Sorry, but your answer is incorrect. Return to Page 93.

From Page 41

Okay, You've learned some basic information on how to group displays and controls. What should you do, or how should you group 20 controls that are activated sequentially (the type of control device is unimportant for this question)?

(1) Place the controls so that the operator goes down the left column to activate controls 1-5, then goes down the next column to the right to activate controls 6-10, etc. Go to Page 67.

(2) Place the controls so that controls 1 to 5 are on the top row in left to right order, controls 6-10 are on the second row in left to right order, and so on. Go to Page 34.

(3) Place the controls in a starburst pattern. Go to Page 72.

(4) Place the controls so that the top row reads left to right, the next row right to left, and the next left to right, and so in in a 'snake-like' pattern. Go to Page 86.

From Page 87

(2) You've inferred a little too much. We never said this, and as a general statement, it's untrue. Return to Page 87.

From Page 11

(2) C , this was the definition of intrinsic feedback, not extrinsic. Retur.ı to Page 11.

From Page 90

(4) Knowing the requirements of the operator is important, but there are many others things you need to know as well. Return to Page 90.

From Page 91

(1) Six G's can be tolerated for a full minute in the headward direction. Return to Page 91.

From Page 7

(2) You're slightly off. Not all of these are good examples of continuous adjustment controls. Only a brake pedal has any sort of continuum. Return to Page 7.

From Page 39

(1) In a prone position, the operator's strength is reduced by about 30 percent; therefore, this means the operator has how much obtainable strength left? One of the answers listed tells you. Return to Page 39.

From Page 91

(4) Not all these answers are incorrect. Look at your figure and find the circular path with .5 tolerance time. Then follow the path until it intersects with the vertical line for headward G forces. Return to Page 91.

From Page 8

(3) This answer takes no account of the machine aspect. Return to Page 8.

From Page 85

(2) You missed the key point. More rapid movement lowers threshold. Return to Page 85.

From Page 9

(1) We haven't set aesthetics as a criterion for anything yet. Return to Page 9.

From Page 84

(4) Very good. Of utmost importance is the operator's ability to activate the control quickly. To do this he must be able to find it immediately and use it quickly.

Before closing this lesson and looking back in on Lt. Eager, a little more needs to be said about quick responding. The process by which controls are made identifiable for the operator is referred to as coding. In general, there are several methods of coding. Which of the following do you think are methods which are often used for coding controls?

(1) Location, color, size, shape, labelling. Go to Page 31.
(2) Color, size, weight, shape, labelling. Go to Page 95.
(3) Odor, taste, texture, size, labelling. Go to Page 62.

From Page 71

(2) If all the primary controls were on the right side of the work space, it would be inefficient to have people constantly having to go over them. Return to Page 71.

From Page 11

(1) Good show, this does refer to extrinsic feedback.

Now that we've differentiated between the two general types of feedback, let's talk in more detail about types of controls, and then, feedback, which is directly related to our earlier discussion of resistance in controls. How much control devices affect the output they control is basically a function of two types of device input that we mentioned in passing when discussing resistance. Thus, displacement of the control (or the overall distance of movement from the idle position), as well as the force applied to the control, influence feedback.

Many controls classified as displacement devices show virtually no resistance. They are usually referred to as free-positioning or isotonic controls, and provide feedback to the operator only in terms of movement of the controlling body part (as detected by the sense of movement). Other displacement controls do have some amount of resistance present. These require some degree of force to operate. On the other hand, force (pressure of isometric) controls are such that the result is associated with the force applied to the control by the operator. Here, the feedback to the control operator is in terms of the feel of the control resistance as different amounts of pressure are applied. An example of each type of displacement device is shown in Figure 13.2A (Isotonic Control) and Figure 13.2B (Isometric Control).

Now, try your expertise on this one. You are the operator of a vehicle and, as such, must manipulate an isotonic control device (say, a free-positioning joy stick). In the course of doing so, you receive what type of feedback?

(1) A picture of you standing in front of the old homestead. Go to Page 20.
(2) No feedback whatsoever. Go to Page 52.
(3) Arm movement feedback. Go to Page 56.
(4) All of these. Go to Page 57.

From Page 11

(3) Cone on, are you serious? Let's put it this way, if one definition refers to extrinsic (or external) feedback, and one definition refers to intrinsic (or internal) sources of feedback, they both can't refer to extrinsic feedback. We think you'd better reread this section before continuing. Return to Page 11.

From Page 33

(1) No watch we've ever seen is wound counterclockwise; therefore, this is an example of a design flaw. But then, so are the other answers given here. Return to Page 33.

From Page 67

(1) The control would not likely be activated accidentally at this position. This question was about G forces, not accidental activation. Return to Page 67.

From Page 30

(1) An accelerator pedal is an ankle-actuated pedal. Return to Page 30.

From Page 50

(2) Some feedback is provided by isotonic controls. Return to Page 50.

From Page 81

(3) The acceleration value of 0.2 RMS is the lowest shown on the accompanying graph, but you should have read the appropriate subsection titled "Vibration" under section titled "Environment" to correctly answer this question.

From Page 4

(1) Control-display ratios have not been discussed, but because of their importance to control dynamics, we will deal with them in this lesson. Return to Page 4.

From Page 78

(2) Resistance can be used in some instances as a feedback mechanism to the operator. Return to page 78.

From Page 64

(2) Sorry. This answer is one way of establishing priority, but there are other factors to consider. Go back to Page 64.

From Page 62

(1) All of these resistance forces do not come into play here. Viscous damping resistance is independent of displacement and, as such, plays no part in the use of a spring-centered joy stick. Return to Page 62.

From Page 88

(3) These aren't the only environmental effects which need to be taken into account. Return to Page 88.

From Page 90

(6) Knowing the consequences of accidental activation is important, but there are many other things you need to know. Return to Page 90.

From Page 4

(4) Strength requirements have not been dealt with, but we will do so in this lesson as they are of importance to a discussion of controls. Return to Page 4.

From Page 25

(1) While this is a consideration, it may best be considered when designing the type of knob rather than the positioning of controls. Return to Page 25.

From Page 22

(5) Think about it a little more and reread the assumption. The lever slides (indicating a continuum) horizontally (indicating linearity). Return to Page 22.

From Page 50

(3) Way to go, we can tell you've been paying attention. Most isotonic control devices provide feedback only in terms of movement of the body part doing the controlling (as is the case with the isotonic joy stick alluded to).

Before leaving this section, we think you need to be exposed to several addtional pieces of information, one of which is the response lag present in control systems. In the operation of all systems, there is some delay between input from the operator and the eventual response. How time lag affects performance has been the subject of a number of studies in recent years. However, conflicting findings have resulted from these studies. Some evidence indicates that time lag brings about performance deterioration. In other circumstances, however, time lag has been found to have a positive effect on performance. In general, the most that can be said on this topic is that performance effects are related to the control-display ratio utilized, and one must carefully examine each situation to determine the effect of time lag on system efficiency.

Enough said on this topic. We just want you to be aware of this aspect of control systems. So far you have been exposed to S-R compatibility, control/display ratios, resistance, feedback, and response lag.

You have now reached a point where most of this lesson is behind you. However, there is still one area related to controls which you need to consider before you end this lesson. A short, general discussion of the nature of continuous control systems must be included here.

A complex system for any man-machine interaction can be thought of as a hierarchy of control relationships. Such a system is depicted in Figure 13.3 on Page 33 of the supplement. In such a hierarchical system, each level consists of a loop that is related to all other loops in the system. The output at any given point in the system serves as the input to the next higher or (outer) loop. Thus, as was shown in Figure 13.2, a continual process of input, decision making, output, and feedback occur as man interacts with the control system.

Think for a minute about why we presented this last short section to you. Do you think the main reason was to:

(1) Sum up this discussion on controls by once again re-emphasizing the importance of man-machine interface in Human Factors Engineering in general, and control system specifically. Go to Page 8.
(2) Act as space and time filler at the end of the lesson. Go to Page 14.
(3) Demonstrate the importance of hierarchical arrangement of system development. Go to Page 16.

From Page 85

(3) This may be true, but it doesn't follow from what was just said; and if you use this rationale for designing controls, you might have a lot of bloody fingers. Return to Page 85.

From Page 50

(4) You're just kidding, right? You really picked this one after reading answer #1? We think you'd better reread this section if you're serious. Return to Page 50.

From Page 84

(2) Although this was a good guess, we wouldn't expect the relationship to decrease just yet. This frequency range (3-6 Hz) seems to produce the peak vibratory intensity for the head relative to the seat. At higher frequencies, the relationship decreases until at 79 Hz only about 10 percent of the seat vibration intensity reaches the head. Return to Page 84.

From Page 10

(2) Very good. Exactly right.

Location of controls was dealt with in some detail in Lesson 12. As you recall, you reviewed three factors: priority, grouping, and association. Controls of highest importance should be located at optimum areas--e.g. within easy reach (priority); controls involving similar functions should be placed together--e.g. radar groups (grouping); controls should be located near their display (association).

In this lesson a detailed description of labelling will be presented. Following that, the cutaneous senses (pressure, pain, temperature change), size coding, and shape coding will be discussed in some detail.

Labelling is a simple and effective way of coding controls and usually requires no special training for the operator. The following general rules pertain:

(1) Labels should be located above the controls.
(2) Labels should be brief with only common abbreviations used.
(3) Labels should indicate what is being controlled--speed, brakes, etc.
(4) Unusual technical terms should be avoided.
(5) Abstract symbols should not be used unless they are commonly known (diamonds, circles, etc., should be avoided; a red cross or poison symbol is okay).
(6) Numbers and letters should be standard and easily read under all conditions of possible use.
(7) Labels should be located so they can be observed while the operator is adjusting controls.

Now that you've reviewed some general rules on label coding, answer the following question: Which of the following would suggest the need to use a coding technique other than labelling on a control?

(1) Illiterate operators. Go to Page 23.
(2) Limited space for displays and controls. Go to Page 13.
(3) Poorly lit spaces. Go to Page 100.
(4) All of these. Go to Page 85.

From Page 88

(4) Very good. You are 100 percent correct (and, if we might add, getting to be quite good at these human engineering questions).

We won't go into any of these considerations in the body of the lesson, because this lesson would become too long. However, your supplement contains a summary of these environmental considerations as well as a few more factors and how they may affect control manipulation and, therefore, control design. This summary (Figure 12.2) is found on Page 30 of your supplement. Please refer to it when this lesson ends. In future lessons, we will assume that you are familiar with this chart. Using this summary, which of the following environmental conditions would affect the operator's manual dexterity in his use of controls?

(1) Weightlessness, vibration, and heat. Go to Page 5.
(2) Illumination, general safety, and weightlessness. Go to Page 26.
(3) Heat, vibration, and general safety. Go to Page 69.

From Page 84

(1) Correct, at this rate of seat vibration the intensity of head movement is 150-300 percent of that of the seat. This frequency range (3-6 Hz) seems to produce the peak vibratory intensity for the head relative to the seat. At higher frequencies the relationship decreases until at 70 Hz only about 10 percent of the seat vibration intensity reaches the head.

Okay, you now know what vibration is (sound waves) and which frequencies are considered to be most damaging (1-20 Hz). You also know that body posture and seating design can be used to help control some of the effects of vibration. Let's examine those effects.

Most people have some personal reaction to vibration. You may or may not love those amusement park rides which whirl you around like a spinning top and bounce you slightly up and down. Just thinking about these experiences is enough to get to you. As you can see then, reactions can range from pleasure--to mild annoyance--right on through the extreme discomfort. One of the difficulties in dealing with the effects of vibrations on performance is this very wide range of subjective reaction to such a stress. Some people are prepared to accept it, some may not even notice it, while others take an instant dislike to it.

If you will turn to Page 149 in your copy of MIL-STD-1472, you will find a figure which depicts the amount of time you can expose an individual to a vibrating condition without interfering with the proficiency level required for operational and maintenance tasks. On this graph the acceleration or intensity values are on the Y axis, or left hand side of the graph, and the frequency of vibration is on the X axis, or bottom of the graph. Within the body of the graph, levels of proficiency have been plotted as a function of intensity, frequency, and time. To ensure the comfort of the individual, you should divide the acceleration values by 3.15 (as recommended in MIL-STD-1472, Paragraph 5.8.4.1.3). For example, without regard for comfort, according to the 'upper' graph, if the frequency is between 4 and 10 Hz and the acceleration is .3 RMS, how long would an individual be able to maintain his proficiency level?

(1) 2.5 hours. Go to Page 94.
(2) 4 hours. Go to Page 74.
(3) 8 hours. Go to Page 66.

From Page 4

(2) We have not devoted time in previous lessons to a discussion of size and distance trade-offs, but we will do so in this lesson, as it is an important aspect of control dynamics. Return to Page 4.

From Page 83

(3) What good would it do to equalize positive and negative feedback? You'd better stop and think this through. Return to Page 83.

From Page 38

(1) You could use this, but there's a much better option available to you. Return to Page 38.

From Page 84

(3) It is only at frequencies that are higher than 70 Hz that the head and seat amplitude are the same. Return to Page 84.

From Page 78

(3) Very good, you're right. Resistance can be used in some instances to aid feedback, but in other instances resistance must be eliminated or reduced as much as possible, or serious problems may result.

In general, resistance can be either a friend or foe for the human factors engineer in designing controls. Depending on the situation, increasing or decreasing the resistance can be used to improve the man-machine performance. The important things to recognize are the existence of the various types of resistance and the fact that they can affect the performance of the system.

Okay, take a stab at this question. In the case of a spring-centered joy stick (a control with elastic resistance) which type (or types) of resistance would you guess to be present?

(1) All of the resistances come into play here. Go to Page 54.
(2) Viscous damping, elastic, and inertial. Go to Page 26.
(3) Elastic and viscous damping. Go to Page 38.
(4) Elastic, inertial, static, and sliding friction. Go to Page 11.

From Page 49

(3) C'mon, have you read anything about smell or taste? Return to Page 49.

- -

From Page 20

(2) Very good. A combination lock won't open unless the right sequence of numbers and directions has been performed prior to reaching the last digit.

So you see that a combination lock is a good example of operationally sequencing the steps involved in control activation. Controls which have a high potential for danger are usually protected by this method (if not others as well). For example, a bomb-release control cannot be operated unless the arming control has already been activated.

It is always necessary to reduce the possibility of accidental activation of controls. However, when choosing a method to prevent such activation you should always keep in mind that trade-offs need to be considered. If you protect the control so well that it is too difficult to reach, or it increases precious time to activate, you may have undermined your mission. While you, as a human factors engineer, always want to consider the performance requirements and the human's capabilities, it is also necessary to look at and examine these trade-offs.

So far, in this lesson you have learned seven methods which can be used to help prevent the unintentional activation of a control device: recessing, location, orientation, locking, covering, resistance, and operation sequencing. In your last lesson you studied various ways controls could be coded. Coding methods, such as location, labelling, color, size, and shape were discussed. We also mentioned that several methods should be combined to achieve maximum differentiation and identification. The coding schemes presented in the last lesson will help prevent inadvertent activation by making the control easy to identify. This improves not only operator performance, but reduces the occurrence of accidentally selecting a control when it shouldn't be selected.

(Go on to the next page)

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From Page 1

(1) The standard location for the high beam control in a car is on the floor by the left foot. We're looking for a deviation from the standard. Return to Page 1.

- -

From Page 63

Okay, We're moving right along. In this section of the lesson you will learn about how to locate controls within their allotted spaces so that they provide the most functional work space possible. These factors apply to displays, as well. There are three major factors to consider when deciding on the location of controls. These factors are priority, grouping, and association. The priority factor has to do with the importance of the controls. The most important ones should be assigned to optimum areas. For example, in I. M. Eager's helicopter, the joy stick and the altimeter display were within easy reach and viewing distance. Of course as you recall, they weren't in the optimum areas initially. At first, Eager found the altimeter display mounted on the wall panel behind his seat. Needless to say, someone really goofed, since Eager was going to be required to turn in his seat in order to see how high he was.

The grouping factor requires that the controls and displays be placed in logical locations. That would mean having all sonar displays in the same physical location as their controls and having all this type of equipment in one general location. After all, there is a bridge, a radio room, and an engine room on board a ship, not functional units of the bridge, radio room, or engine room spread throughout the ship.

The third factor to consider in locating controls and displays is association. This means that the control and its display should bear a consistent relation to each other. For example, if you turn a knob to the right, or clockwise, you have every right to expect the display pointer to move to the right as well.

Now, let's talk about each of these factors in somewhat more detail. We will begin with priority. Before we can talk about rules to use for locating priority controls, let's establish whether or not a device is a priority one. We can measure the priority of a display or control in a number of ways. Which of the following could be used to establish the importance of a control or display?

(1) Both can be used to establish priority. Go to Page 71.
(2) Measure the frequency and extent of the use of the control. Go to Page 53.
(3) Determine how much of a decrease in system performance would occur if there was an error or delay in using the device. Go to Page 2.

From Page 10

(3) Almost right, but recessing is not a coding method; it is a method used to prevent accidental activation. Return to Page 10.

From Page 71

(3) Sorry, but this is the wrong answer. Return to Page 71.

From Page 60

(3) Correct. As you can see, the exposure curve for 8 hours does suggest that these frequencies at the intensity level would allow proficiency maintenance for this length of time.

To ensure the comfort of the individual for 8 hours by using the recommendations in the MIL-STD, you would divide the .3 intensity level by 3.15, which would give you the recommended intensity of about .09 RMS; barely anything at all.

To get a little more practice in using this type of graph, let's try another problem. Up to how many hours should you expect an individual to be able to maintain his proficiency level if the vibrating frequency is 16 Hz and the intensity is 2.0 RMS?

(1) 1 minute. Go to Page 96.
(2) 1 hour. Go to Page 75.
(3) 8 hours. Go to Page 94.

From Page 43

(2) Oops! We fooled you. Placing a protective cover over the controls will help prevent accidental activation, but placing a protective cover over the display will prevent you from obtaining the proper information. Return to Page 43.

From Page 91

(3) Very good. Eight G's can be tolerated for 30 seconds if the acceleration is headward; however, if the direction was footward, 8 G's can only be tolerated for .02 minutes or 1.2 seconds.

Let's look at some of the effects acceleration has on performance. Even if the accelerating load is within limits that are considered to be safe, it may cause degradation of performance. This degradation could be extremely important, especially if you are considering activities that must be performed by such people as a space crew.

Figure 15.2 on Page 39 of your supplement show the G forces at various body parts which just barely allow those body parts to perform the indicated motion. Look at the figure for a moment and then answer the next question.

Given the information on this picture, would you consider it wise to place the ejection-control device on an airplane above the pilot's head?

(1) No, the pilot might accidentally activate it. Go to Page 51.
(2) No, the pilot may not be able to activate it if the G force were up to 6 G's. Go to Page 78.
(3) Yes, it is the logical place to locate it. Go to Page 82.
(4) There is not enough information to answer the question. Go to Page 86.

From Page 45

(1) This isn't the most efficient way to group the controls; it is the second best way of the methods presented. If the user population typically read in columns, then this presentation pattern would be the best way. Whenever possible, take advantage of any population stereotypes that exist. Return to Page 45.

From Page 39

(2) Sorry, but this is a wrong guess. Return to Page 39.

From Page 36

(3) We know you don't know, but we want you to give it a shot. Return to Page 36.

From Page 78

(1) This is one type of protective device, but it isn't the best one presented. It is however, the most practical of the answers given. Return to Page 78.

From Page 98

(1) That's right, the use of both shape and size coding are dependent upon the cutaneous senses for their validity. Therefore, we waited until you were aware of these senses before describing these coding methods.

Let's look at shape coding. Figure 14.1, Page 34 in your supplement, presents some examples of shapes. Just looking at these, what comment could you make concerning shape coding?

(1) Both the sense of touch and the sense of vision benefit from shape coding. Go to Page 99.
(2) Rotary controls are well suited to shape coding. Go to Page 14.
(3) It is relatively easy to discriminate controls properly coded by shape. Go to Page 17.
(4) All of these. Go to Page 89.

From Page 85

(1) You're inferring too much from the data presented. There is a positive relationship, but it's surely not totally linear. Return to Page 85.

From Page 59

(3) Only two of these choices are correct. General safety doesn't affect the operator's dexterity. Return to Page 59.

From Page 89

(4) Very good. You've got the idea. By the definition of Class 'A' controls, you knew that the control could not be essential to operation. You also indicated your understanding of adjustment requirements and standardization.

The second type of knob design Hunt describes is the fractional rotation or Class 'B' design. The main defference between these and multiple rotation knobs is that these knobs have an adjustment range which is usually less than one full turn. The brightness control on a radar set would be a good example of a Class 'B' control, since this control, while important, is not really crucial for operations, and a range of full brightness to complete darkness can be achieved with less than one rotation.

Finally, Hunt describes the discrete setting or Class 'C' controls. For an example of this, look again at a radar console. Quite often more than one type of radar can be fed into the console; for example, long range air search and close-in air search. A Class 'C' design would be used to control the switching from one to another.

A major reason for designing specific shapes to fit each class of knob is ease of discrimination. An operator comes to 'recognize the feel' of a knob designed to control brightness, as opposed to one used to change radars. Hunt's research verified the assumption that these shapes were 'discriminable' by touch. The term describing the underlying factor in coding radar equipment, or the other systems discussed above is:

(1) Color of controls. Go to Page 24.
(2) Standardization of controls. Go to Page 18.
(3) Labelling of controls. Go to Page 99.
(4) Somesthetic discrimination. Go to Page 40.

From Page 64

(1) Absolutely. Both of these are important.

Each choice provides a different way of establishing the priority of a control or display. Besides determining the frequency of use and determining the detrimental effect on system performance if an error occurs, you could also determine the speed and/or accuracy with which the display must be read or the control positioned.

Now, you're determined that a control has top priority. Aside from announcing in a loud clear voice, 'This control has priority,' what do you do about it? Well, we're glad you asked that, because, as usual, we have a few rules to give you.

(1) Highest priority controls should be placed within optimum areas. Remember the joy stick placement in Eager's chopper? If you were piloting any sort of aircraft, we're sure one of the highest priority items you'd want to consider would be the instrument which controls the height of the vessel, right? Right. If two or more operators need to have access to priority controls, which of the following do you think would be the best way to design the work place?

(1) Place all priority controls between both operators. Go to Page 26.
(2) Place all priority controls on the right of all operators, because most people are right handed. Go to Page 49.
(3) None of these is the best design. Go to Page 65.
(4) Have a set of priority controls for each operator. Go to Page 41.

From Page 45

(3) Starbursts are great for clock designs and ladies' brooches, but not for controls. Return to Page 45.

From Page 39

(4) In the prone position the operator's strength is reduced, but not this much. Return to Page 39.

From Page 89

(2) The problem of dark adaptation is real, but you're forgetting other important ideas. Return to Page 89.

From Page 76

(3) Nicely done.

As human factors engineers, we first want to design equipment and facilities that ensure tolerable vibration levels. We are concerned about the effects of vibration because we are anxious to control those effects so that the human can operate effectively. Which of the following do you think can be used by the human factors engineer to amplify or attenuate (decrease) the effects of vibration?

(1) Body posture. Go to Page 15.
(2) Type of seating. Go to Page 17.
(3) Both of these can be used. Go to Page 81.

From Page 20

(1) A car's ignition system only requires the turning of a key. Some systems had been designed so that the car could only be operated after the seat belt was engaged. However, the general public didn't care for this, and the design feature was soon dropped. You get half a pat on the back if you chose this answer with that system in mind, but this isn't the best answer. Return to Page 20.

From Page 60

(2) Find 4-10 Hz on the bottom of the graph and move your finger up until it reaches the 4 hour curve. Now, move straight over to the left axis and you will find an intensity level of about .5 or .6, not .3. Return to Page 60.

From Page 75

(2) A very severe vibration may cause spinal cord damage, but, thankfully, that doesn't happen often. However, hearing may be decreased, so you are half right. Return to Page 75.

From Page 84

(1) You've got things backwards. Usually, automated systems have manual backups. Return to Page 84.

From Page 66

(2) Very well done. You're going to do very well in your job if you keep this up.

If you're still having a problem interpreting the graph, go to your supervisor. Sometimes it takes the interaction of explanation and watching someone else do it in order to understand.

Now, let's discuss some of the more common behavioral effects of vibration. Which of the following do you think are the most common behavioral deficits which occur during vibration?

(1) Increased hearing ability and visual acuity. Go to Page 32.
(2) Spinal cord damage and decreased hearing. Go to Page 74.
(3) Loss of gross muscle coordination and decreased visual acuity. Go to Page 35.
(4) Decreased visual acuity and loss of fine motor coordination. Go to Page 76.

From Page 12

(1) Look a little more closely. There is an example of a toggle switch presented here. Return to Page 12.

From Page 75

(4) Correct, a decrease in visual acuity and loss of fine motor coordination are the most frequent effects of vibration. Have you ever tried reading or writing while traveling on a bus? If you have, or if you can imagine trying to do so, you know what this answer was all along.

As you now know, the most common behavioral deficits of vibration are loss of visual acuity and fine motor coordination. Disturbances of visual acuity are greatest in frequency ranges of 10-25 Hz, whereas fine motor coordination is affected most by frequencies below 5 Hz; both effects are proportional to the amplitude of the vibration. Not every type of human performance is adversely affected by vibration. Things such as reaction time, pattern recognition, and various types of monitoring tasks do not seem to be degraded during vibration. Anyway, you get the idea; vibration can adversely affect performance, and people seem to have a wide range of individual tolerance levels to vibration. Now, as a human factors professional, which of the following do you see as your primary mission?

(1) To require only reaction time (and similar) tasks to be performed in a situation in which vibration will be present. Go to Page 40.
(2) To select as personnel only those individuals who have a high tolerance level for vibratory effects. Go to Page 13.
(3) To design facilities and equipment to control the transmission of body vibration levels within the specified tolerance levels. Go to Page 73.

From Page 30

(3) An organ pedal is an ankle-actuated pedal. Return to Page 30.

From Page 83

(1) Bravo, by emphasizing the positive feedback aspects of resistance, while avoiding or reducing negative feedback resistance, performance is enhanced.

You see, by taking advantage of the positive feedback aspects of resistance, you can aid the operator in terms of performance by giving him or her clues as to the correctness of the response.

Take the stick shift in an automobile, for instance. A familiarity with the tensions associated with the right and wrong positions as you move through the three, four, or five speeds permits you instant, easily identifiable feedback as to whether you have correctly positioned the gear shift.

There are various types of resistance that come into play in control devices, and, although we will not detail them here, we feel it is important that you be exposed briefly to the types of resistance encountered. 'Static friction' refers to initial resistance to movement and is maximum at onset, but drops off sharply. 'Sliding friction' continued as a resistance to movement. In general, these two types of resistance tend to affect performance adversely, and thus should be minimized in controls where possible.

'Elastic resistance' refers to increases in resistance that result from displacement from the null or disengaged (as in spring-loaded controls such as emergency brakes) position. Thus, the greater the displacement (or stretching), the greater the resistance. This feedback can thus provide valuable information in terms of control positioning. 'Viscous-damping' resistance, on the other hand, is independent of displacement, but varies as a direct result of control velocity (thus, it is not affected by speed of movement). It generally has the effect of aiding the execution of a smooth, constant rate of movement. Thus, for example, changes in the ailerons on the wings of an airplane force a change in the air flow around the wing. Finally, 'inertial resistance' involves general resistance to movement caused by the weight of the device. As such, it can have both positive and negative consequences. On the negative side, it hinders any changes in direction of speed of movement, as well as increasing the difficulty of making small or precise adjustments quickly and efficiently. However, inertia does aid in making smooth movement or gradual change in velocity. An example of how the negative effects of inertial resistance can be overcome, and then used to your advantage is the plane catapult on a carrier, where after initial G forces are overcome, additional velocity is gained to help lift the plane skywards.

(Go on to the next page)

From Page 77

Okay, considering what has just been said about resistance, which of the following statements is most accurate?

(1) It is quite beneficial to take advantage of existing resistance whenever possible. Go to Page 8.
(2) Whenever possible, resistance should be eliminated. Go to Page 53.
(3) Resistance can be either a friend or foe for the human factors specialist. Go to Page 62.

From Page 67

(2) Right, if the G force were greater than 6 G's, the pilot would not be able to move his arm to reach the ejection control.

Acceleration in mild doses may not require any type of protection. We can feel the acceleration in commercial airplanes and when we start our car from the stoplight, but, typically, we don't need to be protected from this mild form of acceleration. However, with higher levels of acceleration, as in spacecraft, there is a need for some sort of protective euqipment. Which of the following do you think is probably the best protection from the effect of acceleration?

(1) Nylon netting. Go to Page 68.
(2) Head helmet. Go to Page 23.
(3) Immersion in water. Go to Page 92.

LESSON 15: VIBRATION AND ACCELERATION, OR TAKE IT EASY, I HAVE A WEAK STOMACH

Welcome back to your Human Factors Engineering Course. This lesson, Lesson 15, is concerned with vibration and acceleration and their effects upon the individual. At our last get-together you were presented with Lt. I. M. Eager's perfect dream helicopter. So far in this dream (nightmare?), Eager had designed, or approved the design, of several versions of his perfect helicopter. MOD 1 didn't fit his body proportions, MOD 2 didn't take any work space dimensions into considerations, and MOD 3 had such poorly lighted instrument panels that they were impossible to read. Eventually, Eager got MOD 4 off the ground only to crash because of poorly designed visual displays. When MOD 5 arrived, the communications equipment didn't function properly and Eager started to focus his frustration on his copilot. (That was when the copilot pushed the wrong button and Eager's fantastic 'perfect chopper' slowly disassembled.) After Eager ordered MOD 6 from the Basic Air Rework Facility (B.A.R.F.), he discovered that the spring tension was too tight for the door handle. Eager tried valiantly to avoid embarrassment and preserve his dignity and military bearing in front of his superiors.

In this lesson, Eager conveniently remembered his magic chopper repair kit. With a flourish, he produced super glue and proceeded to repair all actual and potential malfunctions. Finally, he entered the ship, revved the engine, and gingerly lifted off. Isn't it nice that things seemed to turn out just right for Eager? But wait...Eager did not know one very important thing...His pilot was not an expert flyer. Immediately, the pilot began pushing and pulling levers and switches, which caused MOD 6 perfect chopper to accelerate faster than a speeding bullet and autorotate in a series of spins which would do credit to any amusement park ride.

Now, let's take a look at what you will learn in this lesson to improve your human factors engineering knowledge. In the first section we will deal with the topic of vibration. You will learn some definitions as to what vibration really is, how it is measured, and what parts of the body are affected by vibrations. Next, we'll talk about the results of whole body vibrations and its effects on both performance and subjective feelings. We will also discuss some of the limits of vibration that are allowable for safety, comfort, and proficiency. To do this, we refer you to MIL-STD-1472 and its section on vibration. In the second section of this lesson you will learn similar things about acceleration: its effects on performance capabilities, protective measures, etc. So, without further ado, let's shake, rattle, and roll!.

(Go on to the next page)

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From Page 79

Frequently, during the course of his work, an individual will be subjected to vibration from various sources. By the technological ingenuity, man has created methods of mobility which our ancestors of even a few generations ago would find unbelievable. Many of these methods, such as aircraft, space capsules, and zero ground-pressure vehicles make it possible for man to move at speeds never before possible. However, as in most events, there are trade-offs. The variables which allow such increased mobility also produce vibration, acceleration, deceleration, and weightlessness.

Vibration is transmitted to man from the vibratory source (the machine) through man's body parts. The parts of the body which come in contact with the source of vibrations and transmit that vibration most often are the hands, feet, and buttocks. The effects of such vibration may range from motion sickness, due to a barely discernible vibration, up to physical damage from gross vibrations.

Before discussing the effects of vibration, you need to be familiar with the terminology. Remember when you learned that sound was a wave form and the range of sound frequencies between 20 and 20,000 Hz could be heard by man? Well, sounds below 16 Hz are perceived by man as vibration, not noise. Both noise and vibration, then, are the same physical force. Therefore, we can talk about the frequency of vibration (how many wave forms that occur in a second) and the intensity of vibration.

Intensity can be measured in five ways:

(1) Displacement measured in inches (in.) or centimeters (cm)
(2) Velocity measured in cm per second or cm/s
(3) Acceleration or cm/s^2
(4) Rate of change of acceleration, or jerk, or cm/s^3
(5) Power--spectral density measured in terms of root mean square or RMS. In figure titled "Vibration Exposure Criteria in MIL-STD-1472, the amount of vibrations is presented as a function of RMS. We don't think you need at this point to concern yourself with the different types of measurements, but be aware that they all indicate intensity.

You should also be aware that every object, including man, has a resonant frequency. Your limbs and organs are not rigidly attached to the body structure and they tend to vibrate at differing frequencies. Each structure has its own frequencies. The ultimate effects of vibration are the result of the interaction of the frequency of the vibrating source and the resonant frequency of the body members.

(Turn to Page 84)

From Page 73

(3) Correct, both body posture and seating type can be used by the human factors engineer in designing to decrease or increase the effects of vibration.

Body posture is important in determining the effects of vibration. If an individual is standing, the legs absorb a great deal of the vibration as they bend and straighten in response to the movement. Sitting, on the other hand, amplifies the vibratory effects. Seating designs, using springs, foam, or any absorbing material, and construction design will help reduce vibration.

In MIL-STD-1472, a subsection of section titled "Environment" which deals with vibration, some recommendations are made as to levels of vibrations acceptable for various factors. For example, when safety limits are established, what is the recommended procedure for establishing acceleration values?

(1) Whole body vibration should not exceed twice the acceleration values shown in the accompanying figure. Go to Page 91.
(2) Whole body vibration should not exceed the acceleration values when they are divided by 3.15. Go to Page 44.
(3) Whole body vibrations should not exceed 0.2 RMS. Go to Page 52.

From Page 88

(1) These aren't the only environmental effects which need to be taken into account. Return to Page 88.

From Page 36

(1) Sorry, but this answer is not correct. Return to Page 36.

From Page 67

(3) We don't think it is logical to locate the device in this position. If the G forces are too great, the control will not be functionally useful here. Return to Page 67.

From Page 90

(2) Knowing the function of the control is important, but there are many other things you need to know as well. Return to Page 90.

From Page 96

(2) Excellent, you're right again. A fine movement is attempted after the gross movement to home in on the desired reading or direction.

In moving to adjust an indicator to the correct spot, fine adjustment movements do follow gross adjustment movements. These two movements must be taken into account when attempting to determine an optimum C/D ratio. In addition, C/D ratios differ sharply, depending on the type of control and display being evaluated. Thus, the only real way to determine an optimum control/display ratio is to test continually these two aspects of movement from each situation of interest.

Thus, as you can see, things such as C/D ratio and S-R compatibility affect performance in terms of the human's control of any system or system aspect. While we have begun to deal with the interaction of displays and controls and how they influence human interaction with the system, it is also important to deal with other specific features of controls that impact on system performance.

For instance, a good bit of research in this area has focused on the amount of resistance inherent in controls. In general, it can be stated that all control devices have some resistance (for example, they are not totally free from friction or gravity. This force can be (and often is) used as a source of feedback to the operator. Resistance, however, can supply both positive and negative feedback.

Okay, if that is the case, what would you suppose the role of the human factors engineer is in dealing with resistance?

(1) To design or select those controls with resistance characteristics that either minimize negative effects, or possess positive feedback characteristics that enhance performance. Go to Page 77.
(2) To attempt to eliminate all resistance in controls. Go to Page 2.
(3) To attempt to equalize the positive and negative resistance feedback in controls. Go to Page 61.

From Page 38

(3) Very good. A discrete setting or detent control would be used here. It would be much more precise and easier to use.

The equipment you are working with contains noxious gases. If an unsafe amount escapes, a warning bell is sounded, and you, as operator, must manually shut down the system. Which of the following should be true of the shut-down control?

(1) It must have an automated backup. Go to Page 74.
(2) It should be a leg-actuated pedal. Go to Page 32.
(3) The control should be a toggle switch. Go to Page 28.
(4) The control should be easily identifiable and easy to use. Go to Page 49.

From Page 80

Most research on vibration has been concerned with vibrating frequencies between 1-20 Hz. These frequencies are the ones that are expected to occur in low altitude high speed flight, and it is these frequencies that seem to have detrimental consequences for human performance.

In order for you to get the feel of what happens to you at these frequencies, we will give you an example. Picture an individual who is seated. His platform is vibrating between 0 and 1 Hz. At this frequency of vibration his head is also vibrating at about the same amplitude or intensity as the seat. However, if the frequency of the seat vibration is increased to 3-6 Hz, what do you think the amplitude of the head vibration would be in relation to the seat intensity?

(1) 150-300 percent higher intensity than the seat. Go to Page 60.
(2) 150-300 percent less intensity than the seat. Go to Page 57.
(3) Seat intensity and head vibration intensity remain the same. Go to Page 61.

From Page 58

(4) Well done. You're right. Any one of these factors would indicated that come coding procedure other than labelling should be used.

So, by now you've demonstrated a knowledge of color coding, labelling, and coding by location. Before you study shape and size coding, a description of the sense of touch is appropriate.

The sense which we refer to as the 'sense of touch' is also termed the 'cutaneous,' 'somesthetic,' or 'skin' senses. The plural is used because there is general agreement that there is more than one sensation involved. There is much less agreement as to how many "sensations" should be listed. For your purposes, the cutaneous senses will be divided into three areas:

(1) pressure
(2) pain
(3) temperature changes

That area of the somesthetic senses which you probably assign as 'one of the five senses' is pressure sensitivity (also known as the tactile or touch sense). This sensation provides the most information for task performance. Pain and temperature, although useful, primarily act as sources of information for body protection.

Touch sensitivity is dependent on the movement of the skin. The rate at which the skin moves when an object 'touches' it is important in determining thresholds. Thresholds, you recall, are boundary values separating stimuli that elicit responses from those which do not. In vision, for example, you can determine the amount of light required before one can 'see' an object. This would be the visual detection threshold. With touch sensitivity, the more rapid the movement or depression of skin, the lower the threshold. Which of the following conclusions would you draw from this discussion?

(1) There is a linear relationship between speed of skin movement and threshold. Go to Page 69.
(2) If a stimulus is applied quickly, the person will be unaware of the pressure. Go to Page 48.
(3) The sharper an object is, the lower the threshold will be, and, therefore, a sharp dial will be easier to recognize. Go to Page 57.
(4) If a stimulus is applied slowly enough, the person will be unaware of the pressure. Go to Page 97.

From Page 43

(1) Sorry, but not all of these are correct. Return to Page 43.

From Page 45

(4) While this sounds plausible, reading from right to left is difficult and doesn't rely on S-R compatibility. This isn't the best design pattern. Return to Page 45.

From Page 67

(4) Aw, we did give you enough information for this question. Look at the figure again. According to this figure, if needed, it would be just barely possible for the pilot to activate his control at 6 G's. Do we really want to limit the pilot's abilities this way? Return of Page 67.

From Page 18

(3) Very good. Figure 14.5 in the supplement presents an example of concentric knobs.

Also illustrated in Figure 14.5 is the example of dimensions that provide easy discrimination and use of the various knobs. When sizing is used for individual coding devices, effective discrimination requires that the height or thickness of larger knobs exceed smaller ones by 20 percent.

In summary, you have been presented with some information regarding controls and the cutaneous senses. Examine the following example. An airline pilot has many tasks to perform when taking off and landing. He visually scans the horizon for other aircraft as well as his instrument panel for unusual readings. He listens to ground control for take-off or landing instructions. If an additional requirement were placed on the pilot at this point, a designer might decide to employ a tactile display and control in order to present this requirement. From what you have just learned regarding controls and the cutaneous senses, why would you consider this correct?

(1) I don't think it is correct. Tactile displays and controls are a viable means of providing man-machine interface, but should not be used in conjunction with visual or auditory displays and controls. Go to Page 100.
(2) Tactile controls or displays can provide more information to an operator than any other type in this type of situation. Go to Page 45.
(3) Tactile displays and controls provide an option for use when the auditory and visual senses are overburdened or cannot be used. Go to Page 43.

From Page 89

(3) You have understood the definition of Class 'A' controls to an extent, but you've overlooked some other important ideas. Return to Page 89.

From Page 25

(4) Very good. Personal equipment, such as gloves, clothing, etc., does need to be considered in laying out a control panel. After all, if your operator has to wear heavy arctic gloves, his overall hand space and finger space will have to be increased to take the clothing bulk into consideration.

In addition to the above factors, you also should give consideration to the force required in operating various types of controls. MIL-STD-1472 specifies the maximum force which can be required for hand-gripped and finger-thumb gripped controls. Also, both MIL-STD-1472 and MIL-HDBK-759 have discussions on the recommended amounts of resistance various controls should have.

Okay, now that you've considered these factors in designing the control spacing, and you're familiar with control layout requirements, what next? Well, remember way back in Lesson 2 we discussed the fact that human factors engineers needed to be concerned with man in his environment? When designing controls, we also need to concern ourselves with the environment in which those controls will be used. For example, in very cold climates the operators may be wearing protective glasses. Which of the follow may also influence conrol design?

(1) Heat and weightlessness. Go to Page 81.
(2) Altitude, vibration, and illumination. Go to Page 8.
(3) Humidity. Go to Page 54.
(4) All of these may influence control design. Go to Page 59.

From Page 20

(3) A thermostat was mentioned as an example of the method of covering to prevent accidental activation. However, this type of method doesn't apply here. Return to Page 20.

From Page 69

(4) Very good, all of these statements are correct.

Shape coding does provide both tactile identification of controls and assistance in visual identification. Since rotary controls are, indeed, well suited to shape coding, you will most often see different shapes associated with this type of control.

The Air Force has conducted a study defining three types of knob designs and the particular purpose of each. Figure 14.21 on Page 35 of your supplement illustrates the various designs. This study, conducted by Hunt in 1953, determined that tactile discrimination was relatively easy among the three classes of knobs. All multiple reaction knobs were listed as Class 'A' knobs. By multiple rotation controls, Hunt meant those controls which had an adjustment range of one full turn or more, and for which position was not a critical item of information in control operation. Think of yourself in your car. On the dashboard is a knob which controls the lighting of your dashboard. As you turn this knob, your speedometer lighting will increase or decrease. Why do you think a designer would use what Hunt calls a Class 'A' control on the dashboard?

(1) It is similar to a room dimmer switch, and it's important to use controls which are standard. Go to Page 13.
(2) To allow a very gradual change in level of lighting so as to minimize interference with dark adaptation. Go to Page 72.
(3) This control is important, but not essential to the operation of the car. Go to Page 87.
(4) All of these. Go to Page 70.

From Page 30

(2) Very good. The brake pedal is the only example listed of a leg-actuated pedal.

Both leg and ankle actuated pedal-type controls are illustrated in a figure titled "Pedals" in the section on Controls.

Well, we've gone into quite a bit of detail about controls. We've examined functional categories, general types, and specific types of controls. But, the first question in the checklist we presented earlier, 'Have you chosen the best type of control?' Is still unanswered. You've read some specifics on selection, so let's review with some general comments.

Before selecting a control, you need to gather some information about the overall system. Which of the following do you think is important in determining what controls to use?

(1) All of the answers presented here are correct. Go to Page 37.
(2) The function of the control. Go to Page 82.
(3) The requirements of the control task. Go to Page 27.
(4) The needs of the operator. Go to Page 46.
(5) The work space requirements. Go to Page 11.
(6) The consequences of accidental activation. Go to Page 54.

From Page 81

(1) Very good, you are correct. Keep up the good work.

Now it is time to learn about acceleration. Acceleration refers to the rate of change of motion of an object. For example, if the vehicle you are riding in changes its rate of speed or velocity quite rapidly, you (the object) will also change your rate of motion; initially, you'll be thrown back in the seat if you try to reach 110 mph in 20 seconds in an automobile. When you are thrown back, you, in essence, have increased the weight of the body. A body in free fall travels at the rate of 32.24 feet per second. We call this rate 1 G. If during acceleration you double the effective body weight, you have accelerated to 2 G's.

We can also talk about acceleration and its effects in terms of the direction of the accelerating force. For example, if you are shot out of a cannon head first while the cannon is pointed straight up, that is headward acceleration, and its reverse direction (strangely enough) is called footward acceleration. To give you an idea of the effect of different G forces, lets try a few headward examples:

(1) At 2.5 G's it would be difficult to raise one's self from a seating to standing position.
(2) At 3-4 G's it would be impossible.
(3) At about 5-6 G's your vision would diminish after five seconds; above 5 G's, you'd probably lose consciousness.

Some examples of the effects of footward vibration will show you what it feels like to be pushed downward by various G forces. At 1 G your face gets suffused with blood, but it is tolerable. At 2 to 3 G's there is severe facial congestion, throbbing headache, and your vision blurs, grays or perhaps reddens. 5 G's can only be tolerated by a small percentage of the subjects who were tested.

There are other directions in which linear acceleration can occur; the G forces which can be tolerated in the forward and backward directions and side-to-side (lateral) directions are much greater than those which are tolerable in the vertical directions. The knowledge that people can tolerate the greatest G force in the forward direction has been used in designing the seating in our space vehicles. In the forward direction, some subjects have been able to tolerate up to 12 to 15 G's for over a minute with only symptoms of discomfort and breathing difficulty. Find Figure 15.1 on Page 39 in your supplement. Using this figure, which show the average G force that can be tolerated for various time limits, answer the following question: How many G's can be tolerated for one-half minute if the acceleration is headward.

(1) 6 G's. Go to Page 46.
(2) 12 G's. Go to Page 28.
(3) 8 G's. Go to Page 67.
(4) None of the answers listed here. Go to Page 47.

From Page 78

(3) Very good, this answer is technically correct. However, we hope you can also see that it is the most impractical answer, as well.

Most protective devices are in the form of restraining devices, anti-G suits, and body contoured couches, as well as net couches. Contoured couches provide the individual with good protection if the acceleration is in the forward direction but do not offer proper support if the force is in a rearward direction. In the rearward direction, the individual is usually protected by anti-G suits, restraint helmets. and support equipment for his frontal area. Nylon netting as well as head and chin straps may be used for this purpose.

In a manner of speaking, rearward acceleration has the same impact on an individual as deceleration (sudden stop) does. In both cases the individual is thrown forward. Restraining devices for instances of rearward acceleration and deceleration are probably already familiar to you. The seat belts and shoulder harness on your car are examples of such restraining devices. In addition to harnesses, air bags and rear facing seats are used to help prevent any adverse effects of deceleration or rearward acceleration.

So, in this lesson you have learned about vibration and its effects. In addition, you have studied acceleration, some of its effects, and some types of restraining devices to use. In this lesson, as in the others, you should have been thinking about the human performance requirements and the human's capabilities.

Well, it's time to call a halt to this lesson. But before we go, perhaps you'd be interested to know about I. M. Eager and how he solved his current whirl of an adventure. Eventually, Eager gained control of the spinning chopper and set it down on the landing pad. He got out of his perfect helicopter with his head reeling and his stomach queasy. Poor guy, instead of being comforted in his distress, an angry general confronted him instead...see you next lesson.

AD-A132 558 HUMAN FACTORS ENGINEERING A SELF-PACED TEXT LESSONS 11-15(U) HUMAN ENGINEERING LAB ABERDEEN PROVING GROUND MD R BROGAN ET AL. AUG 81 2/2

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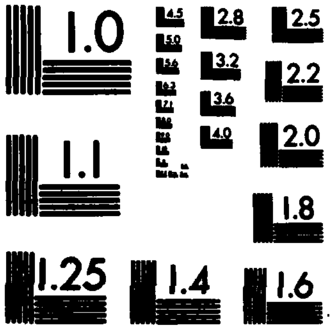
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From Page 4

(3) Very good, you get an A+ for memory. Stimulus-response compatibility was a point of discussion in Lesson 11.

Size-distance trade-offs, control-display ratio, and strength requirements are all important aspects of control dynamics, and we will spend a considerable amount of time discussing each concept in turn. However, before we mention any one of these, let's deal once more with stimulus-response (or S-R) compatibility. If you remember from Lesson 11, we discussed S-R compatibility as the relationship between a stimulus and a response which is consistent with human expectations.

Previously, we pointed out that the primary sensory modalities used by man are vision and audition. In upcoming chapters we also will deal with the importance of other senses--those of smell and the skin and how they serve as channels of useful information input. Primary output channels are the motor responses, concentrated mainly on the hands and feet. In addition, speech also must be included in this category.

As we discussed in Chapter 4, between input and output, some form of information processing and decision takes place. To a large extent, the amount of information processed is dependent on the inter-relatedness of stimulus and response. This processing of information has important implications for the design of displays and controls. Earlier, we referred to compatibility in the sense that it's consistent with what an operator expects. We can now broaden this definition somewhat to include how well the operation of a control device "fits" with its effect on a particular display indicator.

A focus on this type of compatibility is known as the control-display ratio. Thus, if we were to be dealing with a control task of some sort, and were discussing the ratio of the movement of the control device to the movement of the display indicator, we would be talking about the:

(1) Ratio movement. Go to Page 44.
(2) Control-display ratio (C/D ratio). Go to Page 96.
(3) Neither of these two answers. Go to Page 27.

From Page 20

(4) The handle was recessed to prevent accidental engagement. This example doesn't apply here. Return to Page 20.

From Page 60

(1) Find 4-10 Hz on the bottom of the graph and move your fingers up until it reaches the 2.5 Hz curve. Now, move straight over to the left axis and you will find an intensity level of about .7, not .3. Return to Page 60.

From Page 66

(3) For 8 hours at 16 Hz the intensity levels could be about 0.5 RMS. If the intensity level was 2.0 RMS for 8 hours, your frequency would be about 63 Hz. Return to Page 66.

From Page 25

(3) We are presenting only five factors to be taken into account; there are bound to be a host of others that will require your attention. We'd be surprised if no other consideration was important. Return to Page 25.

From Page 49

(2) Close, but no cigar! Weight is not a real criteria. Return to Page 49.

From Page 93

(2) Well done, you're absolutely right.

Very good, we have been discussing C/D ratios, and we hope we've gotten the point across. The greater the compatibility between movement of control device and display indicator, the better the performance of the operator. For instance, when a small movement of a control device (such as the slight turn of a knob) is required to affect a small change in a display indicator, we would have a relationship between the two approximating a 1:1 C/D ratio. Examples of low and high C/D ratios can be seen in Figure 13.1 on Page 31 of your supplement.

When one desires to determine the best C/D ration for a given situation, several human performance aspects must be taken into account. One aspect concerns the gross adjustment movement which the operator must utilize in order to bring the indicator to the approximate desired location. This movement gets the indicator in the general desired area. Now, can you guess the second performance aspect required of the operator?

(1) Perfect adjustment movement where the operator sets the indicator at exactly the desired location. Go to Page 28.
(2) Fine adjustment movement in which the operator attempts to bring the indicator to the precise desired location. Go to Page 83.
(3) Semi-fine adjustment movement where the operator brings the indicator to within 5° of the desired location. Go to Page 39.

From Page 66

(1) If 1 minute was correct, the intensity would have to be changed to about 4.0 RMS. Return to Page 66.

From Page 30

(4) Think again. Only one of these is ankle-actuated. Return to Page 30.

From Page 85

(4) Very good, you hit the nail on the head. Since increased speed of skin movement helps lower the threshold (makes it 'easier to notice'), if the speed is slowed enough, it will take considerable pressure to reach the threshold.

In addition to threshold, another important facet of touch is adaptability. Once a constant pressure has been reached, the sense will adapt and the person will cease to be aware of the contact. You have probably experienced this. A person may be unaware of his clothing until he moves and creates a different pressure gradient. Of course this is a general rule and there are exceptions. If you're wearing 200 lbs. of equipment (a diver, for example), it will take you a long time to adapt to this. But, except at the extremes, the process of adaptability is an important aspect of the sense of touch.

Finally, it is important to note that the threshold for touch, or pressure, is different for different parts of the body. For example, the palm of the hand is more sensitive than the back of the hand, and the face is more sensitive than the bottom of the feet.

Not much needs to be said of pain. As mentioned before, pain acts as a source of information to the body. Of importance to you, as a human factors engineer, is the fact that man reacts to pain and you can use pain as an alarm.

Change of temperature, too, can be used as an alarm. By 'changes of temperature' we are referring to a sensitivity to variance from an expected or normal temperature. For example, anyone who has ever worked in a computer room knows that the room is always kept cool to accommodate the equipment. If the room were to suddenly warm up, the operator would know that something was amiss. In addition, and perhaps more importantly, temperature itself is a critical factor to be considered in the system development process. Think back to the last time you shoveled snow, or scraped ice from your car with no gloves. Your numb hands quickly lost a great deal of the sensitivity to touch. Or think about working in the yard on a sweltering day; you probably got a lot less work done than you would have on a cool spring day. So, while change of temperature is one of the somesthetic senses and does play a role in the design of alarms, temperature, per se, is a more crucial consideration for the human engineer. Lesson 17 will explain these factors for you in detail.

(Go on to the next page)

From Page 97

Let's move on and examine the implications of the somesthetic senses for human engineering design. The most significant consideration about man's somesthetic sensing capabilities has to do with the design of controls that are easily identifiable by touch. Also of interest is the design of gloves and other personal gear which will not excessively reduce tactile sensitivity. Of secondary consideration will be the use of temperature and pain as alarms.

Since you now have a basic understanding of the tactile senses, let's see what implications they have for design. At the beginning of this lesson you were introduced to coding. We have already discussed location, labelling, and color coding; size and shape coding remain to be discussed. Why do you think we've waited until now to talk about these methods?

(1) They both depend in part on the cutaneous senses. Go to Page 69.
(2) They must be used in conjunction with labelling. Go to Page 14.
(3) They must be used in conjunction with color coding. Go to Page 24.
(4) They are primary methods of coding and, as such, should be presented last. Go to Page 17.

From Page 69

(1) You're only partially correct. Return to Page 69.

From Page 70

(3) Labelling of controls is an important aspect in reducing confusion, but remember, we are discussing equipment often used in an environment providing little or no light. Return to Page 70.

From Page 58

(3) You're partially correct. You do need adequate lighting for labelling, but you also need adequate space and literate operators. Poor lighting is a tough factor to overcome. Color coding is also inadequate since color discrimination disappears at low levels of illumination. Return to Page 58.

From Page 87

(1) You've missed the overall picture. All types of controls and displays can be used in tandem to provide necessary information and interface. Return to Page 87.

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