So you want to learn more about people ...

Step in for a journey to discover the potential, capabilities, strengths (and limitations) of this essential element in systems design!

Module 3

Developed by: Yvonne Toft

(Sincere thanks to Prue Howard, Amanda Brain and Steve McKillup for their valuable contributions)

Cognitive ergonomics

3

Contents

Introduction to module

The first of the modules we will explore in detail in the psychosocial domain is cognitive ergonomics. This topic is frequently hot on the Ergoweb electronic discussion list and below is just a few of the definitions proposed by contributors to the list:

> ...simply refers to the application of ergonomic principles to the mental work environment. 'Cognitive' ... means 'thinking'. How workers think while doing work and what they think about the work they do can be included ... Cognitive ergonomics means that the worker is more than just a biomechanical machine. What a radical idea?!
>
> (Lindsay, D. 1997, pers. comm., 19 September)
>
> ... is about developing knowledge about how the inherent limitations of people's mental capacities affect their ability to interact with information processing systems (such as computer systems). This knowledge should be applied to constrain the design of information processing systems, to make them easier to learn and use. In addition, the knowledge should be applied in the design of training materials for the users, and in the design of operating methods and procedures too.
>
> (Baxter, G. 1997, pers. comm., 19 September)

In this module we will explore the design of equipment, jobs, tasks and functions in relation to way the human mind processes the information presented. The next module will also consider how we can optimise information input so that the human operators are able to carry out the functions required of them as part of their jobs. Check the International Ergonomics Association homepage for the official definition of cognitive ergonomics.

This module will be much more condensed than Module 2. This is not because cognitive ergonomics is less important than physical ergonomics, but because fewer very important topics are covered. This are is an important and rapidly growing area in ergonomics and the MOST CRITICAL to prevent design-induced end-operator error.

In our everyday lives at home and at work we are constantly bombarded with information.

Imagine for a moment that you are driving your car, think of all the sources of information which are important to sound decision making as you drive along the road.

You hear the sound of the car, what does it tell you?

There are displays on the dashboard, what do you need to note?

What is the car in front of you going to do?

Is that the light switch you are adjusting?

What is the car behind going to do?

How will you know when it is time to turn right or left?

Will you make it through before the traffic light turns red?

Was that your friend who just passed you?

Will that kid follow the ball out on to the street?

How can you change the music over while driving? .....?.....?

Activity 3–1

Now, consider the questions below and jot down your ideas. What types of information did you need to process?

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How did you perceive this information?

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How did you decide what action to take from the information?

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You would have probably found from the activity above that operators are required to process a plethora of information in a very short time span. We are required to use our senses simultaneously and decide through previous experience, memory, natural and learned actions and reactions, what output is required. These special 'human' talents can be harnessed and optimised through good design of workplace tasks and equipment.

Information processing

The first step in understanding information processing is to understand the Information Processing Model. Take a moment to look at it now and then revisit as required during your learning journey through this module. You should note the three stages at which information gets transformed, that is, (1) perception of information about the environment, (2) central processing or transforming that information, and (3) responding to that information. The model highlights typical aspects that influence cognition, which is, perceiving, thinking about, and understanding the world. The context of this author's discussion was instructional design but consider for a moment what the implications might be for engineering design.

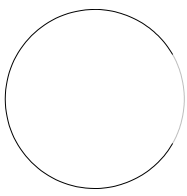
We will now look at some of the important areas in information processing that you need to understand.

Perception

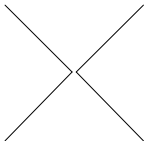
One of the simplest levels of perception is detection. It is quicker to detect an object than to identify it. It is important to consider the way humans sense, which is the process of sensing our environment through touch, taste, sight, sound, and smell.

The second link introduces the notion of Signal Detection Theory (SDT). The most important concept that you need to take from this introduction to SDT is the variables that influence the setting of response criterion. After detection more complex levels of perception are required including identification and recognition. It is proffered that constancy and the organisation of information influences the way we identify (Gestalt, in Hilgard et al. 1979):

Figure 3–1

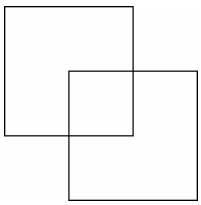
Proximity	**II II II I**	Identified in pairs
Similarity	**x o x o x o** **x o x o x o** **x o x o x o** **x o x o x o**	Identified in groups
Closure		Seen as closed circle

Continuity



Seen as continuing lines.

Pragnanz



Perceived as two squares overlapping not one little square and two other shapes.

Object recognition depends on our ability to recognise *features* (for example, the recognisable features of A might be the two straight sides), *templates* (all A's will look the same—A), and *prototypes* (***a***) which have one common example plus differences.

The context of the display is also important in its aid to perceived interpretation, for example:

- the *eel is on the axle
- the *eel is on the shoe
- the *eel is on the orange.

An understanding of, and incorporation of, these principles of sensation (including SDT) and perception in workplace design, will be imperative to its usability.

Memory

Before you are able to design tasks you must first understand how information is stored. The basics of memory theory are outlined in the next link.

The second link will take this concept further and highlight some areas where engineers are able to use this knowledge to improve the match between task and operators. A number of techniques, which can optimise the way information is presented and recalled in the workplace, were presented. In the next activity we will explore these techniques a little further.

Activity 3–2

Imagine now that you are assessing the match of operators, tasks and equipment in a room which houses the schematic of a production line (a brewery). The lights are normally green at each check point of the schematic but show up red when there is a fault and orange when the plant is under repair or being serviced. The operator's task is to communicate with shop floor personnel and maintenance personnel when they note any faults. Consider your studies thus far in Module 3 and decide how you would assess the match noting any improvement opportunities. Use a separate sheet of paper for this activity as you will be adding further information as you work through Module 3.

Another important consideration highlighted (in third link) is that memory is critical to incident recall, features of the event will determine the way that the event is recalled, and later information can change the initial perception. Take a moment to consider how the various sections of this module fit with that notion.

Attention

In the design of equipment and tasks it is necessary to consider the types of attention which may be demanded of the operator, they include:

- selective attention
- focused attention
- divided attention
- sustained attention.

This link discusses attention and offers guidelines for developing each type of task according to the type of attention required (go to the very end of page).

Activity 3–3

Go back to your earlier activity (re brewery), use the guidelines presented by above to enhance the tasks required in terms of attention.

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The information gained from the above exercise you should have helped you add a few more items into your evaluation tool regarding attention. If you didn't do this add them now.

Decision making

Check this link for guidance about how we make decisions.

Activity 3–4

The author outlined bias which can occur in decision making. Think about bias in context of your role as engineer? What issues do you need to consider in system design? Jot down your ideas.

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Displaying and coding information

The following link focuses on some themes which will be important concepts for you to grasp for further discussion in this module. You should pay particular attention to the types of information presented by displays and the selection of display modalities. We will build on these concepts later in this section and assist in your development of "usable" displays.

Activity 3–5

Return now to driving your car, consider the principles of display design, sketch the dashboard displays of your car and label where these principles have been considered in the design of your vehicle.

Now make a list of the displays you have labelled, describe the type of information presented. Note beside these entries the display modality and whether it is the appropriate modality for the type of information conveyed.

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Congratulations! You now have a draft of your first working tool for information cognitive evaluation of equipment. This tool will be used for data collection and analysis. Hold onto this paper as you will further develop this tool for your assessment.

Compatibility

There are some actions and effects which seem to be “natural”, for example, turning the car steering wheel to the right and the car turning to the right. There are others which are a “learned” compatibility, for example, that “red” equals “hot” or “danger”, these learned stereotypes can almost seem “natural”.

In times of stress or panic we are most likely to react in the way which reflects our natural, then our learned compatibility. For example, turning a knob to the left in an effort to turn something off in an emergency. Compatible relationships are easier to learn than non-compatible ones. Some of the advantages in designing for compatibility include:

- reduction of error, particularly in an emergency
- reduction in the amount of training required
- ease of use.

Try the following questions which will highlight the effects of compatibility on the way we process information:

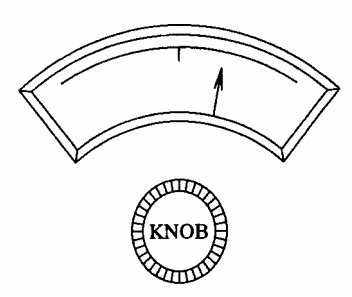
Activity 3–6

1. Knob turn

To move the arrow indicator to the centre of the display, how would you turn the knob?

_____ clockwise

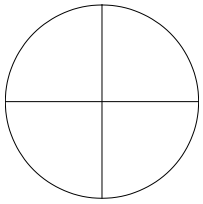
_____ counter-clockwise



2. Quadrant label

In what order would you label the four quadrants of the circle?

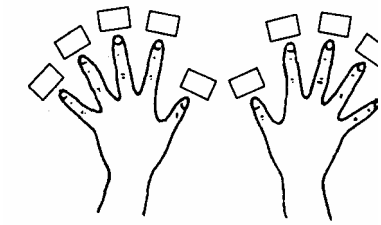
Write in the letters A, B, C and D, assigning one letter to each quadrant.



3. Numbered keys

A worker is required to duplicate numbers as they appear on a screen, by pressing 10 keys, one for eachfinger.

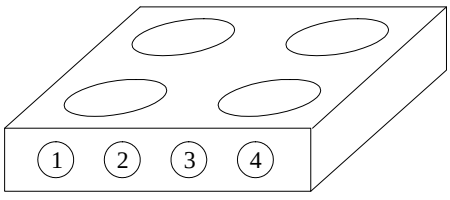
Label the diagram to show how you would assign the 10 numerals to the 10 fingers.



4. Stove burners

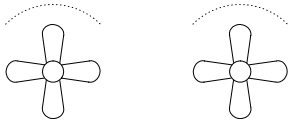
Here is a stove, with four burners on top, and four controls on the front.

Put a number on each burner to show which control should operate it.



5. Cross taps

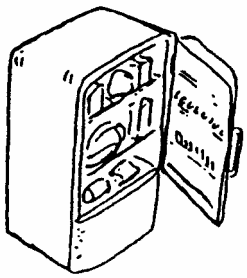
Here are two knobs on a bathroom sink, looking down at them.



Put an arrow on each dotted line, to show how you would operate these knobs to turn the water on.

6. Refrigerator door

Here is a refrigerator.



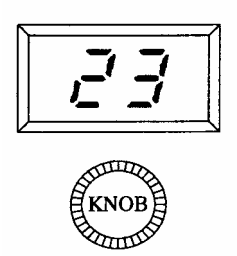
Is its door

_____ left-opening?

_____ right-opening?

7. Digital counter

To increase the number displayed in the window, how would you turn the knob?

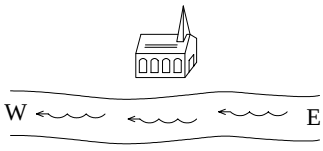


_____ clockwise

_____ counter-clockwise

8. River bank

Here is a river, flowing from East to West.



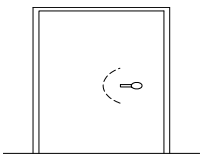
Is the church on the

_____ left bank?

_____ right bank?

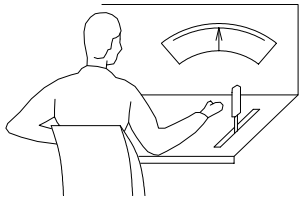
9. Door handle

Put an arrow on the dotted line, to show how you would operate the handle to open this door.



10. Lever control

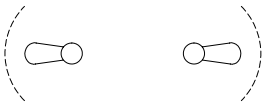
To move the arrow indicator to the right of the display, how would you move the lever?



11. Lever taps

Here are two knobs on a bathroom sink, looking down on them.

Put an arrow on each dotted line, to show how you would operate these knobs to turn the water on.



There are no right or wrong answers. Did you find that your response to the question almost felt "automatic" and if you thought about it too long it actually become more difficult to decide? For an introduction to the concepts of compatibility and system control check the next link as example design guidance.

This link outlines compatible relationships. These concepts are important and critical to reducing design-induced end operator error.

Activity 3–7

Take time now to look around the environment in which you are studying. Can you see examples of where the following compatible relationships have been optimised:

conceptual?

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movement?

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spatial?

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modality?

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I'll assume that you are probably sitting at a computer. The "trash can or recycle bin" on your screen is an example of conceptual compatibility. If you were told to delete a file by putting it in the rubbish, you would have little difficulty next time remembering that you use that icon to delete files. Conceptually we associate unwanted documents with rubbish bins. An example of movement compatibility in this context is the window scroll bar, even a novice computer user would realise that pressing the left hand arrow would result in moving in the left direction across the page. The name of program appearing directly below the associated icon is a very simplistic example of spatial compatibility. An illustration of modality compatibility (visual/manual in this case) is the use of prompt boxes to ensure the computer user follows up with an action (manual response). You may like to explore this topic further by looking up "tracking" as a concept; unfortunately it is outside of the scope of what can be achieved here.

You should have gleaned from your further study that the assessment of equipment for compatible relationships will also depend upon the arrangement of components, physical orientation of displays/controls relative to the user and the function of the equipment. Think now about how you will incorporate assessment of compatible relationships into your design work.

Process of seeing

It is imperative when designing visual displays that we understand how information is processed from the visual environment. From this understanding we can then design displays which optimise that capability

If you do not have a sound knowledge of the process of seeing you should take the opportunity now of finding a simple anatomy and physiology text and revise this process or have a look at the ThinkQuest linked here. The second link provides an example of how important the visual environment is to many common operator tasks. (Also think back to SDT and the absolute importance of vision to that concept).

Most of us tend to assume that people have a very good knowledge of their visual capabilities and that they would make the necessary adaptions for optimal vision, for example, wearing corrective lenses. They would, therefore, be safe in the work environment. Research has found that not only do some people have a poor knowledge of their visual capabilities but also not all people will make the necessary adaptations for something as fundamental as being able to see while they drive.

Given that multiple research highlights that people do work with poor vision it is necessary to include consideration of this "fact" in the design of information displays.

Static displays

There are three major considerations for static displays, that is, legibility (most important), lettering and symbols (Pollock, 1990). In summary:

- **Legibility**: The size will depend upon the viewing distance (visual angle is used). Do not design to acuity limits, Murrell (1965) recommends a 10 minute arc. Increase the visual angle if conditions require, for example, low illumination, low contrast, critical data and short exposure time.
- **Lettering**: Some letters are less legible than others, for example, L is less legible than G. Some letters or numerals are easily confused, for example, b/d and 5/6. Most fonts are suitable but San Serif is better than Serif for displays intended for children. Highlighting with ALL CAPITALS, *Italic* or **Bold** print can slow reading time and should be used sparingly. Looking ahead while reading may be compromised by the use of short lines.
- **Symbols**: Symbols should be legible and easily recognisable in their intended context. Optimal displays will be simple and enclosed in boundary with the figure easily distinguishable from the background.

You should now look at the corresponding link which will provide more detail regarding the above areas.

List and describe the most important principles for designing static displays before moving on from this section this section then put them to one side, you will refer to this list again later in the module.

Uses of dynamic information

Designing dynamic displays for effective operation requires an assessment of the intended use. The ease of use will depend upon the type of display. The way we present information in a dynamic display will promote or disrupt the flow of information from the display.

Dynamic displays can be used for one or more of the following types of readings:

- **Quantitative readings** are used when exact readings are required, for example, the loadmeter of the crane showed the weight of the load to be lifted was 2 tonnes.
- **Qualitative readings** are used for identifying trends, rate of change or change in direction, for example, a pilot flying in poor visual conditions will use four different displays to reference the attitude of an ascending aircraft to assure the aircraft is climbing, straight and the wings are level.
- **Check readings** are used to check if parameters are within normal bounds, for example, a powerhouse operator would check on a regular basis; levels of electrical output and various temperature levels.
- **Situation awareness** involves a representative display of a physical space which allows the operator to project the status of the elements, for example, air traffic controllers use a radar screen to identify and control the aircraft movements within a given area.

It is important to note the strengths and weaknesses of analogue and digital displays.

Analogue displays should be used when quick estimates of values are required or for getting rates of change. They are not very effective for exact value readings.

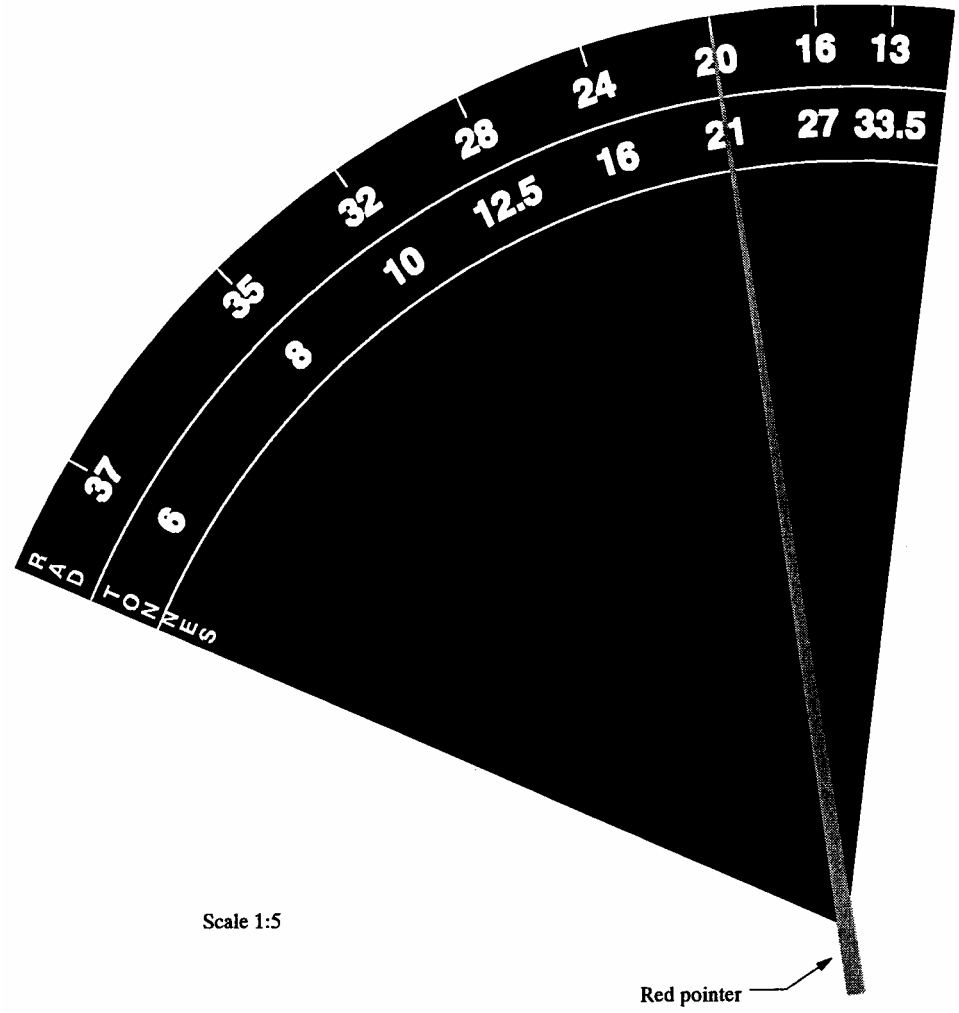
Digital displays are excellent for exact readings but are not useful for establishing rates of change or if operator is only able to get a quick look at the instrument panel.

The following activity is designed for you to test out your knowledge regarding static and dynamic displays.

Activity 3–8

This display is vital to the safe operation of cranes. On the crane in question it was located outside of the cabin, read through the window and had very low illumination at night.

Figure 3–2



How would you redesign the display?

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I'm sure you found many changes to make, if they included the length of pointer, colour, scale increments, lettering—well done!

You should leave the leave this section on displays with a thorough understanding of the main principles for designing effective visual displays.

Auditory displays

This section will explore some alternative display options. These options are important for displays for the disabled as well as reinforcing the information gained from more conventional displays.

Before there can be meaningful discussion with regard to displays intended for auditory sensation you will first need to have some understanding of how we hear and the nature of sound.

Think about the general principles presented by the link. Go back to your control room in the brewery. How might you incorporate these principles?

Other displays

Olfactory displays are rarely used due to the wide variation in sensitivity of odours. An example of an olfactory display would be the quick detection of a gas leak in our homes by smelling the natural gas odour additive. Tactual displays can also be used.

Activity 3–9

Think of the warning signals in your work environment:

(a) Have fun thinking of some alternative olfactory displays!

(b) What do you think the worker acceptance level would be?

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(c) Describe the effectiveness of your system.

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Mental workload

When people think of mental workload frequently the only consideration is overload of information. Underload can be of major importance when designing tasks and equipment especially if the job requires shift work. Consider the implications of this important area to system design. Take some time to consider the implications of workload, how do they relate to your earlier scenario (brewery)?

Summary

In this module we explored the area of cognitive ergonomics. This is an extremely important area because many accidents blamed on human error are actually a result of latent design error (see link). We have looked at research methods, physical ergonomics and cognitive ergonomics. Your next module will continue the theme of psychosocial issues, organisational ergonomics.

Review questions

Review question 3–1

Draw a concept map of human information processing showing the major processes and the interrelationships—try to bring together the various concepts covered in this module.

Review question 3–2

Can you assume that all workers will be able to read information in standard print (e.g. the text of this Study Guide)? Why/why not?

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Review question 3–3

What needs to be considered when static displays are being designed? List as many features as you can.

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Review question 3–4

How can visual displays of information be ineffective (or even dangerous)? List all the factors you can think of.

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Review question 3–5

Think of a work environment with which you are familiar:

(a) Describe any auditory displays which may be in use.

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(b) Does the design of the auditory displays in use reflect understanding of the above principles?

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(c) If not, what could be done to improve the design?

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Review question 3–6

Identify and give function of five general sense organs.

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Review question 3–7

Think of your study environment:

(a) How could you improve the efficiency of this environment for a hearing impaired student?

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(b) How could you improve the efficiency of this environment for a visually impaired student?

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(c) Would the above recommendations cause any difficulties for a student without hearing or visual impairment?

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(d) Think of one example where the use of tactual display would highlight the advantage of this type of display for "tracking"?

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Review question 3–8

Discuss how odours are detected and perceived.

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Review question 3–9

What type of sense receptor is used for smell (the answer is not nose!)?

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Review question 3–10

Why should the nature of speech communication be of interest to an occupational health and safety professional? Outline a number of areas in an occupational setting you know of where an understanding of the strengths and limitations of speech communication would be important.

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