Chapter 4. Cognitive Psychology

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Context

To carry out effective User Centred Design, designers need to something of how humans process information: how they perceive the world, focus their attention, use memory, make choices and respond. Cognitive psychology is the study of such information processing. Knowing the capabilities and limitations of your users will lead to you making better design choices. This Unit introduces cognitive psychology and deals with one key aspect, namely visual perception – i.e., how we process visual information that is presented to us. You will learn about theories of visual perception and how this knowledge might help build better interactive systems.

Objectives

At the end of this unit you will be able to:

- Define cognitive psychology
- Give reasons why interactive system designers should study cognitive psychology
- Discuss 2 theories of visual perception. The ones presented are constructivism and the ecological approach.
- Show how knowledge of the two theories can improve in, for example, icon (constructivism) and affordance design (ecological approach)

Cognitive Psychology

Cognitive psychology is the branch of psychology concerned with how our minds process the information sent from our various senses. Most of the work from cognitive psychologists has been to quantify how efficient we are at processing this type of information – how much we can process and how quickly. More recently, however, cognitive psychologists have become interested in how the mind processes information generated from working with other humans and external artefacts such as computers.

The study of cognitive psychology as a branch of psychology was started around the same time as researchers became interested in the possibility of artificial intelligence (roughly in the mid 1950's). Psychologists believed that the human brain was some sort of information processing machine, which was fed input from senses and stored images, thoughts etc. in memory. The discipline of cognitive psychology describes the mind as:

" *A general purpose system for processing symbols that is limited by both structural and resource limitations.*"

In this context, a symbol is a pattern stored in memory which represents, or 'points-to' something in the external world. Various processes in the mind manipulate and transform symbols from one sort to another. The goal of cognitive psychologists is to define these processes and representations; to give an understanding of how well our mind will perform a given task.

Obviously, human–computer interaction can benefit from this work by building models of user performance and defining design guidelines which are sympathetic to the way our mind processes the information being displayed on a computer screen. Cognitive psychology also offers the possibility of building user models – essentially computer programs which react the same way to certain stimuli as humans. These models can be used to test an interface and predict the types of problems users could experience. Cognitive psychology can also be used after an interface has been constructed to give insight into why users are experiencing problems with that interface.

In a future unit, you will be shown different models of how the brain processes its inputs. In this unit, however, we are primarily concerned with how humans process visual information. We will investigate how our minds process visual information and how this processing can be exploited to improve interface design. You will also discover that our eye is a lot more complex than a simple camera, and that our minds often "embellish" the images received from the eye.

Review Question 1

List the main goals of cognitive psychologists

Answer to this question can be found at the end of the chapter.

Review Question2

What can cognitive psychology offer computer interface designers?

Answer to this question can be found at the end of the chapter.

Visual Perception

Have you ever stopped to consider how amazing the human vision system is? It allows you to see in very bright and dull environments; it allows you to detect minute variations in colour and it also allows you to detect rapid movement, be that a darting animal or a sudden flash of lightning. However, the eye is not perfect. We are limited to a narrow spectrum of colours (between ultra-violet and infra-red). Some objects move too quickly (or too slowly) to see any movement.

These aspects, however, are governed by the physical composition of the eye. What we are interested in is how the brain processes the information which the eye does manage to capture. If we are to create usable interfaces, then we need to examine how the brain processes the information presented to it.

There are a number of theories which have been proposed to explain how we process what we see. Broadly speaking, they fall in to two main categories: constructivist and ecological. Constructivist theories state that our visual perception of the world is constructed by applying our knowledge of the world to what our eyes are currently seeing. Ecological theories, however, state that there is no high level processing, we extract information directly from the light captured by the eye. Neither approach is exclusively correct and there is much evidence supporting both points of view.

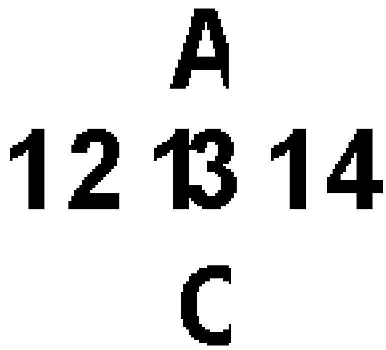
Constructivism

Constructivist theories are all based on the idea that we do not perceive the world directly – that we process any image we see before it is consciously recognised. (There are many different types of constructivist theory, perhaps the best known is Gestalt theory which we shall discuss in the next section.) This has quite a few, far reaching, implications For instance, one consequence of the constructivist approach is that a child must learn some base amount of knowledge before it can ‘see’ (as we understand the term ‘see’).

To illustrate their point, the constructivists show how the mind uses contextual information and world knowledge to affect what we see. By using optical illusions we are challenged to question if what our eye detects is really what we “see.”

Theory - Contextual Information

Consider the following figure



What do you see? Is the middle symbol a “B” or a “13” ? The context in which we see a symbol has a huge influence over how we “see” it. What about the sentence in figure2? The symbol in the middle of each word is clearly identical, yet we are able to “see” it differently in each context!

Our brain is able to use information about the context in which a symbol appears. It can use the contextual information to disambiguate the symbol, so that we “see” complete and meaningful words.

Application - Contextual information

Contextual perception obviously has applications in interface design. For instance an icon design which means one thing in one part of the interface, might mean something completely different in another place. A good example of this is the check box.

Usually this symbol is used to show whether an item is selected or not. But, it is also the symbol used to denote “Close” when used in the top right corner of a window in Windows 95/98/2000. Again, in the different contexts, we see different buttons, even though the representation is identical.

Activity 1 - Using Context Information

Can you find examples of interface elements (like the check box) which appear identical, but have different meanings in different contexts? You may find that pictures denoting actions/verbs rely more on context than those representing nouns.

A discussion on this activity can be found at the end of the chapter.

Review Question 3

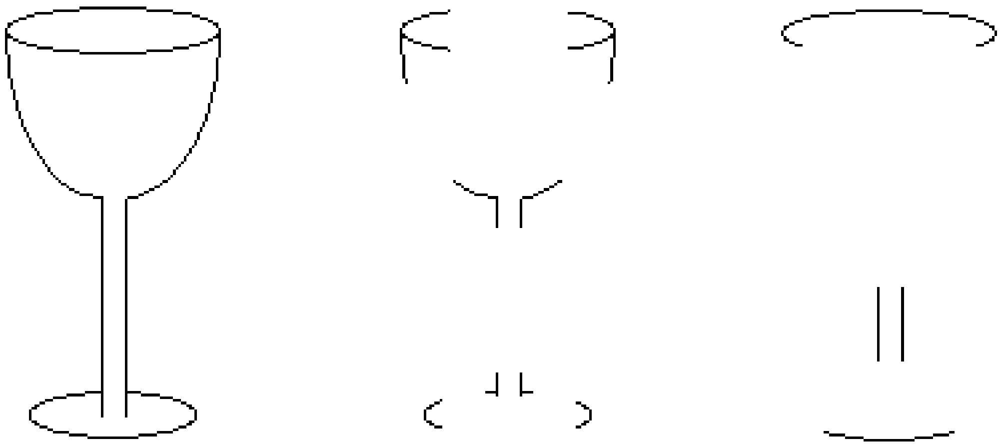
Explain why context is important when designing an interface?

Answer to this question can be found at the end of the chapter.

Theory - World Knowledge

From childhood, humans develop a huge knowledge about objects and how to recognise them. Our perceptual systems exploit this knowledge, allowing us to recognise objects when parts of that object are obscured. In figure 3 below, we can readily identify the wine glass, even though roughly half the original information is obscured. The final glass is much harder to identify. Not only is much more information missing, but crucial details (such as the contour of the glass) is not present.

Using world knowledge to recognise partial shapes



A lot of research has been conducted in to the types of information our perceptual systems need to identify objects. Edge information and contour information is vital – other information, in particular colour, is largely redundant. (Even an object which is heavily reliant on colour to identify it, such as a banana, can be as quickly recognised in black and white).

Application : World Knowledge

Again, this information about our ability to perceive incomplete objects is useful at the user interface. When designing graphics were screen area is restricted (as is the case for an icon), we can show those edges which most define an object, without worrying about colour information.

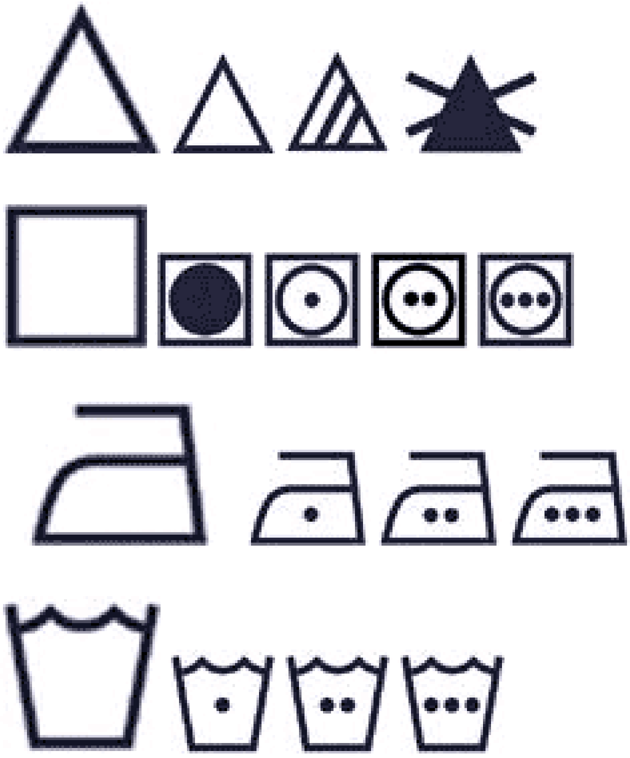
Activity 2– Constructivism; using world knowledge

Look at the icons at the top of your browser window (Back, Forward etc.) and have a go at re-designing them to exploit your world knowledge.

A discussion on this activity can be found at the end of the chapter.

Activity 3 – Icon design

Look at the laundry labels in the images beneath. Each represents a separate class of operation you can perform on your laundry (e.g. dry, wash, dry clean and bleach). Can you guess which symbol represents each operation? Do you think that the symbols exploit world knowledge sufficiently well to depict each action? If not, suggest some alternatives.

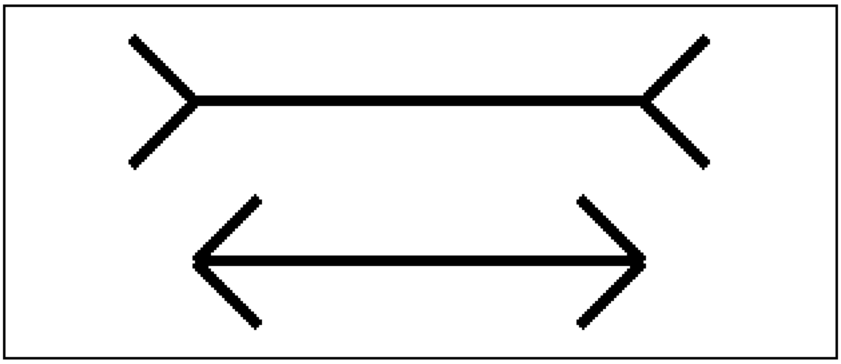


A discussion on this activity can be found at the end of the chapter.

Gestalt psychology

The term gestalt refers to something which has a well structured form; a form which is often more than the sum of its parts. For instance, four lines arranged in a square form something which we primarily recognise as ‘square’ – not as a collection of four lines arranged in some fashion. Gestalt theory would argue that our perception of the lines is influenced by the knowledge we have about geometric shapes (in this case the square) which causes us to perceive a square and not individual lines. The constructivism described by Gestalt theory, therefore, is the way our mind’s knowledge of different types of form affect our perception.

The relationship between the lines in the Müller-Lyer illusion (below) serves as a good example of how our brain constructs something more from the lines than is actually found in the diagram. In this instance, our brain constructs views from the two groups of three lines such that the top horizontal line looks longer than the horizontal line beneath it. In actual fact, there are both the same length.



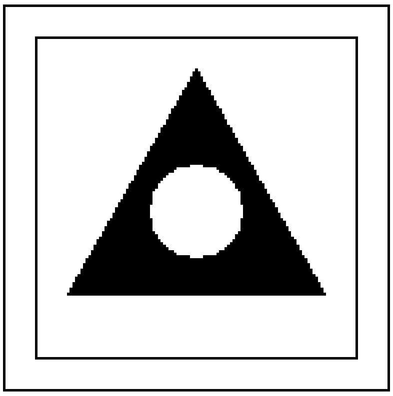
Review Question 4

What is meant by a 'gestalt,' illustrating your answer with an example?

Answer to this question can be found at the end of the chapter.

Theory : Figure and Ground

One key “form” in the Gestalt theory is the idea of “Figure and Ground.” Look at the figure below. What do you see? Do you see a complete triangle with a circle placed on top of it? Or, do you see a triangle with a circular hole through which you can see the square beneath? In other words, is the circle part of the ‘figure’ or is it part of the ‘ground’?



Presenting the distinction between figure and ground is essential if we are to produce pictures and icons which are unambiguous. Consider the following symbols (figure 6) which could be used to represent “exit”:

Application : Figure and Ground

When drawing images like this on a page, or a computer screen, you need to be careful that you are not confusing your user about what is part of the foreground and what is part of the background in your image. The idea of “figure and ground” has implications when designing symbols such as icons. One rule we can infer is in marking boundaries: it is better to use a solid shape than just[1] an outline. By using a contrast boundary, the black arrow stands out more than the outlined arrow.

Activity 4

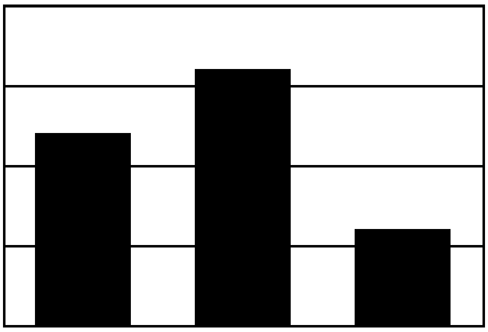
Consider the following laundry symbol. Could it be improved using figure and ground rules?

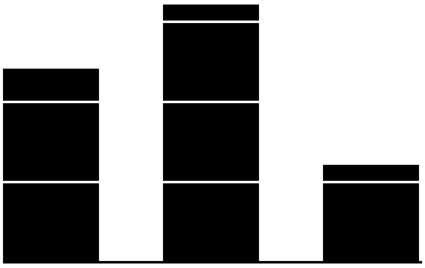
A discussion on this activity can be found at the end of the chapter.

Too much foreground

Another application of figure and ground distinction is increasing the amount of information conveyed without increasing the amount of “ink” used to represent that information. Often, computer graphics can become cluttered and hard to read because the designer is trying to convey a lot of information in a small space.

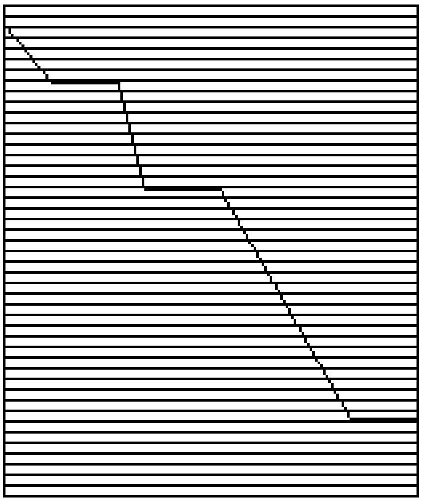
To illustrate the point, consider the graph on the left. Here the information being presented (as represented by the height of the bars) is drawn in the same colour as the contextual information (the lines of the graph). The graph on the right, however, exploits figure and ground to show the information in one colour but keep the context information as part of the ground.





Activity 5 – Foreground clutter

How can we improve the following graph using the rules of figure and ground?

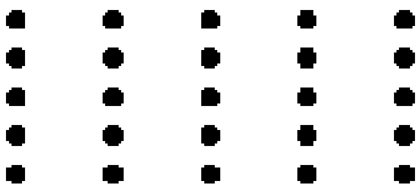


A discussion on this activity can be found at the end of the chapter.

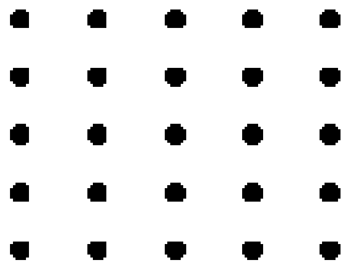
Theory : Perceptual Organisation and grouping laws

One of the main contributions of Gestalt theory is in the principles by which objects group themselves in visual perception. There are five different types of grouping:

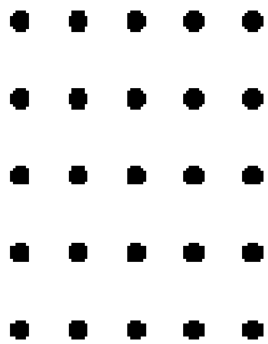
Proximity: In the figure below, the dots could be organised in rows or columns.



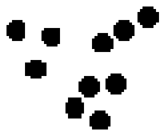
Due to the proximity of dots in the figure below, the dots arrange themselves in columns.



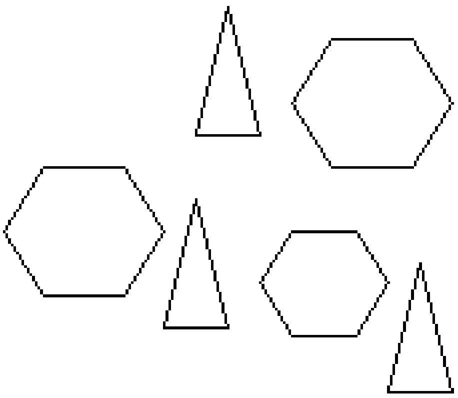
Conversely, the dots in the figure below appear in rows.



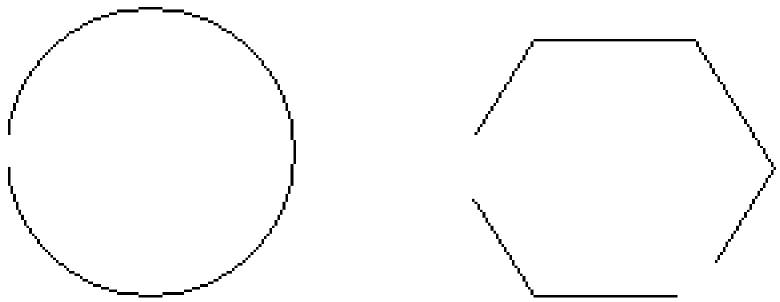
Proximity need not only apply to organised items, then tendency to group by proximity can be seen in random allocations such as in the figure below:



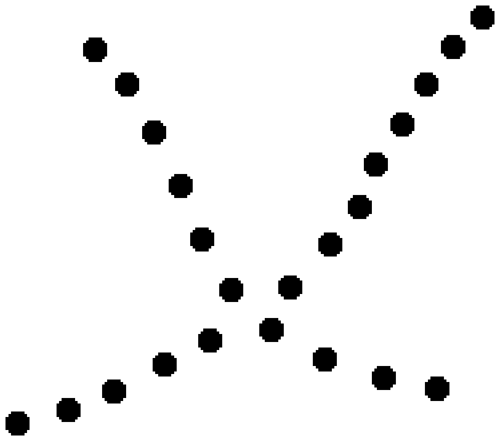
Similarity: Objects of similar shape or colour will be perceived to be grouped together, as in figure below.



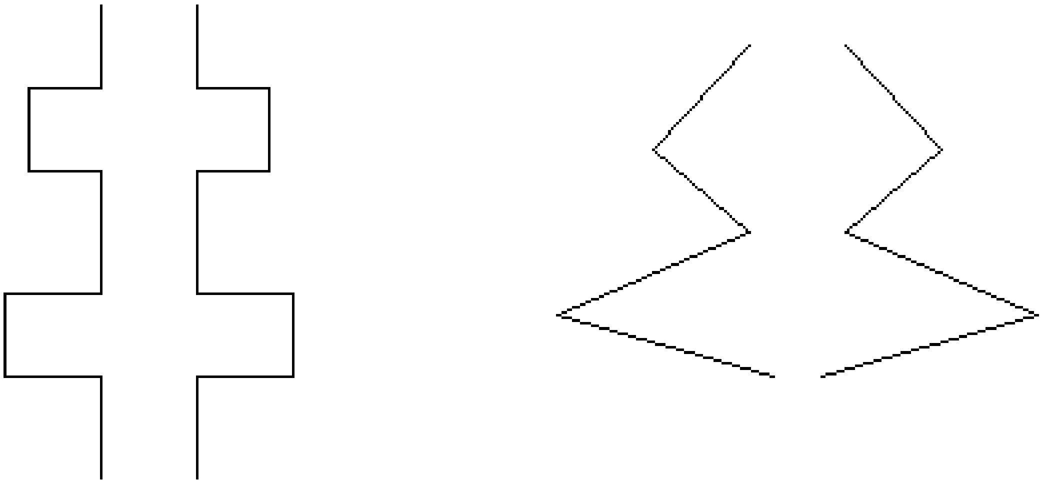
Closure: Rather than appearing as three separate lines, the application of closure to perception means that we see a circle and hexagon in this figure below:



Continuity: By using continuity in perception, we tend to see two distinct trails of dots in the following figure.



Symmetry: Areas that are surrounded by symmetrical lines tend to be recognised as shapes, rather than the lines being perceived as shapes in their own right. (see below)

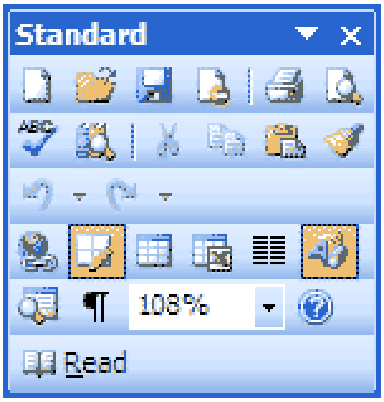


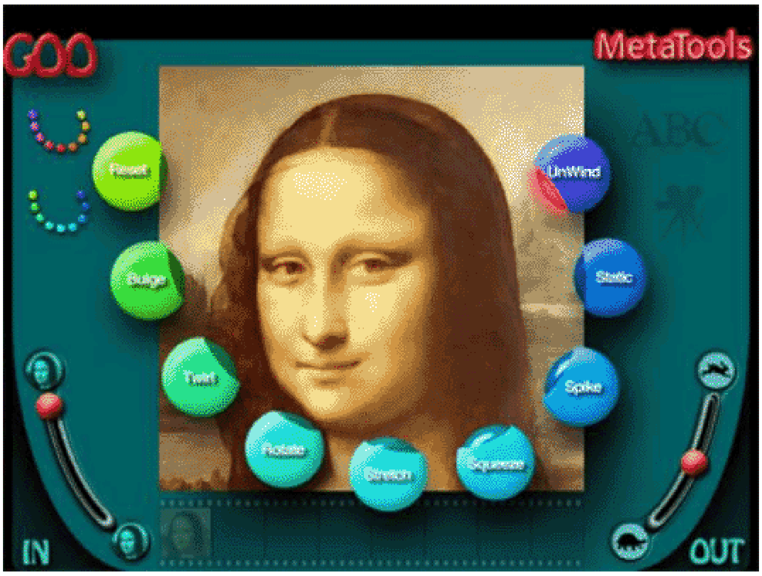
Application : Perceptual Organisation and grouping laws

Activity 6

The five grouping rules discussed above give the interface designers ideas about how to arrange interface objects so that they will be perceived to belong together in some way.

Consider the following dialog boxes and tool bars from various applications. Discuss how grouping rules have been used to design each one.

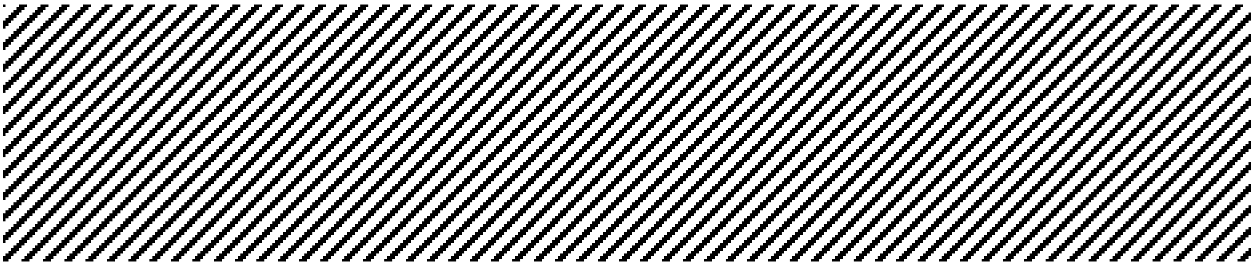




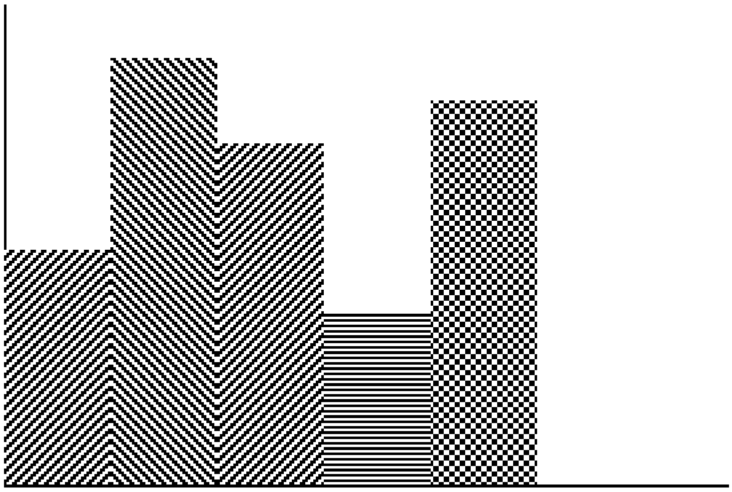
A discussion on this activity can be found at the end of the chapter.

Grouping too closely

Grouping objects too closely together can play tricks on your perceptual system, causing an illusion called moiré movement. Stare at the following image and you should experience the effect.



This can be a problem in computer graphics, as in figure below,



Review Question 5

Choose the most appropriate word from *Symmetry*, *Similarity*, *Closure*, *Continuity* or *Proximity* to describe each of the Gestalt grouping descriptions beneath.

- Objects arranged regularly, but which are close vertically, tend to be grouped in rows
- Objects of similar shape or colour will be perceived to be grouped together
- Objects which follow each other in an un-broken line are grouped together
- Even though parts of regular objects are missing, we tend to fill in the gaps

Answer to this question can be found at the end of the chapter.

Ecologist

There is a lot of evidence to support the theories of constructivist perception. In particular, the grouping laws of Gestalt theory have proven themselves in a wide variety of experiments and applications. But do our minds process every image we see in such detail?

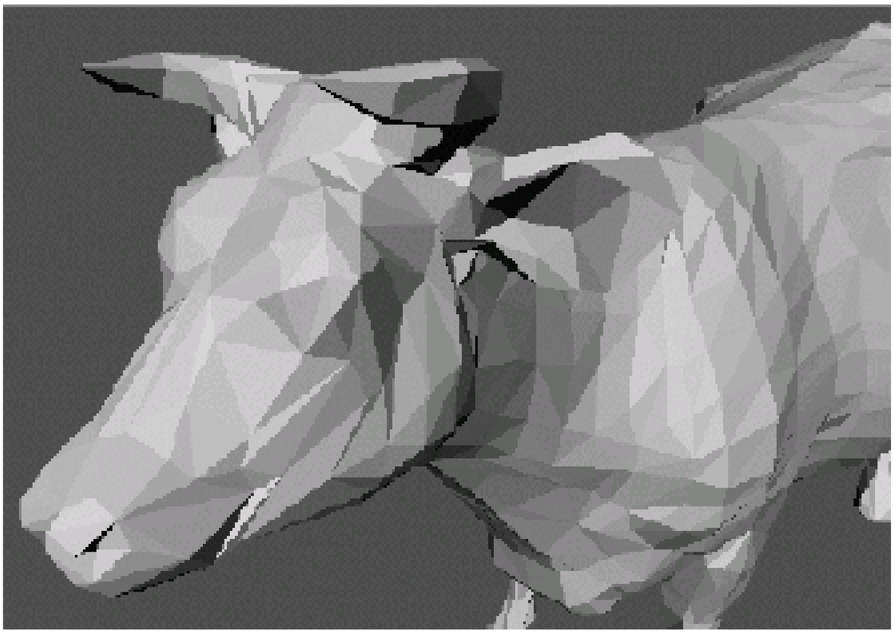
Whilst working on training fighter pilots in the second world war, psychologist J.J Gibson came to the conclusion that constructivism was not the whole story. Instead, Gibson and his followers claimed that we could perceive information directly from our environment without any higher level processing. Ecologists argue that our eyes and minds have adapted to our environment over millions of years of evolution and therefore are optimised to perceive that environment very efficiently. Furthermore, they argue that the experiments of the constructivists operate in a controlled environment (the laboratory) which cannot capture how an eye perceives in its natural environment. Ecologists are therefore interested in what cues our eyes can take directly from the light in the surrounding environment.

Theory - Optical flow and Invariants

One of Gibson's main arguments about perception is that movement is a crucial part of the process. Our eyes are rarely presented with a static view of a scene, instead we tend to walk around, giving our eyes a constantly changing range of viewpoints. Consider a textured surface which we are trying to observe. As we walk closer the that surface, our perception of it changes are we are able to see increasing levels of detail. The changes in this surface are not random – there is a gentle change in detail to which our eyes are accustomed. Gibson calls this change in perception optic flow.

Application - Optical flow and Invariants

Reproducing optical flow convincingly is a big problem in computer interfaces. In a virtual environment, for instance, we can model object surfaces by giving them a fixed texture. As we walk around the virtual environment, objects change size in accordance with perspective rules (object sizes can be rescaled according to well understood mathematical rules.) What does not change, however, is the texture, or detailing, on surfaces. The transitions in surface detail are not well understood and quite often the "solution" is to store a model for remote viewing and one for close viewing. The resultant effect is unsettling as object suddenly change from blurred to pin-sharp detail with only the smallest of movements through the virtual environment. This problem is called popping and can be seen in the images below. In figure below, the viewer is standing back from the cow.



As they move a few millimetres forward, the computer decides that they should be able to see more detail and suddenly the cow has an eye, as can be seen in this figure.

Optical flow turns out to be just one case in a wider family of invariants. “Invariant” is the word Gibson uses for any perceived pattern of change within the observed environment – invariants are the patterns of change which are familiar to our visual system. One particularly important class of invariant is the affordance, which we shall investigate next.

Review Question 6

What is a moiré movement and what does it tell us about the visual system?

Answer to this question can be found at the end of the chapter.

Theory : Affordance

One idea of Gibson’s which is crucial to interface design, is that of an affordance. Gibson says that our environment contains invariant information, the successful detection of which has survival implications for the observer. These affordances which objects provide give the observer clues about how they might be used – sit on-able, grasp-able, throw-able etc. In effect, the affordances provide the meaning the environment has for the observer, showing them what is possible within that environment. The interaction possibilities provided by the affordances has been called the effectivities of an environment.

Remember that the ecologists are claiming that these affordances are being perceived directly – there is no conscious processing. Therefore, the properties of an object which make it appear graspable can be directly inferred from nothing more than the reflected light from that object striking our eyes.

This is quite a bold claim, which the ecologists defend by arguing the subtle and inextricable links between observer and observed environment. Regardless of the exact mechanism of how we perceive affordances, there effect in computer interfaces is profound.

Review Question 7

What is popping and how does it relate to the idea of optic flow?

Answer to this question can be found at the end of the chapter.

Application : Affordances (Donald Norman)

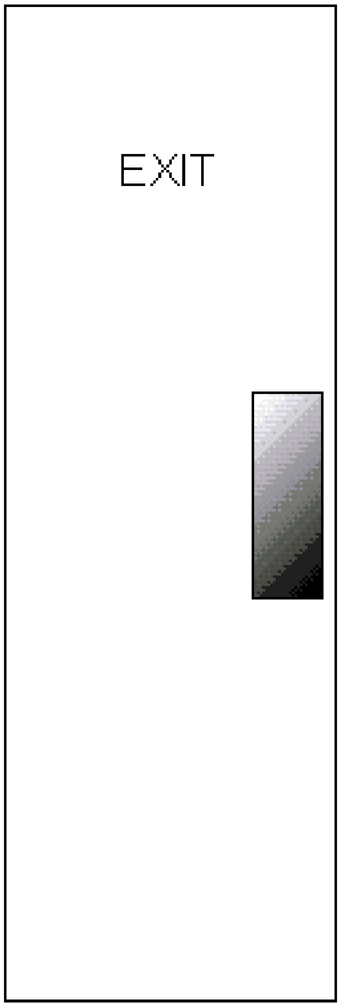
One psychologist who recognised the importance of affordances in designing interfaces was Donald Norman. He showed that interface elements could be designed to afford how the user should interact with them. Consider the button below, part of the original Macintosh interface.

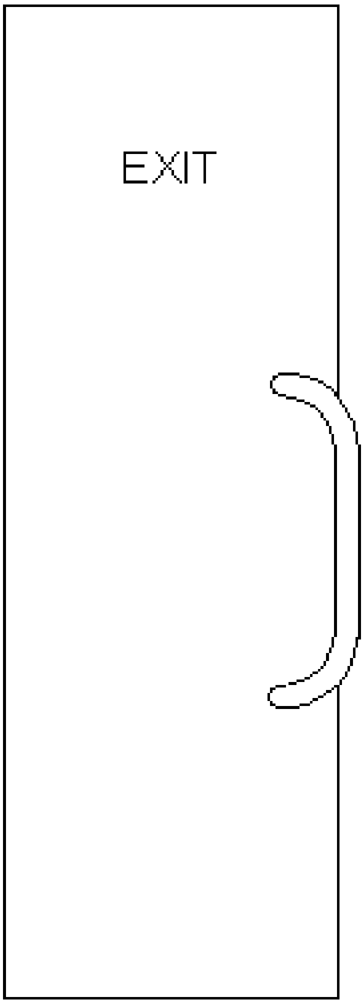
How do we know that this is in fact a button? How does it afford pushing? A better version of the button would be…

In this case, we can see that the button is raised off the page, so could perhaps be pushed level with the page. As computers became more powerful, colour could be added to interfaces providing even better affordances, as in…

By using a bevelled edge and a metallic colour, the button now looks like its real world counterpart. The result is an on screen button which provides the same affordances as its more familiar real-world counterpart.

Norman used a wide variety of examples ranging from computer interfaces to door handles showing how badly designed objects could afford one style of interaction, but actually use another. A common example of this are door handles. Handles of the type found in the left side afford pushing whilst those on the right afford pulling. Quite often the plates on the left door are used for pulling the door open. This is why people often spend ages pushing pull doors (or indeed pulling push doors) as the handle affords the wrong type of interaction. Where handles are used inappropriately, they are often marked with an instruction.





Review Question 8

What is the key difference between the ecologists and the constructivists?

Answer to this question can be found at the end of the chapter.

Review Question 9

Why is this door not going to work for most humans?

Answer to this question can be found at the end of the chapter.

Activity 7 - Web Affordance

On a Web page, how do you know what is a hyperlink and what is regular text or image? What affordance is provided?

Take an example Web page with poor affordance and re-design it to improve its affordances.

A discussion on this activity can be found at the end of the chapter.

Reinforcing Affordances - Shading Convention

Look at the two graphics below. One is a button and the other is a text box. How do you know which is which?

The one on the left is the button, the one on the right is the text box. The only difference between them is the shading on their edges. In the convention of user interfaces, buttons are raised and text boxes are recessed. This only works, however, if we imagine a light source shining from the top left hand corner of the screen.

If the light shone from the bottom right of the screen, we would perceive the left image to be the text box, and the right hand image to be the button.

Fortunately all graphical user interfaces assume a light source at the top left hand corner of the screen. Therefore, any image or icon you create on the screen should have its top and left edge drawn in a lighter colour if it is to be perceived as a raised object. All recessed images should have their top and left edges drawn in a darker colour.

Look at the buttons at the top of this browser and you will see that the top and left edges are drawn in a lighter colour than the rest of the button.

Activity 8

Draw three-dimensional versions of the following symbols – make the first raised and the second recessed.

A discussion on this activity can be found at the end of the chapter.

Culture

One consideration to bear in mind is that our perceptual systems are shaped by the culture in which we grow up. Therefore, if you are creating an interface for a different culture than your own, it is well worth investigating cultural differences between you and the target user group. Culture can affect both constructivist and ecological perception, as seen in the following examples.

Affordances between cultures can also become confused. Work from anthropologists reveals many anecdotes such as the tribe which when first were presented with spoons used the bowl of the spoon to grasp and scooped with the handle.

So, if you are designing an interface for a culture other than your own, spend some time learning how their culture may have influenced their visual perception systems.

Activity 9

Although not strictly a perception problem, there are strong cultural reasons why the most used menu (usually the "File" menu) is in the top left corner of the screen. Why is this and how would you change the interface for a user who is from China?

A discussion on this activity can be found at the end of the chapter.

Discussion Topics

How do you think we see? Do you think that the constructivist and ecological approaches fully describe all the aspects of the human perceptual system? Think about the following issues:

Can you think of any visual effect, which is not adequately described by the two theories we have looked at? What are the biggest strengths and weaknesses of each theory? Do you think that the theories are mutually exclusive, or can you use on theory in some instances and the other theory at other times? What do you think about affordances – it is really an ecological phenomenon, or is there some constructivism at play? What do you think of the constructivist's assertion that babies see in a completely different way to adults?

Answers and Discussions

Answer to Review Question 1

To understand what processes our brain uses to understand and store the input (symbols) it receives.

Answer to Review Question 2

By understanding how our brain processes information, we can design interfaces, which exploit the strengths of how our brain works.

Answer to Review Question 3

Context gives meaning to a symbol. Without context, symbols such as the box with a cross in it can be ambiguous. Context can remove that ambiguity.

Answer to Review Question 4

A gestalt is a recognisable form; a standard object which our perceptual system can readily identify. Examples range from geometric shapes, through to more complex common structures, like wineglasses.

Answer to Review Question 5

Proximity, Similarity, Continuity, Closure

Answer to Review Question 6

Moire effects arrive from the perception of movement, a shimmering, in lines that are grouped too closely together. Essentially it tells us that we cannot trust our visual perception – patently the page is not moving but yet we see movement.

Answer to Review Question 7

Popping is the sudden appearing and disappearing of detail as you move around in virtual reality. This is at odds with optic flow, which says that detail changes in a smooth way, as our eyes are able to detect gradually more and less information.

Answer to Review Question 8

Constructivists say that we only perceive images once our brain has worked on them. Ecologists say that a scene is perceived as soon as the light from that scene is received by our eyes.

Answer to Review Question 9

Ecologists tell us that affordances are acted on without processing by the brain. Therefore humans will attempt to push this door before our brain has a chance to process the word “Pull” on the handle and tell our conscious selves to pull instead of push.

Discussion on Activity 1

One group of symbols which have different meanings are arrows. For instance the back arrow can mean “scroll left” or “Undo” or “Go back to previous Web page” depending on context. Actions tend to be more ambiguous than nouns as nouns refer to concrete static objects whilst actions describe transformations to nouns which happen over time – this could be solved by providing animated icons.

Discussion on Activity 2

No answer is possible to provide here as it relies entirely on how you perceive the Web.

Discussion on Activity 3

The triangles represent bleach. The crossed out triangle obviously means no bleach.

The squares are the tumble dryers. The dots in the centre of the squares represent the heat at which the garment may be dried – three dots being the hottest.

The third row of symbols represents ironing. Again, the dots represent the heat of the iron.

Finally, the last row represents how the garment should be washed. Dots denote temperature and a hand in the bucket would indicate hand wash only.

These symbols would be more effective if laundry equipment (e.g. irons and washing machines) used the same symbols so that the user need not even understand the meaning of the symbol. This is the best solution as you will discover when you try to design alternatives that they will most likely only make sense to you. If you sell garments worldwide, symbols will inevitably be miss-interpreted.

Discussion on Activity 4

Possibly. It may be possible to better separate the water line from the hand line. However, our perceptual system, using the gestalt laws allows us to group the water and the hand separately, so they are not confused.

Discussion on Activity 5

Simply remove the horizontal lines (apart from the X-axis) and the right-most vertical line. You may want to replace the horizontal lines with lines drawn in light grey rather than remove them altogether in order to improve accuracy of reading the Y-axis (if this is important).

Discussion on Activity 6

In the first dialog box, light grey lines are used to enforce grouping. Proximity is therefore used to group functions, which have a similar task, or work on the same object (file, clipboard etc.) Shape similarity is also used for the table tool. Word allows the insertion of a Word table or an Excel table. The icons are identical, except the Excel table has the Excel logo placed on it.

In the second dialog box, all the functions act on the image. Shape is used to show similarity between the picture function buttons and functions (e.g. the OUT and IN options). In this case the colour of the buttons is purely aesthetic.

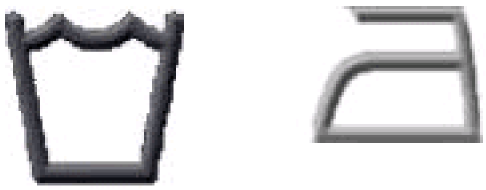
Discussion on Activity 7

The usual affordance is underlined text in blue. Sometime web pages contain underlined text, which is not a link – this is a poor affordance. Also, web page authors change text colour so that you cannot be sure blue text is a link – again, a bad affordance.

Pictures which link are also confusing as picture which are not links look identical to pictures which are links. One way to improve affordance is to use “roll-overs.” Rollovers are images which change when the mouse rolls-over them.

Of course, if all else fails, look at the mouse pointer. When it is an arrow, there is no link. When it is a little hand, the object under the pointer is a hyperlink.

Discussion on Activity 8



Discussion on Activity 9

The menu is here as people in western culture start reading from the top left hand corner and proceed across the top until moving on to the next line. Someone from China on the other hand, reads in columns, so it might be more sensible to put the menu down the left edge of the screen.