Chapter 7

INTERFACES

Objectives

The main goals of the chapter are to accomplish the following:

- Provide an overview of the many different kinds of interfaces.
- Highlight the main design and research considerations for each of the interfaces.
- Discuss what is meant by a natural user interface (NUI).
- Consider which interface is best for a given application or activity.

7.1 Introduction

When considering how to solve a user problem, the default solution that many developers choose to design is an app that can run on a smartphone. Making this easier still are many easy-to-use app developer tools that can be freely downloaded. It is hardly surprising, therefore, to see just how many apps there are in the world. In December 2018, Apple, for example, had a staggering 2 million apps in its store, many of which were games.

Despite the ubiquity of the smartphone app industry, the web continues to proliferate in offering services, content, resources, and information. A central concern is how to design them to be interoperable across different devices and browsers, which takes into account the varying form factors, size, and shape of smart watches, smartphones, laptops, smart TVs, and computer screens. Besides the app and the web, many other kinds of interfaces have been developed, including voice interfaces, touch interfaces, gesture interfaces, and multimodal interfaces.

The proliferation of technological developments has encouraged different ways of thinking about interaction design and UX. For example, input can be via mice, touchpads, pens, remote controllers, joysticks, RFID readers, gestures, and even brain-computer interaction. Output is equally diverse, appearing in the form of graphical interfaces, speech, mixed realities, augmented realities, tangible interfaces, wearable computing, and more.

The goal of this chapter is to give you an overview of the diversity of interfaces that can be developed for different environments, people, places, and activities. We present a catalog of 20 interface types, starting with command-based and ending with smart ones. For each interface, we present an overview and outline the key research and design considerations. Some are only briefly touched upon, while others, which are more established in interaction design, are described in greater depth.

NOTE
This chapter is not meant to be read from beginning to end; rather, it should be dipped into as needed to find out about a particular type of interface.

7.2 Interface Types

Numerous adjectives have been used to describe the different types of interfaces that have been developed, including *graphical*, *command*, *speech*, *multimodal*, *invisible*, *ambient*, *affective*, *mobile*, *intelligent*, *adaptive*, *smart*, *tangible*, *touchless*, and *natural*. Some of the interface types are primarily concerned with a function (for example, to be intelligent, to be adaptive, to be ambient, or to be smart), while others focus on the interaction style used (such as command, graphical, or multimedia), the input/output device used (for instance, pen-based, speech-based, or gesture-based), or the platform being designed for (for example, tablet, mobile, PC, or wearable). Rather than cover every possible type that has been developed or described, we have chosen to select the main types of interfaces that have emerged over the past 40 years. The interface types are loosely ordered in terms of when they were developed. They are numbered to make it easier to find a particular one. (See the following list for the complete set.) It should be noted, however, that this classification is for convenience of reference. The interface entries are not mutually exclusive since some products can appear in two or more categories. For example, a smartphone can be considered to be mobile, touch, or wearable.

The types of interfaces covered in this chapter include the following:

1. Command
2. Graphical
3. Multimedia
4. Virtual reality
5. Web
6. Mobile
7. Appliance
8. Voice
9. Pen
10. Touch
11. Gesture
12. Haptic
13. Multimodal
14. Shareable

15. Tangible
16. Augmented reality
17. Wearables
18. Robots and drones
19. Brain-computer interaction
20. Smart

Here is a selection of classic HCI videos on the Internet that demonstrate pioneering interfaces:

The Sketchpad: Ivan Sutherland (1963) describes the first interactive graphical interface: **https://youtu.be/6orsmFndx_o**.

The Mother of All Demos: Douglas Engelbart (1968) describes the first WIMP: **http://youtu.be/yJDv-zdhzMY**.

Put that there (1979): MIT demonstrates the first speech and gesture interface: **https://youtu.be/RyBEUyEtxQo**.

Unveiling the genius of multitouch interface design: Jeff Han gives a TED talk (2007): **http://youtu.be/ac0E6deG4AU**.

Intel's Future Technology Vision (2012): See **http://youtu.be/g_cauM3kccI**.

7.2.1 Command-Line Interfaces

Early interfaces required the user to type in commands that were typically abbreviations (for example, ls) at the prompt symbol appearing on the computer display, to which the system responded (for example, by listing current files). Another way of issuing commands is by pressing certain combinations of keys (such as Shift+Alt+Ctrl). Some commands are also a fixed part of the keyboard, such as delete, enter, and undo, while other function keys can be programmed by the user as specific commands (for instance, F11 commanding print action).

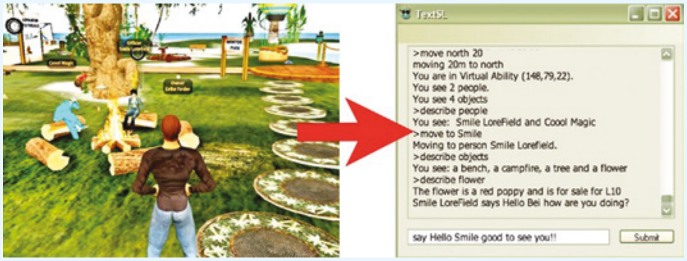
Command-line interfaces were largely superseded by graphical interfaces that incorporated commands such as menus, icons, keyboard shortcuts, and pop-up/predictable text commands as part of an application. Where command-line interfaces continue to have an advantage is when users find them easier and faster to use than equivalent menu-based systems (Raskin, 2000). Users also prefer command-line interfaces for performing certain operations as part of a complex software package, such as for CAD environments (such as Rhino3D and AutoCAD), to allow expert designers to interact rapidly and precisely with the software. They also provide scripting for batch operations, and they are being increasingly used on the web, where the search bar acts as a general-purpose command-line facility, for example, www.yubnub.org.

System administrators, programmers, and power users often find that it is much more efficient and quicker to use command languages such as Microsoft's PowerShell. For example, it is much easier to delete 10,000 files in one go by using one command rather than scrolling through that number of files and highlighting those that need to be deleted. Command languages have also been developed for visually impaired people to allow them to interact in virtual worlds, such as Second Life (see Box 7.1).

BOX 7.1

Command Interfaces for Virtual Worlds

Virtual worlds, such as Second Life, have become popular places for learning and socializing. Unfortunately, people who are visually impaired cannot interact in a visual capacity. A command-based interface, called TextSL, was developed to enable them to participate using a screen reader (Folmer et al., 2009). Commands can be issued to enable the user to move their avatar around, interact with others, and find out about the environment in which they are located. Figure 7.1 shows that the user has issued the command for their avatar to smile and say hello to other avatars who are sitting by a log fire.



```
>move north 20
moving 20m to north
You are in Virtual Ability (148,79,22).
You see 2 people.
You see 4 objects
>describe people
You see:  Smile LoreField and Coool Magic
>move to Smile
Moving to person Smile Lorefield.
>describe objects
You see: a bench, a campfire, a tree and a flower
>describe flower
The flower is a red poppy and is for sale for L10
Smile LoreField says Hello Bei how are you doing?
```

```
say Hello Smile good to see you!!
```

Figure 7.1 Second Life command-based interface for visually impaired users

Source: Used courtesy of Eelke Folmer ■

Watch a video demonstration of TextSL at **http://youtu.be/0Ba_w7u44MM**.

Research and Design Considerations

In the 1980s, much research investigated ways of optimizing command interfaces. The form of the commands (including use of abbreviations, full names, and familiar names), syntax (such as how best to combine different commands), and organization (for instance, how to structure options) are examples of some of the main areas that have been investigated (Shneiderman, 1998). A further concern was which command names would be the easiest to remember. A number of variables were tested, including how familiar users were with the chosen names. Findings from a number of studies, however, were inconclusive; some found specific names were better remembered than general ones (Barnard et al., 1982), others showed that names selected by users themselves were preferable (see Ledgard et al., 1981; Scapin, 1981), while yet others demonstrated that high-frequency words were better remembered than low-frequency ones (Gunther et al., 1986).

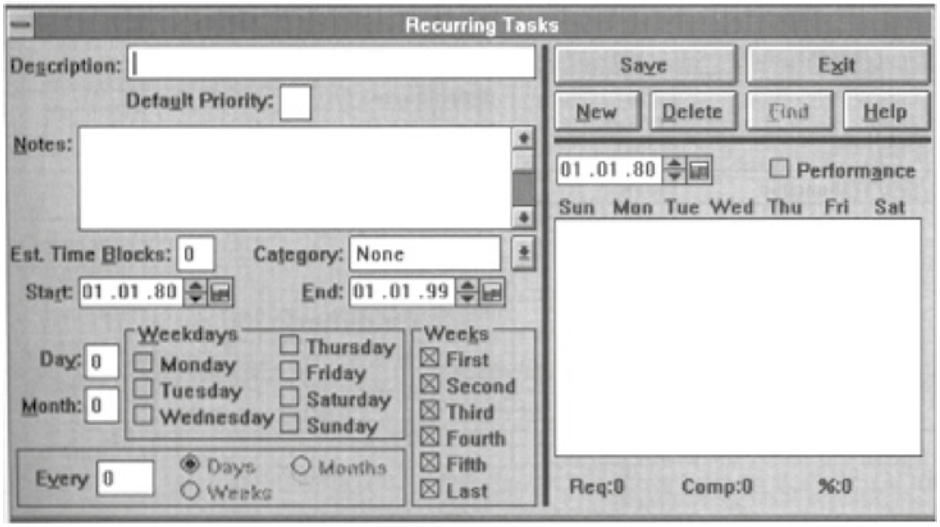
The most relevant design principle is consistency (see Chapter 1, "What Is Interaction Design?"). Therefore, the method used for labeling/naming the commands should be chosen to be as consistent as possible; for example, always use the first letters of the operation when using abbreviations.

7.2.2 Graphical User Interfaces

The Xerox Star interface (described in Chapter 3, "Conceptualizing Interaction") led to the birth of the graphical user interface (GUI), opening up new possibilities for users to interact with a system and for information to be presented and represented within a graphical interface. Specifically, new ways of visually designing the interface became possible, which included the use of color, typography, and imagery (Mullet and Sano, 1995). The original GUI was called a WIMP (windows, icons, menus, pointer) and consisted of the following:

- *Windows*: Sections of the screen that can be scrolled, stretched, overlapped, opened, closed, and moved using a mouse
- *Icons*: Pictograms that represent applications, objects, commands, and tools that are opened or activated when clicked on
- *Menus*: Lists of options that can be scrolled through and selected in the way a menu is used in a restaurant
- *Pointing device*: A mouse controlling the cursor as a point of entry to the windows, menus, and icons on the screen

The first generation of WIMP interfaces were primarily boxy in design; user interaction took place through a combination of windows, scroll bars, checkboxes, panels, palettes, and dialog boxes that appeared on the screen in various forms (see Figure 7.2). Developers were largely constrained by the set of widgets available to them, of which the dialog box was most prominent. (A widget is a standardized display representation of a control, like a button or scroll bar, that can be manipulated by the user.) Nowadays, GUIs have been adapted for mobile and touchscreens. Instead of using a mouse and keyboard as input, the default action for most users is to swipe and touch using a single finger when browsing and interacting with digital content. (For more on this subject, see the sections on touch and mobile interfaces.)



Recurring Tasks

Description:

Default Priority:

Notes:

Est. Time Blocks: 0 Category: None

Start: 01 .01 .80 End: 01 .01 .99

Day: 0

Month: 0

Weekdays: □ Monday □ Tuesday □ Wednesday □ Thursday □ Friday □ Saturday □ Sunday

Weeks: ☒ First ☒ Second ☒ Third ☒ Fourth ☒ Fifth ☒ Last

Every 0 ● Days ○ Weeks ○ Months

01 .01 .80 □ Performance

Sun Mon Tue Wed Thu Fri Sat

Req:0 Comp:0 %:0

Figure 7.2 The boxy look of the first generation of GUIs

The basic building blocks of the WIMP are still part of the modern GUI used as part of a display, but they have evolved into a number of different forms and types. For example, there are now many different types of icons and menus, including audio icons and audio menus, 3D animated icons, and even tiny icon-based menus that can fit onto a smartwatch screen (see Figure 7.3). Windows have also greatly expanded in terms of how they are used and what they are used for; for example, a variety of dialog boxes, interactive forms, and feedback/error message boxes have become pervasive. In addition, a number of graphical elements that were not part of the WIMP interface have been incorporated into the GUI. These include toolbars and docks (a row or column of available applications and icons of other objects such as open files) and rollovers (where text labels appear next to an icon or part of the screen as the cursor is rolled over it). Here, we give an overview of the design considerations concerning the basic building blocks of the WIMP/GUI: windows, menus, and icons.

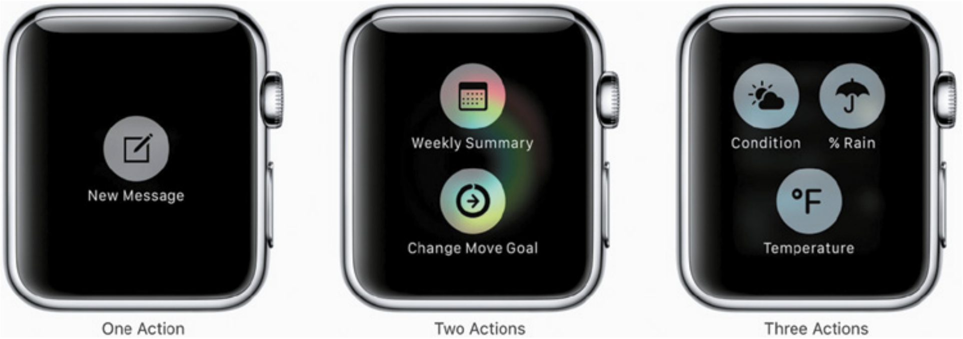


Figure 7.3 Simple smartwatch menus with one, two, or three options

Source: https://developer.apple.com/design/human-interface-guidelines/watchos/interface-elements/menus/

Window Design

Windows were invented to overcome the physical constraints of a computer display, enabling more information to be viewed and tasks to be performed on the same screen. Multiple windows can be opened at any one time, for example, web browsers, word processing documents, photos, and slideshows, enabling the user to switch between them when needing to look at or work on different documents, files, and apps. They can also enable multiple instances of one app to be opened, such as when using a web browser.

Scrolling bars within windows also enable more information to be viewed than is possible on one screen. Scroll bars can be placed vertically and horizontally in windows to enable upward, downward, and sideway movements through a document and can be controlled using a touchpad, mouse, or arrow keys. Touch interfaces enable users to scroll content simply by swiping the screen to the left or right or up or down.

One of the problems of having multiple windows open is that it can be difficult to find specific ones. Various techniques have been developed to help users locate a particular window, a common one being to provide a list as part of an app menu. macOS also provides a function that shrinks all windows that are open for a given application so that they can be seen side by side on one screen. The user needs only to press one function key and then move the cursor over each one to see what they are called in addition to a visual preview. This technique enables users to see at a glance what they have in their workspace, and it also allows them easily to select one to bring forward. Another option is to display all of the windows open for a particular application, for example, Microsoft Word. Web browsers, like Firefox, also show thumbnails of the top sites visited and a selection of sites that you have saved or visited, which are called *highlights* (see Figure 7.4).

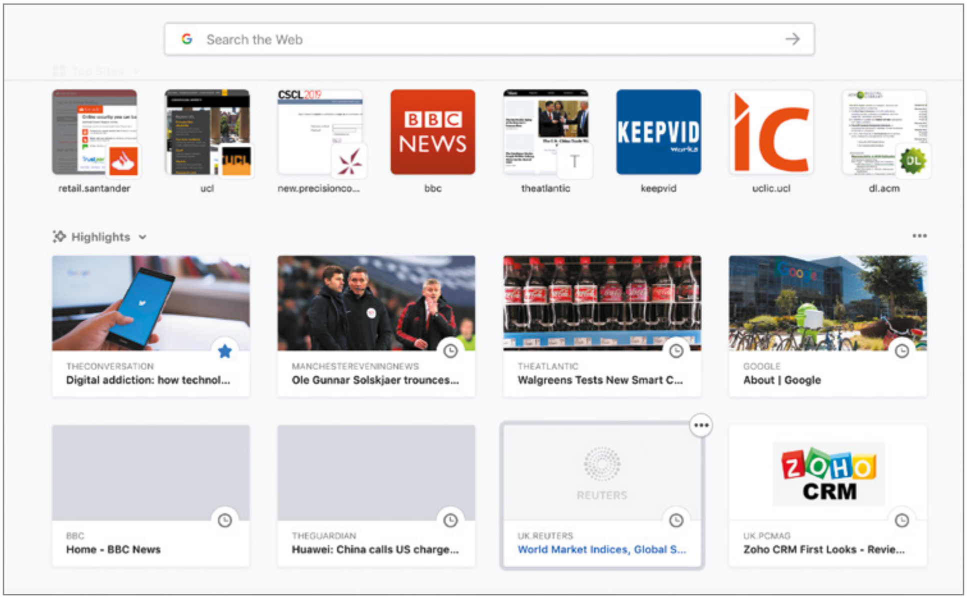


Figure 7.4 Part of the home page for the Firefox browser showing thumbnails of top sites visited and suggested highlight pages (bottom rows)

A particular kind of window that is commonly used is the *dialog box*. Confirmations, error messages, checklists, and forms are presented through dialog boxes. Information in the dialog boxes is often designed to guide user interaction, with the user following the sequence of options provided. Examples include a sequenced series of forms (such as Wizards) presenting the necessary and optional choices that need to be filled in when choosing a PowerPoint presentation or an Excel spreadsheet. The downside of this style of interaction is that there is a tendency to cram too much information or data entry fields into one box, making the interface confusing, crowded, and difficult to read (Mullet and Sano, 1995).

BOX 7.2

The Joys of Filling In Forms on the Web

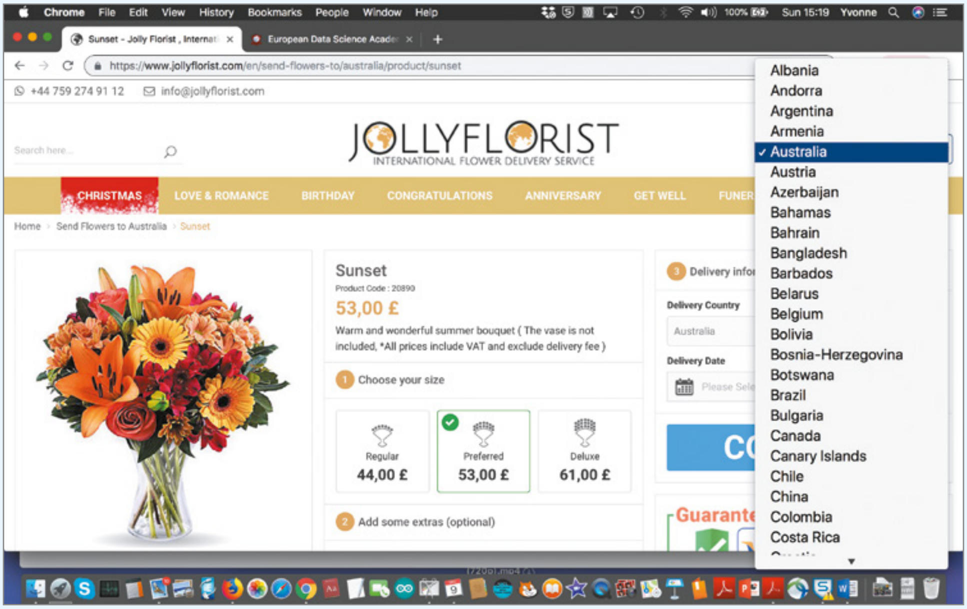
For many of us, shopping on the Internet is generally an enjoyable experience. For example, choosing a book on Amazon or flowers from Interflora can be done at our leisure and convenience. The part that we don't enjoy, however, is filling in the online form to give the company the necessary details to pay for the selected items. This can often be a frustrating and time-consuming experience, especially as there is much variability between sites. Sometimes, it requires users to create an account and a new password. At other times, guest checkout is enabled. However, if the site has a record of your email address in its database, it won't allow you to use the guest option. If you have forgotten your password, you need to reset it, and this requires switching from the form to your email account. Once past this hurdle, different kinds of interactive forms pop up for you to enter your mailing address and credit card details. The form may provide the option of finding your address by allowing you to enter a postal or ZIP code. It may also have asterisks that denote fields that must be filled in.

Having so much inconsistency can frustrate the user, as they are unable to use the same mental model for filling in checkout forms. It is easy to overlook or miss a box that needs to be filled in, and after submitting the page, an error message may come back from the system saying it is incomplete. This may require the user to have to enter sensitive information again, as it will have been removed in the data processing stage (for example, the user's credit card number and the three or four-digit security code on the back or front of the card, respectively).

To add to the frustration, many online forms often accept only fixed data formats, meaning that, for some people whose information does not fit within its constraints, they are unable to complete the form. For example, one kind of form will accept only a certain type of mailing address format. The boxes are provided for: address line 1 and address line 2, providing no extra lines for addresses that have more than two lines; a line for the town/city; and a line for the ZIP code (if the site is based in the United States) or other postal code (if based in another country). The format for the codes is different, making it difficult for non-U.S. residents (and U.S. residents for other country sites) to fill in this part.

Another gripe about online registration forms is the country of residence box that opens up as a never-ending menu, listing all of the countries in the world in alphabetical order. Instead of typing in the country in which they reside, users are required to select the one they are from, which is fine if you happen to live in Australia or Austria but not if you live in Venezuela or Zambia (see Figure 7.5).

This is an example of where the design principle of recognition over recall (see Chapter 4, "Cognitive Aspects") does not apply and where the converse is true. A better design is to have a predictive text option, where users need only to type in the first one or two letters of their country to cause a narrowed-down list of choices to appear from which they can select within the interface. Or, one smart option is for the form to preselect the user's country of origin by using information shared from the user's computer or stored in the cloud. Automating the filling in of online forms, through providing prestored information about a user (for example, their address and credit card details), can obviously help reduce usability problems—provided they are OK with this.



+44 759 274 91 12 info@jollyflorist.com

Sunset

Product Code : 20890

53,00 £

Warm and wonderful summer bouquet (The vase is not included, *All prices include VAT and exclude delivery fee)

1 Choose your size

Regular	Preferred	Deluxe
44,00 £	✓ 53,00 £	61,00 £

2 Add some extras (optional)

3 Delivery infor

Delivery Country: Australia

Delivery Date: Please Sel

Figure 7.5 A scrolling menu of country names

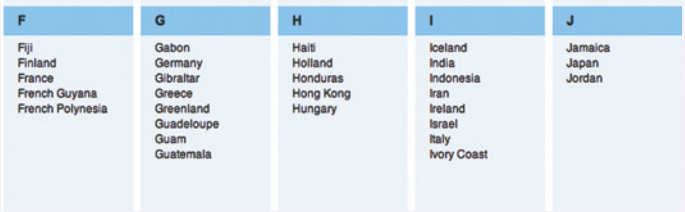
Source: https://www.jollyflorist.com ■

ACTIVITY 7.1

Go to the Interflora site in the United Kingdom, click the international delivery option, and then click "select a country." How are the countries ordered? Is it an improvement over the scrolling pop-up menu?

Comment

Earlier versions of the full list of countries to which flowers could be sent by interflora.co.uk listed eight countries at the top, starting with the United Kingdom and then the United States, France, Germany, Italy, Switzerland, Austria, and Spain. This was followed by the remaining set of countries listed in alphabetical order. The reason for having this particular ordering is likely to have been because the top eight are the countries that have most customers, with the U.K. residents using the service the most. The website has changed now to show top countries by national flag followed by a table format, grouping all of the countries in alphabetical order using four columns across the page (see Figure 7.6). Do you think this is an improvement over the use of a single scrolling list of country names shown in Figure 7.5? The use of letter headings and shading makes searching quicker.



F

Fiji
Finland
France
French Guyana
French Polynesia

G

Gabon
Germany
Gibraltar
Greece
Greenland
Guadeloupe
Guam
Guatemala

H

Haiti
Holland
Honduras
Hong Kong
Hungary

I

Iceland
India
Indonesia
Iran
Ireland
Israel
Italy
Ivory Coast

J

Jamaica
Japan
Jordan

Figure 7.6 An excerpt of the listing of countries in alphabetical order from interflora.co.uk

Source: https://www.interflora.co.uk ■

Research and Design Considerations

A key research concern is *window management*—finding ways of enabling users to move fluidly between different windows (and displays) and to be able to switch their attention rapidly between windows to find the information they need or to work on the document/task within each window without getting distracted. Studies of how people use windows and multiple displays have shown that *window activation time* (that is, the time a window is open and with which the user interacts with it) is relatively short—an average of 20 seconds—suggesting that people switch frequently between different documents and applications (Hutchings et al., 2004). Widgets like the taskbar are often used for switching between windows.

Another technique is the use of tabs that appear at the top of the web browser that show the name and logo of the web pages that have been visited. This mechanism enables users to rapidly scan and switch among the web pages they have visited. However, the tabs can quickly multiply if a user visits a number of sites. To accommodate new ones, the web browser reduces the size of the tabs by shortening the information that appears on each. The downside of doing this, however, is it can make it more difficult to read and recognize web pages when looking at the smaller tabs. It is possible to reverse this shrinking by removing unwanted tabs by clicking the delete icon for each one. This has the effect of making more space available for the remaining tabs.

There are multiple ways that an online form can be designed to obtain details from someone. It is not surprising, therefore, that there are so many different types that are in use. Design guidelines are available to help decide which format and widgets are best to use. For example, see https://www.smashingmagazine.com/printed-books/form-design-patterns/. Another option is to automate form completion by asking the user to store their personal details on their machine or in a company's database, requiring them only to enter security information. However, many people are becoming leery of storing their personal data in this way—fearful because of the number of data breaches that are often reported in the news.

Menu Design

Interface menus are typically ordered across the top row or down the side of a screen using category headers as part of a menu bar. The contents of the menus are also for the large part invisible, only dropping down when the header is selected or rolled over with a mouse.

The various options under each menu are typically ordered from top to bottom in terms of most frequently used options and grouped in terms of their similarity with one another; for example, all formatting commands are placed together.

There are numerous menu interface styles, including flat lists, drop-down, pop-up, contextual, collapsible, mega, and expanding ones, such as cascading menus. *Flat menus* are good at displaying a small number of options at the same time or where the size of the display is small, for example on smartphones, cameras, and smartwatches. However, they often have to nest the lists of options within each, requiring several steps to be taken by a user to get to the list with the desired option. Once deep down in a nested menu, the user then has to take the same number of steps to get back to the top of the menu. Moving through previous screens can be tedious.

Expanding menus enable more options to be shown on a single screen than is possible with a single flat menu list. This makes navigation more flexible, allowing for the selection of options to be done in the same window. An example is the *cascading menu*, which provides secondary and even tertiary menus to appear alongside the primary active drop-down menu, enabling further related options to be selected, such as when selecting track changes from the tools menu leads to a secondary menu of three options by which to track changes in a Word document. The downside of using expanding menus, however, is that they require precise control. Users can often end up making errors, namely, overshooting or selecting the wrong options. In particular, cascading menus require users to move their cursor over the menu item, while holding the mouse or touchpad down, and then to move their cursor over to the next menu list when the cascading menu appears and select the next desired option. This can result in the user under or overshooting a menu option, or sometimes accidentally closing the entire menu. Another example of an expandable menu is a *mega menu*, in which many options can be displayed using a 2D drop-down layout (see Figure 7.7). This type of menu is popular with online shopping sites, where lots of items can be viewed at a glance on the same screen without the need to scroll. Hovering, tapping, or clicking is used to reveal more details for a selected item.

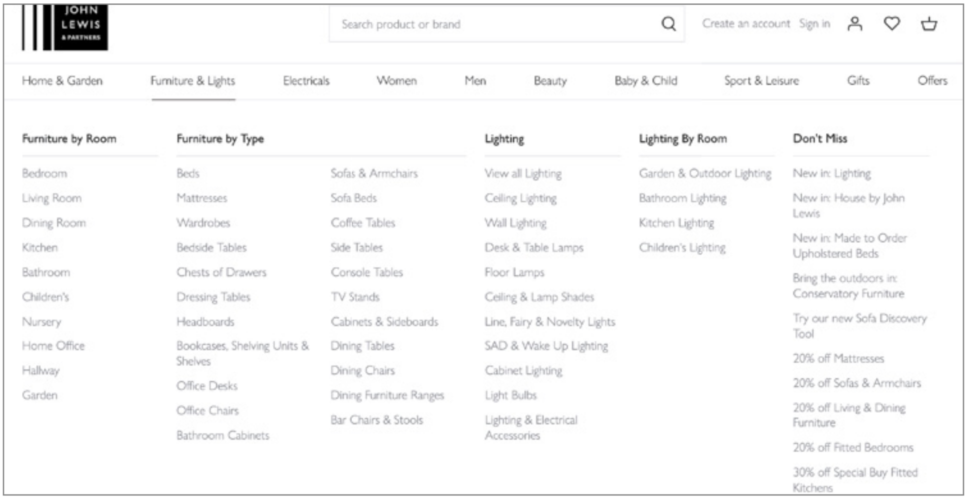


Figure 7.7 A mega menu

Source: https://www.johnlewis.com

Collapsible menus provide an alternative approach to expanding menus in that they allow further options to be made visible by selecting a header. The headings appear adjacent to each other, providing the user with an overview of the content available (see Figure 7.8). This reduces the amount of scrolling needed. *Contextual menus* provide access to often-used commands associated with a particular item, for example, an icon. They provide appropriate commands that make sense in the context of a current task. They appear when the user presses the Control key while clicking an interface element. For example, clicking a photo on a website together with holding down the Ctrl key results in a small set of relevant menu options appearing in an overlapping window, such as open it in a new window, save it, or copy it. The advantage of contextual menus is that they provide a limited number of options associated with an interface element, overcoming some of the navigation problems associated with cascading and expanding menus.

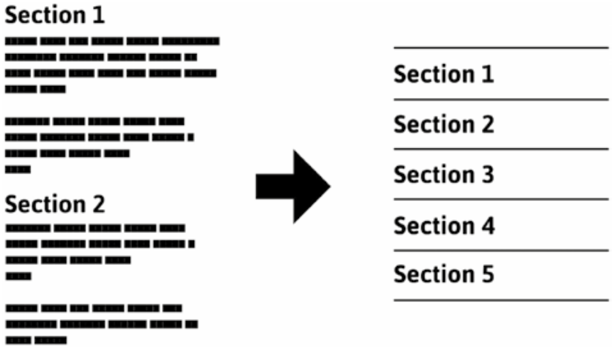


Figure 7.8 A template for a collapsible menu

Source: https://inclusive-components.design/collapsible-sections/. Reproduced with permission of Smashing Magazine

ACTIVITY 7.2

Open an application that you use frequently (for instance, a word processor, email client, or web browser) on a PC/laptop or tablet and look at the menu header names (but do not open them just yet). For each menu header—File, Edit, Tools, and so on—write down what options you think are listed under each. Then look at the contents under each header. How many options were you able to remember, and how many did you put in the wrong category? Now try to select the correct menu header for the following options (assuming that they are included in the application): Replace, Save, Spelling, and Sort. Did you select the correct header each time, or did you have to browse through a number of them?

Comment

Popular everyday applications, like word processors, have grown enormously in terms of the functions they offer. The current version (2019) of Microsoft Word, for example, has 8 menu headers and numerous toolbars. Under each menu header there are on average 15 options, some of which are hidden under subheadings and appear only when they are rolled over with the mouse. Likewise, for each toolbar, there is a set of tools available, be it for Drawing, Formatting, Web, Table, or Borders. Remembering the location of frequently used commands like Spelling and Replace is often achieved by remembering their spatial location. For infrequently used commands, like sorting a list of references into alphabetical order, users can spend time flicking through the menus to find the command Sort. It is difficult to remember that the command Sort should be under the Table heading, since what it is doing is not a table operation, but a tool to organize a section of a document. It would be more intuitive if the command was under the Tool header along with similar tools like Spelling. What this example illustrates is just how difficult it can be to group menu options into clearly defined and obvious categories. Some fit into several categories, while it can be difficult to group others. The placement of options in menus can also change between different versions of an application as more functions are added. ■

Research and Design Considerations

An important design consideration is to decide which terms to use for menu options. Short phrases like "bring all to front" can be more informative than single words like "front." However, the space for listing menu items is often restricted, such that menu names need to be short. They also need to be distinguishable, that is, not easily confused with one another so that the user does not choose the wrong one by mistake. Operations such as Quit and Save should also be clearly separated to avoid the accidental loss of work.

The choice of which type of menu to use will often be determined by the application and type of device for which is being designed. Which is best will also depend on the number of menu options and the size of the display available in which to present them. Flat menus are best for displaying a small number of options at one time, while expanding and collapsible menus are good for showing a large number of options, such as those available in file and document creation/editing applications. Usability testing comparing drop-down menus with mega menus has shown the latter to be more effective and easier to navigate. The main reason is that megamenus enable users to readily scan many items at a glance on the same page, and in doing so find what they are looking for (Nielsen and Li, 2017).

Icon Design

The appearance of icons in an interface came about following the Xerox Star project. They were used to represent objects as part of the desktop metaphor, namely, folders, documents, trashcans, inboxes, and outboxes. The assumption behind using icons instead of text labels is that they are easier to learn and remember, especially for non-expert computer users. They can also be designed to be compact and variably positioned on a screen.

Icons have become a pervasive feature of the interface. They now populate every app and operating system and are used for all manner of functions besides representing desktop objects. These include depicting tools (for example, Paint 3D), status (such as, Wi-Fi strength), categories of apps (for instance, health or personal finance), and a diversity of abstract operations (including cut, paste, next, accept, and change). They have also gone through many changes in their look and feel—black and white, color, shadowing, photorealistic images, 3D rendering, and animation have all been used.

Whereas early icon designers were constrained by the graphical display technology of the day, current interface developers have much more flexibility. For example, the use of anti-aliasing techniques enables curves and non-rectilinear lines to be drawn, enabling more photo-illustrative styles to be developed (*anti-aliasing* means adding pixels around a jagged border of an object to smooth its outline visually). App icons are often designed to be both visually attractive and informative. The goal is to make them inviting, emotionally appealing, memorable, and distinctive.

Different graphical genres have been used to group and identify different categories of icons. Figure 7.9 shows how colorful photorealistic images were used in the original Apple Aqua set, each slanting slightly to the left, for the category of *user* applications (such as email) whereas monochrome straight on and simple images were used for the class of *utility* applications (for instance, printer setup). The former has a fun feel to them, whereas the latter has a more serious look about them. While a number of other styles have since been developed, the use of slanting versus straight facing icons to signify different icon categories is still in use.

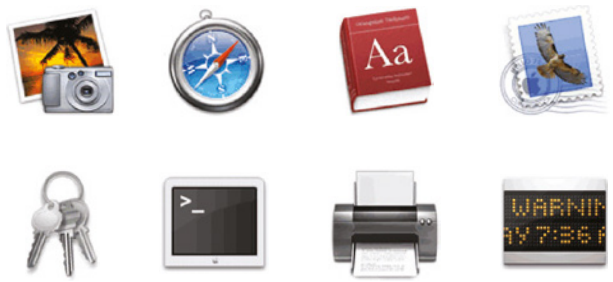


Figure 7.9 Two styles of Apple icons used to represent different kinds of functions

Icons can be designed to represent objects and operations in the interface using concrete objects and/or abstract symbols. The mapping between the icon and underlying object or operation to which it refers can be similar (such as a picture of a file to represent the object file), analogical (for instance, a picture of a pair of scissors to represent cut), or arbitrary (for example, the use of an X to represent delete). The most effective icons are generally those that are isomorphic since they have a direct mapping between what is being represented and how it is represented. Many operations in an interface, however, are of actions to be performed on objects, making it more difficult to represent them using direct mapping. Instead, an effective technique is to use a combination of objects and symbols that capture the salient part of an action by using analogy, association, or convention (Rogers, 1989). For example, using a picture of a pair of scissors to represent cut in a word-processing application provides a sufficient clue as long as the user understands the convention of cut for deleting text.

Another approach that many smartphone designers use is flat 2D icons. These are simple and use strong colors and pictograms or symbols. The effect is to make them easily recognizable and distinctive. Examples shown in Figure 7.10a include the white ghost on a yellow background (Snapchat), a white line bubble with a solid white phone handset in a speech bubble on a lime-green background (WhatsApp), and the sun next to a cloud (weather).

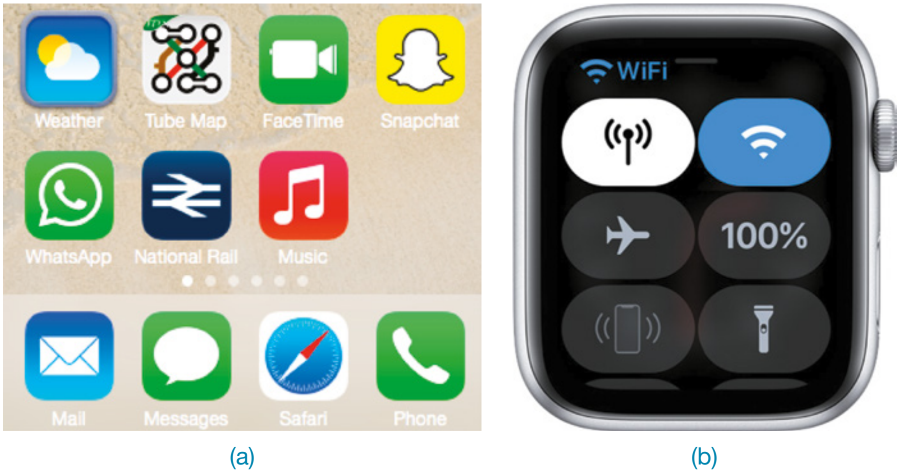


Figure 7.10 2D icons designed for (a) a smartphone and (b) a smartwatch

Source: (a) Helen Sharp (b) https://support.apple.com/en-ca/HT205550

Icons that appear on toolbars or palettes as part of an application or presented on small device displays (such as digital cameras or smartwatches) have much less screen real estate available. Because of this, they have been designed to be simple, emphasizing the outline form of an object or symbol and using only grayscale or one or two colors (see Figure 7.10b). They tend to convey the status, tool, or action using a concrete object (for example, the airplane symbol signaling whether the airplane mode is on or off) and abstract symbols (such as three waves that light up from none to all to convey the strength/power of the area's Wi-Fi).

ACTIVITY 7.3

Sketch simple icons to represent the following operations to appear on a digital camera screen:

- Turn image 90-degrees sideways.
- Crop the image.
- Auto-enhance the image.
- More options.

Show them to someone else, tell them that they are icons for a new digital camera intended to be really simple to use, and see whether they can understand what each represents.

Comment

Figure 7.11 shows the basic Edit Photo icons on an iPhone that appear at the bottom of the screen when a user selects the edit function. The box with extended lines and two arrows is the icon for cropping an image; the three overlapping translucent circles represents "different lenses" that can be used, the wand in the top-right corner means "auto-enhance," and the circle with three dots in it means more functions.

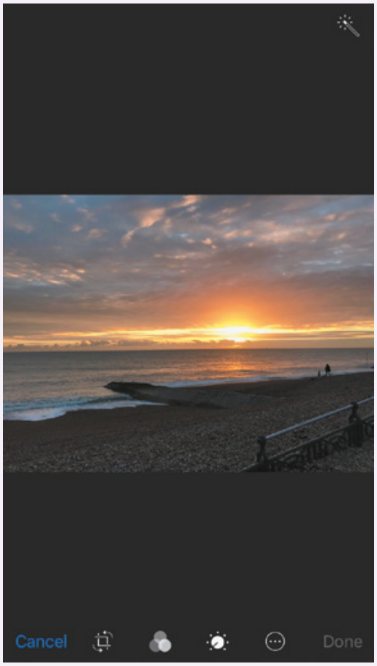


Figure 7.11 The basic Edit Photo icons that appear at the top and bottom of an iPhone display ■

Research and Design Considerations

There are many icon libraries available that developers can download for free (for instance, https://thenounproject.com/ or https://fontawesome.com/). Various online tutorials and books on how to design icons are also available (see Hicks, 2012) together with sets of proprietary guidelines and style guides. For example, Apple provides its developers with style guides, explaining why certain designs are preferable to others and how to design icon sets. Style guides are also covered in more depth in Chapter 13, “Interaction Design in Practice.” On its developers’ website (developer.apple.com), advice is given on how and why certain graphical elements should be used when developing different types of icon. Among the various guidelines, it suggests that different categories of application (for example, Business, Utilities, Entertainment, and so on) should be represented by a different genre, and it recommends displaying a tool to communicate the nature of a task, such as a magnifying glass for searching or a camera for a photo editing tool. Android and Microsoft also provide extensive guidance and step-by-step procedures on how to design icons for its applications on its website.

To help disambiguate the meaning of icons, text labels can be used under, above, or to the side of their icons. This method is effective for toolbars that have small icon sets, such as those appearing as part of a web browser, but it is not as good for applications that have large icon sets, for example, photo editing or word processing, since the screen can get cluttered making it sometimes harder and longer to find an icon. To prevent text/icon clutter on the interface, a hover function can be used where a text label appears adjacent to or above an icon after the user holds the cursor over it for a second and for as long as the user keeps the cursor on it. This method allows identifying information to be temporarily displayed when needed.

7.2.3 Multimedia

Multimedia, as the name implies, combines different media within a single interface, namely, graphics, text, video, sound, and animation, and links them together with various forms of interactivity. Users can click links in an image or text that triggers another media such as an animation or a video. From there they can return to where they were previously or jump to another media source. The assumption is that a combination of media and interactivity can provide better ways of presenting information than can a single media, for example, just text or video alone. The added value of multimedia is that it can be easier for learning, better for understanding, more engaging, and more pleasant (Scaife and Rogers, 1996).

Another distinctive feature of multimedia is its ability to facilitate rapid access to multiple representations of information. Many multimedia encyclopedias and digital libraries have been designed based on this multiplicity principle, providing an assortment of audio and visual materials on a given topic. For example, when looking to find information about the heart, a typical multimedia-based encyclopedia will provide the following:

- One or two video clips of a real live heart pumping and possibly a heart transplant operation
- Audio recordings of the heart beating and perhaps an eminent physician talking about the cause of heart disease
- Static diagrams and animations of the circulatory system, sometimes with narration
- Several columns of hypertext, describing the structure and function of the heart

Hands-on interactive simulations have also been incorporated as part of multimedia learning environments. An early example was the *Cardiac Tutor*, developed to teach students about cardiac resuscitation. It required students to save patients by selecting the correct set of procedures in the correct order from various options displayed on the computer screen (Eliot and Woolf, 1994). Other kinds of multimedia narratives and games have also been developed to support discovery learning by encouraging children to explore different parts of the display by noticing a hotspot or other kind of link. For example, https://KidsDiscover.com/apps/ has many tablet apps that use a combination of animations, photos, interactive 3D models, and audio to teach kids about science and social studies topics. Using swiping and touching, kids can reveal, scroll through, select audio narration, and watch video tours. Figure 7.12, for example, has a "slide" mechanism as part of a tablet interface that enables the child to do a side-by-side comparison of what Roman ruins looks like now and in ancient Roman times.

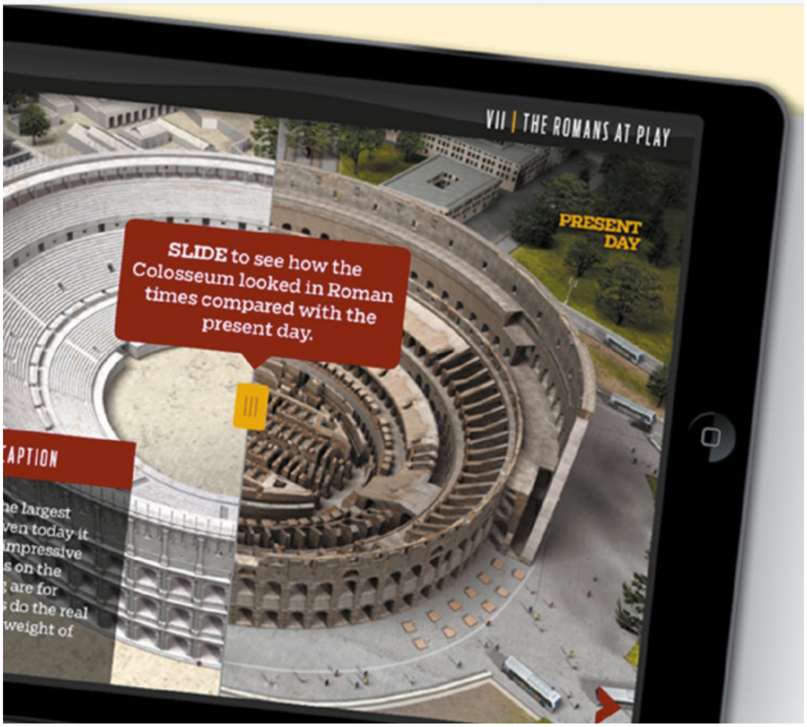


Figure 7.12 An example of a multimedia learning app designed for tablets

Source: KidsDiscover app "Roman Empire for iPad"

Another example of a learning app with an interesting UI can be seen at https://www.abcmouse.com/apps.

Multimedia has largely been developed for training, educational, and entertainment purposes. But to what extent is the assumption that learning (such as reading and scientific inquiry skills) and playing can be enhanced through interacting with engaging multimedia interfaces true? What actually happens when users are given unlimited, easy access to multiple media and simulations? Do they systematically switch between the various media and "read" all of the multiple representations on a particular subject, or are they more selective in what they look at and listen to?

ACTIVITY 7.4

Watch this video of Don Norman appearing in his first multimedia CD-ROM book (1994), where he pops up every now and again in boxes or at the side of the page to illustrate the points being discussed on that page: http://vimeo.com/18687931.

How do you think students used this kind of interactive e-textbook?

Comment

Anyone who has interacted with educational multimedia knows just how tempting it is to play the video clips and animations while skimming through accompanying text or static diagrams. The former is dynamic, easy, and enjoyable to watch, while the latter is viewed as static and difficult to read from the screen. In an evaluation of the original Voyager's "First Person: Donald Norman, Defending Human Attributes in the Age of the Machine," students consistently admitted to ignoring the text on the interface in search of clickable icons of the author, which when selected would present an animated video of him explaining some aspect of design (Rogers and Aldrich, 1996). Given the choice to explore multimedia material in numerous ways, ironically, users tend to be highly selective as to what they actually pay attention to, adopting a channel-hopping mode of interaction. While enabling the users to select the information they want to view or features to explore for themselves, there is the danger that multimedia environments may in fact promote fragmented interactions where only part of the media is ever viewed. In a review of research comparing reading from screens versus paper, Lauren Singer and Patricia Alexandra (2017) found that despite students saying they preferred reading from screens, their actual performance was worse than when using paper-based textbooks.

Hence, online multimedia material may be good for supporting certain kinds of activities, such as browsing, but less optimal for others, for instance reading at length about a topic. One way to encourage more systematic and extensive interactions (when it is considered important for the activity at hand) is to require certain activities to be completed that entail the reading of accompanying text, before the user is allowed to move on to the next level or task. ■

Research and Design Considerations

A core research question is how to encourage users to interact with all aspects of a multimedia app, especially given the tendency to select videos to watch rather than text to read. One technique is to provide a diversity of hands-on interactivities and simulations that require the user to complete a task, solve a problem, or explore different aspects of a topic that involves reading some accompanying text. Specific examples include electronic notebooks that are integrated as part of the interface, where users can type in their own material; multiple-choice quizzes that provide feedback about how well they have done; interactive puzzles where they have to select and position different pieces in the right combination; and simulation-type games

(*Continued*)

where they have to follow a set of procedures to achieve some goal for a given scenario. Another approach is to employ *dynalinking*, where information depicted in one window explicitly changes in relation to what happens in another. This can help users keep track of multiple representations and see the relationship between them (Scaife and Rogers, 1996).

Specific guidelines are available that recommend how best to combine multiple media in relation to different kinds of task, for example, when to use audio with graphics, sound with animations, and so on, for different learning tasks. As a rule of thumb, audio is good for stimulating the imagination, movies for depicting action, text for conveying details, and diagrams for conveying ideas. From such generalizations, it is possible to devise a presentation strategy for online learning. This could be along the lines of the following:

1. Stimulate the imagination through playing an audio clip.
2. Present an idea in diagrammatic form.
3. Display further details about the concept through hypertext.

7.2.4 Virtual Reality

Virtual reality (VR) has been around since the 1970s when researchers first began developing computer-generated graphical simulations to create "the illusion of participation in a synthetic environment rather than external observation of such an environment" (Gigante, 1993, p. 3). The goal was to create user experiences that feel virtually real when interacting with an artificial environment. Images are displayed stereoscopically to the users—most commonly through VR headsets—and objects within the field of vision can be interacted with via an input device like a joystick.

The 3D graphics can be projected onto Cave Automatic Virtual Environment (CAVE) floor and wall surfaces, desktops, 3D TV, headsets, or large shared displays, for instance, IMAX screens. One of the main attractions of VR is that it can provide opportunities for new kinds of immersive experiences, enabling users to interact with objects and navigate in 3D space in ways not possible in the physical world or a 2D graphical interface. Besides looking at and navigating through a 360-degree visual landscape, auditory and haptic feedback can be added to make the experience feel even more like the real world. The resulting user experience can be highly engaging; it can feel as if one really is flying around a virtual world. People can become completely absorbed by the experience. The sense of presence can make the virtual setting seem convincing. *Presence*, in this case, means "a state of consciousness, the (psychological) sense of being in the virtual environment" (Slater and Wilbur, 1997, p. 605), where someone behaves in a similar way to how they would if at an equivalent real event.

VR simulations of the world can be constructed to have a higher level of fidelity with the objects they represent compared to other forms of graphical interfaces, for example, multimedia. The illusion afforded by the technology can make virtual objects appear to be very life-like and behave according to the laws of physics. For example, landing and take-off terrains developed for flight simulators can appear to be very realistic. Moreover, it is assumed that learning and training applications can be improved through having a greater fidelity to the represented world.

Another distinguishing feature of VR is the different viewpoints it can offer. Players can have a first-person perspective, where their view of the game or environment is through their own eyes, or a third-person perspective, where they see the world through an avatar visually represented on the screen. An example of a first-person perspective is that experienced in first-person shooter games such as DOOM, where the player moves through the environment without seeing a representation of themselves. It requires the user to imagine what they might look like and decide how best to move around. An example of a third-person perspective is that experienced in Tomb Raider, where the player sees the virtual world above and behind the avatar of Lara Croft. The user controls Lara's interactions with the environment by controlling her movements, for example, making her jump, run, or crouch. Avatars can be represented from behind or from the front, depending on how the user controls its movements. First-person perspectives are typically used for flying/driving simulations and games, for instance, car racing, where it is important to have direct and immediate control to steer the virtual vehicle. Third-person perspectives are more commonly used in games, learning environments, and simulations, where it is important to see a representation of self with respect to the environment and others in it. In some virtual environments, it is possible to switch between the two perspectives, enabling the user to experience different viewpoints on the same game or training environment.

In the beginning, head-mounted displays were used to present VR experiences. However, the visuals were often clunky, the headset uncomfortable to wear, and the immersive experience sometimes resulting in motion sickness and disorientation. Since then, VR technology has come of age and improved greatly. There are now many off-the-shelf VR headsets (for example Oculus Go, HTC Vive, and Samsung Gear VR) that are affordable and comfortable. They also have more accurate head tracking that allow developers to create more compelling games, movies, and virtual environments.

"Out of Home Entertainment" and VR arcades have also become popular worldwide and provide a range of social VR experiences, targeted at the general public. For example, Hyper-Reality has developed a number of spooky games, for 1–4 players, such as Japanese Adventures, Escape the Lost Pyramid, and the Void. Each game lasts for about 40 minutes, where players have to carry out a set of tasks, such as finding a lost friend in a realm. The immersive entertainment is full of surprises at every turn. One moment a player might be on solid ground and the next in complete darkness. The pleasure is often in not knowing what is going to happen next and being able to recount the experiences afterward with friends and family.

Another application area is how VR can enrich the experience of reporting and witnessing current affairs and news, especially feelings of empathy and compassion to real-life experiences (Aronson-Rath et al., 2016). For example, the BBC together with Aardman Interactive and University College London researchers developed a VR experience called "We Wait," where they put the viewer in a place that few foreign reporters have been, namely, on a boat with a group of refugees crossing the Mediterranean Sea (Steed et al., 2018). The goal was to let news reporters and other participants experience how it felt to be there on the boat with the refugees. They used a particular artistic polygon style rather than realism to create the characters sitting on the boat (see Figure 7.13). The characters had expressive eyes intended to convey human emotion in response to gaze interaction. The avatars were found to generate an empathic response from participants.

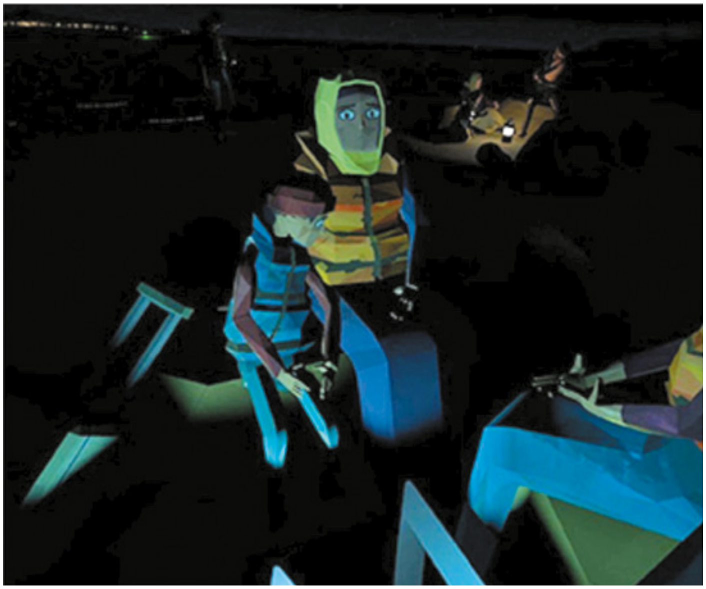


Figure 7.13 Snapshot of polygon graphics used to represent avatars for the "We Wait" VR experience
Source: Steed, Pan, Watson and Slater, https://www.frontiersin.org/articles/10.3389/frobt.2018.00112/full. Licensed Under CC-BY 4.0

VR is also starting to be used by airlines and travel companies to enrich someone's planning experience of their travel destinations. For example, the airline KLM has developed a platform called iFly VR (https://360.iflymagazine.com/) that provides an immersive experience intended to inspire people to discover more about the world. A potential danger of this approach, however, is that if the VR experience is too lifelike it might make people feel they have 'been there, done that' and hence don't need to visit the actual place. However, KLM's rationale is quite the opposite; if you make the virtual experience so compelling people will want to go there even more. Their first foray into this adventure follows the famous "Fearless Chef" Kiran Jethwa into a jungle in Thailand to look for the world's most remarkable coffee beans.

MagicLeap has pushed the envelope even further into new realms of virtual reality; combining cameras, sensors, and speakers in a headset that provides quite a different experience—one where the user can create their own worlds using various virtual tools, for example, painting a forest or building a castle—that then come alive in the actual physical space in which they reside. In this sense, it is not strictly VR, as it allows the wearer to see the virtual world and virtual objects they have created, or curated, blend with the physical objects in their living room or other space in which they are located. It is as if by magic the two are in the same world. In some ways it is a form of augmented reality (AR) - described in section 7.2.16.

Watch this video of MagicLeap's *Create World* where the virtual world meets the physical world in magical ways: **https://youtu.be/K5246156rcQ**.

Peter Rubin's (2018) guide to VR published in *Wired* magazine provides a summary and speculation about its future: **https://www.wired.com/story/wired-guide-to-virtual-reality/**.

Research and Design Considerations

VR has been developed to support learning and training for numerous skills. Researchers have designed apps to help people learn to drive a vehicle, fly a plane, and perform delicate surgical operations—where it is very expensive and potentially dangerous to start learning with the real thing. Others have investigated whether people can learn to find their way around a real building/place before visiting it by first navigating a virtual representation of it, see Gabrielli et al. (2000).

An early example of VR was the Virtual Zoo project. Allison et al. (1997) found that people were highly engaged and very much enjoyed the experience of adopting the role of a gorilla, navigating the environment, and watching other gorillas respond to their movements and presence.

Virtual environments (VE) have also been designed to help people practice social and speaking skills and confront their social phobias, see Cobb et al. (2002) and Slater et al. (1999). An underlying assumption is that the environment can be designed as a safe place to help people gently overcome their fears (for example, spiders, talking in public, and so forth) by confronting them through different levels of closeness and unpleasantness (such as by seeing a small virtual spider move far away, seeing a medium one sitting nearby, and then finally touching a large one). Studies have shown that people can readily suspend their disbelief, imagining a virtual spider to be a real one or a virtual audience to be a real audience. For example, Slater et al. (1999) found that people rated themselves as being less anxious after speaking to a virtual audience that was programmed to respond to them in a positive fashion than after speaking to virtual audiences programmed to respond to them negatively.

Core design considerations include the importance of having a virtual self-body as part of a VR experience to enhance the feeling of presence; how to prevent users from experiencing simulator sickness through experimenting with galvanic stimulation; determining the most effective ways of enabling users to navigate through them, for instance, first person versus third person; how to control their interactions and movements, for example, use of head and body movements; how best to enable users to interact with information in VR, for example, use of keypads, pointing, joystick buttons; and how to enable users to collaborate and communicate with others in the virtual environment.

(*Continued*)

A central concern is the level of realism to target. Is it necessary to design avatars and the environments that they inhabit to be life-like, using rich graphics, or can simpler and more abstract forms be used, but which nonetheless are equally capable of engendering a sense of presence? Do you need to provide a visual representation of the arm and hands for holding objects for a self-avatar, or is it enough to have continuous movement of the object? Research has shown that it is possible for objects to appear to be moving with invisible hands as if they were present. This has been coined as the "tomato presence," that is, where presence is maintained using a stand-in object in VR (for instance, a tomato). (See https://owlchemylabs.com/tomatopresence/.)

3D software toolkits are also available, making it much easier for developers and researchers to create virtual environments. The most popular is Unity. 3D worlds can be created using their APIs, toolkits, and physics engines to run on multiple platforms, for example, mobile, desktop, console, TV, VR, AR, and the Web.

7.2.5 Website Design

Early websites were largely text-based, providing hyperlinks to different places or pages of text. Much of the design effort was concerned with the information architecture, that is, how best to structure information at the interface level to enable users to navigate and access it easily and quickly. For example, Jakob Nielsen (2000) adapted his and Rolf Molich's usability guidelines (Nielsen and Molich, 1990) to make them applicable to website design, focusing on simplicity, feedback, speed, legibility, and ease of use. He also stressed how critical download time was to the success of a website. Simply, users who have to wait too long for a page to appear are likely to move on somewhere else.

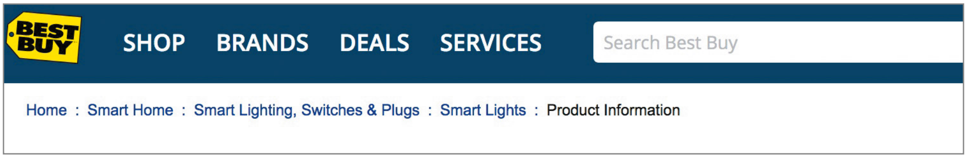
Since then, the goal of web design has been to develop sites that are not only usable but also aesthetically pleasing. Getting the graphical design right, therefore, is critical. The use of graphical elements (such as background images, color, bold text, and icons) can make a website look distinctive, striking, and pleasurable for the user when they first view it and also to make it readily recognizable on their return. However, there is the danger that designers can get carried away with the appearance at the expense of making it difficult to find something and navigate through it.

Steve Krug (2014) discusses this usability versus attractiveness dilemma in terms of the difference between how designers create websites and how users actually view them. He argues that many web designers create sites as if the user was going to pore over each page, reading the finely crafted text word for word; looking at the use of images, color, icons, and so forth; examining how the various items have been organized on the site; and then contemplating their options before they finally select a link. Users, however, often behave quite differently. They will glance at a new page, scan part of it, and click the first link that catches their interest or looks like it might lead them to what they want.

Much of the content on a web page is not read. In Krug's words, web designers are "thinking great literature" (or at least "product brochure"), while the user's reality is much closer to a "billboard going by at 60 miles an hour" (Krug, 2014, p. 21). While somewhat of a caricature of web designers and users, his depiction highlights the discrepancy between the meticulous ways that designers create their websites and the rapid and less than systematic approach that users take to view them. To help navigate their way through the many choices that web developers have to make, Jason Beaird and James George (2014) have come up with a number of guidelines intended to help web developers achieve a balance between using color, layout and composition, texture, typography, and imagery. They also cover mobile and responsive web design. Other website guidelines are mentioned in Chapter 16.

Web designers now have a number of languages available to design websites, such as Ruby and Python. HTML5 and web development tools, such as JavaScript and CSS, are also used. Libraries, such as React, and open source toolkits, such as Bootstrap, enable developers to get started quickly when prototyping their ideas for a website. WordPress also provides users with an easy-to-use interface and hundreds of free templates to use as a basis when creating their own website. In addition, built-in optimization and responsive, mobile-ready themes are available. Customized web pages are available for smartphone browsers that provide scrolling lists of articles, games, tunes, and so on, rather than hyperlinked pages.

Another interface element that has become an integral part of any website is *breadcrumb navigation*. Breadcrumbs are category labels that appear on a web page that enable users to peruse other pages without losing track of where they have come from (see Figure 7.14). The term comes from the way-finding technique that Hansel used in the Brothers Grimm fairy tale *Hansel and Gretel*. The metaphor conjures up the idea of leaving a path to follow back. Breadcrumbs are also used by search engine optimization tools that match up a user's search terms with relevant web pages using the breadcrumbs. Breadcrumbs also extol usability in a number of ways, including helping users know where they are relative to the rest of the website, enabling one-click access to higher site levels, attracting first time visitors to continue to browse a website after having viewed the landing page (Mifsud, 2011). Therefore, using them is good practice for other web applications besides websites.



Home : Smart Home : Smart Lighting, Switches & Plugs : Smart Lights : Product Information

Figure 7.14 A breadcrumb trail on the BestBuy website showing three choices made by the user to get to Smart Lights

Source: https://www.bestbuy.ca

With the arrival of tablets and smartphones, web designers needed to rethink how to design web browsers and websites for them, as they realized the touchscreen affords a different interaction style than PC/laptops. The standard desktop interface was found to not work as well on a tablet or smartphone. In particular, the typical fonts, buttons, and menu tabs were too small and awkward to select when using a finger. Instead of double-clicking interface elements, as users do with a mouse or trackpad, tablet and smartphone screens enable finger tapping. The main methods of navigation are by swiping and pinching. A new style of website emerged that mapped better to this kind of interaction style but also one that the user could interact with easily when using a mouse and trackpad. Responsive websites were developed that change their layout, graphic design, font, and appearance depending on the screen size (smartphone, tablet, or PC) on which it was being displayed.

If you look at the design of many websites, you will see that the front page presents a banner at the top, a short promotional video about the company/product/service, arrows to the left or right to indicate where to flick to move through pages, and further details appearing beneath the home page that the user can scroll through. Navigation is largely done by swiping pages horizontally or scrolling up and down.

Tips on designing websites for tablets versus mobile phones can be found here: **https://css-tricks.com/a-couple-of-best-practices-for-tablet-friendly-design/**

BOX 7.3

In-Your-Face Web Ads

Web advertising has become pervasive and invasive. Advertisers realized how effective flashing and animated ads were for promoting their products, taking inspiration from the animated neon light advertisements used in city centers, such as London's Piccadilly Circus. But since banner ads emerged in the 1990s, advertisers have become even more cunning in their tactics. In addition to designing even flashier banner ads, more intrusive kinds of web ads have begun to appear on our screens. Short movies and garish cartoon animations, often with audio, now pop up in floating windows that zoom into view or are tagged on at the front end of an online newspaper or video clip. Moreover, this new breed of in-your-face, often personalized web ads frequently requires the user either to wait until they end or to find a check box to close the window down. Sites that provide free services, such as Facebook, YouTube, and Gmail, are also populated with web ads. The problem for users is that advertisers pay significant revenues to online companies to have their advertisements placed on their websites, entitling them to say where, what, and how they should appear. One way users can avoid them is to set up ad blockers when browsing the web. ■

Research and Design Considerations

There are numerous classic books on web design and usability (for example, Krug, 2014; Cooper et al., 2014). In addition, there are many good online sites offering guidelines and tips. For example, the BBC provides online guidance specifically for how to design responsive websites that includes topics such as context, accessibility, and modular design. See https://www.bbc.co.uk/gel/guidelines/how-to-design-for-the-web. Key design considerations for all websites are captured well by three core questions proposed by Keith Instone (quoted in Veen, 2001): Where am I? What's here? Where can I go?

ACTIVITY 7.5

Look at a fashion brand's website, such as Nike, and describe the kind of interface used. How does it contravene the design principles outlined by Jeffrey Veen? Does it matter? For what type of user experience is it providing? What was your experience in engaging with it?

Comment

Fashion companies' sites, like Nike, are often designed to be more like a cinematic experience and use rich multimedia elements, including videos, sounds, music, animations, and interactivity. Branding is central. In this sense, it contravenes what are considered core usability guidelines. Specifically, the site has been designed to entice the visitor to enter the virtual store and watch high-quality and innovative movies that show cool dudes wearing their products. Often, multimedia interactivities are embedded into the sites to help the viewer move to other parts of the site, for example by clicking on parts of an image or a video playing. Screen widgets are also provided, such as menus, skip over, and next buttons. It is easy to become immersed in the experience and forget that it is a commercial store. It is also easy to get lost and not to know—Where am I? What's here? Where can I go? But this is precisely what companies such as Nike want their visitors to do and to enjoy: the experience. ■

7.2.6 Mobile Devices

Mobile devices have become pervasive, with people increasingly using them in all aspects of their everyday and working lives—including phones, fitness trackers, and watches. Customized mobile devices are also used by people in a diversity of work settings where they need access to real-time data or information while walking around. For example, they are now commonly used in restaurants to take orders, at car rental agencies to check in car returns, in supermarkets for checking stock, and on the streets for multiplayer gaming.

Larger-sized tablets are also used in mobile settings. For example, many airlines provide their flight attendants with one so that they can use their customized flight apps while airborne and at airports; sales and marketing professionals also use them to demonstrate their products or to collect public opinions. Tablets and smartphones are also commonly used in classrooms that can be stored in special "tabcabbies" provided by schools for safe keeping and recharging.

Smartphones and smartwatches have an assortment of sensors embedded in them, such as an accelerometer to detect movement, a thermometer to measure temperature, and galvanic skin response to measure changes in sweat level on one's skin. Other apps may be designed for fun. An example of an early app developed by magician Steve Sheraton simply for a moment of pleasure is iBeer (see Figure 7.15). Part of its success was due to the ingenious use of the accelerometer inside the phone. It detects the tilting of the iPhone and uses this information to mimic a glass of beer being consumed. The graphics and sounds are also very enticing; the color of the beer together with frothy bubbles and accompanying sound effects gives the illusion of virtual beer being swished around a virtual glass. The beer can be drained if the phone is tilted enough, followed by a belch sound when it has been finished.

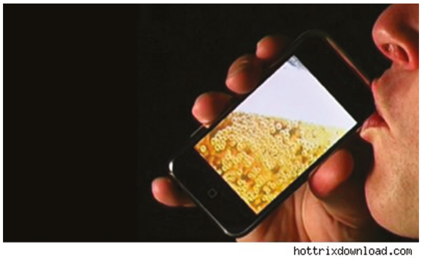


Figure 7.15 The iBeer smartphone app
Source: Hottrix

Smartphones can also be used to download contextual information by scanning barcodes in the physical world. Consumers can instantly download product information by scanning barcodes using their iPhone when walking around a supermarket, including allergens, such as nuts, gluten, and dairy. For example, the GoodGuide app enables shoppers to scan products in a store by taking a photo of their barcode to see how they rate for healthiness and impact on the environment. Others include concert tickets and location-based notifications.

Another method that provides quick access to relevant information is the use of quick response (QR) codes that store URLs and look like black-and-white checkered squares (see Figure 7.16). They work by people taking a picture using their camera phone that then takes them to a particular website. However, despite their universal appeal to companies as a way of providing additional information or special offers, not many people actually use them in practice. One of the reasons is that they can be slow, tricky, and cumbersome to use *in situ*. People have to download a QR reader app first, open it, and then try to hold it over the QR code to take a photo, which can take time to open up a webpage.

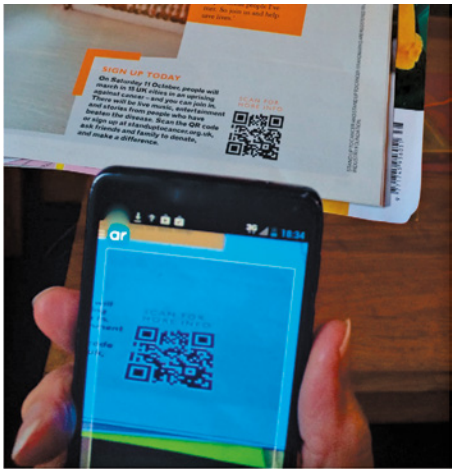


Figure 7.16 QR code appearing on a magazine page

ACTIVITY 7.6

Smartwatches, such those made by Google, Apple, and Samsung, provide a multitude of functions including fitness tracking, streaming music, texts, email, and the latest tweets. They are also context and location aware. For example, on detecting the user's presence, promotional offers may be pinged to them from nearby stores, tempting them in to buy. How do you feel about this? Do you think it is the same or worse compared to the way advertisements appear on a user's smartphone? Is this kind of context-based advertising ethical?

Comment

Smartwatches are similar to smartphones in that they, too, get pinged with promotions and ads for nearby restaurants and stores. However, the main difference is that when worn on a wrist, smartwatches are ever-present; the user only needs to glance down at it to notice a new notification, whereas they have to take their phones out of their pockets and purses to see what new item has been pinged (although some people hold their smartphone permanently in their hands). This means that their attention is always being given to the device, which could make them susceptible to responding to notifications and spending more money. While some people might like to get 10 percent off on coffee if they walk into the cafe that has just sent them a digital voucher, for others such notifications may be seen as very annoying as they are constantly bombarded with promotions. Worse still, it could tempt children and vulnerable people who are wearing such a watch to spend money when perhaps they shouldn't or to nag their parents or caretakers to buy it for them. However, smartwatch companies are aware of this potential problem, and they provide settings that the user can change in terms of the level and type of notifications they want to receive. ■

Research and Design Considerations

Mobile interfaces typically have a small screen and limited control space. Designers have to think carefully about what type of dedicated hardware controls to include, where to place them on the device, and then how to map them to the software. Apps designed for mobile interfaces need to take into account the ability to navigate through content when using a mobile display is constrained, whether using touch, pen, or keypad input. The use of vertical and horizontal scrolling provides a rapid way of scanning though images, menus, and lists. A number of mobile browsers have also been developed that allow users to view and navigate the Internet, magazines, or other media in a more streamlined way. For example, Microsoft's Edge browser was one of the first mobile browsers that was designed to make it easier to find, view, and manage content on the go. It provides a customized reading view that enables the user to re-organize the content of a web page to make it easier for them to focus on what they want to read. The trade-off, however, is that it makes it less obvious how to perform other functions that are no longer visible on the screen.

(*Continued*)

Another key concern for mobile display design is the size of the area on the display that the user touches to make something happen, such as a key, icon, button, or app. The space needs to be big enough for "all fingers" to press accurately. If the space is too small, the user may accidentally press the wrong key, which can be annoying. The average fingertip is between one and two centimeters wide, so target areas should be at least 7 mm to 10 mm so that they can be accurately tapped with a fingertip. Fitts' law (see Chapter 16) is often used to help with evaluating hit area. In their developer design guidelines, Apple also suggests providing ample touch targets for interactive elements, with a minimum tappable area of 44 pts. × 44 pts. for all controls.

A number of other guidelines exist providing advice on how to design interfaces for mobile devices (for instance, see Babich, 2018). An example is avoiding clutter by prioritizing one primary action per screen.

7.2.7 Appliances

Appliances include machines for everyday use in the home (for example, washing machines, microwave ovens, refrigerators, toasters, bread makers, and smoothie makers). What they have in common is that most people using them will be trying to get something specific done in a short period of time, such as starting a wash, watching a program, buying a ticket, or making a drink. They are unlikely to be interested in spending time exploring the interface or looking through a manual to see how to use the appliance. Many of them now have LED displays that provide multiple functions and feedback about a process (such as temperature, minutes remaining, and so on). Some have begun to be connected to the Internet with companion devices, enabling them to be controlled by remote apps. An example is a coffee maker that can be controlled to come on at a certain time from an app running on a smartphone or controlled by voice.

Research and Design Considerations

Alan Cooper et al. (2014) suggest that appliance interfaces require the designer to view them as transient interfaces, where the interaction is short. All too often, however, designers provide full-screen control panels or an unnecessary array of physical buttons that serve to frustrate and confuse the user where only a few, presented in a structured way, would be much better. Here the two fundamental design principles of simplicity and visibility are paramount. Status information, such as what the photocopier is doing, what the ticket machine is doing, and how much longer the wash is going to take should be provided in a simple form and at a prominent place on the interface. A key design question is: as soft displays increasingly become part of an appliance interface, for example, LCD and touchscreens, what are the trade-offs with replacing the traditional physical controls, such as dials, buttons, and knobs, with these soft display controls?

ACTIVITY 7.7

Look at the controls on your toaster (or the one in Figure 7.17 if you don't have one nearby) and describe what each does. Consider how these might be replaced with an LCD screen. What would be gained and lost from changing the interface in this way?

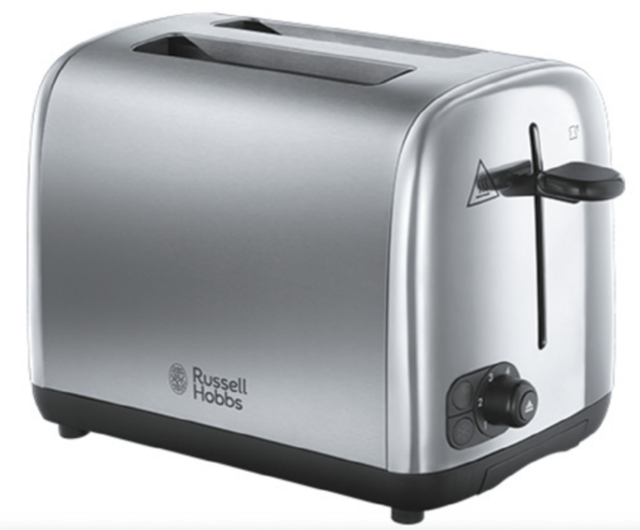


Figure 7.17 A typical toaster with basic physical controls

Source: https://uk.russellhobbs.com/product/brushed-stainless-steel-toaster-2-slice

Comment

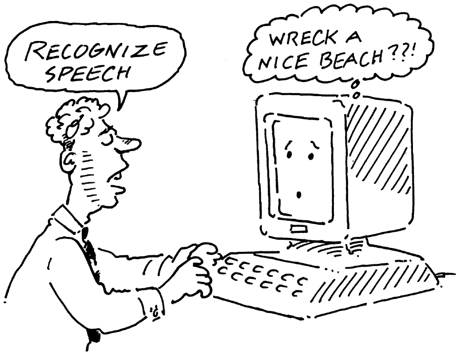
Standard toasters have two main controls, the lever to press down to start the toasting and a knob to set the amount of time for the toasting. Many come with a small eject button that can be pressed if the toast starts to burn. Some also come with a range of settings for different ways of toasting (such as one side, frozen, and so forth), selected by moving a dial or pressing buttons.

Designing the controls to appear on an LCD screen would enable more information and options to be provided, for example, only toast one slice, keep the toast warm, or automatically pop up when the toast is burning. It would also allow precise timing of the toasting in minutes and seconds. However, it is likely to increase the complexity of what previously was a set of logical and very simple actions. This has happened in the evolution of microwaves, washing machines, and tea kettles that have digital interfaces. They also offer many more options for warming food up, washing clothes, or the temperature to heat water. The downside of increasing the number of choices, especially when the interface is not designed well to support this, is that it can make for a more difficult user experience for mundane tasks. ■

7.2.8 Voice User Interfaces

A *voice user interface* (VUI) involves a person talking with a spoken language app, such as a search engine, a train timetable, a travel planner, or a phone service. It is commonly used for inquiring about specific information (for instance, flight times or the weather) or issuing a command to a machine (such as asking a smart TV to select an Action movie or asking a smart speaker to play some upbeat music). Hence, VUIs use an interaction type of command or conversation (see Chapter 3), where users speak and listen to an interface rather than click on, touch, or point to it. Sometimes, the interaction style can involve the user responding where the system is proactive and initiates the conversation, for example, asking the user if they would like to stop watching a movie or listen to the latest breaking news.

The first generation of speech systems earned a reputation for *mishearing* all too often what a person said (see cartoon). However, they are now much more sophisticated and have higher levels of recognition accuracy. Machine learning algorithms have been developed that are continuing to improve their ability to recognize what someone is saying. For speech output, actors are often used to record answers, messages, and prompts, which are much friendlier, more convincing, and more pleasant than the artificially-sounding synthesized speech that was typically used in the early systems.



Source: Reproduced with permission of King Features Syndicate

VUIs have become popular for a range of apps. Speech-to-text systems, such as Dragon, enable people to dictate rather than have to type, whether it is entering data into a spreadsheet, using a search engine, or writing a document. The words spoken appear on the screen. For some people, this mode of interaction is more efficient, especially when they are on the move. Dragon claims on their website that it is three times faster than typing and it is 99 percent accurate. Speech technology is also used by people with visual impairments, including speech recognition word processors, page scanners, web readers, and VUIs for operating home control systems, including lights, TV, stereo, and other home appliances.

One of the most popular applications of speech technology is call routing, where companies use an automated speech system to enable users to reach one of their services during a phone call. Callers voice their needs in their own words, for example, “I’m having problems with my Wi-Fi router,” and in response are automatically forwarded to the appropriate service (Cohen et al., 2004). This is useful for companies, as it can reduce operating costs. It can also increase revenue by reducing the number of lost calls. The callers may be happier, as their call can be routed to an available agent (real or virtual) rather than being lost or sent to voicemail.

In human conversations, people often interrupt each other, especially if they know what they want, rather than waiting for someone to go through a series of options. For example, they may stop the waitress at a restaurant in midflow when describing the specials if they know what they want, rather than let her go through the entire list. Similarly, speech technology has been designed with a feature called *barge-in* that allows callers to interrupt a system message and provide their request or response before the message has finished playing. This can be useful if the system has numerous options from which the caller may choose, and the chooser knows already what they want.

There are several ways that a VUI dialog can be structured. The most common is a directed dialogue where the system is in control of the conversation, asking specific questions and requiring specific responses, similar to filling in a form (Cohen et al., 2004):

System: Which city do you want to fly to?
Caller: London
System: Which airport: Gatwick, Heathrow, Luton, Stansted, or City?
Caller: Gatwick
System: What day do you want to depart?
Caller: Monday next week.
System: Is that Monday, May 5?
Caller: Yes

Other systems are more flexible, allowing the user to take more initiative and specify more information in one sentence (for example, "I'd like to go to Paris next Monday for two weeks"). The problem with this approach is that there is more chance for error, since the caller might assume that the system can follow all of their needs in one pass as a real travel agent would (for example, "I'd like to go to Paris next Monday for two weeks, and would like the cheapest possible flight, preferably leaving from Gatwick airport and definitely with no stop-overs …"). The list is simply too long and would overwhelm the system's parser. Carefully guided prompts can be used to get callers back on track and help them speak appropriately (for instance, "Sorry, I did not get all that. Did you say you wanted to fly next Monday?").

A number of speech-based phone apps exist that enable people to use them while mobile, making them more convenient to use than text-based entry. For example, people can voice queries into their phone using Google Voice or Apple Siri rather than entering text manually. Mobile translators allow people to communicate in real time with others who speak a different language by letting a software app on their phone do the talking (for example, Google Translate). People speak in their own language using their phone while the software translates what each person is saying into the language of the other one. Potentially, this means people from all over the world (there are more than 6,000 languages) can talk to one another without having to learn another language.

Voice assistants, like Amazon's Alexa and Google Home, can be instructed by users to entertain in the home by telling jokes, playing music, keeping track of time, and enabling users to play games. Alexa also offers a range of "skills," which are voice-driven capabilities intended to provide a more personalized experience. For example, "Open the Magic Door" is an interactive story skill that allows users to choose their path in a story by selecting different options through the narrative. Another one, "Kids court," allows families to settle arguments in an Alexa-run court while learning about the law. Many of the skills are designed to support multiple users taking part at the same time, offering the potential for families to play together. Social interaction is encouraged by the smart speaker that houses Alexa or Home. Smart speakers sit in a common space for all to use (similar to a toaster or refrigerator). In contrast, handheld devices, such as a smartphone or tablet, support only single use and ownership.

Despite advances in speech recognition, conversational interaction is limited mainly to answering questions and responding to requests. It can be difficult for VUIs to recognize children's speech, which is not as articulate as adults. For example, Druga et al. (2017) found that young children (3–4 years old) experienced difficulty interacting with conversational and chat agents, resulting in them becoming frustrated. Also, voice assistants don't always recognize who is talking in a group, such as a family, and always need to be called by their name each time someone wants to interact with it. There is still a way to go before voice assistant interaction resembles human conversation.

Research and Design Considerations

Key research questions are what conversational mechanisms to use to structure the voice user interface and how human-like they should be. Some researchers focus on how to make it appear natural (that is, like human conversation), while others are concerned more with how to help people navigate efficiently through a menu system by enabling them to recover easily from errors (their own or the system's), to be able to escape and go back to the main menu (similar to the undo button of a GUI), and to guide those who are vague or ambiguous in their requests for information or services using prompts. The type of voice actor, male, female, neutral, or dialect, and form of pronunciation are also topics of research. Do people prefer to listen to and are more patient with a female or male voice? What about one that is jolly versus one that is serious?

Michael Cohen et al. (2004) discuss the pros and cons of using different techniques for structuring the dialogue and managing the flow of voice interactions, the different ways of expressing errors, and the use of conversational etiquette—all still relevant for today's VUIs. A number of commercial guidelines are available for voice interfaces. For example, Cathy Pearl (2016) has written a practical book that provides a number of VUI design principles and topics, including which speech recognition engine to use, how to measure the performance of VUIs, and how to design VUIs for different interfaces, for example, a mobile app, toy, or voice assistant.

7.2.9 Pen-Based Devices

Pen-based devices enable people to write, draw, select, and move objects on an interface using light pens or styluses that capitalize on the well-honed drawing and writing skills that are developed from childhood. They have been used to interact with tablets and large displays, instead of mouse, touch, or keyboard input, for selecting items and supporting freehand sketching. Digital ink, such as Anoto, uses a combination of an ordinary ink pen with a digital camera that

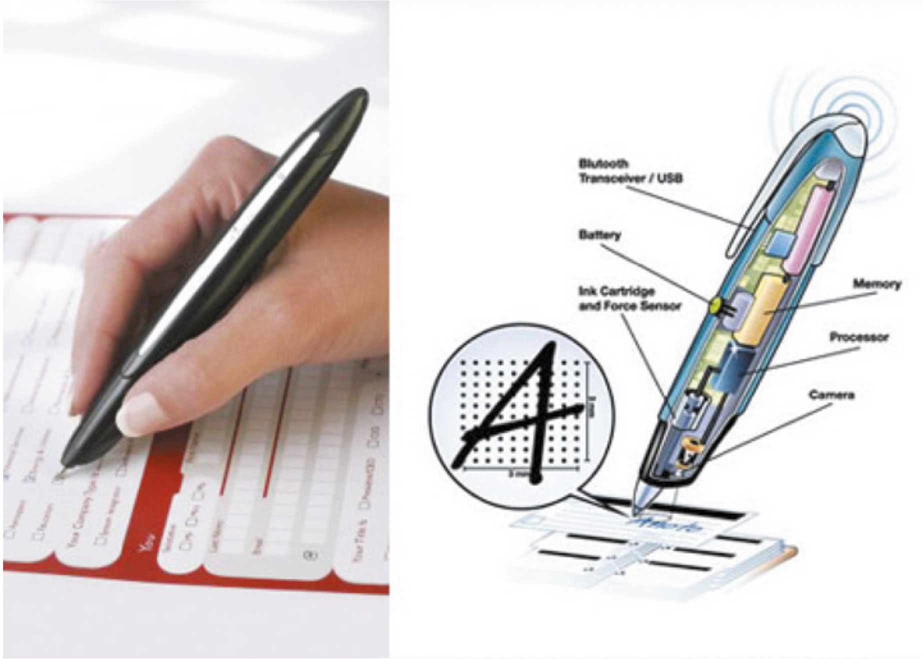


Figure 7.18 The Anoto pen being used to fill in a paper form and a schematic showing its internal components

Source: www.grafichewanda.it/anoto.php?language=EN

digitally records everything written with the pen on special paper (see Figure 7.18). The pen works by recognizing a special nonrepeating dot pattern that is printed on the paper. The nonrepeating nature of the pattern means that the pen is able to determine which page is being written on and where on the page the pen is pointing. When writing on digital paper with a digital pen, infrared light from the pen illuminates the dot pattern, which is then picked up by a tiny sensor. The pen decodes the dot pattern as the pen moves across the paper and stores the data temporarily in the pen. The digital pen can transfer data that has been stored in the pen via Bluetooth or a USB port to a computer. Handwritten notes can also be converted and saved as standard typeface text. This can be useful for applications that require people to fill in paper-based forms and also for taking notes during meetings.

Another advantage of digital pens is that they allow users to annotate existing documents, such as spreadsheets, presentations, and diagrams quickly and easily in a similar way to how they would do this when using paper-based versions. This is useful for a team who is working together and communicating to each other from different locations. One problem with using pen-based interactions on small screens, however, is that sometimes it can be difficult to see options on the screen because a user's hand can obscure part of it when writing.

BOX 7.4

Electronic Ink

Digital ink is not to be confused with the term *electronic ink* (or *e-ink*). Electronic ink is a display technology designed to mimic the appearance of ordinary ink on paper used in e-readers, such as the Kindle. The display used reflects light like ordinary paper. ■

7.2.10 Touchscreens

Single touchscreens, used in walk-up kiosks such as ticket machines or museum guides, ATMs, and cash registers (for instance, restaurants), have been around for a while. They work by detecting the presence and location of a person's touch on the display; options are selected by tapping on the screen. *Multitouch surfaces*, on the other hand, support a much wider range of more dynamic fingertip actions, such as swiping, flicking, pinching, pushing, and tapping. They do this by registering touches at multiple locations using a grid (see Figure 7.19). This multitouch method enables devices, such as smartphones and tabletops, to recognize and respond to more than one touch at the same time. This enables users to use multiple digits to perform a variety of actions, such as zooming in and out of maps, moving photos, selecting letters from a virtual keyboard when writing, and scrolling through lists. Two hands can also be used together to stretch and move objects on a tabletop surface, similar to how both hands are used to stretch an elastic band or scoop together a set of objects.

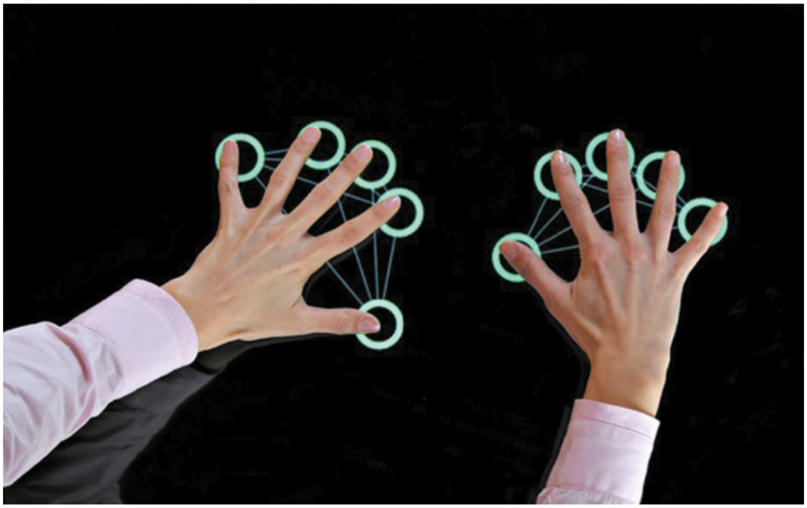


Figure 7.19 A multitouch interface

Source: www.sky-technology.eu/en/blog/article/item/multi-touch-technology-how-it-works.html

The flexibility of interacting with digital content afforded by finger gestures has resulted in many ways of experiencing digital content. This includes reading, scanning, zooming, and searching interactive content on tablets, as well as creating new digital content.

Research and Design Considerations

Touchscreens have become pervasive, increasingly becoming the main interface that many people use on a daily basis. However, they are different from GUIs, and a central design concern is what types of interaction techniques to use to best support different activities. For example, what is the optimal way to enable users to choose from menu options, find files, save documents, and so forth, when using a touch interface? These operations are well mapped to interaction styles available in a GUI, but it is not as obvious how to support them on a touch interface. Alternative conceptual models have been developed for the user to carry out these actions on the interface, such as the use of cards, carousels, and stacks (see Chapter 3). The use of these objects enables users to swipe and move through digital content quickly. However, it is also easy to swipe too far when using a carousel. Typing on a virtual keyboard with two thumbs or one fingertip is also not as fast and efficient as using both hands when using a conventional keyboard, although many people have learned to be very adept at pecking at virtual keys on a smartphone. Predictive text can also be used to help people type faster.

Both hands may be used on multitouch tabletops to enable users to make digital objects larger and smaller or to rotate them. Dwelling touches (pressing and holding a finger down) can also be used to enable a user to perform dragging actions and to bring up pop-up menus. One or more fingers can also be used together with a dwell action to provide a wider range of gestures. However, these can be quite arbitrary, requiring users to learn them rather than being intuitive. Another limitation of touchscreens is that they do not provide tactile feedback in the same way that keys or mice do when pressed. To compensate, visual, audio, and haptic feedback can be used. See also the section on shareable interfaces for more background on multitouch design considerations.

7.2.11 Gesture-Based Systems

Gestures involve moving arms and hands to communicate (for instance, waving to say goodbye or raising an arm to speak in class) or to provide information to someone (for example, holding two hands apart to show the size of something). There has been much interest in how technology can be used to capture and recognize a user's gestures for input by tracking them using cameras and then analyzing them using machine learning algorithms.

David Rose (2018) created a video that depicts many sources of inspiration for where gesture is used in a variety of contexts, including those made by cricket umpires, live concert signers for the deaf, rappers, Charlie Chaplin, mime artists, and Italians. His team at IDEO developed a gesture system to recognize a small set of gestures and used these to control a Philips HUE light set and a Spotify station. They found that gestures need to be sequential to be understood in the way a sentence is composed of a noun, then verb, and object plus operation. For example, for "speaker, on," they used a gesture on one hand to designate the noun, and another on the other hand to designate the verb. So, to change the volume, the user needs to point to a speaker with their left hand while raising their right hand to signal turn the volume up.

Watch David Rose's inspirations for gesture video at **https://vimeo.com/224522900**.

One area where gesture interaction has been developed is in the operating room. Surgeons need to keep their hands sterile during operations but also need to be able to look at X-rays and scans during an operation. However, after being scrubbed and gloved, they need to avoid touching any keyboards, phones, and other nonsterile surfaces. A far from ideal workaround is to pull their surgical gown over their hands and manipulate a mouse through the gown. As an alternative, Kenton O'Hara et al. (2013) developed a touchless gesture-based system, using Microsoft's Kinect technology, which recognized a range of gestures that surgeons could use to interact with and manipulate MRI or CT images, including single-handed gestures for moving forward or backward through images, and two-handed gestures for zooming and panning (see Figure 7.20).

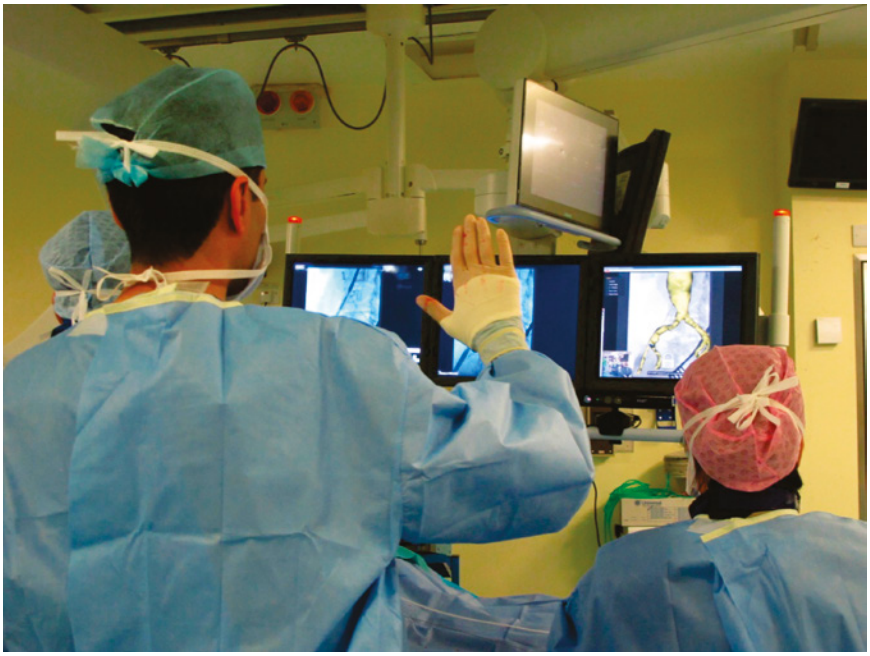


Figure 7.20 Touchless gesturing in the operating theater

Source: Used courtesy of Kenton O'Hara

Research and Design Considerations

A key design concern for using gestural input is to consider how a computer system recognizes and delineates the user's gestures. In particular, how does it determine the start and end point of a hand or arm movement, and how does it know the difference between a deictic gesture (a deliberate pointing movement) and hand waving (an unconscious gesticulation) that is used to emphasize what is being said verbally?

In addition to being used as a form of input, gestures can be represented as output to show real-time avatar movement or someone's own arm movements. Smartphones, laptops, and some smart speakers (for example, Facebook's Portal) have cameras that can perceive three dimensions and record a depth for every pixel. This can be used to create a representation of someone in a scene, for example, how they are posing and moving, and also to respond to their gestures. One design question that this raises is how realistic must the mirrored graphical representation of the user be in order for them to be believable and for the user to connect their gestures with what they are seeing on the screen.

7.2.12 Haptic Interfaces

Haptic interfaces provide tactile feedback, by applying vibration and forces to the person, using actuators that are embedded in their clothing or a device that they are carrying, such as a smartphone or smartwatch. Gaming consoles have also employed vibration to enrich the experience. For example, car steering wheels that are used with driving simulators can vibrate in various ways to provide the feel of the road. As the driver makes a turn, the steering wheel can be programmed to feel like it is resisting—in the way that a real steering wheel does.

Vibrotactile feedback can also be used to simulate the sense of touch between remote people who want to communicate. Actuators embedded in clothing can be designed to recreate the sensation of a hug or a squeeze by being buzzed on various parts of the body. Another use of haptics is to provide real-time feedback to guide people when learning a musical instrument, such as a violin or drums. For example, the MusicJacket (van der Linden et al., 2011) was developed to help novice violin players learn how to hold their instrument correctly and develop good bowing action. Vibrotactile feedback was provided via the jacket to give nudges at key places on the arm and torso to inform the student when they were either holding their violin incorrectly or their bowing trajectory had deviated from a desired path (see Figure 7.21). A user study with novice players showed that they were able to react to the vibrotactile feedback and adjust their bowing or their posture in response.

Another form of feedback is called *ultrahaptics*, which creates the illusion of touch in midair. It does this by using ultrasound to make three-dimensional shapes and textures that can be felt but not seen by the user (www.ultrahaptics.com). This technique can be used to create the illusion of having buttons and sliders that appear in midair. One potential use is in the automotive industry to replace existing physical buttons and knobs or touchscreens. The ultra-haptic buttons and knobs can be designed to appear next to the driver when needed, for example, when detecting the driver wants to turn down the volume or change the radio station.

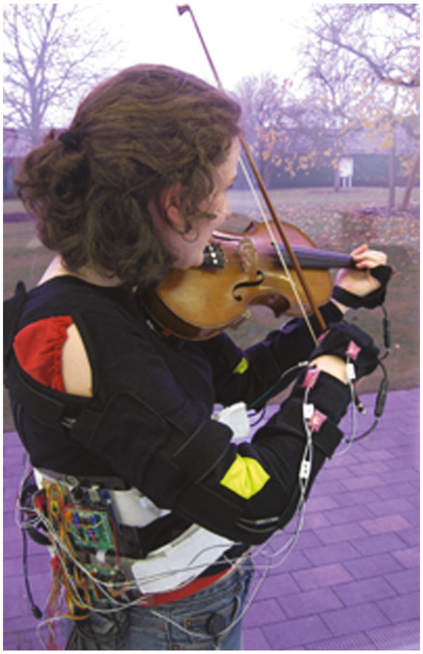


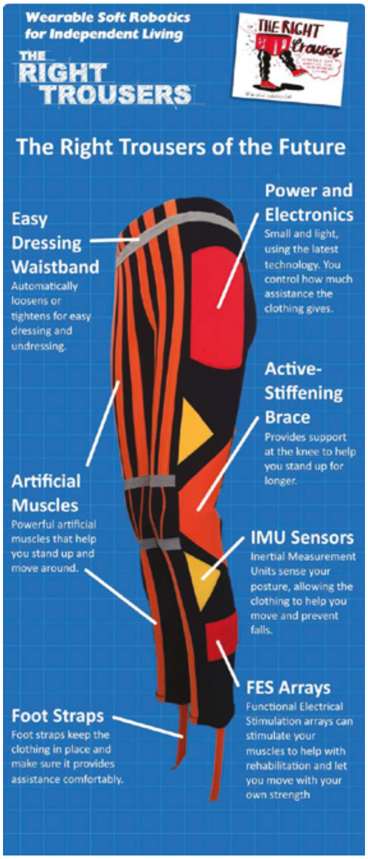
Figure 7.21 The MusicJacket with embedded actuators that nudge the player to move their arm up to be in the correct position

Source: Helen Sharp

Haptics are also being embedded into clothing, sometimes called *exoskeletons*. Inspired by the "right trousers" in the Wallace and Gromit animated short movie, Jonathan Rossiter and his team (2018) developed a new kind of exoskeleton that can help people stand up and move around using artificial muscles that consist of air bubbles which are activated using tiny electric motors (see Figure 7.22). These are stiffened or relaxed using grapheme parts to make the trousers move. One application area is to help people who have walking difficulties and those who need to exercise but find it difficult to do so.

7.2.13 Multimodal Interfaces

Multimodal interfaces are intended to enrich user experiences by multiplying the way information is experienced and controlled at the interface through using different modalities, such as touch, sight, sound, and speech (Bouchet and Nigay, 2004). Interface techniques that have been combined for this purpose include speech and gesture, eye-gaze and gesture, haptic and audio output, and pen input and speech (Dumas et al., 2009). The assumption is that multimodal interfaces can support more flexible, efficient, and expressive means of human–computer interaction that are more akin to the multimodal experiences that humans encounter in the physical world (Oviatt, 2017). Different input/outputs may be used at the same time, for example, using voice commands and gestures simultaneously to move through a virtual environment, or alternately using speech commands followed by gesturing. The most common combination of technologies used for multimodal interfaces is speech and vision processing (Deng and Huang, 2004). Multimodal interfaces can also be combined with multisensor input to enable other aspects of the human body to be tracked. For example, eye gaze, facial expressions, and lip movements can also be tracked to provide data about a user's



Wearable Soft Robotics for Independent Living

THE RIGHT TROUSERS

The Right Trousers of the Future

Easy Dressing Waistband
Automatically loosens or tightens for easy dressing and undressing.

Power and Electronics
Small and light, using the latest technology. You control how much assistance the clothing gives.

Active-Stiffening Brace
Provides support at the knee to help you stand up for longer.

Artificial Muscles
Powerful artificial muscles that help you stand up and move around.

IMU Sensors
Inertial Measurement Units sense your posture, allowing the clothing to help you move and prevent falls.

FES Arrays
Functional Electrical Stimulation arrays can stimulate your muscles to help with rehabilitation and let you move with your own strength

Foot Straps
Foot straps keep the clothing in place and make sure it provides assistance comfortably.

Figure 7.22 Trousers with artificial muscles that use a new kind of bubble haptic feedback

Source: Used courtesy of The Right Trousers Project: Wearable Soft Robotics for Independent Living

Research and Design Considerations

Haptics are now commonly used in gaming consoles, smartphones, and controllers to alert or heighten a user experience. Haptic feedback is also being developed in clothing and other wearables as a way of simulating being touched, stroked, prodded, or buzzed. A promising application area is sensory-motor skills, such as in sports training and learning to play a musical instrument. For example, patterns of vibrations have been placed across snowboarders' bodies to indicate which moves to take while snowboarding. A study reported faster reaction times than when the same instructions were given verbally (Spelmezan et al., 2009). Other uses are posture trainers that buzz when a user slouches and fitness trackers that also buzz when they detect that their users have not taken enough steps in the past hour.

(*Continued*)

A key design question is where best to place the actuators on the body, whether to use a single or a sequence of touches, when to activate, and at what intensity and how often to use them to make the feeling of being touched convincing (e.g., Jones and Sarter, 2008). Providing continuous haptic feedback would be simply too annoying. People would also habituate too quickly to the feedback. Intermittent buzzes can be effective at key moments when a person needs to attend to something but not necessarily tell them what to do. For example, a study by Johnson et al. (2010) of a commercially available haptic device, intended to improve posture by giving people a vibrotactile buzz when they slouched, found that while the buzzing did not show them how to improve their posture, it did improve their body awareness.

Different kinds of buzzes can also be used to indicate different tactile experiences that map to events; for example, a smartphone could transmit feelings of slow tapping to feel like water dropping, which is meant to indicate it is about to rain and transmit the sensation of heavy tapping to indicate a thunderstorm is looming.

attention or other behavior. This kind of sensing can provide input for customizing user interfaces and experiences to the perceived need, desire, or level of interest.

A person's body movement can also be tracked so that it can be represented back to them on a screen in the form of an avatar that appears to move just like them. For example, the Kinect was developed as a gesture and body movement gaming input system for the Xbox. Although now defunct in the gaming industry, it proved effective at detecting multimodal input in real time. It consisted of an RGB camera for facial and gesture recognition, a depth sensor (an infrared projector paired with a monochrome camera) for movement tracking, and downward-facing mics for voice recognition (see Figure 7.23). The Kinect looked for

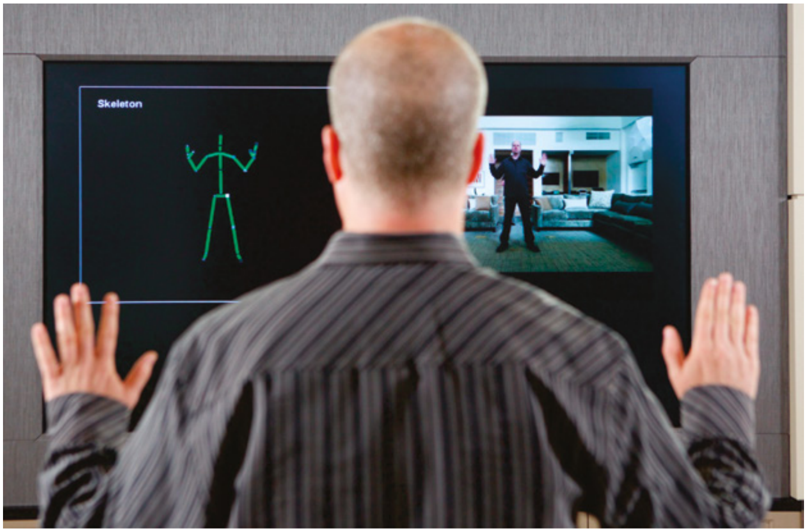


Figure 7.23 Microsoft's Xbox Kinect

Source: Stephen Brashear / Invision for Microsoft / AP Images someone's body. On finding it, it locked onto it and measured the three-dimensional positioning of the key joints in their body. This information was converted into a graphical avatar of the user that could be programmed to move just like them. Many people readily saw themselves as the avatar and learnt how to play games in this manner.

Research and Design Considerations

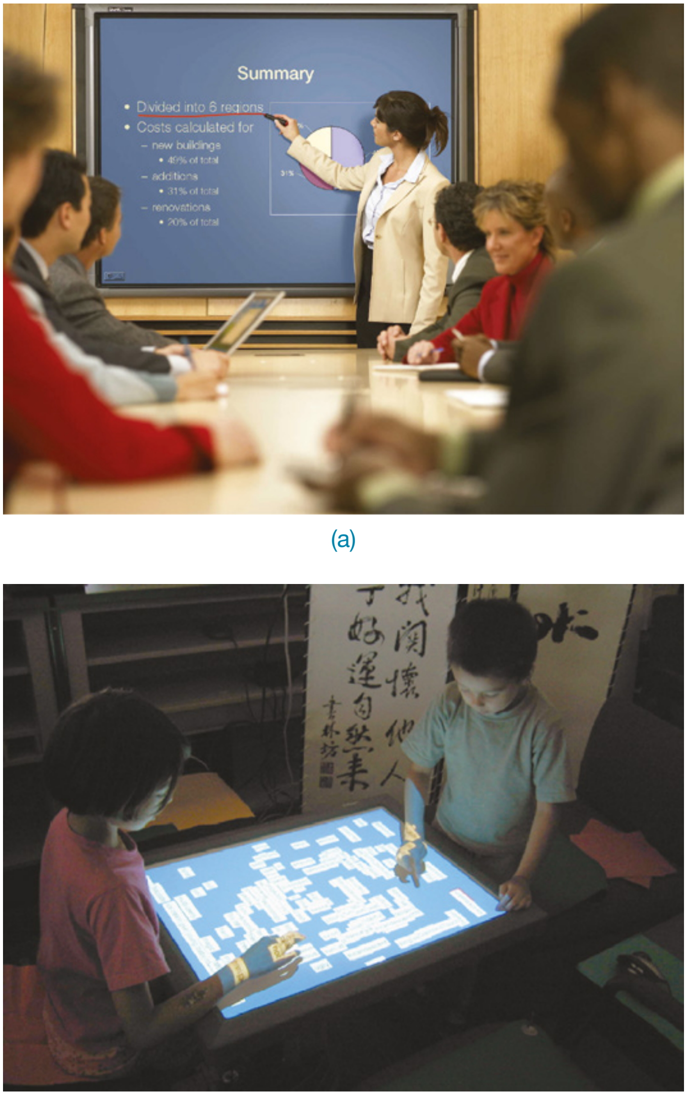
Multimodal systems rely on recognizing aspects of a user's behavior, including handwriting, speech, gestures, eye movements, or other body movements. In many ways, this is much harder to accomplish and calibrate than single modality systems that are programmed to recognize one aspect of a user's behavior. The most researched modes of interaction are speech, gesture, and eye-gaze tracking. A key research question is what is actually gained from combining different input and outputs and whether talking and gesturing as humans do with other humans is a natural way of interacting with a computer (see Chapter 4). Guidelines for multimodal design can be found in Reeves et al. (2004) and Oviatt et al. (2017).

7.2.14 Shareable Interfaces

Shareable interfaces are designed for more than one person to use. Unlike PCs, laptops, and mobile devices, which are aimed at single users, shareable interfaces typically provide multiple inputs and sometimes allow simultaneous input by collocated groups. These include large wall displays, for example SmartBoards (see Figure 7.24a), where people use their own pens or gestures, and interactive tabletops, where small groups can interact with information being displayed on the surface using their fingertips. Examples of interactive tabletops include Smart's SmartTable and Circle Twelve's DiamondTouch (Dietz and Leigh, 2001; see Figure 7.24b). The DiamondTouch tabletop is unique in that it can distinguish between different users touching the surface concurrently. An array of antennae is embedded in the touch surface and each one transmits a unique signal. Each user has their own receiver embedded in a mat on which they're standing or a chair in which they're sitting. When a user touches the tabletop, very small signals are sent through the user's body to their receiver that identifies which antenna has been touched and sends this to the computer. Multiple users can interact simultaneously with digital content using their fingertips.

Watch this video of Circle Twelve's demonstration of the Diamond Touch tabletop: **http://youtu.be/S9QRdXlTndU**.

An advantage of shareable interfaces is that they provide a large interactional space that can support flexible group working, enabling groups to create content together at the same time. Compared with a co-located group trying to work around a single-user PC or laptop, where typically one person takes control, making it more difficult for others to take part,



(a)

(b)

Figure 7.24 (a) A SmartBoard in use during a meeting and (b) Mitsubishi's interactive tabletop interface

Source: (a) Used courtesy of SMART Technologies Inc. (b) Mitsubishi Electric Research Labs

multiple users can interact with large display. Users can point to and touch the information being displayed, while simultaneously viewing the interactions and having the same shared point of reference (Rogers et al., 2009). There are now a number of tabletop apps that have been developed for museums and galleries which enable visitors to learn about various aspects of the environment (see Clegg et al., 2019).

Another type of shareable interface is software platforms that enable groups of people to work together simultaneously even when geographically apart. Early examples included shared editing tools developed in the 1980s (for example, ShRedit). Various commercial products now exist that enable multiple remote people to work on the same document at the same time (such as Google Docs and Microsoft Excel). Some enable up to 50 people to edit the same document at the same time with more watching on. These software programs provide various functions, such as synchronous editing, tracking changes, annotating, and commenting. Another collaborative tool is the Balsamiq Wireframes editor, which provides a range of shared functions, including collaborative editing, threaded comments with callouts, and project history.

Research and Design Considerations

Early research on shareable interfaces focused largely on interactional issues, such as how to support electronically based handwriting and drawing, and the selecting and moving of objects around the display (Elrod et al., 1992). The PARCTAB system (Schilit et al., 1993) investigated how information could be communicated between palm-sized, A4-sized, and whiteboard-sized displays using shared software tools, such as Tivoli (Rønby-Pedersen et al., 1993). Another concern was how to develop fluid and direct styles of interaction with large displays, both wall-based and tabletop, involving freehand and pen-based gestures (see Shen et al., 2003). Current research is concerned with how to support ecologies of devices so that groups can share and create content across multiple devices, such as tabletops and wall displays (see Brudy et al., 2016).

A key research issue is whether shareable surfaces can facilitate new and enhanced forms of collaborative interaction compared with what is possible when groups work together using their own devices, like laptops and PCs (see Chapter 5, "Social Interaction"). One benefit is easier sharing and more equitable participation. For example, tabletops have been designed to support more effective joint browsing, sharing, and manipulation of images during decision-making and design activities (Shen et al., 2002; Yuill and Rogers, 2012). Core design concerns include whether size, orientation, and shape of the display have an effect on collaboration. User studies have shown that horizontal surfaces compared with vertical ones support more turn-taking and collaborative working in co-located groups (Rogers and Lindley, 2004), while providing larger-sized tabletops does not necessarily improve group working but can encourage a greater division of labor (Ryall et al., 2004).

The need for both personal and shared spaces has been investigated to see how best to enable users to move between working on their own and together as a group. Several researchers have designed cross-device systems, where a variety of devices, such as tablets, smartphones, and digital pens can be used in conjunction with a shareable surface. For example, SurfaceConstellations was developed for linking mobile devices to create novel cross-device workspace environments (Marquardt et al., 2018). Design guidelines and summaries of empirical research on tabletops and multitouch devices can be found in Müller-Tomfelde (2010).

7.2.15 Tangible Interfaces

Tangible interfaces use sensor-based interaction, where physical objects, such as bricks, balls, and cubes, are coupled with digital representations (Ishii and Ullmer, 1997). When a person manipulates the physical object(s), it is detected by a computer system via the sensing mechanism embedded in the physical object, causing a digital effect to occur, such as a sound, animation, or vibration (Fishkin, 2004). The digital effects can take place in a number of media and places, or they can be embedded in the physical object itself. For example, Oren Zuckerman and Mitchel Resnick's (2005) early Flow Blocks prototype depicted changing numbers and lights that were embedded in the blocks, depending on how they were connected. The flow blocks were designed to simulate real-life dynamic behavior and react when arranged in certain sequences.

Another type of tangible interface is where a physical model, for example, a puck, a piece of clay, or a model, is superimposed on a digital desktop. Moving one of the physical pieces around the tabletop causes digital events to take place on the tabletop. One of the earliest tangible interfaces, Urp, was built to facilitate urban planning; miniature physical models of buildings could be moved around on the tabletop and used in combination with tokens for wind and shadow-generating tools, causing digital shadows surrounding them to change over time and visualizations of airflow to vary. Tangible interfaces differ from other approaches, such as mobile, insofar as the representations are artifacts in their own right that the user can directly act upon, lift up, rearrange, sort, and manipulate.

The technologies that have been used to create tangibles include RFID tags and sensors embedded in physical objects and digital tabletops that sense the movements of objects and subsequently provide visualizations surrounding the physical objects. Many tangible systems have been built with the goal of encouraging learning, design activities, playfulness, and collaboration. These include planning tools for landscape and urban planning (see Hornecker, 2005; Underkoffler and Ishii, 1998). Another example is Tinkersheets, which combine tangible models of shelving with paper forms for exploring and solving warehouse logistics problems (Zufferey, et al., 2009). The underlying simulation allows students to set parameters by placing small magnets on the form.

Tangible computing has been described as having no single locus of control or interaction (Dourish, 2001). Instead of just one input device, such as a mouse, there is a coordinated interplay of different devices and objects. There is also no enforced sequencing of actions and no modal interaction. Moreover, the design of the interface objects exploits their affordances to guide the user in how to interact with them. A benefit of tangibility is that physical objects and digital representations can be positioned, combined, and explored in creative ways, enabling dynamic information to be presented in different ways. Physical objects can also be held in both hands and combined and manipulated in ways not possible using other interfaces. This allows for more than one person to explore the interface together and for objects to be placed on top of each other, beside each other, and inside each other; the different configurations encourage different ways of representing and exploring a problem space. In so doing, people are able to see and understand situations differently, which can lead to greater insight, learning, and problem-solving than with other kinds of interfaces (Marshall et al., 2003).

A number of toolkits have been developed to encourage children to learn coding, electronics, and STEM subjects. These include littleBits (https://littlebits.com/), MicroBit (https://microbit.org/), and MagicCubes (https://uclmagiccube.weebly.com/). The toolkits provide children with opportunities to connect physical electronic components and sensors to make digital events occur. For example, the MagicCubes can be programmed to change color depending on the speed at which they are shaken; slow is blue and very fast is multicolor. Research has shown that the tangible toolkits provide many opportunities for discovery learning, exploration, and collaboration (Lechelt et al., 2018). The Cubes have been found to encourage a diversity of children, between the ages of 6 and 16, and those with cognitive disabilities, to learn through collaborating, frequently showing and telling each other and their instructors about their discoveries. These moments are facilitated by the cube's form factor, making it easy to show off to others, for example, by waving a cube in the air (see Figure 7.25).

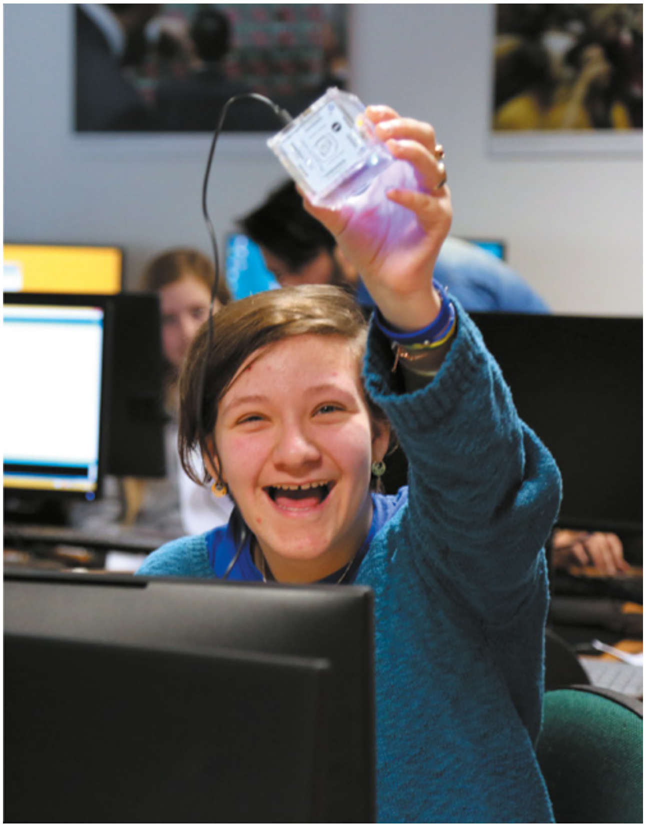


Figure 7.25 Learning to code with the MagicCubes; sharing, showing, and telling
Source: Elpida Makriyannis

Tangible toolkits have also been developed for the visually impaired. For example, Torino (renamed by Microsoft to Code Jumper) was developed as a programming language for teaching programming concepts to children age 7–11, regardless of level of vision (Morrison et al., 2018). It consists of a set of beads that can be connected and manipulated to create physical strings of code that play stories or music.

BOX 7.5

VoxBox—A Tangible Questionnaire Machine

Traditional methods for gathering public opinions, such as surveys, involve approaching people *in situ*, but it can disrupt the positive experience they are having. VoxBox (see Figure 7.26) is a tangible system designed to gather opinions on a range of topics *in situ* at an event through playful and engaging interaction (Golsteijn et al., 2015). It is intended to encourage wider participation by grouping similar questions, encouraging completion, gathering answers to open and closed questions, and connecting answers and results. It was designed as a large physical system that provides a range of tangible input mechanisms through which people give their opinions, instead of using, for example, text messages or social media input. The various input mechanisms include sliders, buttons, knobs, and spinners about which people are all familiar. In addition, the system has a transparent tube at the side that drops a ball step by step as sets of questions are completed to act as an incentive for completion and as a progress indicator. The results of the selections are aggregated and presented as simple digital visualizations on the other side (for example, 95 percent are engaged; 5 percent are bored). VoxBox has been used at a number of events drawing in the crowds, who become completely absorbed in answering questions in this tangible format.

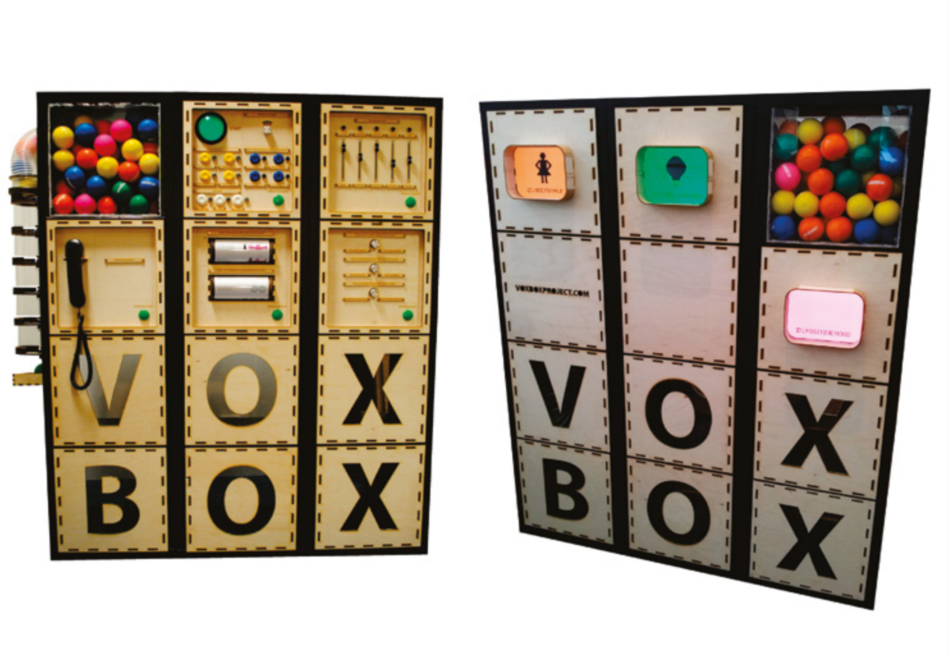


Figure 7.26 VoxBox—front and back of the tangible machine questionnaire
Source: Yvonne Rogers ■

Research and Design Considerations

Researchers have developed conceptual frameworks that identify the novel and specific features of a tangible interface (see Fishkin, 2004; Ullmar et al., 2005; Shaer and Hornecker, 2010). A key design concern is what kind of coupling to use between the physical action and digital effect. This includes determining where the digital feedback is provided in relation to the physical artifact that has been manipulated. For example, should it appear on top of the object, beside it, or in some other place? The type and placement of the digital media will depend to a large extent on the purpose of using a tangible interface. If it is to support learning, then an explicit mapping between action and effect is critical. In contrast, if it is for entertainment purposes, for example, playing music or storytelling, then it may be better to design them to be more implicit and unexpected. Another key design question is what kind of physical artifact to use to enable the user to carry out an activity in a natural way. Bricks, cubes, and other component sets are most commonly used because of their flexibility and simplicity, enabling people to hold them in both hands and to construct new structures that can be easily added to or changed. Sticky notes and cardboard tokens can also be used for placing material onto a surface that is transformed or attached to digital content (Klemmer et al. 2001; Rogers et al., 2006).

Another research question is with what types of digital outputs should tangible interfaces be combined? Overlaying physical objects with graphical feedback that changes in response to how the object is manipulated has been the main approach. In addition, audio and haptic feedback has also been used. Tangibles can also be designed to be an integral part of a multimodal interface.

7.2.16 Augmented Reality

Augmented reality (AR) became an overnight success with the arrival of Pokémon Go in 2016. The smartphone app became an instant hit worldwide. Using a player's smartphone camera and GPS signal, the AR game makes it seem as if virtual Pokémon characters are appearing in the real world—popping up all over the place, such as on buildings, on streets, and in parks. As players walk around a given place, they may be greeted with rustling bits of grass that signal a Pokémon nearby. If they walk closer, a Pokémon may pop up on their smartphone screen, as if by magic, and look as if they are actually in front of them. For example, one might be spotted sitting on a branch of a tree or a garden fence.

AR works by superimposing digital elements, like Pokémons, onto physical devices and objects. Closely related to AR is the concept of *mixed reality*, where views of the real world are combined with views of a virtual environment (Drascic and Milgram, 1996). To begin, augmented reality was mostly a subject of experimentation within medicine, where virtual objects, for example X-rays and scans, were overlaid on part of a patient's body to aid the physician's understanding of what was being examined or operated on.

AR was then used to aid controllers and operators in rapid decision-making. One example is air traffic control, where controllers are provided with dynamic information about the aircraft in their section that is overlaid on a video screen showing real planes landing, taking off, and taxiing. The additional information enables the controllers to identify planes easily, which were difficult to make out—something especially useful in poor weather conditions. Similarly, *head-up displays* (HUDs) are used in military and civil planes to aid pilots when landing during poor weather conditions. A HUD provides electronic directional markers on a fold-down display that appears directly in the field of view of the pilot. A number of high-end cars now provide AR windshield technology, where navigation directions can literally look like they are painted on the road ahead of the driver (see Chapter 2, "The Process of Interaction Design").

Instructions for building or repairing complex equipment, such as photocopiers and car engines, have also been designed to replace paper-based manuals, where drawings are superimposed upon the machinery itself, telling the mechanic what to do and where to do it. There are also many AR apps available now for a range of contexts, from education to car navigation, where digital content is overlaid on geographic locations and objects. To reveal the digital information, users open the AR app on a smartphone or tablet and the content appears superimposed on what is viewed through the screen.

Other AR apps have been developed to aid people walking in a city or town. Directions (in the form of a pointing hand or arrow) and local information (for instance, the nearest bakery) are overlaid on the image of the street ahead that appears on someone's smartphone screen. These change as the person walks up the street. Virtual objects and information are also being combined to make more complex augmented realities. Figure 7.27 shows a weather alert with animated virtual lightning effects alongside information about a nearby café and the price of properties for sale or rent on a street. Holograms of people and other objects are also being introduced into AR environments that can appear to move

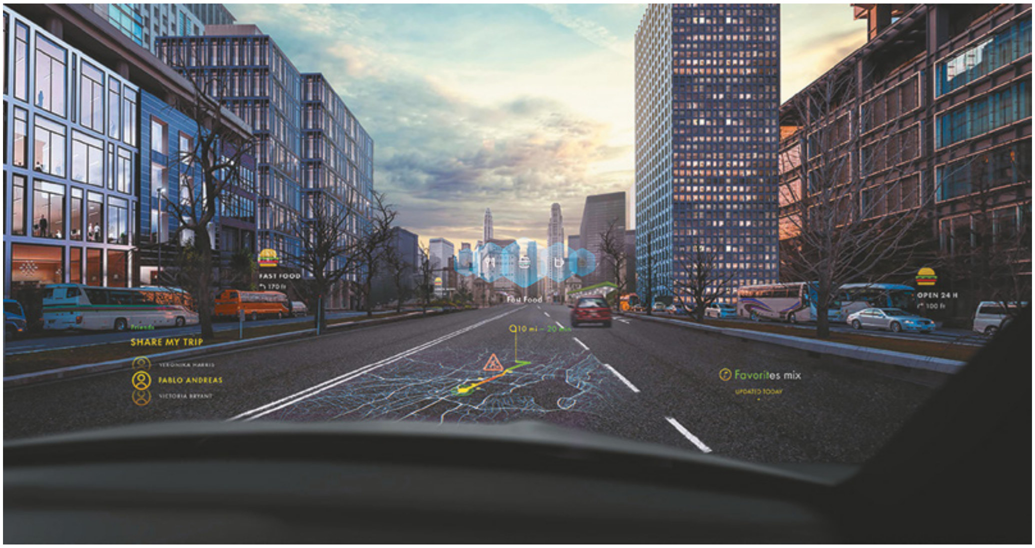


Figure 7.27 Augmented reality overlay used on a car windshield
Source: https://wayray.com

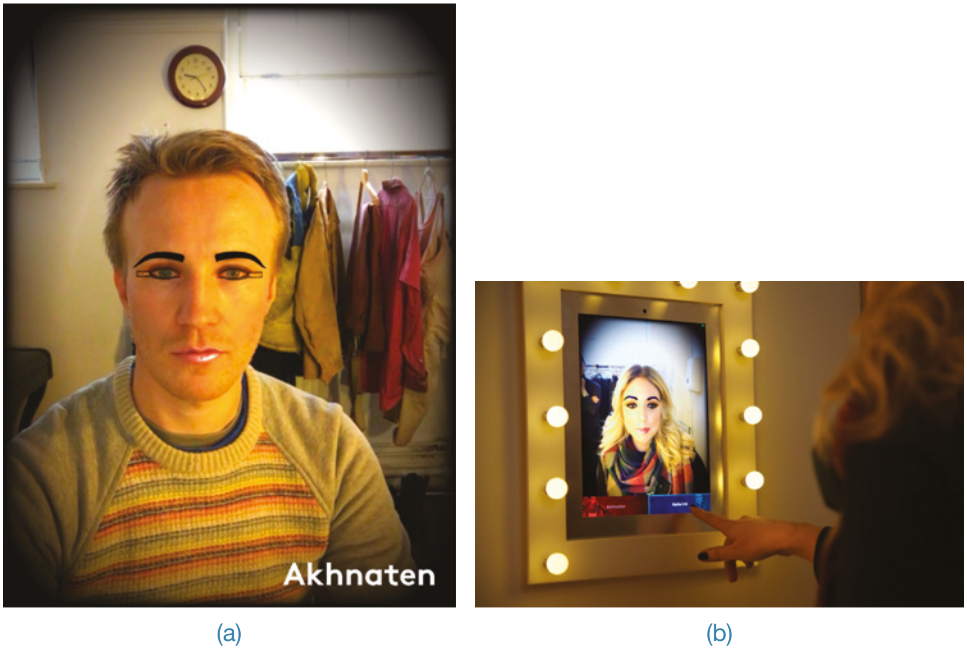
and/or talk. For example, virtual tour guides are beginning to appear in museums, cities, and theme parks, which can appear to by moving, talking, or gesturing to visitors who are using an AR app.

The availability of mapping platforms, such as those provided by Niantics and Google, together with Apple's ARKit, SparkAR Studio, and Google's ARCore, has made it easier for developers and students alike to develop new kinds of AR games and AR apps. Another popular AR game that has emerged since Pokémon Go is Jurassic World Alive, where players walk around in the real world to find as many virtual dinosaurs as they can. It is similar to Pokémon Go but with different gaming mechanisms. For example, players have to study the dinosaurs they come across by collecting their DNA and then re-creating it. Microsoft's Hololens toolkit has also enabled new mixed reality user experiences to be created, allowing users to create or interact with virtual elements in their surroundings.

Most AR apps use the backward-facing camera on a smartphone or tablet to overlay the virtual content onto the real world. Another approach is to use the forward-facing camera (used for selfies) to superimpose digital content onto the user's face or body. The most popular app that has used this technique is SnapChat, which provides numerous filters with which people can experiment plus the opportunity to create their own filters. Adding accessories such as ears, hair, moving lips, and headgear enables people to transform their physical appearance in all sorts of fun ways.

These kinds of virtual try-ons work by analyzing the user's facial features and building a 2-D or 3-D model in real time. So, when they move their head, the make-up or accessories appear to move with them as if they are really on their face. Several AR mirrors now exist in retail that allow shoppers to try on sunglasses, jewelry, and make-up. The goal is to let them try on as many different products as they like to see how they look with them on. Clearly, there are advantages to virtual try-ons: it can be more convenient, engaging, and easier compared to trying on the real thing. There are disadvantages too, however, in that they only give an impression of what you look like. For example, the user cannot feel the weight of a virtual accessory on their head or the texture of virtual make-up on their face.

The same technology can be used to enable people to step into historical, famous, film, or stage characters (for instance, David Bowie or Queen Victoria). For example, a virtual try-on app that was developed as part of a cultural experience was the MagicFace (Javornik, et al., 2017). The goal was to enable audiences to experience firsthand what it was like to try on the make-up of a character from an opera. The opera chosen was Philip Glass's Akhnaten, set in ancient Egyptian time (see Figure 7.28a). The virtual make-up developed were for a Pharaoh and his wife. The app was developed by University College London researchers alongside the English National Opera and AR company, Holition. To provide a real-world context, the app was designed to run on a tablet display that was disguised as a real mirror and placed in an actor's dressing room (see Figure 7.28b). On encountering the mirror *in situ*, visiting school children were fascinated by the way the virtual make-up made them look like Akhnaten and his wife, Nefertiti. The singers and make-up artists who were in the production also tried it out and saw great potential for using the app to enhance their existing repertoire of rehearsal and make-up tools.



(a)

(b)

Figure 7.28 (a) A principal singer trying on the virtual look of Akhnaten and (b) a framed AR mirror in the ENO dressing room

Source: Used courtesy of Ana Javornik

Research and Design Considerations

A key research concern when designing augmented reality is what form the digital augmentation should take and when and where it should appear in the physical environment (Rogers et al., 2005). The information (such as navigation cues) needs to stand out but not distract the person from their ongoing activity in the physical world. It also needs to be simple and align with the real-world objects taking into account that the user will be moving. Another concern is how much digital content to overlay on the physical world and how to attract the user's attention to it. There is the danger that the physical world becomes overloaded with digital ads and information "polluting" it to the extent that people will turn the AR app off.

One of the limitations of current AR technology is that sometimes the modeling can be slightly off so that the overlaying of the digital information appears in the wrong place or is out of sync with what is being overlaid. This may not be critical for fun applications, but it may be disconcerting if eye shadow appears on someone's ear. It may also break the magic of the AR experience. Ambiguity and uncertainty may be exploited to good effect in mixed reality games, but it could be disastrous in a more serious context, such as the military or medical setting.

7.2.17 Wearables

Wearables are a broad category of devices that are worn on the body. These include smartwatches, fitness trackers, fashion tech, and smart glasses. Since the early experimental days of wearable computing, where Steve Mann (1997) donned head and eye cameras to enable him to record what he saw while also accessing digital information on the move, there have been many innovations and inventions, including Google Glass.

New flexible display technologies, e-textiles, and physical computing (for example, Arduino) provide opportunities to design wearables that people will actually want to wear. Jewelry, caps, glasses, shoes, and jackets have all been the subject of experimentation designed to provide the user with a means of interacting with digital information while on the move in the physical world. Early wearables focused on convenience, enabling people to carry out a task (for example, selecting music) without having to take out and control a handheld device. Examples included a ski jacket with integrated music player controls that enabled the wearer to simply touch a button on their arm with their glove to change a music track. More recent applications have focused on how to combine textiles, electronics, and haptic technologies to promote new forms of communication. For example, CuteCircuit developed the KineticDress, which was embedded with sensors that followed the body of the wearer to capture their movements and interaction with others. These were then displayed through electroluminescent embroidery that covered the external skirt section of the dress. Depending on the amount and speed of the wearer's movement, it changed patterns, displaying the wearer's mood to the audience and creating a magic halo around her.

Exoskeleton clothing (see section 7.2.12) is also an area where fashion meets technology in order to augment and assist people who have problems with walking by literally walking or exercising the person wearing them. In this way, it combines haptics with a wearable. Within the construction industry, exoskeleton suits have also been developed to provide additional power to workers—a bit like Superman—where metal frameworks are fitted with motorized muscles to multiply the wearer's strength. It can make lifting objects feel lighter and in doing so protect the worker from physical injuries.

DILEMMA

Google Glass: Seeing Too Much?

Google Glass was a wearable that went on sale in 2014 in various fashion styles (see Figure 7.29). It was designed to look like a pair of glasses, but with one lens of the glass being an interactive display with an embedded camera that could be controlled with speech input. It allowed the wearer to take photos and videos on the move and look at digital content, such as email, texts, and maps. The wearer could also search the web using voice commands, and the results would appear on the screen. A number of applications were developed beyond those for everyday use, including WatchMeTalk, which provided live captions to help the

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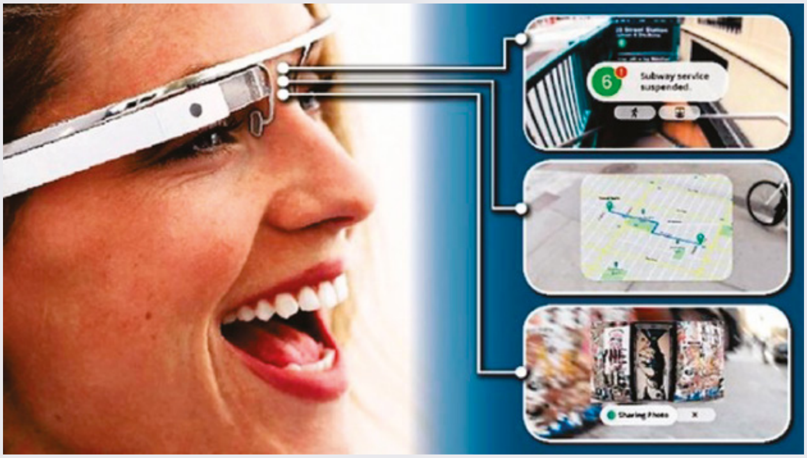


Figure 7.29 Google Glass
Source: Google Inc.

hearing-impaired in their day-to-day conversations and Preview for Glass that enabled the wearer to watch a movie trailer the moment they looked at a movie poster.

However, being in the company of someone wearing a Google Glass was felt by many to be unnerving, as the wearer looked up and to the right to view what was on the glass screen rather than looking at you and into your eyes. One of the criticisms of wearers of Google Glass was that it made them appear to be staring into the distance. Others were worried that those wearing Google Glass were recording everything that was happening in front of them. As a reaction, a few bars and restaurants in the United States implemented a "no Glass" policy to prevent customers from recording other patrons.

The original Google Glass was retired after a couple of years. Since then, other types of smart glasses have come onto the market that synch a user's smartphone with the display and camera on the glasses via Bluetooth. These include Vuzic Blade, which has a camera onboard and voice control that is connected to Amazon Echo devices, along with the provision of turn-by-turn navigation and location-based alerts; and Snap's Spectacles, which simply allows the wearer to share photos and video with their friends on Snapchat they take when wearing these glasses.

Watch the interesting video of London through Google Glass at **http://youtu.be/Z3AIdnzZUsE** and the Talking Shoe concept at **http://youtu.be/VcaSwxbRkcE**.

Research and Design Considerations

A core design concern specific to wearable interfaces is comfort. Users need to feel comfortable wearing clothing that is embedded with technology. It needs to be light, small, not get in the way, fashionable, and (with the exception of the displays) preferably hidden in the clothing. Another related issue is hygiene. Is it possible to wash or clean the clothing once worn? How easy is it to remove the electronic gadgetry and replace it? Where are the batteries going to be placed, and how long is their lifetime? A key usability concern is how does the user control the devices that are embedded in their clothing. Are touch, speech, or more conventional buttons and dials preferable?

A number of technologies can be developed and combined to create wearables including LEDs, sensors, actuators, tangibles, and AR. There is abundant scope for thinking creatively about when and whether to make something wearable as opposed to mobile. In Chapter 1, "What Is Interaction Design?" we mentioned how assistive technology can be designed to be fashionable in order to overcome stigmas of having to wear a monitoring device (for instance, for glucose levels), substitution (for example, a prosthetic) or amplifying device (for example, hearing aids).

7.2.18 Robots and Drones

Robots have been around for some time, most notably as characters in science-fiction movies, but they also play an important role as part of manufacturing assembly lines, as remote investigators of hazardous locations (for example, nuclear power stations and bomb disposal), and as search and rescue helpers in disasters (for instance in forest fires) or faraway places (like Mars). *Console interfaces* have been developed to enable humans to control and navigate robots in remote terrains, using a combination of joysticks and keyboard controls together with cameras and sensor-based interactions (Baker et al., 2004). The focus has been on designing interfaces that enable users to steer and move a remote robot effectively with the aid of live video and dynamic maps.

Domestic robots that help with the cleaning and gardening have become popular. Robots are also being developed to help the elderly and disabled with certain activities, such as picking up objects and cooking meals. Pet robots, in the guise of human companions, have been commercialized. Several research teams have taken the "cute and cuddly" approach to designing robots, signaling to humans that the robots are more pet-like than human-like. For example, Mitsubishi developed Mel the penguin (Sidner and Lee, 2005) whose role was to host events, while the Japanese inventor Takanori Shibata developed Paro in 2004, a baby harp seal that looks like a cute furry cartoon animal, and whose role was as a companion (see Figure 7.30). Sensors were embedded in the pet robots, enabling them to detect certain human behaviors and respond accordingly. For example, they can open, close, and move their eyes, giggle, and raise their flippers. The robots encourage being cuddled or spoken to, as if they were real pets or animals. The appeal of pet robots is thought to be partially due to their therapeutic qualities, being able to reduce stress and loneliness among the elderly and infirm (see Chapter 6, "Emotional Interaction," for more on cuddly robot pets). Paro has since been used to help patients with dementia to make them feel more at ease and comforted (Griffiths, 2014). Specifically, it has been used to encourage social behavior among patients who often anthropomorphize it. For example, they might say as a joke "it's farted on me!" which makes them and others around them laugh, leading to further laughter and joking. This form of encouraging of social interaction is thought to be therapeutic.

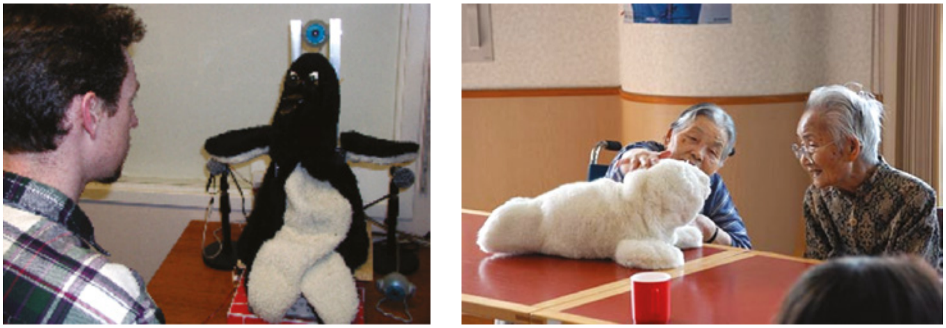


Figure 7.30 (a) Mel, the penguin robot, designed to host activities; (b) Japan's Paro, an interactive seal, designed as a companion, primarily for the elderly and sick children

Source: (a) Mitsubishi Electric Research Labs (b) Parorobots.com

Watch the video of Robot Pets of the Future at **http://youtu.be/wBFws1lhuv0**.

Drones are a form of unmanned aircraft that are controlled remotely. They were first used by hobbyists and then by the military. Since then, they have become more affordable, accessible, and easier to fly. As a result, they have begun to be used in a wider range of contexts. These include entertainment, such as carrying drinks and food to people at festivals and parties; agricultural applications, such as flying them over vineyards and fields to collect data that is useful to farmers (see Figure 7.31); and helping to track poachers in wildlife parks in Africa (Preece, 2016). Compared with other forms of data collection, they can fly low and stream photos to a ground station where the images can be stitched together into maps and then used to determine the health of a crop or when is the best time to harvest the crop.

Watch the video of Rakuten delivering beer via drone to golfers on a golf course at **https://youtu.be/ZameOVS2Skw**.

Figure 7.31 A drone being used to survey the state of a vineyard

Source: Drone inspecting vineyard / Shutterstock

Research and Design Considerations

An ethical concern is whether it is acceptable to create robots that exhibit behaviors that humans will consider to be human- or animal-like. While this form of attribution also occurs for agent interfaces (see Chapter 3), having a physical embodiment—as robots do—can make people suspend their disbelief even more, viewing the robots as pets or humans.

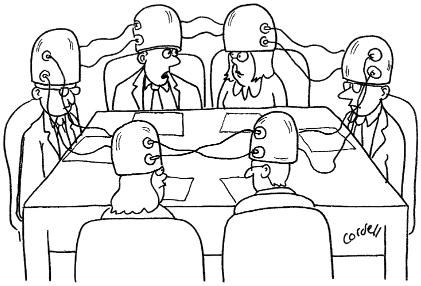
This raises the moral question as to whether such anthropomorphism should be encouraged. Should robots be designed to be as human-like as possible, looking like us with human features, such as eyes and a mouth, behaving like us, communicating like us, and emotionally responding like us? Or, should they be designed to look like robots and behave like robots, for instance, vacuum cleaner robots that serve a clearly defined purpose? Likewise, should the interaction be designed to enable people to interact with the robot as if it were another human being, for example, by talking to it, gesturing at it, holding its hand, and smiling at it? Or, should the interaction be designed to be more like human–computer interaction, in other words, by pressing buttons, knobs, and dials to issue commands?

For many people, the cute pet approach to robotic interfaces seems preferable to one that seeks to design them to be more like fully fledged human beings. Humans know where they stand with pets and are less likely to be unnerved by them and, paradoxically, are more likely to suspend their disbelief in the companionship they provide.

Another ethical concern is whether it is acceptable to use unmanned drones to take a series of images or videos of fields, towns, and private property without permission or people knowing what is happening. They are banned from certain areas such as airports, where they present a real danger. Another potential problem is the noise they make when flying. Having a drone constantly buzzing past your house or delivering drinks to golf players or festival goers nearby can be very annoying.

7.2.19 Brain–Computer Interfaces

Brain–computer interfaces (BCI) provide a communication pathway between a person's brain waves and an external device, such as a cursor on a screen or a tangible puck that moves via airflow. The person is trained to concentrate on the task (for example, moving the cursor or the puck). Several research projects have investigated how this technique can be used to assist and augment human cognitive or sensory-motor functions. The way BCIs work is by detecting changes in the neural functioning of the brain. Our brains are filled with neurons that comprise individual nerve cells connected to one another by dendrites and axons. Every time we think, move, feel, or remember something, these neurons become active. Small electric signals rapidly move from neuron to neuron, which to a certain extent can be detected by electrodes that are placed on a person's scalp. The electrodes are embedded in specialized headsets, hairnets, or caps.



"Frankly, I'm not sure this whole idea-sharing thing is working."

Source: Tim Cordell / Cartoon Stock

Brain–computer interfaces have also been developed to control various games. For example, Brainball was developed as a game to be controlled by players' brain waves in which they compete to control a ball's movement across a table by becoming more relaxed and focused. Other possibilities include controlling a robot and being able to fly a virtual plane. Pioneering medical research, conducted by the BrainGate research group at Brown University, has started using brain-computer interfaces to enable people who are paralyzed to control robots (see Figure 7.32). For example, a robotic arm controlled by a tethered BCI has enabled patients who are paralyzed to feed themselves (see video mentioned next). Another startup company, NextMind, is developing a noninvasive brain-sensing device intended for the mass market to enable users to play games and control electronic and mobile devices in real time using just their thoughts. It is researching how to combine brain-sensing technology with innovative machine-learning algorithms that can translate brain waves into digital commands.

Watch a video of a woman who is paralyzed moving a robot with her mind at **http://youtu.be/ogBX18maUiM**.

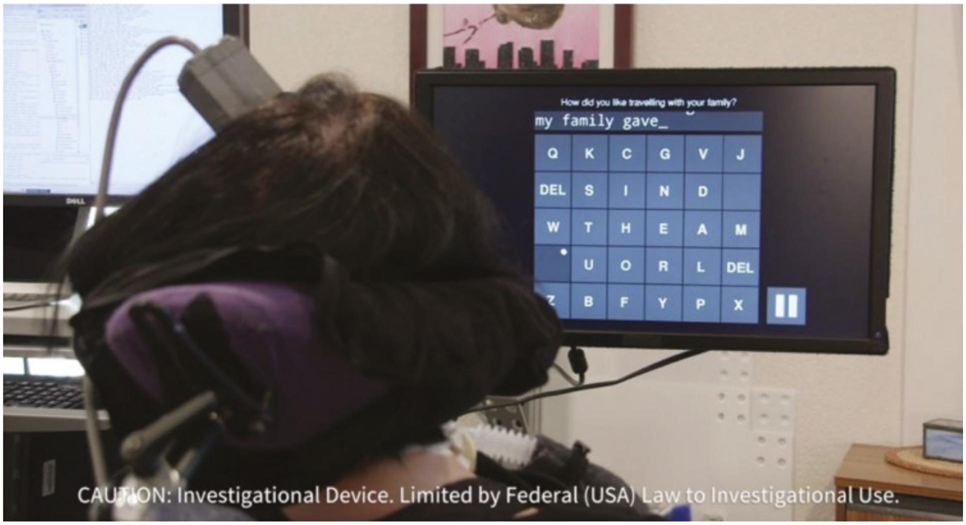

How did you like travelling with your family?
my family gave_
Q K C G V J
DEL S I N D
W T H E A M
U O R L DEL
Z B F Y P X
CAUTION: Investigational Device. Limited by Federal (USA) Law to Investigational Use.

Figure 7.32 A brain-computer interface being used by a woman who is paralyzed to select letters on a screen (developed by BrownGate)

Source: Brown University

7.2.20 Smart Interfaces

The motivation for many new technologies is to make them smart, whether it is a smartphone, smartwatch, smart building, smart home, or smart appliance (for example smart lighting, smart speakers, or virtual assistants). The adjective is often used to suggest that the device has some intelligence and it is connected to the Internet. More generally, smart devices are designed to interact with users and other devices connected to a network, many of which are automated, not requiring users to interact with them directly (Silverio-Fernández et al., 2018). The goal is to make them context-aware, that is, to understand what is happening around them and execute appropriate actions. To achieve this, some have been programmed with AI so that they can learn the context and a user's behavior. Using this intelligence, they then change settings or switch things on according to the user's assumed preferences. An example is the smart Nest thermostat that is designed to learn from a householder's behavior. Rather than make the interface invisible, the designers chose to turn it into an aesthetically pleasing one that could be easily viewed (see Box 6.2).

Smart buildings have been designed to be more energy efficient, efficient, and cost effective. Architects are motivated to use state-of-the-art sensor technology to control building systems, such as ventilation, lighting, security, and heating. Often, the inhabitants of such buildings are considered to be the ones at fault for wasting energy, as they may leave the lights and heating on overnight when not needed, or they forget to lock a door or window. One benefit of having automated systems take control of building services is to reduce these kinds of human errors—a phrase often used by engineers is to take the human "out of the loop." While some smart buildings and homes have improved how they are managed and cut costs, they can also be frustrating to the user, who sometimes would like to be able to open a window to let fresh air in or raise a blind to let in natural lighting. Taking the human out of the loop means that these operations are no longer available. Windows are locked or sealed, and heating is controlled centrally.

Instead of simply introducing ever more automation that takes the human out of the loop further, another approach is to consider the needs of the inhabitants in conjunction with introducing smart technology. For example, a new approach that focuses on inhabitants is called *human–building interaction* (HBI). It is concerned with understanding and shaping people's experiences with, and within, built environments (Alavi et al., 2019). The focus is on human values, needs, and priorities in addressing people's interactions with "smart" environments.

7.3 Natural User Interfaces and Beyond

As we have seen, there are many kinds of interfaces that can be used to design for user experiences. The staple for many years was the GUI, then the mobile device interface, followed by touch, and now wearables and smart interfaces. Without question, they have been able to support all manner of user activities. What comes next? Will other kinds of interfaces that are projected to be more natural become more mainstream?

A *natural user interface* (NUI) is designed to allow people to interact with a computer in the same way that they interact with the physical world—using their voice, hands, and bodies. Instead of using a keyboard, mouse, or touchpad (as is the case with GUIs), NUIs enable users to speak to machines, stroke their surfaces, gesture at them in the air, dance on mats that detect feet movements, smile at them to get a reaction, and so on. The naturalness refers to the use of everyday skills humans have developed and learned, such as talking, writing, gesturing, walking, and picking up objects. In theory, they should be easier to learn and map more readily onto how people interact with the world than compared with learning to use a GUI.

Instead of having to remember which function keys to press to open a file, a NUI means a person only has to raise their arm or say "open." But how natural are NUIs? Is it more natural to say "open" than to flick a switch when you want to open a door? And is it more natural to raise both arms to change a channel on the TV than to press a button on a remote device or tell it what to do by speaking to it? Whether a NUI is natural depends on a number of factors, including how much learning is required, the complexity of the app or device's interface, and whether accuracy and speed are needed (Norman, 2010). Sometimes a gesture is worth a thousand words. Other times, a word is worth a thousand gestures. It depends on how many functions the system supports.

Consider the sensor-based faucets that were described in Chapter 1. The gesture-based interface works mostly (with the exception of people wearing black clothing that cannot be detected) because there are only two functions: (1) turning on the water by waving one's hands under the tap, and (2) turning off the water by removing them from the sink. Now think about other functions that faucets usually provide, such as controlling water temperature and flow. What kind of a gesture would be most appropriate for changing the temperature and then the flow? Would one decide on the temperature first by raising one's left arm and the flow by raising one's right arm? How would someone know when to stop raising their arm to get the right temperature? Would they need to put a hand under the tap