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Icon design for the user interface

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The use of icons at the user interface is becoming increasingly pervasive. System information including objects, operations, states and messages are now being represented in such a pictorial form. This paper sets out to outline the major issues surrounding the suitability and design of icons for this purpose. In particular, it focuses on the merits and disadvantages of this type of communication and compares it with the use of verbal language. A number of pertinent design characteristics are also discussed. These include considerations such as shape, size, colour, discriminability within a set of icons and the use of textual labels with icons. Finally, some future trends are suggested.

1. *Introduction*

During the last few years there have been many changes at the human–computer interface. In particular, there has been a shift towards the use of graphically oriented displays consisting of windows, menus, icons and scroll-bars. Behind this development is the idea that by presenting essentially abstract information in a graphical form the computer system's apparent complexity can be reduced, making it easier to learn and use. The general assumption underlying this notion is that since we live in a strongly visual and spatially organized environment it seems more compatible to learn interfaces that also use visual and spatial information representations (e.g., Lodding 1983, Smith *et al.* 1982). For example, many commercial system operating environments, such as Apple's Macintosh and Digital Research's GEM, currently employ an extensive range of graphic images as a way of simplifying the operation of the system.

One of the main areas of concern which has arisen from this *Zeitgeist* is the use of icons at the interface. These are pictographic symbols, generally the size of a postage stamp, which are displayed on the screen. Their function is to represent underlying system objects, data structures and processes in a form which corresponds to the real world. They can be highly pictorial representations, bearing a close resemblance to a familiar object associated with the task (e.g., folders, files, sheets of paper), an analogy to the object or process (e.g., the use of scissors to represent 'to cut', the use of in-trays to represent 'mail') or simply abstract symbols used to represent system information (e.g., the use of different shapes to represent various system states). Examples of the various forms are illustrated in figure 1.

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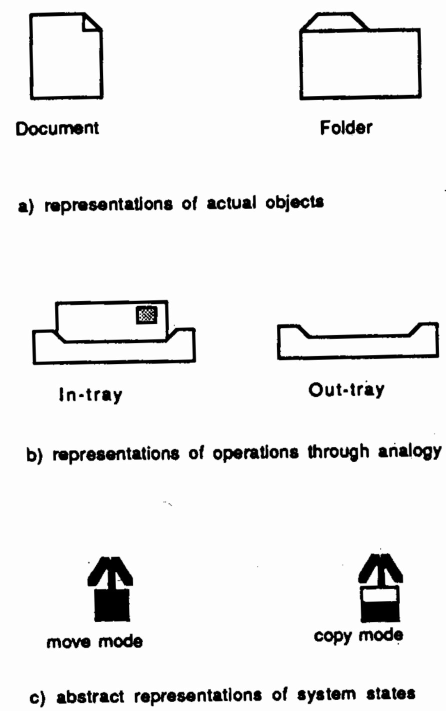

Figure 1. Examples of icon types.

2. Historical background

Icons were first incorporated as part of the user-interface for the Xerox 'Star' office workstation (Smith *et al.* 1982). As part of the design philosophy for the new product it was decided to develop an interface based on the metaphor of an actual physical office. The idea was that by representing the electronic 'world' as an electronic version of the physical environment of the office, it would make the computing system seem 'more familiar, less alien and require less training'. Hence electronic counterparts to the physical objects of an office were created in the form of icons. These included paper, folders, file cabinets and mail boxes (see figure 2).

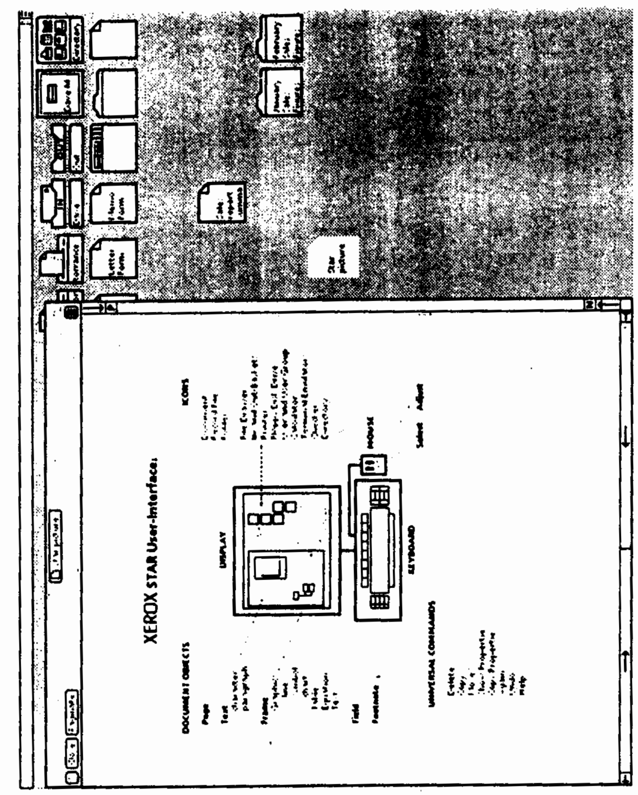

Figure 2. The desktop with icons as it appears on the Star Screen (From Smith et al. 1982)

The icons were designed to be used by a mouse-driven cursor. Icons were selected by first pointing at them and then clicking on a mouse button. Once selected they could be moved, copied or deleted by clicking on another mouse button. For example, moving a document was considered to be the electronic version of picking up a piece of paper and taking it somewhere.

The nature of the 'pointing, selecting and moving' action was intended to give the impression to the users that they were operating on actual objects. Hence, unlike traditional programming languages where interaction with the system is through abstract computational mediums, iconic interfaces have been designed to allow users to communicate with the system as if they were carrying out actual activities. Shneiderman (1982) has since described this approach to human–computer interaction (HCI) as *direct manipulation*. He also argues that the benefit of direct manipulation is that it can make interfaces easier to learn and use. Moreover, this should be so for all types of users, be they novices, infrequent users or experts.

3. Advantages of iconic interfaces

3.1. Universality

One of the main arguments used in support of iconic interfacing is that users find it more natural to understand and manipulate icons representing system information than to use other programming languages. Underlying this is the assumption that pictorial representations are, in general, a potentially universal means of communication and hence able to transcend the limitations imposed by a verbal language. In particular, it is often considered that the power of pictorial communication comes from its inherent meaningfulness. For example, for those who know the code, a picture of a pair of scissors looks like a pair of scissors in English, French, Chinese and Arabic, even though they are called by a different name in each of these languages.

The use of graphic symbols as a means of conveying messages is in fact already well established for public information and road signs, warning labels for toxic materials, procedures for washing clothes, and instructions for industrial and commercial equipment; the idea being that they can be universely understood across cultures. More recently, they have been used as a way of discriminating between the ever-increasing range of options available with the new generation of micro-electrical goods such as washing machines, cameras, ovens and video recorders. Many of these products are geared for a multinational market and, therefore, there is a need for a universal language that is easily understood. It comes as no surprise that just as the major motivation behind using pictorial representations in the applications mentioned above has been to overcome the 'language barrier', the use of graphic symbols at the computer interface can be seen as a move towards meeting the similar demands of an ever-increasing generation of naïve computer users. This time, the problem is one of 'computer illiteracy', in which there are an increasing number of people who need and want to use computers but who do not have the necessary programming skills.

3.2. Compactness

One of the main advantages of using graphic symbols as an alternative form of sign-posting to verbal labelling is that, because of their inherent compactness, they can be

presented in a more spatially condensed form (Zwaga and Boersema 1983). For example, the pictogram of a telephone set is able to convey the location of telephone facilities more compactly than words can (Kolers 1969). In addition they can sometimes present certain types of complex information more effectively. For instance, a highly successful use of symbolic images was of the pictograms used for the Montreal Olympic Games, which portrayed athletic events very effectively. The images used were of simplified people and objects associated with the sport. Not only were the designs easily identifiable but they were also able to embody more abstract underlying patterns of forces such as intensity, strength, balance and movement, thus enabling them to be powerful icons representing various qualities of the sporting event (see figure 3).

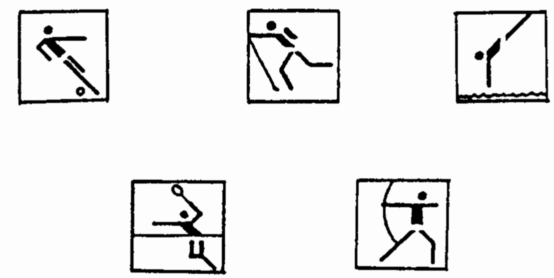

Figure 3. Icons based on those used for the Montreal Olympic Games.

3.3. Recognition

Human factors research has also demonstrated that graphic symbols can be recognized more rapidly and are legible at a greater distance (Dewar *et al.* 1976, Ells and Dewar 1979, Walker *et al.* 1965). Besides having an essentially denotative function, therefore, discrete pictographic symbols can also be effective when used for precautionary and alertive purposes. In particular, they have become an integral part of our roadsides, warning pedestrians and motorists of hazards ahead. For these types of messages the most efficient signs tend to be those that employ graphic images that correspond to real-world objects associated with the message, e.g., rocks falling, slippery road, humped back bridge; the main advantage being that they can be interpreted in a more effective way and more directly than words (Ballinger and Ballinger 1972).

3.4. Comprehensibility

Studies of the comprehensibility of graphic symbols intended for other settings, e.g. tractors and farm implements (Purcell 1967, Cahill 1975), fire safety symbols (Collins and Lerner 1982) and automotive applications (Green and Pew 1978) have also shown that, providing the symbols have been well designed, they can act as an efficient means of communication.

Findings such as these suggest that it is possible to use symbols efficiently to communicate a range of concepts. On this basis it would seem feasible to assume that using graphic symbols at the computer interface should make it easier for new users to understand the complex and often abstract nature of the underlying system functioning.

4. Disadvantages

One of the main difficulties with iconic communication is that the meaning of a symbol may be interpreted in different ways. Unlike verbal language, in which there is a set of syntactic and semantic rules which provide us with a means of disambiguating the meaning of verbal language, pictorial language has as yet no equivalent universal rules underlying its comprehension. Similarly, when words or sentences are ambiguous, then often the context in which they are used facilitates our interpretation. This is not necessarily the case with pictorial information. For example, we are able to determine the intended meaning of a word which has more than one meaning (e.g., bank) from the context in which it is used (e.g., the mole jumped onto the bank and dried herself). On the other hand, when we look at a picture depicting a mole sitting on a bank, it is not clear whether the mole has jumped out of the water or is about to jump into the water. Moreover, there are a number of other possible things that the mole might be doing besides sitting on the bank, which can be expressed succinctly in language but which cannot be shown in the picture.

An important factor which can help towards disambiguating our understanding of pictures, however, is a person's prior knowledge and expectations of the domain for which the picture is intended. Hence, successful comprehension of a set of icons will depend on our ability to make the link between the pictorial code used in the icon and our knowledge of the task domain and/or the underlying system operations. For those who have a good knowledge, the link between the two may be obvious; for those who have little understanding of the domain, the link will be very difficult to comprehend. In this sense icons are imprecise because they can represent different things to different people.

Since we do not have a clearly defined set of rules by which to interpret the meaning of pictures, it may be the case, therefore, that icons are actually a poor substitute for the preciseness of language. In particular, if users are forced to look up the meaning of icons in a manual to understand what they mean or just to get a more accurate description, then clearly this type of communication has failed. Instead, the icon has become an arbitrary symbol offering no advantage over other coding mechanisms (Jervell and Olsen 1985).

If pictures are being considered as a general form of communication such a pessimistic view may be valid. For example, the few attempts at developing a complete pictorial language which could be read in all languages (e.g., Bliss 1965, Ota 1973) have had little success because of their lack of precision, versatility and flexibility. In relation to the specific use for which icons are intended, i.e., as labels of certain types of system information or as indicators of underlying states and messages, it is not necessarily the case; the reason being that the specific domain for which iconic inter-

facing is intended predefines a limited number of interpretations. For example, : icon depicting a cross can always be used to mean 'to delete' since other interpre tions, such as to indicate an option selected, can be prevented if an appropri alternative icon is used for the latter purpose (e.g., a tick). The point is that a set icons can be designed which has its own set of syntax and semantics which c distinguish between all the system operations. The use of shape, spatial location, ty size and other pictorial attributes can all be exploited for this purpose. For examp operations can be differentiated from objects by the use of very basic forms of codi such as grouping and size. The aim is to devise as simply as possible 'a gramm which is consistent within the whole set of icons used and easy enough for the user understand and learn with minimum effort. Thus what appears to be a lack of p cision and flexibility has in fact the potential for being a very powerful form of co munication.

5. Classification of icons

In order that iconic interfaces are designed so that they are universally understandal it is important that some form of classification scheme is developed. Originally, Sm *et al.* (1982) proposed that the icons designed for the Xerox Star should be classi into two high-level categories: data icons and function icons. Data icons are define representing objects on which actions are performed (e.g., documents, folders : record files). Function icons represent objects that perform actions (e.g., file draw in- and out-trays, calculators). The two categories also differ accordingly:

1. anything that can be done to one data icon can be done to all, e.g., all data ic can be moved, copied, deleted etc.,
2. most function icons will accept any data icon, e.g., you can move any data ico a file drawer.

Since this initial dichotomy, there have been a number of other classifica schemes suggested which have attempted to distinguish further the different type icons and their functions (e.g., Lodding 1982, Jervell and Olson 1985, Gittins 19 The main characterization that has evolved has been to make the distinction betw the *form* and *function* of the icon.

5.1. Form

The form of an icon is the type of representation that is used in the depiction general this can consist of (a) concrete objects, e.g., files, folders; (b) abstract symt e.g., arrows, circles, dots, lines, mathematical formulae; and (c) a combination of b

The form can be classified further into the way in which it represents the underl concept, i.e., the referent. These can be either through:

1. resemblance
2. exemplar
3. symbolic, or
4. arbitrary.

5.1.1. Resemblance icons: Resemblance icons are those which depict the underlying referent through an analogous image. A good example is of the road sign for 'rocks falling' (see figure 4a).

5.1.2. Exemplar icons: An examplar icon is one which serves as a typical example for a general class of objects; for example, the knife and fork used in the public information sign to represent 'restaurant services' (see figure 4b). Within the context of public services, this depiction of a very simple image is very powerful as it shows the most salient attributes associated with what one does in a restaurant in the Western world, i.e., eat.

5.1.3 Symbolic icons: Symbolic icons are used to convey the underlying referent at a higher level of abstraction than the image itself. For example, the picture of a wine glass with a fracture in it is intended to convey the concept of 'fragility' (see figure 4c). Again, when used in the appropriate context, such as on the side of a box containing fragile goods, the image can be quite effective for what is a highly abstract concept.

5.1.4 Arbitrary icons: An arbitrary icon is one that is constructed that bears no relationship to the referent; hence the association must be learned. The biohazard sign is an example (see figure 4d). In this sense it is a completely arbitrary form of coding such as the letters that have been developed in verbal language; there is no relationship between the words and their intended meaning.

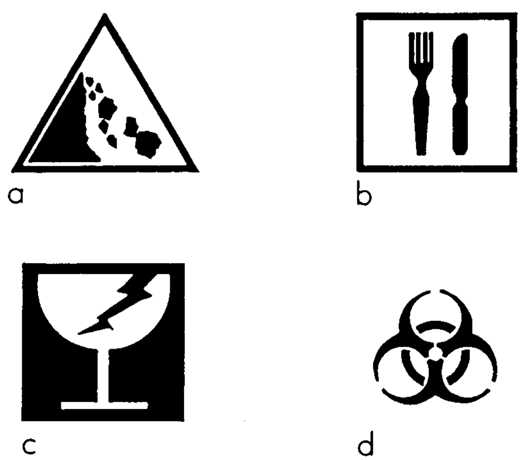

Figure 4. Different forms that icons can take: (a) resemblance; (b) examplar; (c) symbolic; (d) arbitrary.

5.2. Function

Icons can also be classified in terms of their function in relation to the task demai and their intended communication. The function of pictorial symbols used in conv tional settings has mainly been for alertive and identification purposes. For exam; they have been most widely and successfully used to display information that requi rapid comprehension, such as that shown on road signs or radar screens. In additi they have been very effective in providing information regarding object location, as the public information signs at airports.

Icons intended for use at the interface, however, are expected to have a number different functions. Table 1 provides a summary of these.

Table 1. Range of functions underlying interface icons.

Function	Example
labelling	menu item
indicating	system state
warning	error message
identifying	file storage
manipulating	tool for zooming and shrinking
container	object for placing discarded objects
gestalt pattern (detection)	structure in programming language

Although there are a number of possible functions icons can have, it is possible identify the common and distinct relationships between the objects and actions tl are being represented. For example, similar to Smith *et al.*'s (1982) classification, t various functions that an icon can take can be dichotomized as to whether they ; used on objects to perform actions (e.g., manipulating tools) or as objects which ; activated upon (e.g., the wastebin). A further distinction is icons which do not cons of a relationship between objects and actions but are there to provide information (i. indicators). This type of syntactical analysis is very useful when developing a set icons to ensure that the icons are readily distinguishable. As yet, however, there ha been no systematic attempts to incorporate such an analysis into the design of ic sets.

5.3. The referent

The other aspect of icons which we have not yet considered is the underlying nature the referent. The type of information and the psychological attributes whi characterize it will play an important role in determining the success of any rep, sentational form.

Most computer systems have a complex structure, consisting of a range of rep sentational states, data structures and command operations. The question is to wh extent these types of concepts can be represented in an iconic form that is meaningf and will facilitate the learning and memory of the system functioning.

Research in the psychological literature has shown that although abstract concep can be represented in a meaningful form, it becomes more difficult to represent the the more abstract they become (Jones 1983). When asked to generate drawings for a s of abstract verbs, similar to the type of command operations used at the comput interface, subjects found it much easier to produce drawings for high imagery verbs than for low imagery verbs (Rogers and Oborne 1987). Furthermore, the drawings produced for the high imagery verbs were considered to be the most representative and also had the highest stereotype strength. On the other hand, a diversity of drawings were produced for the low imagery verbs of which none really stood out as being the most meaningful.

5.4. Icon-referent mappings

So far we have looked at the form and function that an icon can take and the nature of the underlying referent. In order to design effective icons, however, the *mapping*, i.e., the relationship, between these three aspects also needs to be considered. In general, it is assumed that the more direct the mapping between the surface form of an icon and its underlying referent, the more efficient the icon; in other words, the easier it will be to understand, learn and use (Hemenway 1982, Gaver 1986, Rogers 1988).

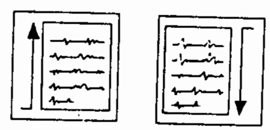

Figure 5. Example of a pair of icons based on a direct mapping: (a) go to top of text; (b) go to bottom of text. (Concrete object with abstract symbol).

The most direct icon-mappings are those which represent the underlying referent as images of that information, for example, the depiction of a file for the data object of a file. For more abstract types of concepts where there is no obvious resemblance between surface form and referent, it has been found that the most direct form of mapping is one which depicts concrete objects being operated on in conjunction with abstract symbols (Rogers 1988). The function of the latter is to provide an indication of the state of the action. For example, the command operations, 'go to the bottom' and 'go to the top' of a page are most effectively conveyed through the depiction of a piece of paper with writing on together with an arrow outside pointing downwards and upwards respectively (see figure 5). The least direct mappings have been found to consist purely of abstract symbols in which there is an arbitrary relationship between the icon and referent.

Another type of mapping is one based on analogical connections where the mapping makes use of the similarities between the entities being represented and the iconic form. These can be either physical or semantical associations. An example of a physically based mapping is the depiction of a pair of scissors to portray the operation 'to cut' where the action of cutting is most commonly performed with a pair of scissors. An example of a semantically based analogy with no physical connection is of

a spinning top, used in some CAD systems to represent the operation 'go to the t
Here the connection is based on the metonymy of the word 'top'. In some instar
this type of mnemonic chaining can be quite effective, especially if the link is biza
On the other hand, if the link is rather tenuous and not made explicit to the user it
actually be counter-productive. For example, Rogers (1988) found that the ic
mappings based on concrete analogies were the most difficult to understand, learn
remember for a range of verbal and user performance tasks in a word process
environment. Examples of the icons included a wheelbarrow with bricks in it for
operation 'to move' and a person with their arms in the air representing the operat
'to quit'. The other mappings which were compared included those based on abstı
symbols, concrete objects and combinations of these.

6. Icons versus names

In order to show that icons can be an effective form of communication at the interfa
it is important to establish that this mode of representation is more advantageous tl
other forms of communication for the task intended. Within the psychologi
literature there has been a large body of studies which have compared the processi
of pictures and words for a variety of tasks. Much of the earlier research (e.g., Jenk
et al. 1967, Paivio and Csapo 1969, Nelson and Brooks 1973) demonstrated t
superiority of pictures over words in a number of memory tasks. The reason for this
considered to be that pictures are processed more than the equivalent words, hen
making them more memorable. The most pervasive theory behind this notion is t
dual coding theory (Paivio 1971, 1986), which proposes that there are two distir
memory stores: first, a visual store, in which information about the picture or obje
appearance is stored in an analogue form, having spatial and configurational properti
similar to the picture; second, a verbal store, in which verbal material is stored. Tl
reasoning behind the theory is that pictures are remembered better than wor
because pictures are more likely to be represented in both stores. It is also assum
that the image storage system is the most effective (Paivio and Csapo 1973). Inde
various studies exclusively concerned with memory for pictures have shown that o
capacity for remembering them may be unlimited and extremely accurate. F
example, after presenting 2560 pictures individually over a number of days, near
90% of them were subsequently correctly identified in a memory task (Standing *et a*
1970).

In relation to the user interface, there have been relatively few studies which hav
compared the effectiveness of icons with command names. An early study b
Whiteside *et al.* (1985) investigating user performance for command, menu and iconi
interfaces for a number of bench mark tests, found that novice subjects in the iconi
interface actually took longer to complete the tasks than for the other two. From thei
results, it appears that subjects spent more time accessing the on-line help facility. Th
reason for this difference, however, may have been caused by other factors besides th
form of representation *per se*. In particular, it was reported that one of the main prob
lems users encountered with the iconic interface was that they found it difficult t
select the icons with a mouse-driven cursor. Hence the reason for the longer per
formance times for the iconic interface may have been more to do with the type o
interaction than with the form of representation.

Two more recent studies have specifically looked at the differences between iconic and command name interfaces, by investigating menu selection performance (Wandmacher and Müller 1987, Arend *et al.* 1987). Both studies used a search and select paradigm where a task description is first presented to the subject (e.g., 'print a document'). Following this a randomized menu of icons or names is shown and subjects are required to search for the correct menu item and then select it by pressing a corresponding number on the keyboard. In contrast to the previous study both showed that overall the response times to the icons were significantly faster than to the names.

In relation to the memorability of icons versus names Rogers (1988) found that the meaning of icons was significantly easier to recall than for command names. After performing a number of word processing tasks, subjects who had learned the icon set were able to correctly recall on average 85% of the underlying operations, whereas those subjects receiving the names could recall only 65%. Moreover, a significant improvement in recall for the icon condition was found in a subsequent session when the tasks were repeated a week later to the extent that almost all the icons were correctly defined. On the other hand, the recall level for the name set remained the same.

These findings suggest, therefore, that icons can be remembered better and can be processed faster than words. Although these are both important criteria for the use of icons, there is still the question of whether icons are the most appropriate medium for the function they are intended for.

7. *Shared attributes in command sets*

One of the main differences between the traditional use of pictorial symbols as a means of communicating public information, etc., and icons to be used at the interface, is that pictorial symbols are often displayed as individual signs whereas icons are generally displayed as a set. Most commonly, icons are used to represent a set of menu items, be they system operations or objects, or as a palette of tools for a given application. The point is that there is a big difference between using icons in isolation and as a group in so far as an individual icon only needs to be able to represent the underlying referent efficiently whereas a set of icons needs also to discriminate effectively between the various referents.

Computer command sets are usually structured in the sense that they can often have something in common with each other. For example, in a text editing domain many of the commands have shared attributes (e.g., delete a line of text, delete a character, delete a paragraph) while retaining distinctive features. In terms of command language, Rosenberg (1983) has suggested that appropriate names can be selected which can reflect this structure. He suggests that a good name is one in which there is a high degree of similarity between the names and the underlying operations. Furthermore, an optimal command name will maximize the similarity, i.e., the mapping of features, between operations and its names, and minimize the similarity between different names. Hence names whose underlying psychological attributes map closely to the psychological attributes of the command operation, but which are also distinctive from the other name operations within the set, are considered to be the easiest to learn and remember.

This type of mapping works well when there is a small set of commands consisting of opposite pairs of commands that are distinct from the rest of the set, e.g., 'create' for open a new file and 'destroy' for deleting a file. The problem arises, however, when there is a lot of overlapping between elements and operations within a larger set of operations. Consider again the delete example, where the same action is used for three different elements. There are even more if we include the possibilty of deleting files, sentences etc. The question is, given that verbal language is linear, how do we go about selecting names that are semantically similar to the underlying referent while being distinct from the other names? While there are several synonyms which can be used to mean delete – e.g., destroy, remove, erase – semantic confusion can arise if they are all used within a set. For instance, if we label the operation 'to delete a file' with the name 'delete'; to delete a block with the name 'erase'; 'to delete a word' with the label 'remove' and so on for the rest of the delete operations, how can we then remember whether the name 'delete' was associated with file and not, say, block? At a semantic level, therefore, it would seem that there is no obvious association between the various forms of 'destroy' and the different elements to be destroyed. In this sense command names *per se* are a very poor means of representation since they are unable to discriminate effectively between the various combinations of same operations with different elements and vice versa.

One of the advantages of pictorial communication over verbal language, on the other hand, is that it is multidimensional, i.e., it has a large number of graphic attributes such as colour, shape, size. If used effectively these can be combined in such a way as to map onto the structure of the command set. For example, in the above case crosses and oblong shapes varying in size can be used together in a way that can depict the similar action of deleting while conveying the distinct types of objects. Figure 6 shows the nature of this relationship.

The potential of pictorial representation, therefore, is that it can provide a means of discriminating between operations which have common features. In doing so it can also provide visual cues about the way in which a particular domain is structured. This in turn has been suggested to facilitate learning and subsequent retention about the structure of the domain (e.g., Gittins 1986).

Relationships between groups or pairs of commands, therefore, can be conveyed through the use of common and distinct pictorial elements. A less direct way of showing the similarities between commands is through the use of icons which have a similar graphic style that distinguishes them from other members of the set. For example, the use of similar cartoon shapes can make the icons appear related. This type of relation can be viewed in terms of the Gestalt law of similarity, where there is a tendency for the perceptual processes to group similar elements together as if they belong to each other. Although such a technique is unable to specifically identify the feature(s) that the corresponding command(s) share, it does provide powerful perceptual cues as to which icons are related. Similarly, the actual physical grouping of different icons on a display can be used to indicate similarities between commands. Hence it would seem logical to position operations which have shared features (e.g., all the delete operations) together in one group and all the distinct operations (e.g., to help, to quit) in another.

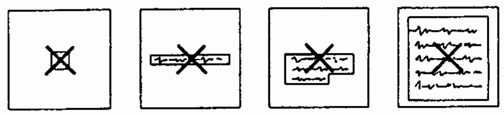

Figure 6. 'Delete' icons for word, line paragraph and page.

8. Considerations for icon design

When deciding on the suitability and design of icons at the user interface, a number of factors should be considered. These include both high-level considerations such as task demands and low-level ones such as the choice of shape and colour.

8.1. Task demands

The types of domains and tasks for which icons will be most suitable will depend on the structure of the domain and the cognitive processes that are required to perform the tasks. For tasks which require the user to specify and to retrieve information, as is the case for alphanumeric data bases, it would seem more compatible for the domain to be represented at the interface in a verbal form, since this would correspond more to the sequential and hierarchical structures often found in this kind of data base. To represent this type of information graphically could actually make the task of retrieving information more difficult, since it might be more cognitively demanding for the user to have to associate visual with verbal forms that may not have much in common. For example, if people want to access specific bibliographic records, it is more natural and efficient for them to do so by asking the system in natural language rather than to have to search for an icon that refers to the material in which they are interested. Moreover, as the results from the study suggest, if the material is highly abstract it would be very difficult to design meaningful and discriminable icons in such a way that they would be able effectively to map onto this type of information.

On the other hand, the use of visual images for other types of verbal retrieval tasks may sometimes be more helpful. For instance, when one is unsure of the precise nature of information, icons may prove useful as cues to guide one's search. An example might be a videotex-type data base containing recipes, whose users are not sure of their requirements. Using pictures at the interface to represent the recipes may be a more effective way to help guide selection. This type of task differs from the previous example in that it involves not recall but cognitive processes of recognition, which may be less demanding.

Other domains where iconic interfacing may prove to be beneficial are those which require the user to make visual judgements (like the design of spatial layouts such as circuit boards) and those in which large amounts of information have to be easily identifiable (such as personal filing systems) where icons could be used as mnemonic tags. Iconic interfacing may also be an effective dialogue for tasks which require a large number of operations to be performed, especially if they are manipulative processes. For example, the numerous drawing and painting techniques necessary for graphical design tasks may best be represented as 'icon tools' where each icon refers to a specific manipulative drawing process. Other domains where they are likely to be effective are those which consist of categories of operations that share similar relations between actions and elements.

8.2. Concept types

For applications which are essentially object oriented (e.g., CAD/CAM), designing effective icons to represent the underlying system is a fairly straightforward task. Isomorphic representations, where there is a direct structural relation to some of the properties of the real object being represented, are relatively easy to construct.

At a higher level of abstraction, icons may also prove to be effective at representing categories of system objects. For example, as demonstrated by Rosch (1975, 1978) people readily associate superordinate categories of objects (e.g., furniture, fruit) with the most typical member of that category (e.g., chair and apple, respectively). Hence for applications which comprise a large number of objects that fall into cognitively compatible categories it may be possible to find prototypical members which could be iconically represented as instances of each category. For example, videotex data bases (e.g., electronic retail services like PRESTEL) and applications consisting of a wide range of operations (e.g., architectural and electronic design systems) may benefit from this approach since they tend to consist of categories of services/objects/actions. If it is the case that a prototypical member can readily be associated with each category, then it may be possible to represent these superordinate categories in a meaningful iconic form.

Another potential benefit of category icons is that they could facilitate recognition and search processes involved in data base querying activities. Muter and Mayson (1986), for example, recently showed that the inclusion of graphics in a videotex system greatly reduced the number of errors subjects made when making a selection. Although the research was not directed towards explicitly investigating the efficacy of prototypical members, it is interesting to note that the types of graphics used in the study were of typical members of categories. For example, a chair was used to represent furniture, a coat for clothing and a kettle for appliances.

Another factor which affects the ability with which an abstract concept can be captured in an iconic form is the underlying imageability and association with the system concept, and how this relates to the actual visible outcome of a command operation at the screen (Rogers 1988). For example, the command 'go to the top of the text' can be very effective when represented in iconic form. The reason for this was considered to be because the outcome of the operation is clearly visible on the screen and hence could be readily mapped onto an iconic form. On the other hand, commands like 'to save' and 'to load' are much more difficult to understand in iconic form. This is because the concepts are much more difficult to visualize, having no direct outcome at the screen, and hence no direct mapping between the iconic form and underlying command.

The reason why some types of commands are easier to comprehend in iconic form has also been suggested by Rohr (1986) to be a function of the existential nature of the command. By this she refers to commands that are abstract, have a poor object-action relation and are assumed to be difficult to visualize (e.g., commands like 'to delete' and 'to erase'). On the other hand, spatial functions such as 'to insert' and 'to move' are better understood in pictorial form because they can depict more effectively the function between object and places.

8.3. Shape

An important factor at the physical level of icon design is the actual visual characteristics of the icon. One of the main criteria for good design is that the shape of the icon should facilitate rapid recognition. This is particularly important for icons which are intended to be part of a menu display where the user will be required to search and select the appropriate option from the rest of the display.

One way in which the shape of the icon can facilitate easy discrimination among

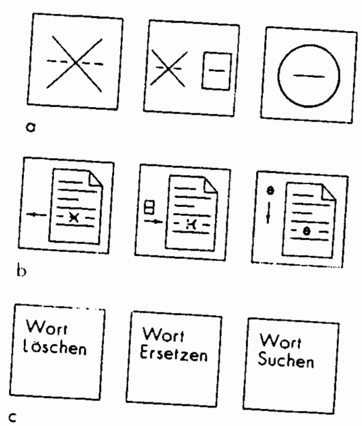

Figure 7. Examples of the icons used in Arend et al.'s (1987) study. (a) abstract icons; (b) representational; (c) names.

alternatives is to maximize the difference between the outline shape of the icons within a set. Hence varying the global structure of each of the icons should make it easier to locate and identify an individual icon. Arend *et al.* (1987) have further proposed that the global features of figures (e.g., the shape, size, colour) can be responded to considerably faster than local features (e.g., lines and structures within figures). Hence icons which differ from each other in global features should be searched and selected faster than icons that have similar outline shapes but differ from each other in local

features. The reason for this is assumed to be because of a 'global superiority effect' (Pomerantz 1983, Wandmacher and Arend 1985), in which the perception of global features in a figure is more rapid than the perception of the local features.

To test their theory, Arend *et al.* (1987) compared the selection and response time for three sets:

1. an abstract icon set, in which the icons differed from each other by their global outline,
2. a representational icon set in which the icons differed from each other by their local features, and
3. a word set.

The results showed that abstract icons were searched and selected faster than both the words and the representational icons. They suggest the reason that the abstract icon can be searched faster is that they can be processed in parallel whereas names and the representational concrete icons have to be searched sequentially. An alternative explanation is that the abstract icons were a lot simpler and hence less information had to be processed than for the representational ones which were much more detailed (see figure 7). Thus the longer search times could have been a function of the amount of processing required rather than the type of processing.

The outline shape of an icon, therefore, can provide a means of making icons more distinctive from one another and hence easier to identify. An icon, though, also needs to be meaningful and memorable. It is important, therefore, to take into account the directness of the mapping between the icon and the underlying referent when considering the global shape of the icons. In order to design meaningful icons, therefore distinctive local features that can depict the state of the various underlying referents will need to be incorporated in the design. The optimal solution, therefore, is to be able to design an icon set in which all the icons have different outline shapes but also contain sufficient local feature information for them to have a direct mapping to the underlying referents.

8.4. Simplicity

Given the limited size of icons when displayed on a screen they should be designed however, to be as simple as possible. Moreover, fine detail makes no contribution to unambiguous and rapid interpretation of pictorial information. Simple outline drawings of object should be used in preference to drawings using shading. In some cases the use of cartoon-like figures may be effective. For example, in a study on the efficacy of different modes of presentation Ryan and Schwartz (1956) found that subjects were able to recognize objects depicted by cartoons more accurately than line drawings or photographs. The reason for this may be due to this type of representation being able to capture the salient features of the referent more effectively.

Where objects need to be positioned in front of each other, an effective technique is to use a solid shape rather than an outline shape (Easterby, 1970). The advantage of this is that it makes the shape in the front stand out better (see figure 8).

8.5. The use of colour

Colour can look very pretty at the interface but can also be very distracting. The use of colour to 'fill-in' images so that they make the icons more lifelike is not recommended

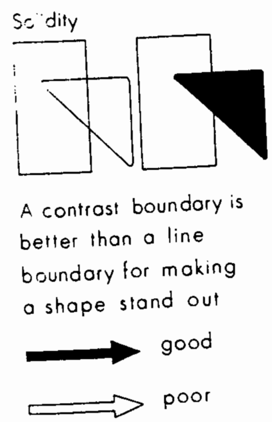

Figure 8. The contrast-boundary superiority effect (based on Easterby, 1970).

Searching for a particular icon from a whole set of individually coloured-in icons may prove to be more of an arduous task than if the icons were simply achromatic. Furthermore, psychological research on object recognition has shown that colour does not play a primary role in visual search. For example, when comparing recognition of fully coloured photographs with recognition of simplified line drawings of common objects (e.g., banana, chair, camera), Biederman and Ju (1988) found no difference in reaction time or errors.

The implication for icon design, therefore, is that colouring in icons does nothing to improve their discriminability and can actually hinder search times. On the other hand, colour has been found to be a very effective form of coding. In an extensive review of the literature on the use of colour in a range of tasks, Davidoff (1988) reported that colour can be used most effectively to divide a display into separate regions. Hence segmentation of a display by colour for detection and search tasks is very useful. In particular, areas that need to be seen as belonging together should have the same colour. In relation to icon design, colour could be used as a coding mechanism to distinguish between icons that are related to each other, e.g., similar operations or file types. Hence, one background colour could be used for manipulating tools, another colour for icons which represent warning messages and so on. The point is that if colour is to be used most effectively it should be used as a coding method. In particular, it is most useful for dividing icons into related subgroups.

Colour coding may also prove to be an effective form of tagging documents for identification purposes (Lansdale 1988). For example, tagging one set of icon documents with a blue dot and another with a green dot could greatly facilitate the rapid identification of a single document. The user, having associated an individual icon with a blue dot, would only need to scan through the blue-tagged files, eliminating the need to search through all the other colour-coded files.

To be most effective, only a limited number of colours should be used since too many colours will increase search times. The combination of colours on a screen is also critical. Various combinations of colours can be very difficult for the observer to discriminate, especially if they are highly saturated (e.g., red next to blue). The presence of two or more bright colours means that the eye will be continuously having to refocus over the image and will suffer strain and fatigue.

8.6. The use of labels with icons

As discussed earlier, one of the main arguments in support of the use of icons at the interface is that they can be universally understood and it can be easy to remember what they mean. For this reason, therefore, it seems unnecessary and redundant to include labels besides each icon. However, as it stands today a lot of commercial iconic interfaces have been designed in which icons are always displayed with a verbal label. Whether the combination of textual labels with the icons is a more effective means of representation than by either presentation alone or whether the icons have been so badly designed that their meaning is not obvious without a label is debatable.

A recent study by Edigo and Patterson (1988) comparing the effectiveness of pictorial icons, verbal labels and the combination of both provides evidence that the combination of the two mediums is the most useful. In their experiment, they compared the utility of the different forms of representation as navigational aids for catalogue browsing to a pictorial data base. They found that subjects were able to reach the target object much quicker and with fewer selections with the combined picture and label condition. The worst condition was the picture only set. They suggest the reason for this is that the pictures help define and disambiguate the verbal labels and in doing so promote deeper processing of the labels. Muter and Mayson (1986), who investigated the role of graphics in the selection of items from a menu, also found that the addition of graphics to a textual label greatly reduced the number of errors in the selection of a correct item.

These two preliminary studies suggest that the combination of text and pictures is the most effective form of representation. Both studies, however, used a search and select paradigm where the subject had to find a specific object from a hierarchy of categories (e.g., look for a new sofa). In this situation the combination may be preferable because the subject is required to match an example to a category. When the category is presented as a label (e.g., furniture) combined with a typical pictorial example e.g., a chair, then presumably the task of identification is made easier for the subject since the link between the superordinate and subordinate categories is provided. On the other hand, in other domains where the function of icons is different, such as when they are used to represent tools, it may be the case that this form of dual coding is not required. Intuitively, this seems to be the case, but empirically it remains to be discovered.

9. Evaluation

Having decided on iconic interfacing, a set of icons needs to be designed which are easy to comprehend, learn and use for the specific domain they are intended for. In general, there are a number of techniques which have been developed for the purpose of evaluating graphic symbols *per se*, of which some are considered appropriate for testing icons (Hakiel and Easterby 1987). These include adapting the various stages of the ISO procedure for the selection and evaluation of symbols (Easterby and Zwaga 1976).

The first stage of the procedure requires the finding of a source from which a selection of the most appropriate icons can be selected. Currently, there are a number of in-house icon catalogues which provide a range of standardized options for the types of system information which support the company's various applications. These, however, are usually confidential. Therefore, other industries and research establishments who do not have the resources for their own code books will need to look elsewhere. A 'quick and dirty' method is to have a few brainstorming sessions in which designers, artists or others are briefed about the application, constraints and user requirements, and then to ask each to produce a set of icons (Milner 1987, Brown and Stammers 1987).

A more extensive procedure, time and resources permitting, is to ask a large number of individuals to produce drawings for the intended icon set. This way, a large body of data can be collected and then analysed to determine which are the most meaningful and stereotypic images (i.e., the largest number of drawings produced by the individuals which are similar to each other). This technique is known as the sign production method. It was first developed and validated by Howell and Fuchs (1968) and since has frequently been used to obtain pictorial representations of verbal concepts for use in visual communication (e.g., Szlichcinski 1980, Collins 1982, Jones 1983, Rogers 1986). The rationale behind this technique is that the drawings people generate when asked to represent a particular referent are the ones they would also be most likely to understand and recognize. Where possible, therefore, it is preferable to get a selection of the intended user group to be involved in the task.

Having obtained a range of possible drawings for each of the intended icons, the next stage is to find out which ones are considered to be the most representative of the meaning of the underlying referent. The ISO procedure suggests that a battery of tests are employed. The initial stage involves an 'appropriate ranking' test in which a different set of subjects from those who produced the drawings are asked to rank the drawings in order of their meaningfulness as representations of the underlying concept. For limited numbers of drawings per referent (say, fewer than ten), the ranking can be done on an individual basis. If, on the other hand, there are a large number of drawings to sort, as would be the case if the sign production technique was used, then it is necessary to adopt a different strategy in which the judges are asked to place the drawings into piles so that each pile contains drawings that express the same idea. Following this, subjects are asked to rank the piles in order of meaningfulness. In this way the task is more manageable for the subject. In addition an index of the degree of stereotypy for the drawings can be obtained.

After selecting one or two icons for each referent, the next stage is to find out how meaningful they actually are. One type of test which is used at this stage is the recognition or naming test. Simply, subjects are first shown an icon and then asked to give a short description of what they think it means. For this to be a useful measure, however, it is important that the subjects have some prior knowledge of the underlying domain to ensure that they have an appropriate context in which to interpret them. If they do not have knowledge of the domain, problems will arise because they will simply interpret them within another context.

Timed tests, in which subjects' speed of response for identifying icons is measured, can also be used. These are very useful for evaluating sets of icons that are being designed for tasks requiring rapid recognition (e.g., icons for radar screens). As icons are usually designed as a set, it is important to carry out a further testing stage in which the discriminability of the icons against each other is tested. The most commonly administered test for this purpose is the matching task, in which the whole set of icons is presented and each referent is matched one at a time to the most appropriate icon. This is a very effective technique as it can provide the frequency with which the same icons are correctly selected as well as an index of the number and types of icons which were incorrectly matched. Subsequently a confusion matrix can be drawn up which can highlight the specific discriminability problems that occur.

These series of 'paper and pencil' methods, as prescribed by the ISO, provide a reliable method for designing and selecting icons in terms of obtaining the most meaningful individual icon-referents and assessing the discriminability between icons within a set. Indeed, the adoption of these methods has been used in the testing of a range of icon sets, including those designed for Xerox Star (Bewley *et al.* 1983), for PCjr's Homeword (Keller and Happ 1984), British Telecom's symbols for supplementary telephone services (Richards 1982) and PAFEC's CAD software package Design Office Graphics System (Milner 1987).

As well as providing a reliable and robust design procedure, it may still be necessary, however, to test the icons *in situ*. This is so that a measure can be obtained to determine the effectiveness of the icons when actually being used for the application they are intended for. The reason for this is that evaluating actual performance can provide measures of 'learnability' and ease of use which cannot otherwise be obtained from the paper and pencil techniques. For example, a set of icons may seem easy to discriminate in isolation but when incorporated within the interface may become much more difficult to select because of other aspects of the display interfering or differing task demands.

It is important, therefore, to also assess user performance of the selected icons at the interface. Depending on the application, performance can be measured on a number of parameters. The most useful and relevant measures for the evaluation of icons are the amount of time spent accessing the help facility to reference the meaning of an icon, the number and type of incorrect selection of icons for intended task operations, the sequencing of icon selection and the time taken to select the appropriate icon. The measures which will be most suitable will obviously depend on the application the icons have been designed for. For example, in a study on user performance for a set of word processing tasks, the main measures obtained by Rogers (1988) were access to the help facility and incorrect icon selection from the menu of options. The former was assumed to be a function of the user's ability to remember what the icons referred to, and the latter an index of the discriminability of the icons. These two sources of data were sufficient to show significant differences between different icon sets which varied in their directness of mapping. Moreover, it highlighted some discriminability problems which did not show up in earlier evaluation methods using the ISO paper and pencil methods.

Another advantage of testing actual performance is that different types of interfaces can be compared. For example, Whiteside *et al.* (1985) were able to compare learning rates and ease of use for command, menu and iconic interfaces. In contrast to Rogers (1988), they evaluated performance using very global measures. These included time to complete the task and the user's subjective assessment of how easy they found the task with the different interfaces. While not able to highlight specific problems with the various interfaces, these measures were able to provide a comparative index of the ease of use of the different interfaces.

Clearly, there are a range of methods available for icon evaluation. Unless resources and time are available, it will be impractical to perform them all. A method should be adopted, therefore, which will provide a reliable measure of meaningfulness and also give some indication of how easy the icons will be to learn and use at the interface.

10. Innovative design for the future

Icons have become standardized in most designer's minds as small static pictures that are of a specified rectangular size and are positioned with other icons in a vertical or horizontal matrix. But there is no reason why the icon cannot be extended beyond this form of display. For example, it may prove to be more effective for icons to be combined in other ways, such as in a hexagonal 'honeycomb' structure or otherwise. Recent research that has investigated the positioning of verbal labels in a menu has found that items can be accessed more quickly and more accurately when they are positioned on a pie chart like the numbers on a clock face rather than in a linear mode (Callaham *et al.* 1988). Hence it may prove that using different shapes and positioning of icons may also be more effective in terms of response times and accuracy.

As costs continue to fall and system functionality becomes increasingly sophisticated, it may also be possible to develop even more innovative graphics. In particular, one approach which is still very much at the research stage is the use of dynamic icons. For example, icons depicting a particular tool function such as a magnifying glass, when clicked on, could provide a short dynamic demonstration of what its function is. Sound could also be used as an accompaniment to provide auditory cues. Hence rather than having to go elsewhere to learn and find out the meaning of operations, the user could learn while actually performing a task. All they would need to know is how to activate an icon to receive a demonstration and subsequently how to activate an icon to use it.

Sound icons or 'earcons' by themselves are currently being developed as an alternative form of coding. Gaver (1986) suggests that sound icons should be well suited to representing dimensional data in which the magnitude of a value is represented by the different levels of sound emitted from an object. For example, a 'boom' could represent a large object or processing job and a 'purr' a small object or processing job. Other uses of sound could make the actual noises associated with actions, e.g., the sound of the letterbox clicking when mail has arrived.

Another feature which could prove to be effective is the use of feedback after icons have been selected. This idea has already been implemented in a limited way with some of the Apple's Macintosh icons. For example, while waiting for a system operation to be executed, an icon of a watch appears in which a pair of hands move round. The idea is to indicate through the moving hands that a process is currently being executed. Another example is the wastebin. When a file has been discarded, this is indicated by the bin expanding into a 'fat' bin. The user knows that the file has been thrown away but is still in the 'bin' and if necessary can be retrieved. Progress bar charts have also been incorporated at the interface to show the relative state of a process and how it is progressing.

The function of these additional visual cues is that they provide the user with immediate feedback which can help to reduce ambiguity. In the watch example, the feedback informs the user that the system is doing something rather than appearing to be temporarily out of use. Clearly this type of information is of great value to users, especially novices, to inform them of the system's response in the course of the dialogue between the user and the system.

11. Summary

The use of icons at the interface is clearly here to stay. The main problem is knowing when best to use them and what form they should take. This paper has outlined some of the main issues that need to be considered when designing icons. In particular, it has shown how there are both advantages and disadvantages with iconic interfacing and that their effectiveness will depend on the types of applications and tasks they have been designed for. Other characteristics such as the use of shape, colouring, spatial positioning and combined textual labels were also discussed. In conclusion, it must be stressed that icons should not be viewed as a panacea for interface design, but if used appropriately they can provide a powerful means of communication.

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