

## **The design, understanding and usage of pictograms**

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### **Abstract**

Pictograms form part of our daily lives through their use in medication, transport, computers, etc., because they indicate - in iconic form - places, directions, actions or constraints on actions in either the real world (a town, a road, etc.) or virtual space (computer desktop, Internet, etc.). This chapter is essentially a review of research on the pictogram effect, which can be summed up as follows: a pictogram is better than a label, and recognizing an image is easier than reading text (Norman, 1990). This review covers theoretical and experimental studies from linguistics, psychology and cognitive ergonomics on the design and validation, comprehension and usage of pictograms. Among the various methods, an emphasis is placed on classification and the creation of pictogram taxonomies as tools for homogenization and design.

This chapter summarizes the results of studies investigating how to use pictograms to convey safety information in the workplace, as well as some new insights into how to study the effects of the iconic nature of pictogram information. Here we are talking about *signaletics*, which we define as being the *science of signalization*, which is to say the study of external representations of object meanings, of object properties, and of mandatory, warning and prohibitive statements for categories of objects and users in more or less well defined situations (Tijus, Chêne, Jadot, Leproux & Poitrenaud, 2001).

The chapter is composed of four main sections. The first section describes empirical data reported in specialised domains publications (related to the use of pictograms in public information, pharmaceuticals, road signs, and the workplace), when assessing the role of pictograms in conveying recommended modes of behaviour. The second section concerns the theoretical contributions of Semiotics, of Cognitive Psychology for pictogram readability and understanding, and of the Contextual Categorization approach, a theory which accounts for the contextual effects involved in the understanding of pictograms. The third section describes the methodology, some examples and some outcomes from studies on the creation of taxonomies and ontologies of pictograms for evaluation and design. This provides a basis for understanding how a signaletic system can more or less help to solve the problem of iconic external representation of categories of objects, as well as of actions, which are two cognitive entities that, on their own, cannot be entirely captured by an image. The final section provides recommendations for the ergonomic conception of pictograms, in order to improve the readability and understanding of pictograms used to convey user safety information in the workplace.

### **Common definitions and uses of pictograms**

A pictogram is a stylized figurative drawing that is used to convey information of an analogical or figurative nature directly to indicate an object or to express an idea. Pictograms can fulfil many functions. They are used to replace written indications and instructions expressing regulatory, mandatory, warning and prohibitory information, when that information must be processed quickly (eg. road traffic signs), when users speak different languages (ie. non-natives), have limited linguistic ability (eg. people with low levels of literacy or little education), or have visual problems (eg. older people), and especially when

there is a legal obligation to inform, and for the user to comply with information, mainly for safety purposes (eg. use of dangerous materials at work). A pictograms needs to capture users' attention (users need to *see* the pictogram), to improve users' comprehension of warnings (users need to *attend to* it), and it also needs to increase their awareness of risk, generally by serving as an "instantaneous memorandum" of a risk (Otsubo, 1988).

There are a number of recognized advantages of pictograms in the literature (see the CACP report for a summary). First of all, they have the potential to be interpreted more accurately and more quickly than words. Thus, they can serve as “instant reminders” of a hazard or an established message. They improve understanding of warnings for those with visual or literacy difficulties. They can make warnings more noticeable or “attention grabbing”, and they can improve their legibility. Pictograms or brief textual information are suitable when users undertake familiar or routine tasks (although this does not apply for novel or highly complex tasks). In addition, pictograms are more easily processed at a distance compared to textual information, although a distinction should be made between abstract symbols and more explicit icons.

However, there are also a number of disadvantages to relying on pictograms. Firstly, very few pictograms are universally understood; therefore, depending on their use, they may not be interpreted correctly by all groups of consumers and across all cultures. Next, it always takes many years for any pictogram to reach maximum effectiveness. There is also the potential for significant confusion (interpreting the opposite or often inappropriate meaning), which can create an additional safety hazard.

### **Understanding pictograms**

In order to be adopted, a pictogram must reach a certain level of effectiveness, especially when the information to be conveyed concerns safety. The method of testing the comprehension and effectiveness of pictograms used in ISO 9186 (Public Information Signs) relies on judges choosing from a number of response categories: correct understanding of the symbol is certain; correct understanding of the symbol is likely; correct understanding of the symbol is fairly likely; the meaning conveyed is the opposite to that intended; incorrect response given; 'don't know' response given; no response given. According to the ISO

standard, a symbol is accepted if 67% of the users understand it in an unquestionable way or almost (ISO 9186-1989). In the United States, the pictogram must be understood by 85% of the users in order to be standardized (ANSIZ 535-1987).

Although the effectiveness of pictograms relies on characteristics such as color (Christ & Corso, 1982), shape (Arend, Muthig, & Wandmacher, 1987), visual complexity (Byrne, 1993), all of which have been widely studied, the main difficulty in processing the iconic information represented in pictograms relates to its meaningfulness. One of the main causes of difficulty in interpreting iconic signs relates to the fact that natural language signs use "text" or sequences of sentences in order to aid interpretation of a given word. For example the word "BANK" cannot be interpreted if used alone. In order to interpret it, one must apply a "context". This "context" can be the "context of use". The only equivalent tool pictograms have to realize the same functions seems to be their "context" of use which allows some type of categorization. For example, an arrow at the corner of a street is not the same as an arrow on the edge of a bottle cap.

### **Empirical data**

Much of the empirical data on pictogram comprehension are to be found in specialised domain literature. Many studies have investigated the legibility of pictograms used to convey information to people about their orientation in public space, use of pharmaceuticals products, road safety, and organization of the workplace.

#### ***Public Information***

Not only do poorly designed pictograms with complex content cause problems for people with limited literacy skills, basic pictograms can be problematic for literate readers. For instance, when computing the first response made by each participant for each basic pictogram, Cross (1994) found that the highest "first word label" score was only 46%; for instance, when shown a drawing of a comb, only 46% of participants gave this as their first response. Davies, Haines, Norris and Wilson (1998) set out to investigate the role of 13 product-related pictograms in conveying consumer safety information. In general, the pictograms were found to be poorly understood. In fact, it appears to be very difficult to design highly representative symbols requiring no learning to convey public information such as consumer information, warnings, or information in public places. For instance, Easterby

and Zwaga (1986) considered the issue of designing symbols to be used for the purpose of public information. When participants were shown an entire set of 29 pictograms for use in a railway station and asked to find the required target, the authors found that only one symbol was identified by almost all (99%) of the sample population of 400. In addition, it has been noted that the chances of two users choosing the same name for a picture is less than 18%. Furthermore, many studies have shown that even after testing and redesign, public information pictograms did not reach optimal levels of comprehension (Magurno, Wogalter, Kohake & Wolff, 1994).

Moreover, with regards to understanding, Easterby and Zwaga (1986) reported that familiarity with a sign improved its comprehension. On the subject of the noticeability of public information warnings, Otsubo (1988) reported that the type of label (words only, pictogram only, or words and pictogram) did not significantly affect whether participants noticed, comprehended or remembered the warning. However, twelve to fifty percent of participants complied with the warning labels as opposed to 0 % in the control group, with the highest level of compliance found for the “words plus pictogram” type warning label on the product perceived as most dangerous. Participants tended to read warnings only when they perceived the product to be dangerous, unfamiliar, or in need of a warning. In general, making warning pictograms more explicit and more severe increases consumers’ intentions to act cautiously.

### ***Pictograms in pharmaceuticals***

Pictograms are also common in patient information leaflets for medicinal products. Pictograms in these leaflets are intended to provide full and comprehensible information because patients’ ability to understand information about medication is crucial to both patient safety and drug effectiveness.

Pictograms are of benefit to the comprehension and recall of prescription instructions, and participants who are given “natural language plus pictogram” labels understand information better than participants with only “natural language labels” (Dowse and Ehlers, 1998, 2003). However, some research has not supported the hypothesis that pictograms are beneficial for the acquisition and comprehension of information. In order to evaluate the effects of pictograms in patient information leaflets, Bernardini and his collaborators (2000)

interviewed 1004 patients in pharmacies and reported that participants usually read the patient information leaflet but they neither understood it easily nor found the required information readily. However, most participants (74.3%) considered the use of symbols helpful in finding the required information. They analyzed to what extent five symbols could be used for each of five topics, and found consistent responses for “side effects”, “pediatric use”, “use in pregnancy” and “dosage”, but not for “therapeutic indications” and “contraindications”.

Such discrepancies may be not related to education, but to familiarity and context. Dowse and Ehlers (2003) collected demographic data together with information on literacy skills for participants asked to interpret 46 pictograms. Results showed misinterpretation across all educational groups. Knapp, Raynor, Jebar and Price (2005), who examined the effects of repeat presentation of pictograms on understandability, found great variability in rate of correct interpretation (8 to 90%) and that only three of the ten different instruction and warning pictograms were understood by at least 85% of the population. After providing their interpretation, participants were informed of the correct meaning and then the experimental trials were repeated a week later. Results showed that participants performed significantly better at the second presentation of pictograms.

In a series of experiments, Barcenilla and Tijus (2002) analysed the responses of 134 participants to the question “what does it mean?” for 14 medicinal pictograms. The average correct response rate was 39 %. This rate increased to 65 % when a scenario introducing the pictogram was provided.

### ***Road Signs***

Drivers encounter many signs on the road. Road sign design includes the use of color, shape, symbols and icons. For instance, warning signs are made up of a white triangle, a red border and black graphics, usually an icon of the hazard. They are standardized across Europe and road sign knowledge is tested as part of the driving test. They are supposed to help drivers deal with road network dangers and driving regulations, to ensure quick recognition and to indicate the category of action to be undertaken. According to Allen, Lunenfeld and Alexander (1971), drivers need information in case they are unsure of their perception of a situation; in this situation, road signs are useful for problem-solving and the task in hand. For example, Dubois and Fleury (1987) have shown that drivers have different representations of

the different types of road they drive along (such as rural roads, town streets, city ring roads etc.), and that they look out for information according to these representations. Do drivers perceive visual information when it is not within the context of the task they are performing? It is probable that information not meeting task requirements is not as well processed as information that responds directly. With reference to speed signs, for example, Triggs and Harris (1982) found that traffic signs tended to generate a very low braking response rate in drivers. For instance, the signs "Traffic Hazard Ahead" and "Road Plant Ahead" caused only about 3% and 4% of drivers respectively to respond. The rate was slightly higher at 6% for the sign "Road works Ahead". The response rate for a "Speed Check Ahead" sign was statistically significantly higher. The investigators found that reaction time depended on the ease with which one signal could be distinguished from other possible signals. For example, one can distinguish between highway signs differing in shape faster than those varying in verbal message alone.

Surprising, driving skill and experience do not appear to mean increased levels of performance on tests of road sign knowledge and understanding. It is often reported that road users' knowledge of road signs is generally rather poor, and this presents an unquestionable source of danger. In France, an investigation concluded that 97.75 % of drivers would need to retake their driving test if they were subjected to a full road sign test; only a third of drivers could recognize signs indicating "Give Way" (Averous, 1975). More recent results corroborate these poor performances (Al-Madani & Al-Janahi, 2001). Similarly, according to Borowski, Shinar and Parmet (2005), experienced drivers pay less attention to road signs located in unexpected places. They found that, under simulation conditions, drivers experienced difficulties in identifying traffic signs when their location did not conform to expectations; the authors felt this was because drivers have a well-learned pre-determined schema for scanning the roadway.

With reference to driving experience, Tijus, Barcenilla, Cambon de Lavalette, Lambinet and Lacaste (2005) compared the understanding of road signs by novices and expert drivers in isolation or in the context of a real road situation. The main results showed that, unlike novices, experts failed on the "what does it mean" question when road signs were displayed in isolation but responded successfully to the "what to do" question. In short, they found that

driving experience does not improve people's understanding of the meaning of road signs. Furthermore, the number of years' experience is inversely correlated with the level of understanding of the intended meaning: the more one drives, the less one is able to provide the intended meaning of road signs.

### *Pictograms at work*

As in studies mentioned above, Wilkinson, Cary, Barr and Reynolds (1997) reported that pesticide users found it significantly easier to obtain information from labels containing text only than from labels with added pictograms. Moreover, labels with pictograms were associated with a significant increase in the proportion of users taking correct safety precautions when storing the pesticides, but not when mixing or applying them. Thus, it appears difficult for pictograms to be used to demonstrate a procedure. Adding pictograms to labels did not significantly alter perceptions of the danger of the pesticide to the user either. Although pictograms did enhance the accessibility of safety information on the labels, some users found them to be confusing.

In the workplace, pictograms are being used more and more frequently in computer applications, rather than written instructions or drop-down lists. Here again, we know that the use of icons is improving usage; however, the effect of icon use on individuals' performance levels for a particular system are to a large extent unknown. Two opposing arguments have been presented. The first states that icons make sense because they have a single unambiguous meaning, while the second position describes the use of icon as metaphor, for instance the use of the scissors icon for "cut" in the text edit function. McDougall (2001) employed either concrete, abstract, or arbitrary icon sets in a computer-based problem-solving task and found that knowledge structures do depend on the nature of graphic information but do not rely as much on the use of visual metaphor. In addition, although most measures were sensitive to initial differences between icon sets, only some measures were sensitive to the long-term differences that remained after users had gained experience with the icon set.

Computers also offer the possibility of animating pictograms. An experiment was conducted by Bodner (1994) to measure differences in identification of static and animated buttons. Twelve subjects were given both static and animated keys and asked to identify the function of each key. Subjects were able to choose the function of animated keys (83%) more



often than that of static ones (68%). The results indicate that animation is useful in helping users identify a key's function. Because animation could be also an effective means of portraying complex processes evolving over time, Baecker, Small and Mander (1991) investigated the use of animated icons to improve comprehension of functions. They found that all users understood the icon's function after seeing the animation, but they also noted that some users did, in fact, make misinterpretations. They also reported that there is the added danger that too much animation can be a distraction.

### **Theoretical basis for understanding pictograms**

The way that humans process iconic information is a complex issue. Although pictograms hold certain advantages related to image processing, research has revealed a number of difficulties and problems related to the interpretation of intended meanings. First of all, although drawings can be used effectively to represent static objects, there are limitations to their use in representing events and actions in which objects are modified. Since pictograms need to incorporate the shapes of specific objects, there are limitations to the use of drawings to represent categories of objects, especially the kind of superordinate categories that group objects of different shapes. For example, the pictogram "No Smoking" which shows a cigarette also applies to cigars and pipes. Another difficulty arises from the symbolic nature and polysemy of pictograms (Olson, 1970). A drawing of a car in a pictogram could refer to the car itself, to driving, or to vigilance, as is the case with medicinal pictograms etc. Thus, one cannot expect an isomorphism between the pictogram and its meaning (Kolers, 1979). The meaning of a pictogram has to be inferred through a process of interpretation constructed from both the task in hand, knowledge and context.

As underlined by Horton (1994), the interpretation of a pictogram depends on multiple subjective and visual factors. However, the science of signaletics might find some basis in psychology, cognitive science, and semiotics.

### **A Cognitive Approach to Pictograms**

Veziin (1984) has provided a number of arguments promoting the pictogram as a powerful tool for the cognitive system: (i) the pictogram reduces mnemonic load and thus allows cognitive saving; (ii) its descriptive nature provides high quality pictorial representation

which facilitates memorization; and (iii) since it can be used to represent a category, it can provide broad information exceeding the specific items it portrays.

The pictogram also benefits from the efficiency of visual imagery: (i) identification is more precise from a single glance, at a greater distance, and at a greater speed than with words (Collins and Lerner, 1982; Lehto, 1992): an image is processed in parallel and therefore more quickly than words, which require serial processing; (ii) higher resistance to cognitive interference (King, 1975, Santa, 1977): an image, memorized and recalled as a single unit, would resist interference better than a text made up of several parts; (iii) images are perceived better in suboptimal conditions (Ells and Dewar, 1979); (iv) a pictogram can also be better stored in memory due to dual encoding, that is both visual and symbolic (Paivio, 1986); this engenders a deeper level of processing and greater consolidation in memory. For instance, Haber and Myers (1982), who were interested in the storage of pictograms in memory, found that recognition accuracy was greatest for pictograms and poorest for words. Although participants were able to disregard shape within pictograms, they were most accurate when presented with the same shapes as those used in the original trials. But across all conditions, participants were most accurate when forced to recall both the shape and the content. These and other results were taken to be mildly supportive of a dual encoding hypothesis.

However, for McDougall (2001), an image's cognitive effect needs to be distinguished from its relationship with function. The author argues that semantic distance, rather than concreteness, should be the main determinant of comprehensibility and performance. Although representations of real-world items, through icons, may help users in their initial encounters with pictograms, forming strong systematic relationships between icons and functions should be more important.

### **Contextual categorization approach**

Pictograms, being symbols, are polysemic. For example, a trash can with a cross on it could mean "do not throw away", "do not empty trash in this area", "pick out household waste" and so on. In fact, the difficulty here is to link image with information. When interpreting danger signs, users not only have to infer the action required of them, linking both the action with the specific danger, but also need to infer which objects are involved in the action. For example,

the round road sign showing two cars where the left one appears in red, means "*Undertaking prohibited*". But does it also mean that a motorcycle or a van can undertake?

In fact, context helps to disambiguate a pictogram's intended meaning. For instance, Hameen-Anttila and colleagues (2004) tested whether children of 11 and 13 years old could understand pictograms developed by the United States Pharmacopoeia. Every second child was given a leaflet with plain text and the others received the same text accompanied by pictograms. Most of the children understood the meanings of the pictograms correctly, the percentage of correct explanations varying from 30 to 99%, according to the pictogram used. Even well understood pictograms did not help the children understand the leaflet information. This study shows that the context in which pictograms are tested makes a difference to their comprehension. Testing plain pictograms without incorporating them within their real context (eg. in a patient information leaflet) may overestimate their usefulness in leaflet information.

In order to evaluate to what extent context can aid understanding of the meaning of pictograms, Tijus and colleagues (2005) tested 167 participants' comprehension of a pictogram presented either in isolation or fixed to a box of medicine. The experimental design aimed to vary the level of information provided by the context in which the pictogram was presented. The results showed that the context in which a pictogram is perceived and used can lead to it being interpreted more accurately; context improved comprehension of the pictogram in an incremental way, starting with the least optimal situation (a pictogram alone: 33 %) to the optimal, where contextual facilitation is maximal (a pictogram with complete packaging, label and user instructions, 91 %).

Thus, contextualization appears to contribute significantly to the understanding of pictograms. The role of context may be explained by contextual categorization (Tijus, 2001), an approach consistent with the theory of perceptual learning proposed by Gibson (1969). Perceptual learning is a process by which one becomes increasingly attuned to optical information specifying properties of the environment and thus becomes increasingly capable of differentiating similar stimuli (Gibson, 1966). According to Gibson "what is learned can be described as the detection of properties, patterns and distinctive features" (1969, pg. 77). Contextual categorization is a theory of information processing which advocates that all objects are seen in the context of other objects, through the construction of a hierarchical, ad

hoc network of categories. It follows that objects are simultaneously put in relation and differentiated. The whole situation in which a user sees a pictogram can be modeled using contextual categorization in order to discover what s/h will infer to be the meaning of the pictogram.

### **A Semiotic and Linguistic approach**

Natural language and iconic signs do have one thing in common: they both use atomic and complex signs to construct sentences. Hence they both can convey information, that is, they both can have a propositionnal meaning of any type (assertion, orders, etc.). But what really differentiates one from another is that iconic signs cannot easily be used to build “texts”, that is sequences of sentences expressing narration, argumentation, demonstration, conversation, etc... which is one of the important functions of natural language.

It seems difficult to accept that symbolic and iconic languages are both semiotic systems. Many researchers suppose that icons and graphic signs have a unique coded meaning, unlike words which they recognize as symbols (one word, different meanings); this is because icons are analogues of what they represent or indicate and graphic signs are used to express a unique meaning (one sign, one meaning). Thus, the “cow” icon (see fig. 1-a) means “cows”, and a red triangle means “danger”, whilst a red circle means “prohibited”; therefore a cow on a red triangle would mean “Danger: Cows” (fig. 1-b), whilst a cow on a red circle would mean “Cows prohibited” (fig. 1-c).

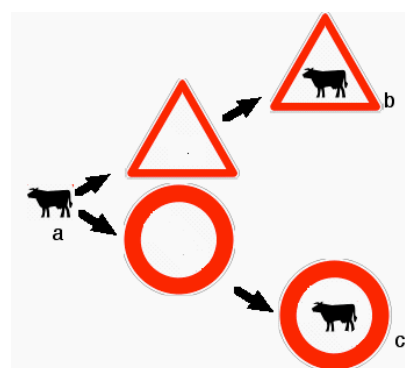


Figure 1: The making of a road sign.

Unlike authors who advocate that iconic languages belong to the analogical mode of external representation, like visual signs and representations such as pictures, semioticians

analyze pictograms as modes of representation (or signs) having structure (syntax), meaning (semantics) and usage (pragmatics). Like any other type of language, iconic languages possess a grammatical structure. They are not generated haphazardly and are not meaningless. For Jean-Guy Meunier (1998), it is not their semantics that renders them so easy to use, but, as we shall discover, their functional structure. This author shows how a particular type of grammar—algebraic or categorial grammar—is heuristic in modeling the compositional structure of iconic languages: iconic languages (i) operate through material carriers; (ii) have distinctive properties, or features, which become the basic constituents of the structure; (iii) are organized according to categories, operations and rules; (iv) therefore are open to systematic interpretation. For Meunier, Features performing an identical functional role make up a category. we recognize a category SHAPE because the features it is composed of can have a COLOR superimposed on them. In other words, the features of the SHAPE class belong to a category not because they resemble geometric figures and respond to an intuitive perception, but because they are the only features that may be colored according to the features of the COLORS category. In contrast, COLORS form a category because of the common possible operation of applying them to a figure (an inverse relation to superposition). It is because of their categorial structure that many semiotic systems are often so easy to learn.

However, iconic languages are not complete languages. A road sign is not a logical proposition that drivers can choose to adopt or ignore in their decision-making (Droste, 1976). As symbolic languages, pictograms are half-way between being rule-governed systems and being ad hoc solutions to communication and expression problems. Languages will often accept very ad hoc configurations. For example, natural language is full of idiomatic expressions; the same applies to iconic languages and notations (Meunier, 1998).

Figure 1 represents the construction of a road sign: the “cow icon” (which stands for any cattle) combined with (b) a red bordered triangle would mean that there is a danger *because* of the eventual presence of cattle on the road; with (c) a red bordered circle, it would mean that this route is prohibited *to* cattle. Note that (b) could be “Danger for cows” and (c) could be “Prohibited due to cows”. Similarly, note that figure 1-b means “danger *because of* cows”, not “danger *for* cows”, and figure 1-c means “Cows prohibited”, not “Prohibited *because of* cows”. Road signs do not provide the nature of the relationship between different

components: the whole of the icon is more than the sum of its parts (Harmon & Julesz, 1973; Szlichcinski, 1980). Given that object category (commonalities of possible instances) and action (at least two states of an event) cannot be pictured in static visual images, at issue here is the problem of icon polysemy or "multi-meaning icons". In linguistics, the word "polysemy" is used to describe how many words can have multiple meanings. Thus, the word "fence" can mean an enclosure, a receiver of stolen goods, to engage in swordplay, or to screen off. The actual meaning within a sentence is determined by the context. The same concept can apply to pictograms (figure 2).



Figure 2. Icons in road signs are of a symbolic nature. The “do not overtake” road sign on the right applies to all kinds of vehicles, including trucks. The left hand “do not overtake” sign is only for trucks.

### **Typologies of pictograms for evaluation and design**

A possible approach to the study of pictograms is to construct taxonomies, or hierarchical typologies, by differentiating classes and subclasses of pictograms. For many researchers (Edworthy & Adams, 1996), three types of pictogram exist: figurative, abstract, and arbitrary (figure 3).



Figure 3. From left to right: a figurative, an abstract and an arbitrary pictogram.

The figurative pictogram is made up of a direct representation of the object. It is supposed to evoke without ambiguity the object or the situation represented (e.g. a flame to indicate a flammable product). The abstract pictogram comprises only certain aspects of the concept to evoke it in its totality (e.g. a curved line to indicate a turn). Lastly, the arbitrary pictogram bears no resemblance to physical reality (e.g. the symbol used to indicate

"radioactive"). Rogers (1989) has provided a more refined description of figurative pictograms, classifying them as either (i) similar images (e.g. landslides), (ii) typical examples or the use of specimens to represent categories (e.g. a book to represent a library), or (iii) symbolic icons, when an image is used to represent a higher level of abstraction than the image itself (e.g. a broken wine glass to show fragility). Similarly, in terms of the way the meaning is expressed, Barcenilla and Tijus (2002) distinguish figurative pictograms as being either (i) metonymic, when one element indicates the whole (e.g. a book for library, a knife and the fork for restaurant), (ii) metaphoric, when another object is used to express an intended meaning (e.g. a bomb for a computer bug), or (iii) categorical, when a pictogram indicates a category (e.g. a car for both cars and trucks).

There are other dimensions such as meticulousness (the degree of detail in object drawings), dimensionality (portraying an object's depth in only two dimensions: with shading, nuances of colors and perspective), and functionality (using drawing to represent a function: for writing, one can show a pencil in isolation or a pencil with drawn lines coming from it). However, a major dimension concerns meaning and classifying pictograms according to categories based on semantic content. According to Easterby and Hakiel (1981), security instructions conveyed by pictograms have three functions: (i) to describe a situation: the image identifies the risk, (ii) to prescribe an action: the image describes the action to be carried out, and (iii) to prohibit an action: the image shows the prohibited action. Tijus and colleagues (2001) showed that pictogram semantics can be described according to a limited set of basic categories organised hierarchically, right from the portrayal of an object ("this is X", a sign saying "Eiffel Tower"), to the representation of procedures ("How to use X", the representation of how to purchase a travel pass from a ticket machine, for example), or to the use of functional objects ("How to use Y on X", for example "how to use the travel pass in the transport system"). These hierarchical levels have an inclusive relationship: one cannot say "X is in this direction" without saying at the same time "this is X" (what you will find will be X). One cannot say "how to get to X" without indicating "the direction that X is in".

The creation of taxonomy for a given set of pictograms can be useful in increasing users' ability to learn them. Tijus and colleagues (2001) used pictograms relating to danger in the workplace (figure 4) in order to study participants' ability to learn pictograms presented

taxonomically. In an initial learning phase, 40 participants were exposed to the above ten signs warning of potential dangers in the workplace together with their written labels for 10 minutes before carrying out a distraction task. Then, in a second phase, they were presented with the danger pictograms without their labels and had to give the corresponding meanings; this learning test was repeated three days later. The group of participants that had been presented with the pictograms within a taxonomy tree (as in figure 4-right) performed significantly better than the group that was shown the pictograms at random (as in figure 4-left), (67 % vs. 49%). There was a significantly higher rate of correct responses after the first learning phase than in the second learning phase three days later (66 % vs. 50), and performance after three days was less diminished for the taxonomic group (12 % less vs. 21 % less).

The creation of pictogram taxonomies makes it possible to illustrate how a signaletic system can solve the problem of representing classes and types of actions to perform. In terms of training, the beginner's task is to learn the categorial organization of pictograms and to understand the basic meanings of actions in intension (what does "to copy" mean vs. "to duplicate", when applied to a computer file?) as well as in extension (to which objects does the "copy" function need to be applied?).

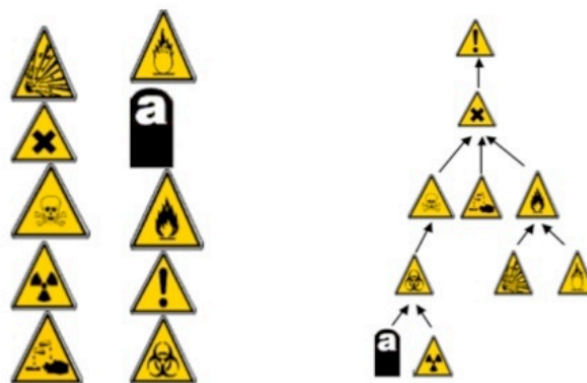


Figure 4. Ten danger pictograms displayed at random (left panel) or in a general-to-specific taxonomy tree (right panel): 1 - General danger; 1.1 - Harmful materials or irritants; 1.1.1 - Poison; 1.1.2 - Corrosive; 1.1.3 - Flammable; 1.1.1.1 - Biohazard; 1.1.3.1 - Explosive; 1.1.3.2 - Flammable gases; 1.1.1.1.1 - Asbestos; 1.1.1.1.2 - Radiation.



## Creating pictogram ontologies

In addition to taxonomies (classes and subclasses of pictograms), it is possible to construct pictogram ontologies, or hierarchical organizations of knowledge based on the components of pictograms. In order to carry out such ontologies, it is necessary to break up pictograms into their components and to compile an inventory of all the basic elements used to create pictograms. As an example, Tijus et al. (2005) used the property tree framework (Poitrenaud, 1995) to describe an entire set of 300 road signs in an attempt to capture the internal structure of the road signs (figure 5). From a semantic point of view, each sign could be described in terms of one property tree. Four types of properties were identified: (i) surface properties corresponding to the shape and color of the sign, (ii) the label indicating the sign's function, (iii) the category of action involved (information, danger, prohibition, obligation), and (iv) the object to which the action is to be applied.

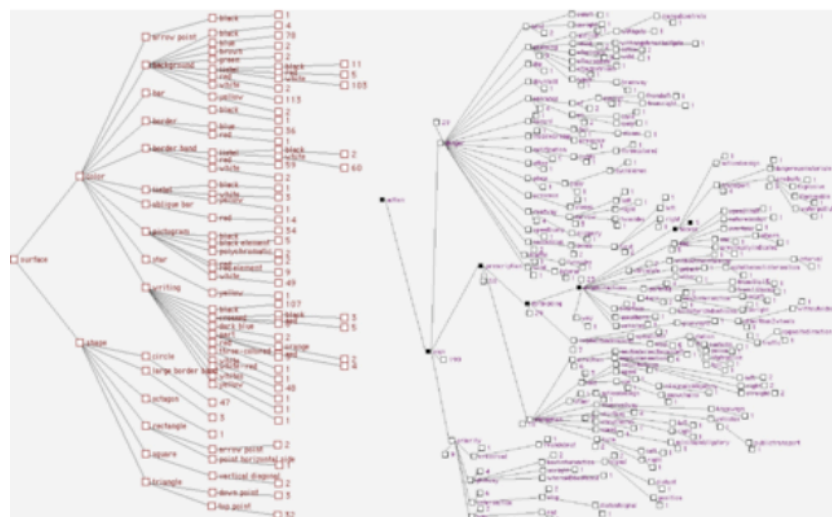


Figure 5. The taxonomy of action properties for a subset of 199 road signs relating to danger, prescription and priority.

The creation of ontologies can fulfil many goals. They can facilitate an evaluation of how closely pictogram properties correspond to information and prescribed action; they enable us to investigate whether a single category of target objects or actions, corresponds to one category of shapes, colors, or icons. Bromberg, Tijus, Georget, Jadot, Leproux and Poitrenaud (2002) have used the construction of ontologies as a means for producing a harmonized signage system that could be used in railway systems across Europe.

### **Conclusion: ergonomic recommendations for conception of pictograms**

A pictogram is better than a label, and recognizing an image is easier than reading text (Norman, 1990). Thus, pictograms are used in a number of situations in which verbal messages are not possible or adequate. Interpreting the meanings of pictograms is part of everyday life, both at home and in town, and also in the workplace in the case of special safety precautions. However, the user's perspective is not always taken into account when pictograms are conceived and implemented. Moreover, many studies reveal poor levels of user understanding of pictogram content. Ultimately a pictogram's effectiveness should be measured primarily in terms of people's ability to understand it.

A number of recommendations for pictogram conception have been proposed: (i) there must be appropriate levels of complexity and detail to maximise visibility and comprehension; a good pictogram should contain little detail and should be easily distinguishable; excessive representations of reality should not be used; objects should not be drawn merely with contours; shading and nuances of color should not be used with thin or flat objects; 3D representations should be used for objects with several dimensions; (ii) uniformity: new symbol designs must be consistent with existing pictograms which are well understood; (iii) discriminability: an effective symbol must be easily distinguishable compared with others; (iii) legibility: the size of elements and their separators, the levels of contrast between elements, and also content familiarity facilitate legibility and comprehension; (iv) lastly, note that an appropriate level of complexity and detail will depend on how the pictogram is to be used. It is advisable to adopt a sequential design approach (component by component): start with a basic shape with few details and add additional details one by one until an optimal level of comprehension is obtained (Magurno, Kohake, Wogalter & Wolff, 1994).

Pelegriana and Gallifa (1994) and Beltran and Auque (1993) recommend that typicality effects should be considered and familiar and typical images used in the contents of pictograms, given that user understanding does not depend on the number of features nor on concreteness but mainly on familiarity. In addition, given the poor levels of understanding associated with some pictograms, certain authors recommend displaying pictograms in conjunction with verbal information in order to ensure the correct message is communicated.

When assessing pictogram effectiveness, Wolff and Wogalter (1998) recommend presenting the pictogram in the environment in which it will eventually be seen. This environment forms part of the context, the task at hand being another part. Context is a support for interpreting a pictogram's meaning. Context helps to reduce a pictogram's polysemy. Studies have demonstrated that increasing the level of contextual information tends to eliminate a certain number of errors, such as those due to activating typical schemas, or selecting the wrong function, or when there is a misunderstanding as to what is actually represented in the pictogram. For instance, when a pictogram on sun cream packaging showing a sun with a cross on it is interpreted as "do not leave the sun cream in the sun", while the correct meaning is "once cream applied, do not expose skin to the sun". Context helps to disambiguate the message expressed in the pictogram.

Recommendations also have been made regarding learning. Pictograms which are not immediately recognized may be learned rapidly, after which the role of the pictogram is to stimulate recall of that information. Thus the ultimate success of a pictogram would depend on trainees' ability to learn it carefully. One recommendation for optimal learning is to use taxonomies to enable trainees to differentiate between pictograms, and to use ontologies in order for trainees to differentiate between the meanings of pictogram components.

All these recommendations can be achieved through the collaboration of sector specialists, designers, ergonomists and psychologists.

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