

symbols

Interaction of
Symbols:

*Multiple symbols
interact to
provoke
meaning,
the foundation
for better icon
design*

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Abstract.

Numerous studies support the thesis that icons frequently fail to communicate because designers have not appreciated that icons combine multiple symbols which interact to evoke meaning. Because symbols interact, a designer must know which symbols to combine and how to draw each symbol so that icons communicate clearly. This article brings together numerous research studies that explored new methods for designing icons based on the interaction of symbols.

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Keywords:

theory;
icons;
symbols;
pictograms;
design methods.

Introduction

Otto Neurath, the inventor of the international symbol language *Isotype*, got the idea for *Isotype* from a 19th-century picture game. "Three of these pictures represented a hammer, a bell, and a hammer and bell combined. I never forgot the particular impression I got from the possibility to combine symbols as one may combine letters..." (Eve & Burke, 2010, p. 89). Neurath eventually combined symbols numerically to represent quantities, but his observation might also apply to combining symbols to convey ideas. Combining symbols to evoke new meaning might sound simultaneously trivial and profound, and it is both. The act of reading combines symbols to bring ideas to mind in ways whose impacts linguists are still exploring. The profundity is magnified by the role symbols, pictures, and icons have come to play in everyday life across the world. Today icons are useful, ubiquitous, and misunderstood. They are useful because they condense information to the scale of a smartphone, which is also an example of icons' ubiquity. Icons are misunderstood for a variety of reasons.



Figure 1.

Symbols which inspired
Otto Neurath

Icons are not well-understood

Icons are misunderstood in the sense of lack of agreement about how they work or what they are. To begin, what we are calling icons here are given different names in different disciplines. For software professionals they are symbols, in healthcare they are called pictograms, in safety they are safety signs. Another reason for misunderstanding is that icons have been studied by different disciplines with differing agendas. Interface experts, for example, want to know "why some symbols are easier to use than others" (McDougall, Curry, & de Bruijn, 1999, p. 487). This is understandable given that icons are used in an interface to identify and use software features. Interface researchers have concluded that the critical

factors of an icon are its visual complexity, concreteness, familiarity, and semantic distance, that is, how much an icon looks like what it means. For example, an icon of a file folder to represent “file” has a close semantic distance, while an icon of a trash-can to suggest “delete” has a greater semantic distance. In Medicine, icons are called “pictograms.” Pictograms are valued by healthcare professionals to the extent that they attract attention, convey information, and help patients remember to do what has been prescribed (retention and adherence). “Pictograms can serve as communication tools to enhance visual attention, comprehension, recall, and adherence of instructions provided” (Barros et al., 2014, p. 14). As a result, healthcare pictographic research focuses on measuring comprehension, retention, and adherence to verbal or written instructions. Safety and Transportation professionals are also concerned with the comprehension of what they call “safety signs” but in the context of rapid recognition by all people. This leads Safety professionals to explore concerns related to safety-sign comprehension by those of various ages and physical limitations. One study found that older adults took longer to process iconic information (Liu & Ho, 2012). All this research might lead you to conclude that icons, or pictograms, or symbol-signs, or whatever you call them, must first attend to visual complexity, or perhaps that retention and adherence are most important, or that overcoming physical limitations such as those brought on by aging is the primary concern. You can see why icons might be misunderstood. Ironically, very few of the many studies in these disciplines have had icon designers as co-PI’s in their research, and most made no attempt to consider the design quality of the icons used for their research studies. It’s as if these studies assumed icons to be naturally occurring objects whose study can ignore the fact that human designers with varying levels of skill and knowledge created them..

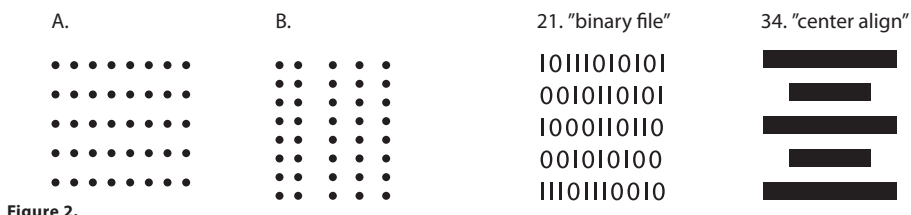


Figure 2.

Misunderstanding previous research

Small objects are perceptually grouped into larger wholes, as explained by the Gestalt principle of spatial proximity. Eight individual dots in the top row of A, are, due to spatial proximity, seen as a horizontal row, meaning A. is perceived as five rows rather than 40 dots.

In B, five vertical columns made of eight dots each are organized into two rectangular blocks due to spatial organization. In a study measuring icon characteristics where “complexity” was considered a key factor, participants rated icons’ complexity based on the number of lines they contained.

Icon 21. “binary file” received a complexity score of 3.88 on a 5 point scale (5 = most complex). Icon 34 was rated 1.90. Yet when Gestalt principles are considered, each icon is perceived as five lines. Author’s drawing after McDougall, 1999.

In addition to the diversity of ideas about what icons are and what makes them work, they are widely misunderstood, meaning poorly comprehended. One needs to look no farther than one's automobile dashboard to be confused by an icon such as the tire inflation pressure light, which 40% of people cannot identify (Woodyard, 2010). ISO and ANSI call for 67% or 85% (respectively) correct comprehension for safety symbols. This means that the "tire-inflation" icon fails badly. It also shows that standards agencies do not agree on the threshold of correct comprehension. Our work found that icon comprehension test design and how responses are scored significantly impact reported levels of correct comprehension (Zender, Han, Fernández, 2011). Multiple choice and matching tests yield a much higher percentage of correct responses than open-ended fill-in-the-blank tests. How the icon's context is described in a test also significantly impacts correct comprehension. No wonder icons are often unsuccessful: we have real difficulty defining and measuring success!



Figure 3.

Tire pressure warning icon.

Tire inflation icon found on automobile dashboards as a warning light indicating "Low Tire Pressure." Forty percent of people do not know what this is or what it means.

Our analysis based on informal research suggests that a primary contributor to the lack of recognition is that the tire symbol is not drawn from a conventional point of view and therefore is not recognized as a tire.

Icons may be common and useful, but icon designers have a plethora of confusing input about what an icon is called, how it functions, and how to measure its success. This led the author and colleagues to study icons for the past 20 years to understand what makes icons work. To simplify, we call icons what other disciplines variously call icons, symbols, pictograms, symbol-signs, and signs. Our definition of an icon is a picture intended to evoke a concept (the referent). Our core findings are

that **most icons have multiple symbols and that these symbols interact to provoke meaning in peoples' minds.**

Multiple Symbols Interact

How people make meaning is outside the scope of Communication Design, so we must look to the disciplines of Psychology and Visual Perception for answers. To learn how people construct meaning, Psychologists studied how infants develop meaning-making skills. Eleanor J. Gibson's 1992 review of 25 years of studies confirmed that at 6 months, infants begin to identify "visually distinct features of objects" (Gibson, 1992, p. 222). Eleanor J. Gibson said, "perceiving is itself a mechanism of learning" (ibid, p. 234) and went on to find that the capacity to categorize visual objects is the foundation for the categorization of knowledge. As children grow, they learn that a small box with blobs of brown inside is a box of candy. Dewey and many others after him have said that as people observe relationships between objects, they infer meanings in an inductive process (Dewey, 1910, pp. 79, 116). Primary school children infer from a candy box with a bundle of flowers and a heart symbol that love is in the air, or at least Valentine's Day is at hand. Clusters of objects seen together can evoke a precise meaning that could not be predicted easily from seeing each object separately. As people mature, they accumulate additional associated meanings. A box of chocolate might even lead one to think of the movie *Forrest Gump* and his famous quip "life is like a box of chocolate you never know what you're gonna get" and from that make a link to the Vietnam War, the 1960's, Tom Hanks, and Hollywood and on and on.

Figure 4.

Combining symbols.

A 20th-century game called "Rory's Story Cubes" uses 9 dice, each die with a different icon on each face of the die. The dice are rolled, and a player invents a story from each face-up icon. This game illustrates our capacity to evoke meaning from the interaction of symbols.



Most past icons combine several symbols.

You might expect that inference to meaning from objects in the physical world transfers to symbols, and according to eminent scientist Paul Kolers, it does. He wrote in 1969 that people naturally infer things implicit in a particular combination of symbols (Kolers, 1969, p. 356). As our physical environment is filled with objects seen in relation to each other, so too, the artificial world of symbols most often brings together multiple symbols to provoke a specific meaning intended by the icon designer. We confirmed this in our 2006 research study of the AIGA/DOT symbol system, the system that launched the ubiquitous Helvetica Man icon seen on men's restroom doors the world over. We found that 40 of the 60 icons, 66%, use more than one symbol in the icon (Zender, 2006, p. 30; Zender & Mejia, 2013). The "Baggage Locker" icon, which combines a symbol of a *bag*, puts that bag-in-a-box, with the symbol of a *key*, is one example. The "Barber Shop" icon is another (see *Figure 5*). In people's minds, these symbols do not remain isolated; they interact to evoke meaning. We found the interaction of multiple symbols in icon systems across disciplines: U. S. Highway signs for Recreational and Cultural Interest Areas – 71% are multi-symbol; SEG D Recreational icons – 83%; DOT/ANSI/ISO Safety Symbols – 83%; Hablamos Juntos Medical icons – 94%. People make meaning from icons and do this most often by looking at icons that contain multiple symbols.

Complex concepts need multiple symbols for expression.

One reason most icons contain multiple symbols could be that most concepts transcend a single object. A case in point is "Helvetica Man." What does a man symbol in isolation mean? The answer is that it means "a man," which is true, but what about the man? Is he in danger or safety, dead or alive, doing or resting? Context is key to interpretation and will be discussed more below, but at this point, it is enough to suggest that it is hard for a single symbol to say much more than it is itself. A *man* symbol symbolizes a man. "Helvetica Man" in the context of a door into a room successfully suggests a room for men, and a men's room in the United States is a "Men's Toilet." A *luggage* symbol with an *arrow* in the context of an airport successfully suggests "Baggage Area this way." But a *luggage* symbol alone does not incline one to think "Baggage Locker" any more than a *man* symbol alone inclines one to think "Barber Shop." Complex concepts like "In-Patient," actions like "Fishing," states of being like "Waiting," all require a combination of symbols for their successful communication. There's a lot to be said about

single symbol



man

multiple symbol



scissors + comb
"Cut Hair"



scissors + comb + man
"Barber Shop"



scissors + comb + woman
"Beauty Salon"

Figure 5.

Multiple-symbol icon.

This illustrates a multi-symbol icon. This icon represents "Barber Shop" by combining three symbols: scissors + comb + man, in a circle containing-shape.

The containing shape affirms to the reader that these symbols should be read together. The icons under the "Barber Shop" icon show the breakdown of single-symbol and multiple-symbol icons in the AIGA/DOT icon system.

cultural determinatives and the ways cultural and physical contexts impact meaning-making, and more will be said later, but for now, the focus is that much of our communication requires multiple symbols.

If designers have been combining symbols from the time of hieroglyphic writing to the present day, what novelty is this paper proposing? Simply this: that while knowledge has advanced, icon designers have failed to develop new icon design methods founded on the interaction of symbols.

Adding symbols improves comprehension.

To understand how multi-symbol icons work, we conducted numerous research studies. In one, we changed symbols in some multi-symbol icons (Zender & Mejia, 2013). In 2006 the University of Cincinnati was part of a five-school consortium commissioned to design icons for medical facilities for the *Hablamos Juntos* project. Several of the icons expressed complex concepts such as the referents “Waiting Area” and “Medical Library” (the intended meaning of an icon is called its “Referent” – referents are in quote marks throughout this paper). At first thought, a waiting area and a medical library may seem difficult to confuse, but that was not the case. The draft “Medical Library” icon combined a *person/man* symbol (from the waist up), holding a *book*, and a *medical cross* (see Figure 6). This combination scored poorly when tested with various cultures and language groups – only 22% correct comprehension. When raw answers were analyzed, the dominant incorrect answer was “Waiting Room.” Apparently, in a medical context, many people sit and read something in a waiting room. The incorrect answers caused us to look at the library’s definition, which says nothing about reading but a lot about collections of books. So for “Medical Library,” we added a symbol of *books* on a *shelf* and transferred the medical cross symbol to the *books* (see Figure 7). Correct comprehension jumped from 22% to 67% (see Figure 8). We also added a line under the man to clarify that he was sitting at a *desk* or *table* to prevent association with a more comfortable *chair* in a waiting area. To check our findings, we created an icon with the *man* symbol sitting in a *lounge chair* but leaving the *bookshelf* and *cross* symbols alone. As expected, comprehension for “Medical Library” was lower – from 67% down to 50% correct – as the number of incorrect answers associated with “Waiting Room” increased. It wasn’t just adding symbols that clarified meaning but adding the right symbols.

Figure 6.

“Medical Library” and
“In-Patient” icons from
Hablamos Juntos
Healthcare icons.



“Medical Library”



“In-patient”

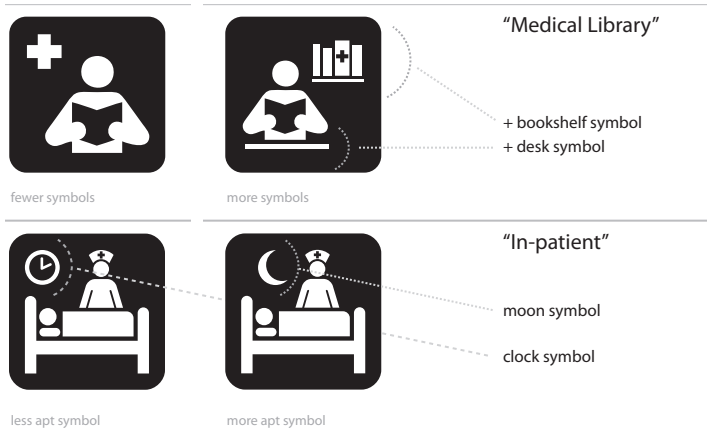


Figure 7.

Revised “Medical Library” and “In-Patient” icons .

These icons have added symbols in “Medical Library,” and with a different symbol - moon instead of a clock - for “In-patient.”

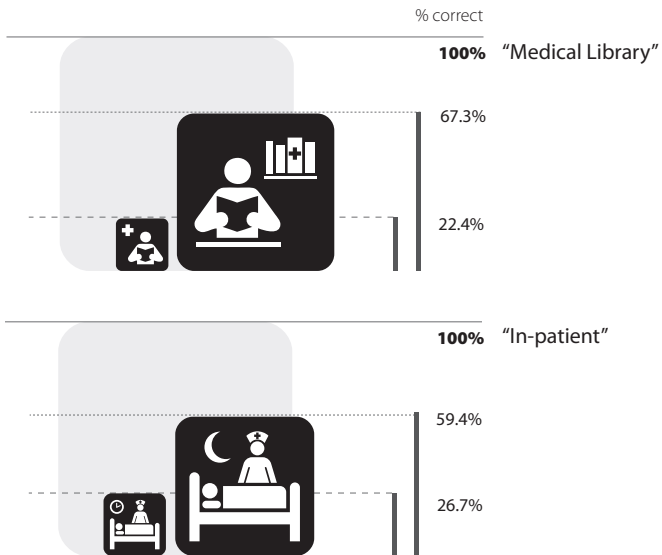


Figure 8.

Comprehension scores for “Medical Library” and “In-Patient” original and revised icons.

Comprehension comparison of “Medical Library” and “In-Patient” icons. The simpler “Medical Library,” which followed ISO guidelines by re-purposing the existing icon for “Library,” was less well comprehended than the icon with more symbols.

Both “In-Patient” icons used the same number of symbols, but the icon with better comprehension used a symbol that better fit the referent definition

Combining symbols that fit the referent definition improves comprehension.

Of course, adding any symbols increases complexity, and this flies in the face of a longstanding preference for icon simplicity in design. So we also looked at whether changing symbols to ones that more accurately fit the definition of the referent would measurably improve comprehension. We again turned to a problematic icon in the Hablamos Juntos Medical Icons, "In-patient." An in-patient is broadly defined as a person who stays in the healthcare facility overnight. The original poorly-comprehended "In-patient" icon combined symbols of a *nurse*, a person-in-a-bed = a *patient*, and a *clock*. This was poorly comprehended at 26%. We changed the *clock* symbol to a *quarter-moon* symbol to better fit the definition "over-night-stay" and comprehension increased to 59% (see Figure 8). Changing to a symbol that better fit the defined meaning increased comprehension.

What is a symbol versus a feature?

It may have occurred to the reader that a symbol can contain multiple physical objects. The *person-in-a-bed* is two objects but functions as one symbol: a *patient*. What gives? One answer might be found in the mechanics of Visual Perception. Research shows that we recognize objects by remembering the key features shared among objects forming a mental category. For example, after seeing many chairs, a visual activation pattern of "four legs, a seat, and a back" is stored and remembered as the mental category *chair*. When a new object is seen, its features are compared with all the existing activation patterns, clusters of visual features associated with each other, until a match is found or not. This process is summarized nicely by Steven Kosslyn in his book, *The Case for Mental Imagery* (Kosslyn, Thompson, & Ganis, 2006). A quick trip back to Psychology shows that our mental categories are connected to the objects of visual perception. Barbara Tversky wrote that "One of the most fundamental aspects of human thought is the ability to perceive similarities and differences in objects and organisms and thereby to group or classify them" (Tversky & Hemenway, 1984, p. 170). She and her colleagues identified three levels of mental category that range from broadly defined and highly abstract Superordinate level to the more narrowly defined Basic and Subordinate levels. Examples given included the Superordinate level "furniture:" large movable objects in a physical space; Basic level "chair:" a seat four legs and a back; and Subordinate level "office chair:" a seat four or more legs with wheels and a back. Tversky and others found that Basic level objects were the most recognizable and the most abstract level that is easily identified. Given these findings from Visual

Perception and Psychology, we can better define a symbol as a basic level object that is defined visually and categorically as a mental pattern combining several individual features.

Returning to the original question, visually-based categories might help define whether *person-in-a-bed* is one symbol or many. A chair has three essential features: *four legs*, a *seat*, and a *back*. Not *three legs*; that would be a *stool*. Not *five legs*; that would be an *office chair*. Whether an object like a *seat* is part of a *chair* or *seat* symbol on its own depends on the context. If the whole chair is shown, the *seat* is a part of the whole. If just a *seat* is shown, the *seat* becomes the symbol. Another example can help clarify. An *eye-on-a-fish* is a necessary feature of a *fish* symbol, yet an *eye* symbol can also be understandable on its own. For an eye symbol to stand on its own, it would likely require additional features like lashes and an eyebrow to make it recognizable. Just a circle will do to symbolize an eye as part of a fish, but a circle by itself will not symbolize *an eye*. The context determines whether an object is a symbol or a feature of a larger symbol. Determining what should be included when drawing symbols that people will recognize as symbols is discussed below, but first, a little more on context.

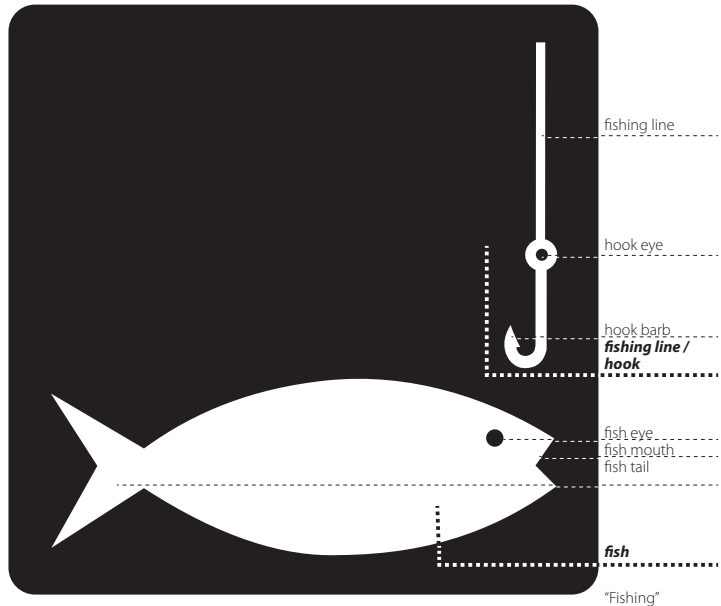


Figure 9.

Distinguishing a feature from a symbol.

Fishing" icon. Note that the eye is one feature of the fish symbol, compared to an eye symbol that can stand alone.

adapted from the *Manual on Uniform Traffic Control Devices for Streets and Highways*, 2003 edition, U.S. Highway signs from the collection in *Official Signs and Icons 2* by *Ultimate Symbol*

Context informs meaning-making

Before going further, a brief digression into the principles governing meaning-making is needed. In the physical world, we interpret objects and actions in contexts. Flowers in a funeral home mean one thing, flowers with candy mean another. Likewise, in the artificial world of human-produced symbols, meaning is guided by context. To illustrate this, I have asked, “what do the three letters “BOW” mean? The answer is that you don’t exactly know. There is a range of possibilities that can only be clarified by context. BOW in the context of SHIP means one thing, BOW in the context of ARROW means another, BOW in the context of DOWN means something else entirely. The meaning we infer to symbols is governed by context. This is the first and fundamental principle of hermeneutics: the science or study of meaning-making.

Hermeneutics and language received a lot of thought in the 20th century. Debates raged about whether people could, or should, understand the meaning an author intended. Michele Foucault famously proclaimed the disappearance of the author (Foucault, 1977, p. 121). Whether the focus should be on authors or the readers as the determiners of meaning, was in some ways a debate about whether people should primarily use their own context to assign meaning to symbols (language or whatever), or whether people should strive to grasp the author’s context (literary, social/cultural, historical) in order to perceive the author’s intended meaning. Overlay this with semiotic theories about how people communicate ideas to each other using symbols to represent things and the role of metaphor which links one thing to another by shared features, and you have a complex field of play. This may sound complex enough, but current ideas about how interaction with objects shapes our minds, the impact communication genres and media types have on thought, the ways preconceptions and cultural worldviews impact our interpretation of communication objects further complicate meaning-making.

Multiple symbols define and refine context.

The thread that ties all of this together is that meaning-making is guided by context. The author’s context matters, the receivers’ contexts matter, the symbols’ context matters, the cultural and media contexts matter. This means that the most crucial principle in hermeneutics, the science of interpretation, is that meaning is governed by context. As you might guess from above, context is not simple but multi-dimensional. Exegetes, those who practice hermeneutics, envision context in layers visualized as a series of concentric contextual circles, each of which has less



Figure 10.

Context

The Circles of Context illustrate that the further one gets from the immediate context, a word in a sentence, for example, the less influence that context has on determining the correct meaning.

significance for meaning-making as you move from the center outward (Figure 10). As a general rule, the immediate text has the most significant impact, the genre has less importance, the cultural context even less, and so on.

The importance of interpretive context also applies to icons. As already noted, in the 21st century, a door in a public place with a *man* symbol on it evokes a particular meaning and does a *bag* symbol hanging in an airport. Knowing that people infer meaning from symbols depending on their physical context is a clue for icon designers to attend to context and control it. Indeed, combining several symbols in a bounding box to create an icon is itself an act of contextual control. Numerous icons in an icon system form a self-referential context that guides meaning-making. The icon exists in some physical context, whether that be an architectural space or a social setting, or an app on a smartphone, all of which add context that guides interpretation. I've called the symbols within an icon the Immediate context, icons in interaction with other symbols and icons in a system the Proximate context, and the icons' interaction with places, people, and cultures, the Environmental context (Zender, 2006, p.183-184). As the Circles of Context illustrates, each context impacts the icon's meaning.

Physical context changes meaning.

People clearly use context to inform the meaning they derive from objects and symbols. But how much influence does context exert, how far can it change the meaning people assign to a symbol? Is the contextual influence in any way predictable? These were some of the questions that led us to study the impact of context. In 2017, we designed three icons: a *bookshelf*, a *toothbrush*, and a *clock*. Each of these icons had been used as a symbol in a previous icon and had been proven to be easily recognized and well understood. We put these three icons in a standard open-ended comprehension survey that showed each icon then asked participants, "Imagine that you are in a _____. Exactly what do you think this icon is? What do you think it means." Different participants were given different contexts (in the blank) in which to interpret the icons: an Olympic venue, an airport, a university campus, a refugee camp. The locations were chosen to be diverse and not overtly associated with any individual icon. The three icons were each given a different context on a given survey. Contexts were randomized from form to form. Sixty-nine University students participated, resulting in between 16 and 18 students seeing a given symbol in each of the four contexts.


same ICON	different PHYSICAL CONTEXT	What object?	What meaning?
	Olympic venue	<i>clock</i> - 44% <i>stopwatch</i> - 25%	timed sporting event - 38% time in general - 38%
	airport	<i>clock</i> - 94%	flight times - 61%
	university campus	<i>clock</i> - 94%	time in general - 44% class time - 38%
	refugee camp	<i>clock</i> - 67% <i>time</i> - 11%	appointment time - 50% time in general - 33% no-answer - 17%

Figure 11.

Context changes meaning.

A 2017 Design Thinking study: the same symbol, a *clock*, was given a different physical context: an Olympic venue, an airport, a university campus, a refugee camp.

People inferred a different meaning in each context. Many people also inferred the clock to be a different object in the Olympic venue: a *stopwatch* instead of a *clock*.

In the Olympic venue, 44% of participants identified the *clock* icon as a clock, but 50% identified *clock* icon as a *timer* or *stopwatch*. In the Olympic venue, the *clock* was interpreted to mean “timed-sporting-events” by 37% and “time-in-general” by 37%. But in the airport context, 94% of the 18 participants identified the *clock* icon as a clock. The same symbol was seen as a different object depending on the context. In the airport it was a *clock*. In the Olympic venue it was a *stopwatch*. The *clock* was interpreted in the airport context to mean “flight-times” by 61% and “world-or-international-time” by 11% in the airport. These high levels of disagreement confirm that the same icon not only means something different depending on its context, but it can also be understood to represent a different object.

Cultural context impacts meaning.

It would be odd if you were not thinking that cultural context can change inferred meaning, and it can. Our 2010 study in Tanzania found that many icons designed to work across cultures didn't. You can see in Figure 12 that for some icons, there was a significant difference between Westerners and Africans (Zender & Cassedy, 2014). While this is not surprising, it is worth noting that more often than not, the misunderstanding was due more to a lack of familiarity with medical technologies and differing levels of medical knowledge than cultural practices. One notable exception was the use of a *stuffed bear* to represent “Pediatric/children's-healthcare.” It turns out that despite the abundance of wild animals in Africa, there are no bears and few stuffed animals. Cultural context matters a lot, and there's a lot more to say about it, but this digression into context has gone too far already.

Conclusions: Symbols interact to evoke meaning in contexts; Managing context is key to guiding correct comprehension

To summarize, thus far, we have seen that findings support that people make meaning from the interaction of multiple symbols, that most icons contain multiple symbols, that adding symbols can improve comprehension, that adding the correct symbols – that is,

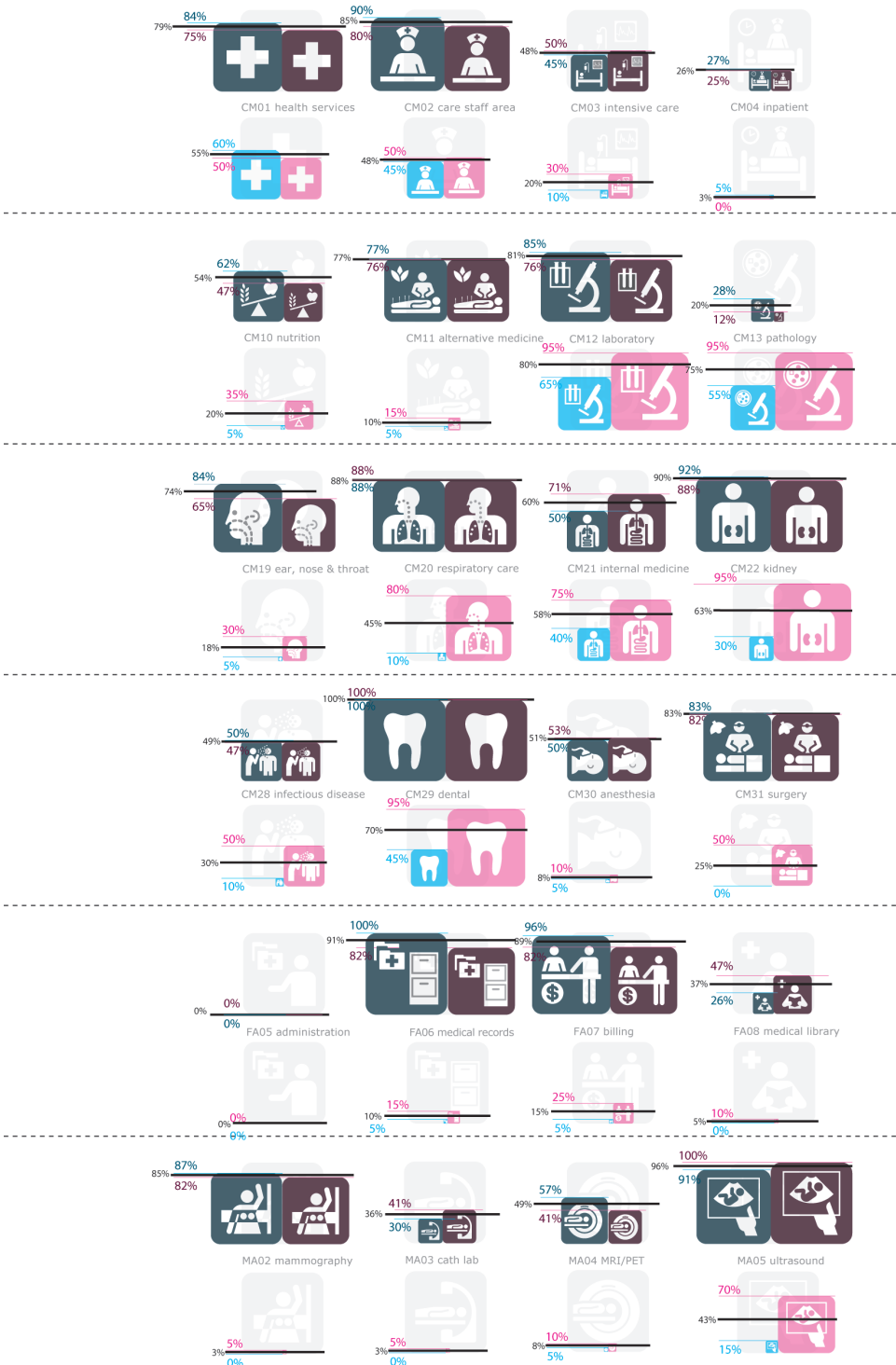
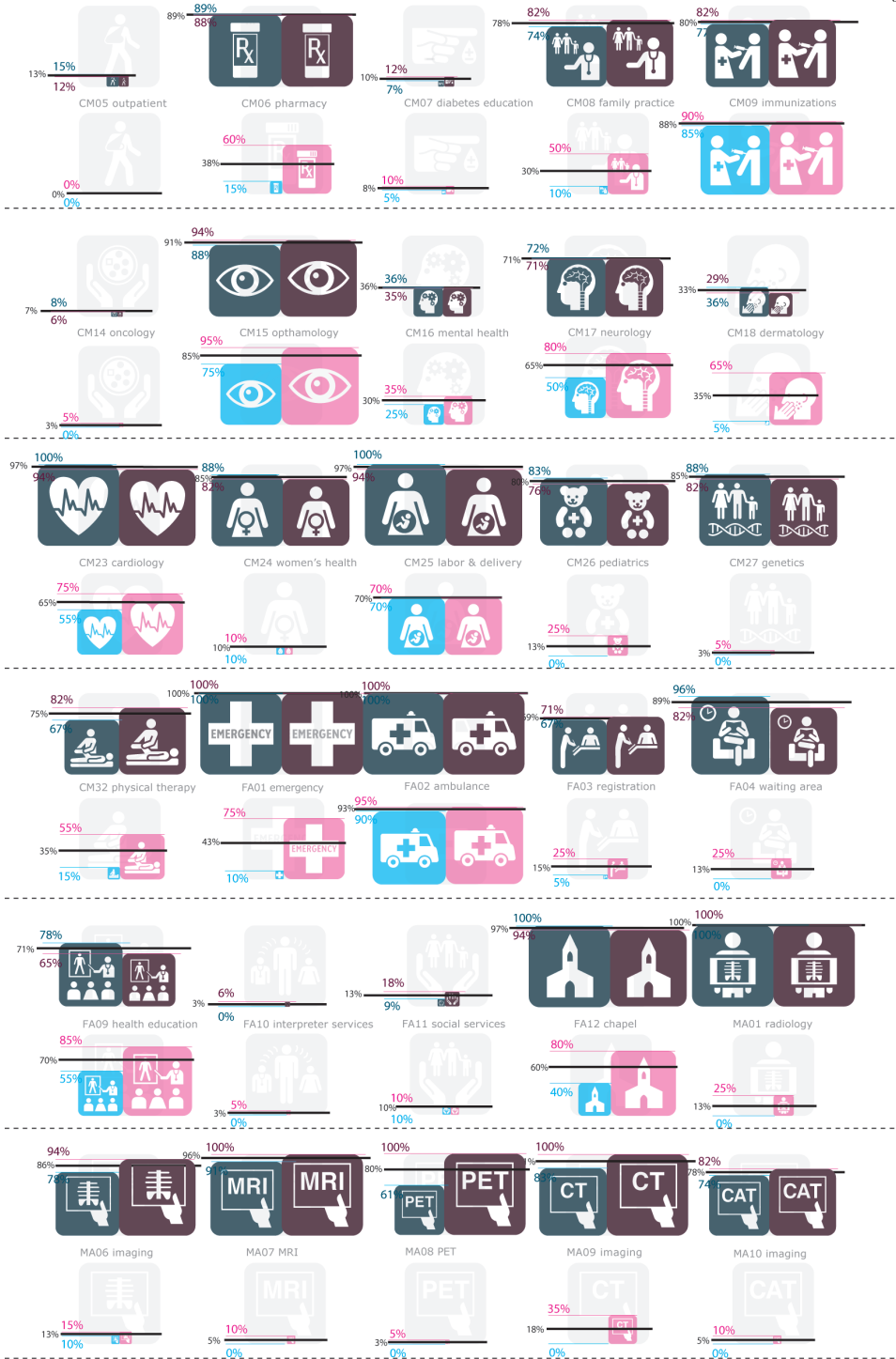


Figure 12.

Comparison of icon comprehension USA and Tanzania.

The top row (darker) shows comprehension by those with and without advanced medical knowledge in the USA.

The bottom row (lighter) shows those with and without advanced medical knowledge in Tanzania.



One conclusion was that the amount of general medical knowledge had more impact on

comprehension than differences in cultural practices or symbolism.

symbols that fit the definition of the referent – can improve comprehension, and that we need to know how to distinguish between a feature of a symbol and a symbol. To that, we've added knowledge that context guides meaning-making.

These facts provide the basis for a theory of icon design. Since multiple symbols interact in contexts that guide people's meaning-making, **if icon designers clarify context by combining the right symbols drawn in the right way, then good icon comprehension should result.** This takes us to the next point.

Know which symbols to draw.

Multiple symbols in an icon add important context, which can improve comprehension. This might suggest that adding more symbols is a kind of icon panacea. It was noted above that icon research in Medicine and Pharmacology (pictogram research) has focused on comprehension and adherence and that several pictogram studies have shown icons significantly improved both. But even so, the "Medical Library" and "In-Patient" icons performed poorly, and our research demonstrated that a poor combination of symbols misled the reader. So just combining any symbols that come to mind will not do. If the wrong combination of symbols is misleading, how does one find the right combination of symbols? Several studies explored this very question.

Processes and Methods.

It's a cliché that process governs product. Our current icon design process was established in the 1960s and '70s and described by Martin Krampen in his 1965 *Design Quarterly* article thus:

- a) Environmental problems arise;
- b) Signs or symbols are created, often anonymously and tentatively, to communicate about these problems;
- c) These signs or symbols are modified or corrected by collective experience;
- d) the modified versions are finally conventionalized;
- e) As new problems appear, the sign code is further amplified, modified, corrected, and so on. (Krampen, 1965, p. 19)

The AIGA/DOT symbol system enhanced the process described above by using a Delphi Panel of experts who reviewed existing icon designs and pooled their expertise to create new icons.

It could be argued that the process has not changed much since the '70s, and indeed, as recently as 2007, the ISO standard for the "Creation and design of public information symbols" laid out the following process:

— 4.1 Preliminary phase

- a) verify what is required for the symbol;
- b) identify the meaning of the required symbol;
- c) identify if a symbol for the required meaning already exists;
- d) assign the symbol meaning to an appropriate category;

— 4.2 Creation phase

- a) consider existing symbols with similar meanings
- b) design a new symbol.

If this process seems a little thin on methods, we would agree. To bring things up to date a bit, an informal 2017 interview with icon designers working for Microsoft confirmed that their icon design process relies on their own creative imagination to conceive an icon design which is then iteratively tested for effectiveness with users. Including user evaluation to measure effectiveness is a significant process improvement. Volumes of papers and books on user-centered design and evaluation support consultation with users. But if, as asserted here, most icons use multiple symbols and if the wrong symbols lead to miscomprehension, then a method for determining which symbol combination will evoke the referent is needed. Enter the social science methods for identifying shared ideas.

sociology, psychology,
anthropology

— The social sciences have developed methods for determining cultural consensus via Consensus Analysis. Alysa Strauss wrote,

— "Consensus analysis "specifies the conditions under which agreement between people can be seen as a sign of knowledge or 'getting it right'" (Borgatti & Halgin, 2011). In other words, consensus analysis provides an empirical means by which a researcher can measure and describe the cultural knowledge of participants in a study (Romney, Weller, & Batchelder, 1986)." (Strauss & Zender, 2017).

Alysa, who has a Masters in Design and a Ph.D. in anthropology, theorized that consensus analysis could be used to learn from people for whom an icon was being designed what they would expect to see in such an icon. She then conducted a series of studies to test that hypothesis.

Free listing identifies candidate symbols.

One method for finding consensus is Free listing: a qualitative research method that determines what users expected to be associated with a concept, in this case, a referent. To test the applicability of Freelisting, Strauss chose three referents whose icons, designed in 2009 using the standard icon design process, had poor comprehension in evaluation studies (Zender & Cassedy, 2014):

- “Oncology” the branch of Medicine specializing in the diagnosis and treatment of cancer;
- “Outpatient” a person who goes to a doctor’s office or hospital for treatment but does not spend the night;
- “Psychiatry” the branch of Medicine specializing in the study and treatment of mental, emotional, and behavioral disorders.

These referents were chosen because their poor performance allowed for improvement, thus enabling comparative measurement of the effectiveness of a new method. Free listing “involves asking subjects from the same culture to list all of the things that they think are in the cultural domains of (in this case) oncology, outpatient, and psychology.” (Strauss, p.12). Fifty-four participants were given the three referents and their definitions and asked to individually generate a list of things they associated with each referent, three lists, one for each referent. The 54 individual lists were combined and organized by which words/concepts were given by most participants. For example, for “Oncology,” 22 people listed *person/patient* and *cells*, 13 listed *IV-therapy*, 12 *chemotherapy*, and so on, down to 2 mentions of *color/red*, *DNA*, and *heart*. This was followed by several other items mentioned only once. It did not matter whether the listed items were technically correct or not. *Heart*, for example, has little to do with “Oncology.” What mattered was that several people thought something was correct. For “Oncology,” 25 items were mentioned more than one time. The list for “Outpatient” yielded 23 items, while the list for “Psychiatry” was 22 items. Though these raw lists were all associated with the referents, they contained many overlapping ideas and were not structured to convey the referent definition. Another step was needed to understand how people would associate the ideas to represent the referent definition.

Pilesorting identifies related items.

“Social scientists use Pilesorting as a means to show which items within a cultural domain are similar or related somehow” (Strauss, p.14).

— “Participants were given a set of cards for each referent. Every card in a set had a different item from the domain for a referent, as determined via freelist, written on it. The sets of cards were randomly ordered so that no two participants received their cards in the same order. Each respondent was then told to simply, “group the cards into piles based on how similar they are.” No instructions were given on the criteria that should be used to form piles and there were no minimum or maximum limits on the number of piles that could be created or how many cards could be in a pile, hence, free pilesorting.” (ibid, p.15)

Forty participants sorted the list items. Participants’ sorts were analyzed and compared to identify the most often associated items in piles. In this process, more than one cluster of items is generated. For example, for “Oncology,” five piles emerged:

- doctor/nurse/patient-person
- head-scarf/bald-person
- tumor/cancerous-part/cancer/chemotherapy
- radiation-symbol/radiation-machine
- DNA/cells.

These participants’ piles reveal potential individual symbols that should be considered for inclusion in an icon for “Oncology.” The nature of the grouped items shows that each item need not be a separate symbol. “For example, in the domain of oncology, a bald person was closely tied to head-scarf, suggesting that bald people might be depicted wearing head-scarves” (Strauss p.16).

Following the Pilesorting activity, participants were asked to Rank the piles. Assisted by software, participants’ rankings were weighted. For “Oncology” *tumor/cancerous-part/cancer/chemotherapy* was of first importance followed by *doctor/nurse/patient-person* then *radiation-symbol/radiation-machine*. Another way to rank these groups would be to compare them to the referent definition.

Results

The hypothesis tested in the Strauss study was whether methods used to study cultures could be used to determine what symbols should be included in an icon. Free listing and Pilesorting did reveal candidate symbols. The next question was whether icons whose design was informed by consensus analysis would outperform the icons whose design relied primarily on the designer's own reflection and imagination. An icon made of symbols identified through consensus analysis was created for each referent to explore this question. The comprehension of each consensus-informed icon was then compared to the comprehension of the existing icon using an open-ended comprehension survey. More than three times as many people correctly identified the new icon for "Oncology" as the icon designed using traditional methods, 21% for the new icon versus 7% for the original icon. Although the "Oncology" icon design based on Free listing and Pilesorting was correctly identified by only 21% of survey participants, results for "Psychiatry" exceeded ISO/ANSI comprehension standards for the first time, 72% correct compared to the original icon 35% correct. Based on this, we concluded that eliciting people's thoughts about what should be included in an icon was an effective means of designing multi-symbol icons that have significantly better comprehension. These findings supported our original observation that multiple symbols interact to evoke meaning.

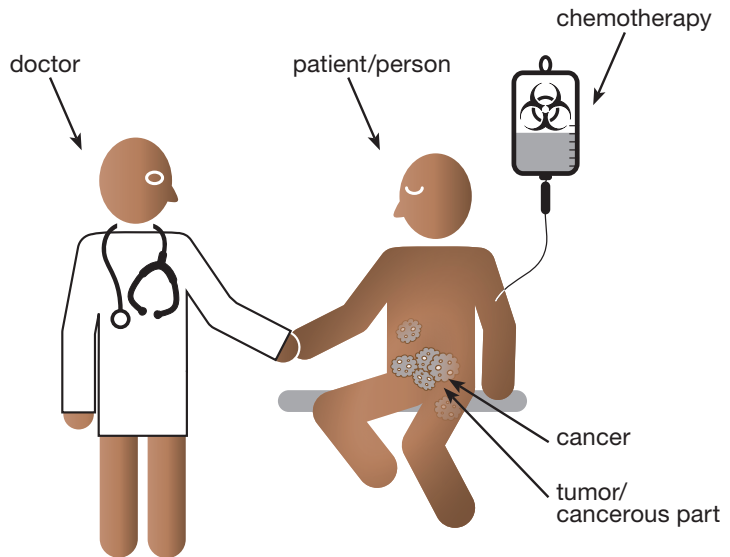


Figure 13.

"Oncology" icon.

"Oncology" icon whose design was guided by determining which symbols to include based on Free listing and Pilesorting.

Comprehension was three times better after using these methods.

Conclusion: learning from people which symbols to combine improved comprehension.

The design processes have evolved over the past few decades to more regularly involve “users.” The ISO Standards cited above for safety symbol design did not require user input in creating the icon. Still, they do require that users be engaged to evaluate the effectiveness of icons before they are deployed. The studies above show that engaging with people during icon design to learn what items they associate with a referent can help a designer create an icon with better comprehension. The studies also contain a couple of caveats. First, the average person may not really understand a referent’s meaning, and to that extent, their ideas may be incorrect. Making sure the users understand the definition can overcome this, but care is needed to ensure the definition does not influence people’s associations. Second, designers need to be alert to synonyms in piles and aware of the possibility of combining what at first appear to be separate symbols into a single symbol, such as the *head-scarf/bald-person* noted above. Third, consulting experts might sort out which symbol to choose among near-synonyms. Whether it is best to include a *doctor*, a *nurse*, or both, along with the *patient/person*, might be determined by checking with medical professionals. User input is no easy recipe for success. But people have helpful input, even if that input only tells the designer the distance between the user’s conception of a referent and the actual definition of a referent.

Once the designer knows which symbols to draw, they then need to know how to draw the necessary symbols so that people will recognize them. So that is the next step.

Know how to draw symbols that people will recognize.

In 2017 I wrote, “How do designers know the best way to draw a symbol for an icon? In my experience, they mostly guess.” By guessing, I meant that designers mostly work from memory, a personal clip file, or an online search. Designers then draw a representation that they feel captures the essence of the object/symbol. This approach works so long as the designer’s sources happen to match what’s in the user’s mind. The problem is that as soon as the designer starts thinking about how to draw an object like a *tire*, their consideration of tires has separated them from the average person for whom the *tire* symbol is being drawn. Designerly reflection

makes the designer an expert of sorts, and in their pondering, designers are just as likely over-think as to think more as the average person thinks. For example, in the "Inflation Pressure" icon in Figure 3 above, the *tire* was drawn from the point of view of a squirrel before being run over. Fortunately, this is not a point of view many people have experienced. In addition, designers' general inclination towards creativity can erect a wall of novelty between the symbols they draw and what users expect to see. In short, designers do not naturally draw symbols that the average person readily recognizes.

Basis

Eminent Professor of Psychology Rudolf Arnheim observed in 1974 that a good picture left out a lot. He wrote, "This means not only not that the better picture is one that omits unnecessary detail and chooses telling characteristics, but also that facts must be unambiguously conveyed to the eye" (Arnheim, 1974, p.157). His insight that a picture excluded irrelevant details and included key object features and essential details to the eye was a prescient insight that later studies in visual perception would verify.

Visual object recognition

We see what is in the world with our eyes and brain. And we can also see the world in our brain without using our eyes. Seeing with the mind's eye is called "mental imaging." Think of the front of your house. With a bit of effort, you can picture your house in your mind and count the number of windows that face the street. You have just pulled up a visual memory of your house and looked at it in your brain. The concept of mental images and whether they were visually or conceptually based was debated hotly through the 1990s. Stephen Kosslyn, William L. Thompson, and Giorgio Ganis' book *The Case for Mental Imagery* set about settling the debate. They wrote, "A mental image occurs when a representation of the type created during the initial stages of perception is present, but the stimulus is not actually being perceived" (Kosslyn et al., 2006, p. 4). Their breakthrough was that mental images are stored representations of objects in our brains, that these representations are visual, and that we can look at these images by pulling them from memory and literally pushing them into the part of our brain that processes the input from our eyes. We see them only in our minds. There is not only solid evidence that this happens, but recently computer scanning has been used to see what people are looking at in their "mind's eye." (Cowen, Chun, & Kuhl, 2014).

Psychology

We can see in our minds because images are stored in our brains. But to store every individual image of every house we ever saw would be horribly inefficient, so our brains form object categories which are a composite of the essential features that every object in a category shares: *tire* or *chair* or *clock*. We previously introduced Eleanor J. Gibson's and Barbara Tversky's pioneering published work which associated visual object recognition with mental categorization. Years of additional study have clarified that our mental object categories are visual in form and that object categories are stored as clusters of key visual features. This process of perception and categorization is shared by everyone who can see. Visual perception is integral to learning.

key features/activation patterns

The key features of all familiar objects are stored in the brain as activation patterns that can be observed by fMRI (see Cowen reference above). These visual patterns knit together the key visual features typical of an object, such as straight lines, curves, circles, rectangles, and their relationships to each other. These activation patterns are used in object recognition (Kosslyn, p.137). You might think of activation patterns as "brain symbols." By their nature, brain symbols integrate features that all objects in a category share and leave out details unique to individual instances. These may be the "telling characteristics" that Arnheim said constituted a "good picture."

Take a chair, for example. Our research has shown that the brain symbol of a chair is a seat, four legs, and a back (see also Tversky 1984 above). We have asked hundreds of people worldwide to draw what comes to mind when they think of a chair. We have found that what they draw is consistent, even to sharing a common point of view - 3/4 from slightly above (Zender, 2017, pp. 39-40). If a designer could "see" the brain symbols in their users' heads, that designer would know how to draw a symbol that matched their users' brain symbol, in other words, a symbol that all people would recognize.

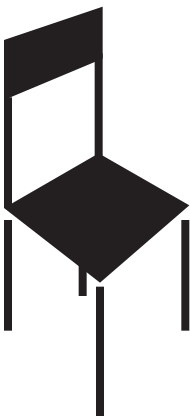


Figure 14.

Typical chair.

Chair drawing is typical of those drawn by people from many cultures and countries.

Perception-based symbol design

"If" is a big word for having just two letters. "IF" a designer knew peoples' brain symbols, the designer could draw a recognizable symbol. But how can one get inside another's head and see what's there? Like charades but with pictures, the game Pictionary was popular some years ago. Its popularity suggested that asking several people to quickly draw what they thought would represent a concept might reveal their brain symbol. To explore this approach, in 2010, UC graduate students and faculty created the Draw-It processes to reveal people's brain symbols. The process asks participants to draw what immediately comes to mind for an object or concept. For example, participants might be asked to draw what comes to mind when they think of *a clock*. After collecting drawings done by many individuals, usually 40-50, researchers analyze the drawings to identify the features that appear most often. For *clock*, we found 98% agreement that a *clock* is a round-face + hands, and 83% agreement that a *clock* consists of a round-face + hands + numbers/tick-marks (Zender, 2017, p. 45). This level of agreement strongly suggests what a *clock* is in most peoples' minds and therefore what a good *clock* symbol should include and leave out. For example, it suggests that a nice, creative drawing of a digital clock would be wholly wrong to represent *clock*. Indeed, of the 41 *clock* drawings collected (see Figure 15), one included a grandfather clock and a mouse, people are creative after all, but not one showed a digital clock. We have used the *Draw-It* method repeatedly to draw symbols for icons.

Research findings

New methods may be good in theory but prove to be unprofitable in practice. So we incorporated the Draw-It method in several icon design projects. In conjunction with colleagues at Cincinnati Children's Hospital Medical Center, we used Draw-It to inform the design of icons to explain to children basic medical procedures such as "drawing blood," "taking a child's temperature," "taking blood pressure," and "giving an injection." A discerning reader will note that these are all processes and that processes are typically hard to communicate with icons. Beginning in 2015, UC students and faculty collaborated with Dr. Regis Vallencourt and his team at the Children's Hospital of Eastern Ontario (CHEO) to design icons for a number of projects, all of which were informed by Draw-It. We collaborated with CHEO to design icons that would be used to inform parents how to care for children after surgery, specifically after a Tonsillectomy. Some of those referents were: "soft-food-diet," "brush-teeth-gently," and "rest." We also

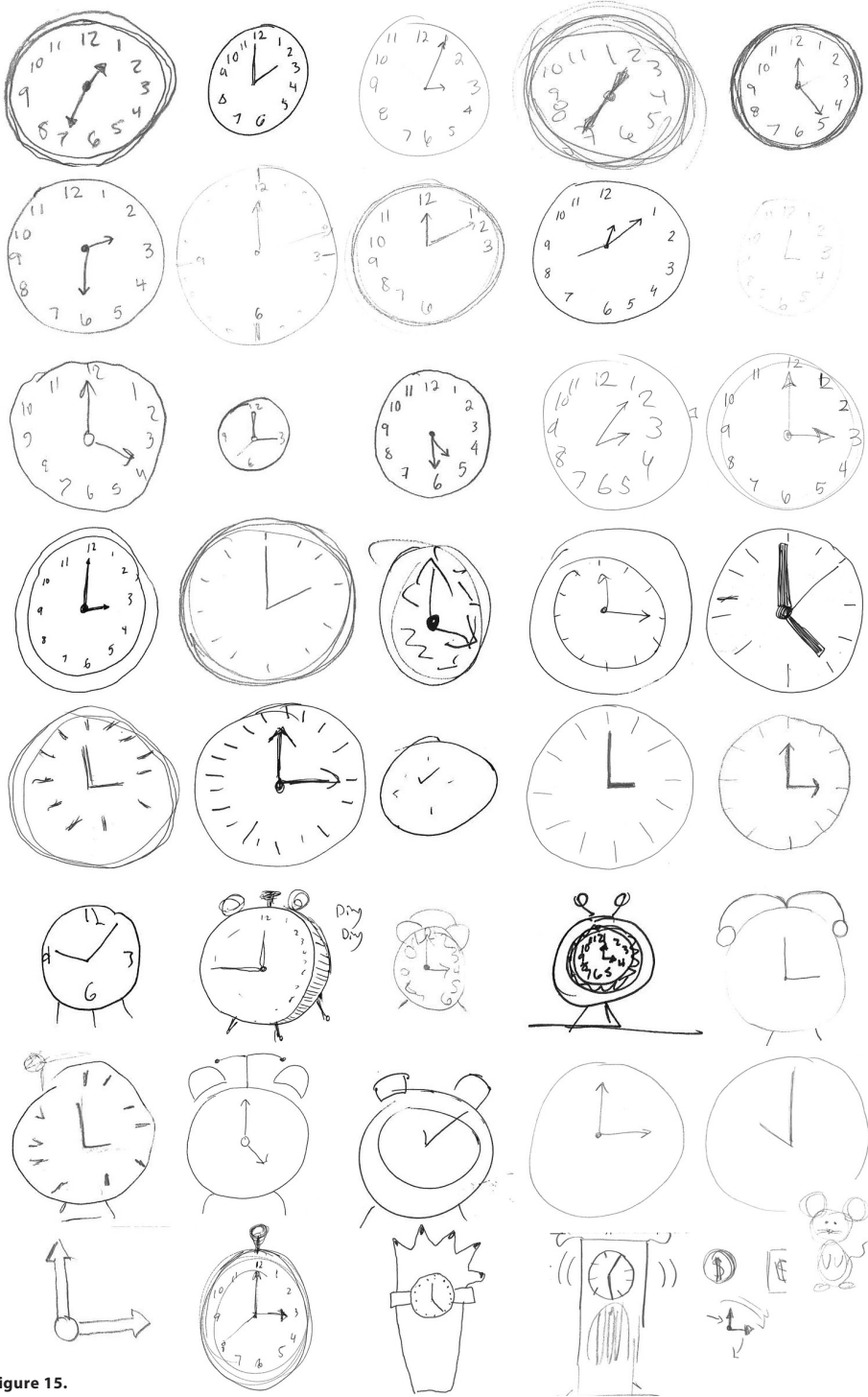


Figure 15.

"clock drawings from Draw-It.

The clock images drawn by 41 university students in a Draw-It activity.

designed pharmaceutical safety icons warning Pharmacists and healthcare workers of safety issues associated with particular medications, such as a “drug-that-must-be-diluted,” a “neuromuscular-blocking-agent,” and “medication-that-can-be-given-only-by-central-line.” Then again, in 2019, we worked with CHEO to design icons to indicate which kinds of pain children were experiencing. “Sharp-pain,” “shooting-pain,” “throbbing-pain,” and “cramping-pain” were some of the referents. In each case, Draw-It was part of the design process, and in each case, the process yielded a significant number of successful candidate icons to evoke very challenging concepts. We specifically noted that Draw-It added to the number of viable icon candidates (Vaillancourt, Zender, Coulon, & Pouliot, 2018, p. 254). This large number was especially useful for successfully communicating challenging concepts such as “medication-that-requires-airway-management-before-administration.”

We did not compare the effectiveness of Draw-It informed icons to the effectiveness of traditionally drawn icons in each of these studies because traditionally drawn icons did not exist in many cases. But where comparisons were possible, the Draw-It informed icons consistently performed better. The Safer Medication Handling Draw-It-based icon for “Medication-that-can-be-given-only-by-central-line” was preferred by 84% compared to 46% for the top-performing traditionally-drawn icon. The Draw-It-based “Neuromuscular-blocking-agent” icon was preferred by 59% compared to 31% for a standard version. These results are typical and show that Draw-It informed icons are routinely preferred. Draw-It has informed the symbol design process to create a large number of effective icons for very challenging concepts.

Conclusion:
What to draw +
How to draw it

We conclude from the above that having the right symbols is critical, and drawing those symbols so that users recognize them is essential to good icon comprehension.

Other issues

If multiple symbols interact to evoke meaning, then knowing which symbols to include and how to draw them so they’ll be recognized are both critical to designing comprehensible icons. But odd as it might sound, there is more to communication than precise comprehension.

Metaphor

Not all communication is based on a straightforward correspondence between object and meaning. For example, in basketball, I might say “he missed by a mile;” and the meaning might be clear even though the communication was not precisely accurate. He didn’t miss by “a mile” but by a lot. He probably put up an “airball;” and while “airball” might perfectly convey meaning, it too is not precisely accurate. The ball was not made of “air” but was a very solid vinyl rubber. These are, of course, examples of the use of metaphor to communicate. Lakoff and Johnson have claimed in “Metaphors We Live By” that metaphor is not only pervasive but essential. If icons are going to communicate using standard communication methods, then icons will undoubtedly need to occasionally use metaphor. But our studies have shown that mixing metaphoric and literal icons is a source of confusion.

Systems

One way to address iconic confusion is to make a system of icons in which individual icons provide their own disambiguating context and thus make each icon more comprehensible. Creating a comprehensive symbol system to enhance meaning-making is as old as the pyramids. Ancient Egyptians added marks, determinatives, to indicate whether a symbol was to be taken to represent an object or whether that same symbol was to be read photographically to represent a sound. More recently, containing shapes are used commonly in highway signs to clarify a sign’s meaning, and modifiers such as the circle-and-diagonal negation symbol are placed over a cigarette to indicate “no-smoking.”

Limitations

Metaphor and icons systems are mentioned briefly to illustrate that many issues impinge on clear communication with icons. Our findings, that most icons combine multiple symbols and that knowing which symbols to combine and how to draw them well are foundational to good comprehension, are accurate and valuable as far as they go. But they only provide a basis. Further study is needed to explore how metaphor can be made to work better, how systems can and cannot disambiguate, the possible clarifying role of modifiers and glyphs, how to scaffold onto existing knowledge to level the cultural field, and much more. To invoke a metaphor and quote a cliché, these are topics for another day.

Summary conclusions

To summarize what we have found, multiple symbols are better than one when it comes to clear communication of most concepts. Not only do most existing icons contain multiple symbols, but study after study has also shown that more accurate comprehension is evoked when the right symbols are brought together and drawn in a way that people expect. Combining multiple symbols is one way to control context, and controlling context is the key to guiding interpretation.

The interaction of symbols and the role of context are the foundation for a new and improved icon design process. Methods informing which symbols people associate with a concept will guide designers to select the right symbols to evoke a particular referent. Exposing peoples' brain icons will guide designers to draw symbols that people will recognize. Employing these processes individually and together has been proven to produce comprehensible icons. Informing these processes with social science methods and findings from human perception and cognition has provided a knowledge base from other disciplines upon which designers can build with confidence.

It can be helpful to summarize not only what we have found to be true but something we have debunked. A shibboleth is that simplicity is paramount in design generally and in icon design particularly. The findings presented here expose that fallacy. One still might say that "as simple as is effective" is true, but even that could send designers chasing after simplicity rather than seeking to determine from people which symbols need to be combined and how they need to be drawn. Designers need to appreciate that simplicity is a distortion of reality that has both benefits and negative consequences. It is clear that when communicating with symbols, simplicity is not the direct path to precise, sophisticated communication of complex concepts. Designers and design educators need to get over the-best-icon-is-the-simplest-icon mantra.

Combining symbols as one might combine letters was Neurath's dream. The ancients did this successfully, but we have neglected their knowledge. Icon's current usefulness and ubiquity suggest that it is time to build on the best of current scientific knowledge and improve our icon-design practice by adopting new design methods based on the interaction of symbols.

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