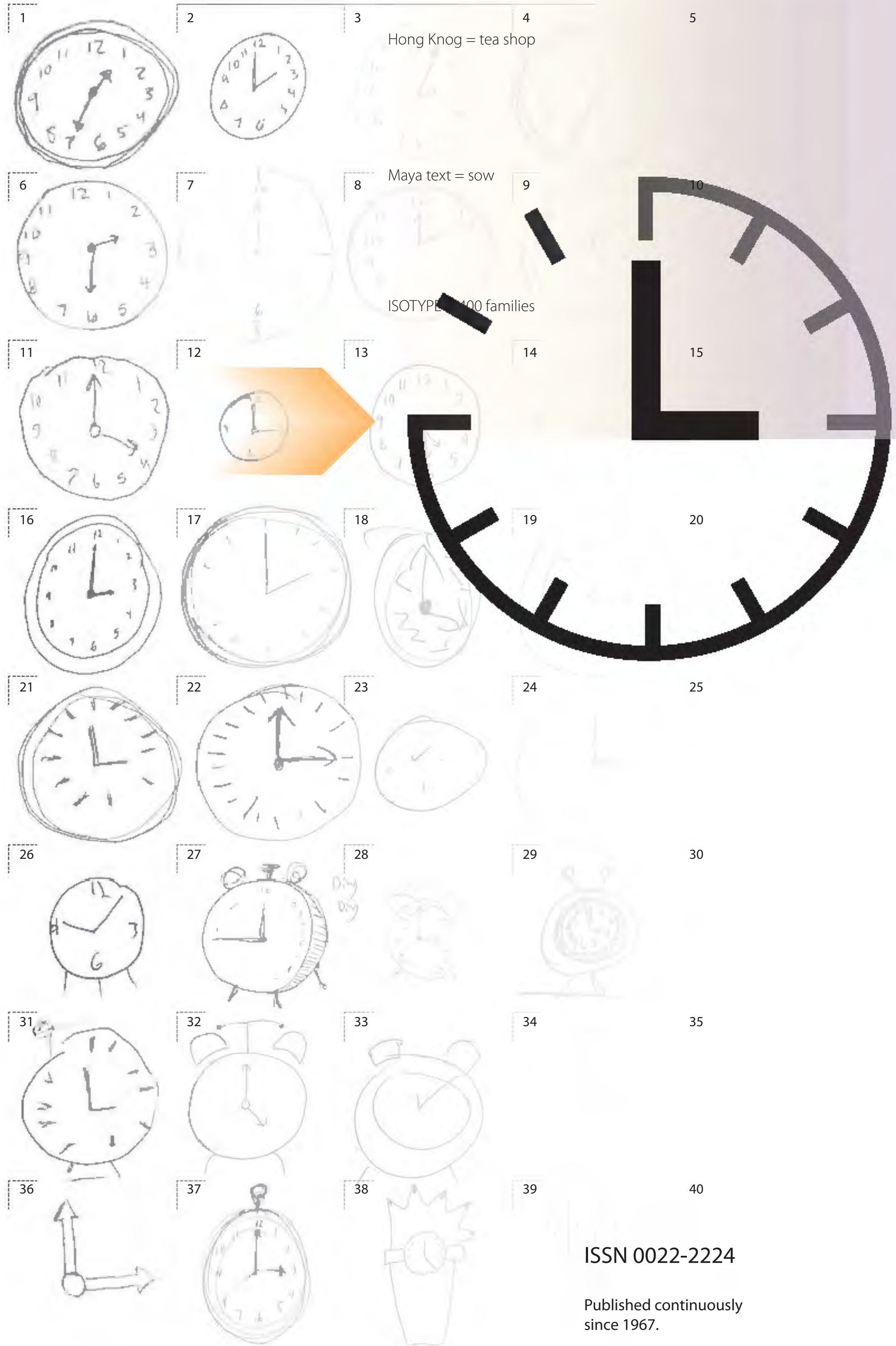

ISSN 0022-2224

Published continuously
since 1967.

Visible Language

51.2

the journal of visual communication research

august 2017

51.2

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the journal of
visual communication
research

august 2017

Before there was reading there was seeing. *Visible Language* has been concerned with ideas that help define the unique role and properties of visual communication. A basic premise of the journal has been that created visual form is an autonomous system of expression that must be defined and explored on its own terms. Today more than ever people navigate the world and probe life's meaning through visual language. This journal is devoted to enhancing people's experience through the advancement of research and practice of visual communication.

If you are involved in creating or understanding visual communication in any field, we invite your participation in *Visible Language*. While our scope is broad, our disciplinary application is primarily design. Because sensory experience is foundational in design, research in design is often research in the experience of visual form: how it is made, why it is beautiful, how it functions to help people form meaning. Research from many disciplines sheds light on this experience: neuroscience, cognition, perception, psychology, education, communication, informatics, computer science, library science, linguistics. We welcome articles from these disciplines and more.

Published continuously since 1967, *Visible Language* maintains its policy of having no formal editorial affiliation with any professional organization — this requires the continuing, active cooperation of key investigators and practitioners in all of the disciplines that impinge on the journal's mission as stated above.

website:
http://visiblelanguagejournal.com

send address changes to:
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College of Design, Architecture, Art, and Planning
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PO Box 210016
Cincinnati, OH 45221-0016

Published tri-annually in April, August, and December

51 . 2 **Visible Language**

the journal of
visual communication
research

special issue:

S y m b o l s _ I c o n s _ P i c t o g r a m s

August 2017

Advisory Board

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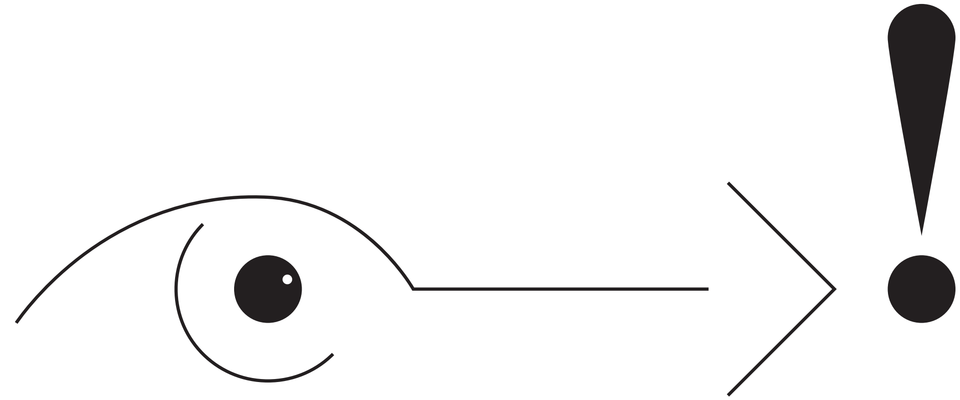


I noted in the previous issue, *Visible Language* 51.1, that people have communicated with visual symbols / icons / pictograms for thousands of years. To punctuate that point - four articles in these issues are on ancient Mesoamerican hieroglyphic communication systems: two in 51.1 "Tz'ihb 'write/ paint': Multimodality in Maya glyphic texts" by Agnieszka Hamann, and "Signs of resistance: Iconography and semasiography in Otomi architectural decoration and manuscripts of the early colonial period" by David Charles Wright-Carr, and two in 51.2 "Metonymic and metaphoric series in the *Codex Borgia*, Plates 33-34" by Angélica Baena Ramírez, and "The Written Adornment: the many relations of text and image in Classic Maya visual culture" by Daniel Salazar Lama and Rogelio Valencia Rivera.

These papers were first given as presentations at the conference *Sign and Symbol in Egypt and Mesoamerica: Exploring the Interrelationships of Writing and Iconography* held June 30 -July 07, 2016 at the University of Warsaw, Warsaw, Poland. The aim of the conference was to address a question that has received little attention: how graphic communication systems - traditionally known as notation/numeration, iconography, and writing - relate to, interact with, and exert influence on each other. The focus was on the civilizations of Egypt and Mesoamerica that provide abundant evidence for the interplay of systems in books and on monuments. The conference also sought contributions relating to cultures and systems beyond the bounds of the focal area, such as Mesopotamia, Anatolia, India, and China.

We appreciate the help of Katarzyna Mikulska, Daniel Tacacs, Gordon Whittaker, and conference organizers in bringing these papers to our attention and helping the authors prepare them for publication.

Mike Zender

Freelist

Person/patient
Cells
IV therapy
Chemotherapy
Doctor
Radiation/radiation symbol
Medical symbol
Head scarf
Bald person
Cancer
Medicine
Tumor/cancerous part
Ribbon symbol
Syringe/needle
X-ray
Chair
Hospital
Nurse
Crab
Color, red
DNA
Heart
Helped/helping
Radiation machine
Surgery

Pilesort

- Cancer
- Tumor/cancerous part
- Chemotherapy

- Head scarf
- Bald person

- Doctor
- Nurse
- Person/patient

- Radiation/radiation symbol
- Radiation machine

- DNA
- Cells

Rank

- **Cancer**
- **Tumor/cancerous part**
- **Chemotherapy**
- **Doctor**
- **Person/patient**

- Crab
- color Red
- Surgery
- Head scarf
- Heart
- Chair

Design by Consensus:

A New Method for Designing Effective Pictograms

Alisa Strauss
Mike Zender

A pictogram is useless if people cannot comprehend its meaning. Current pictogram design practice typically involves a designer envisioning what might represent a concept then drawing a pictogram that they think represents it. In this the designer is informed by their own experience and perhaps some study of pictograms with similar meanings. Unfortunately, this practice has been proven to frequently fail. Our previous studies have shown that designers create more comprehensible pictograms when they are aware that most pictograms consist of several icons and graphemes, know which of those to include, and understand how to draw each icon.

This study focuses on one of these essential processes: what icons people expect to see in a representation of a concept. It explores the use of consensus analysis techniques in determining - before even a rough draft of the pictogram is created - which icons are most needed. Once data obtained via freelisting, pilesorting, and ranking were analyzed using consensus analysis, the symbols that should be included in each pictogram were determined. Pictograms were then designed using those icons and were evaluated for comprehension. Results indicate that using techniques of quantitative ethnography to guide pictogram design improves comprehension of the resulting pictogram.

keywords

icon design
design methods
consensus analysis

Introduction

Pictograms today are ubiquitous and utilitarian. They facilitate succinct communication on smart phones, computer screens, and airport signs. Indeed, pictograms are descendants of some of the earliest known forms of writing and as such have been a functional part of daily life since before the pyramids were built.

Pictograms are used, ideally, to communicate quickly and effectively with people in a variety of contexts. Otto Neurath employed designer Gerd Arntz to create the ISOTYPE (International System Of TYpographic Picture Education) pictograms in the 1930s with the goal of creating a universally understood visual language system that was not affected by language or culture (Cat, 2014; Lee, 2008). Pictograms have been used wherever universal communication is desired: a variety of transportation contexts, public information systems, equipment operations and safety warning labels, understanding of medications, and of course the operation of computer devices of all sorts.

Pictograms promise to communicate apart from verbal language and are thus free from language's limitations. But that does not free these visual symbols from confusion over the definition and classification of pictograms themselves, variously called icons, symbols, logos, indexes, signs, and glyphs. Lacking established terminology we use the following taxonomy based on terms used in a variety of fields that deal with this topic including design, semiotics, linguistics, and anthropology.

Grapheme
Graphemes are the small elements that may or may not have meaning on their own, but that we can group together to form icons. An example of this would be an oval, which by itself does not have a specific meaning, but when placed with other graphemes could represent a head or an eye.

Icon
Icons may be made up of one or more graphemes and represent a simple concept or thing. An example of this would be a face, which could be formed simply by combining one large oval with two smaller ones.

Pictogram
Pictograms are made up of icons and represent complex concepts, stories, or data sets. An example of this would be combining an icon of a face with an icon of a bandage to form a pictogram representing the concept of "head wound."

Traditionally, the pictogram design process involves a designer creating a pictogram that they think represents the referent. This design is refined and if a set of pictograms is made, they are altered so they are drawn in the same style. The pictograms may then be shown to users to see if they understand the meaning correctly and, if not, revisions will be made and the new pictogram will be tested. Ideally, through a series of revisions and comprehension tests, the end result is a pictogram that can be understood by those who view it.

Figure 1.

Tire Inflation Pressure icon

Pictograms can communicate effectively but often don't. Evaluation of a "tire inflation pressure low" warning symbol mandated by law on passenger vehicles (Figure 1) revealed that it was not understood by 60% of drivers: 46% couldn't even identify the symbol as a tire (Woodyard, 2010), a far cry from universally understood visual language. Our own pictogram comprehension studies show depressingly similar results. Only eight of a set of 54 universal medical pictograms that were carefully designed to cross language and cultural barriers were comprehended correctly by American subjects at the 85% comprehension level required by ANSI for safety symbols, and just three of those same 54 pictograms were comprehended at 85% by subjects in Tanzania (Zender & Cassady, 2014, 78-79). Indeed, 19 of the 54 pictograms were correctly identified by fewer than 10% of Tanzanians. That failure rate of 90% for 19 medical pictograms was for a Tanzanian subject pool roughly half of whom had advanced medical training. Clearly, there is ample room for improvement in typical pictogram design practice.

In pursuit of improved pictogram comprehension, many have studied the ways in which people understand pictograms. There are those who think that comprehension of an icon or pictogram is dependent on context: both the context of the icon or pictogram and the context of the person (Werner & Kaplan, 1963). In other words, a person's previous experiences affects comprehension as much as the physical context of the pictogram. Some hypothesize about the difference made by the use of images that resemble the objects they represent versus the use of more arbitrarily symbolic representations have on comprehension (Daddesio, 1995). Others have proposed key pictogram qualities to be: the degree of representationalness

- concrete to abstract for example (Wileman), or *complexity* – a lot of visual information compared to less visual information (Lesch et. al., 2013); or *concreteness* – the extent which a pictogram represents physical objects or actions experienced in the world; or semantic distance – how closely related the image is to the concept (McDougall et. al, 1999). Our studies have found that confusion frequently occurs when people are unaware that a pictogram is intended to be read metaphorically rather than literally (Zender & Cassedy, 2014, 92). It is clear that careful attention to the referent's meaning and semantic range during pictogram design can improve comprehension (Zender & Mejia, 2013) and that adding multiple icons to provide more context, making the pictogram more complex rather than more simple, can improve comprehension (Lesch, et al. 2013; Zender & Mejia, 2013).

A number of pictogram studies have focused on cross-cultural impacts on pictographic communication. Easterby and Zwaga asked users from two different cultures to rank how well they thought pictograms depicted their intended meanings (Easterby & Zwaga, 1976). They intended to find the one best pictogram that was effective in both cultures for each referent, however what they found was that there were conflicting results so that they had to then select the pictograms that scored the highest in both cultures and then test how well people understood them. They found that people could attribute meanings to all of the pictograms, just not always the correct meaning (Easterby & Zwaga, 1976). Useful conclusions of the study include the finding that "pictorial quality of the symbol (as opposed to its degree of abstractness) is an important feature in recognition," and that giving subjects matching tests, tests where they are asked to match a pictogram to a meaning, provides biased, misleading results (Easterby & Zwaga, 1976). A more recent study of cross-cultural pictogram comprehension in the USA and Tanzania revealed that lack of knowledge of the referent concept was a greater factor in miscomprehension than cultural misunderstanding (Zender & Cassedy, 2014, 91). For example, if one has no idea what an MRI is, then they will not comprehend an MRI pictogram no matter how well designed it may be. This corroborates findings on the importance of prior knowledge in comprehension.

Previous studies by the authors suggest that most pictograms are crafted including several discrete icons integrated in a shared space (Zender, 2007, 60). If these icons are well-chosen to match the meaning of the referent and drawn as people expect then comprehension might increase. These recent studies suggest that aside from context the most significant determinants of pictogram comprehension are knowing what icons to include in a pictogram and how to draw those essential icons. It is this recent understanding that this paper exploits.

The study reported here demonstrates that the methods of consensus analysis can be used to inform the design of a pictogram - before even a rough draft of the pictogram is created - by determining what icons users expect to see in a pictogram with a certain meaning and that this, in turn, can contribute to designing more effective pictograms.

Consensus analysis enables a researcher to determine the "culturally correct answer" to any question asked of informants in a culture (Borgatti & Halgin, 1986). Through the use of three separate data collection techniques, freelisting, pilesorting, and ranking, and consensus analysis of those data, this study contends that it is possible to determine what icons need to be included in a final pictogram design to maximize user comprehension before the pictogram is drawn. To test to see if this is a valid method to be used to aid in the design of effective pictograms, user comprehension testing was conducted on the pictograms generated in this study to determine how well they were understood by people viewing them.

Methods

Consensus Analysis

The goal of this study was to determine by cultural consensus what icons should be included in a pictogram representing a complex referent before the creation of the pictogram, thus allowing a designer to generate a more widely comprehended pictogram. Determining cultural consensus is achieved in part through the use of consensus analysis. 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).

To accomplish the goal of this study, apt referents for the pictograms had to be determined. A referent is the word or phrase to which a pictogram refers. Based on a previous study of pictogram comprehension among people from the United States and Tanzania (Zender & Cassedy, 2014) three pictogram referents were chosen that had poor comprehension among all study participants. These pictograms had been designed using the traditional method wherein a designer draws what they think represents the referent, tests it, and makes revisions.

The referents chosen for this study, "outpatient", "oncology", and "psychiatry," all had very low comprehension rates (0%–36%) among people with and without medical training from the United States and Tanzania (Zender & Cassedy, 2014, 78-79). The referents were defined here by combining definitions for the referents from multiple sources into a single, clear definition for each as follows.

Oncology
the branch of medicine specializing in the diagnosis and treatment of cancer (Google, n.d.-a; Medicine, 2015; Merriam-Webster Dictionary, n.d.-a; Oxford English Dictionary, n.d.-a).

Outpatient
a person who goes to a doctor's office or hospital for treatment but who does not spend the night there (Google, n.d.-b; Medicine, 2015; Merriam-Webster Dictionary, n.d.-b; Oxford English Dictionary, n.d.-b).

Psychiatry
the branch of medicine specializing in the study and treatment of mental, emotional, and behavioral disorders (Google, n.d.-c; Medicine, 2015; Merriam-Webster Dictionary, n.d.-c; Oxford English Dictionary, n.d.-c).

These definitions were used in all phases of research to provide informants with a common definition of each referent when participating in this study. Presenting participants with a definition at the time when they were asked to provide information helped ensure that everyone understood each referent in the same terms. Participants in this study had either medical training (i.e. attending and resident physicians) or no medical training (i.e. graduate and undergraduate students, other adults in various non-medical lines of work). Attempts were made to try to get an equal number of medical and non-medical study participants in each of the data collection phases of this research.

A series of quantitative research methods were used to determine the cultural consensus on how pictograms depicting the three referents, outpatient, oncology, and psychology, should be constructed. These data were collected in three phases. First freelist data was collected and analyzed by looking at relative frequencies, then information on pilesorting was assembled, and finally ranking data acquired. Both pilesort and rank data were examined using forms of consensus analysis. After the data collected in these phases was analyzed, the results were used to design pictograms which were then tested to see how well people comprehended their meaning.

Freelisting

The first phase of data collection involved freelisting (Borgatti, n.d.), a qualitative research method used here to determine what users expected to be seen in each pictogram representing a given referent. This data collection technique involves asking subjects from the same culture to list all of the things that they think are in the cultural domains of oncology, outpatient, and psychology. A cultural domain can be defined as "a set of items or things that are all of the same type or category" (Borgatti & Halgin, 1998). For example, to determine what vegetables populate the cultural domain of "vegetables commonly eaten by Americans," one would ask American informants to list all the vegetables they think are commonly eaten by Americans. There are no rules as to what participants can list or how many things they can list, hence, freelist. In this study, subjects were asked to list the elements they thought should be included in pictograms meaning psychology, oncology, and outpatient.

The use of freelisting in anthropological research is not new (Borgatti, n.d.; Furlow, 2003; Gravlee, et al. 2013; Libertino, et al. 2012; Smith & Borgatti, 1998). Freelisting has not, however, been conducted on a visual element like a pictogram before. For this reason, a special freelist survey page was designed to help informants create their freelists in this study. In anthropology, freelisting is most commonly conducted as part of semi-structured interviewing (Borgatti, n.d.). The instructions on the cover sheet take advantage of what is known to psychology as the priming effect (Kahneman, 2011; Molden, 2014), the fact that the mind, immediately after being exposed to an idea, can more readily think of other related ideas. In this case, subjects were shown images of pictograms as part of the instructions for how to freelist in order to get them thinking about pictograms and the icons that compose them. Priming was thought to be important since most participants in this study were unused to designing pictograms because they were either medical professionals or in other fields of study or work. Collection of freelist data is quick. On average, participants took no more than a minute or two to complete each freelist.

The items listed by study participants during freelisting were used to generate the lists of items in each referent's cultural domain used in the next two phases of study, pilesorting and ranking. It is recommended, when trying to have cultural consensus, to have at least 30 informants when collecting freelist data (Borgatti, n.d.). In this study, freelists were obtained from 54 participants for the referent oncology, 54 for outpatient, and 51 for psychiatry. There were about equal numbers of participants with and without medical training, and the ratio of women to men was about 2 to 1 (Strauss, 2016).

While some freelist items were listed only once by one participant, there were a number of items that were listed by more than one person. Table 1 shows the responses for each referent ordered from most frequently mentioned to least for all items listed by more than one participant.

Table 1.

Results of freelisting by participants for three referents, oncology, outpatient, and psychiatry. Each column lists items in the cultural domain for the referent listed at the top. The number next to each item is the frequency with which it was mentioned by informants.

Top items mentioned, ordered by frequency

Oncology		**Outpatient**		**Psychiatry**	
Person/patient	22	Person/patient	54	Person/patient	35
Cells	22	Leaving	23	Brain	30
IV therapy	13	Walking	23	Emotion(s), faces with emotions	23
Chemotherapy	12	Door	17	Couch	15
Doctor	10	Hospital	14	Doctor	15
Radiation/ radiation symbol	10	Doctor	10	Lying/lying down	11
Medical symbol	9	Office	9	Expression(s), faces with expressions	9
Head scarf	8	Bandage or cast	8	Sitting	8
Bald person	7	Entering	8	Chair	8
Cancer	5	Exam table/bed	8	Pill(s)	7
Medicine	5	Clock	7	Talking/speaking	6
Tumor/ cancerous part	5	Day/daytime	7	Listening	6
Ribbon symbol	4	Stethoscope	7	Color, blue	4
Syringe/needle	4	Sun	6	Medical symbol(s)	3
X-ray	3	Time	6	White coat	3
Chair	3	Injury or affliction	5	Analyzing/ examining	3
Hospital	3	Medical symbol	5	Healing signs	2
Nurse	3	Car	4	Medicine	2
Crab	3	Hospital sign/symbol	4	Notepad	2
Color, red	2	Sitting	4	Question mark(s)	2
DNA	2	Healed/fixed	3	Taking notes	2
Heart	2	No sign	3	Brainwaves	2
Helped/helping	2	Waiting room	3		
Radiation machine	2				
Surgery	2				

The terms listed in Table 1 are those that were used in the next two phases of data collection. The cutoff for which items would be used in the pilesorting and ranking phases was that they had to be mentioned by more than one participant (Borgatti, n.d.) so that they are more likely to be part of the larger cultural domain. The lists of terms are not all the same length because of the nature of the data obtained from the study participants (Strauss, 2016).

Pilesorting

While the goal of freelisting is to elicit the basic elements of cultural domains from study participants, pilesorting is used to allow informants to show which items within a cultural domain are similar or related somehow. The method used here is known specifically as unconstrained or free pilesorting (Borgatti, 1999). 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 freelisting, 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.

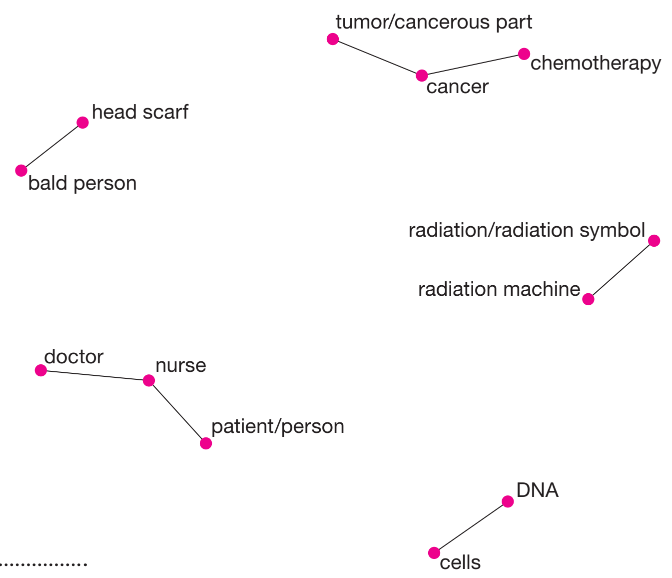
As with freelisting, the pilesorting technique should be conducted with a sample size of at least 30 participants (Borgatti, et al. 2002; Borgatti & Halgin, 1998). In this study, for each of the three referents, 40 participants completed pilesorts, 25 female, 15 male. The sample was almost evenly divided between those with and without medical training (Strauss, 2016). Pilesorting sounds complex, but participants were able to complete the task for all three referents in 5-10 minutes on average.

Once collected and recorded, the data was analyzed using UCINET, a social network analysis software package (S. Borgatti et al., 2002), and Netdraw, a network visualization software package (Steve P. Borgatti, 2002). All the pilesort data was entered into UCINET which converted the raw data into a set of matrices. One matrix was generated for each study participant describing what items in each cultural domain they did and did not group together. UCINET was then used to analyze how frequently items within a cultural domain were placed in the same pile by all the users in the study. The output of this process is an aggregate proximity matrix. Values in an aggregate proximity matrix range from 0, meaning that items were never placed together in the same pile by participants, to 1, meaning that items were placed in the same pile together by 100% of informants. In other words, the aggregate matrix shows the agreement, or consensus, among all the participants in the pilesorting exercise as to what items in each cultural domain are thought to be similar or related to each other. Although the matrix itself can be difficult to read, it becomes very useful as data that can be worked with in Netdraw. Netdraw uses multidimensional scaling (MDS) to display the items in the proximity matrix as a set of points in space, using the aggregate proximity matrix values to determine the distances between the points representing the items in space (Borgatti et al. 2002). Thus, in an MDS display of the proximity matrix, items that are closer to each other spatially are items that were more frequently grouped together by informants when they did the pilesorting.

There was not 100% agreement among any sample of participants as to what groups items belong. For that level of agreement to occur, every informant would have had to have grouped every item into the same number of groups with the exact same items in each group. Figure 2 shows an example of clusters formed using MDS. The clusters of items were used to help determine what elements should be included in each pictogram. Clusters do not represent importance to the cultural domain, they simply indicate that participants think that items clustered together are related to each other in some way. Because the clusters help to show what items users think are related, they indicate elements that might be combined into one icon to enhance comprehension of the pictogram. For example, in the domain of oncology, bald person was closely tied to head scarf, suggesting that bald people might be depicted wearing head scarves (Strauss, 2016).

Figure 2.

Items in the cultural domain of oncology that were grouped together at least 70% of the time by study participants. Items not shown here (see Table 1) did not consistently group with other things at this level of agreement.



Ranking

In the ranking phase of research, study participants were asked to rank the items in each referent's cultural domain in terms of importance to include in an icon with that referent's meaning. Ranking data was collected by presenting participants with a list of all the items in each cultural domain which they then ranked by numbering them beginning with 1, which the most important item in the domain. The purpose of this was to determine which items in each cultural domain were more important to the people surveyed and, therefore, more important to include in a pictogram representing each referent. Ranking items took only 1-2 minutes on average for each of the 37 participants in the group which was almost equally divided into those with and without medical training (Strauss, 2016).

Ranking data for each referent, oncology, outpatient, and psychiatry, were analyzed using consensus analysis in UCINET. Consensus analysis calculates the degree of agreement among participants that is present in their responses (Borgatti et al. 2002; Weller, 2007). In other words, consensus analysis shows whether there is broad agreement among informants about what they have ranked. To do this, all ranking data from all informants for each referent were entered into UCINET. The consensus analysis calculations carried out by UCINET begin by treating each informant's rankings as a matrix and then averaging the responses of all the respondents for the referent (each referent is analyzed separately). This resulting matrix is an agreement matrix that "provides a reasonable estimate of answers that is easy to understand and statistically sound" (Weller, 2007). The agreement matrix is symmetrical, with a diagonal of unknown value. UCINET determines the values for this diagonal by factoring, or creating a mathematical model to complete the agreement matrix (Mertler & Vannatta, 2005). The values for this first factor are referred to as the competence scores for the informants (Borgatti et al. 2002; Weller, 2007). UCINET also provides the first and second eigenvalues for the competence scores. Eigenvalues are used in factor analysis to describe the variance explained by a factor (Mertler & Vannatta, 2005). Importantly, consensus analysis only works if there is enough agreement between the informants that there is a single factor that can explain competence (Weller, 2007). To test to make sure this is the case, one must look at the eigenratio, calculated by dividing the largest eigenvalue by the second largest eigenvalue. If the eigenratio is greater than 3, then one can say that there is broad agreement among everyone in the sample, or in other words, there is consensus (Borgatti & Halgin, 2011; Weller, 2007).

While no participants in this study had very low or negative competence scores, indicating they were not giving the "correct answers" when they ranked items (Borgatti et al., 2002), eigenratios indicated that there were two separate cultures in the study population consisting of those with and those without medical training (Strauss, 2016). The mean competence of those with medical training and those without medical training were compared using a two-tailed T-test, a test used to determine whether two samples are statistically different from each other for each referent (Kohout, 1986:300-301). This test indicated that there is a statistically significant difference between the two groups for all referents (Strauss, 2016).

As a result, two consensus analyses of the ranking data for each referent were conducted, one for rankings made by those with medical training, and one for the rankings made by participants without medical training. The rankings of items for each of the referents was used to indicate the amount of importance to give to different clusters of symbols as determined via pilesorting when designing the pictograms for the three referents.

Pictogram Design

To design pictograms based on the data collected from informants, both the groupings of potential pictogram icons as determined through pilesorting and the relative importance of icons determined through ranking were used. The MDS outputs based on how participants sorted symbols into piles shows what symbols they think are more closely associated with one another. To see which elements or groups of elements were more significant to study participants, an average rank score was used. The average rank score was calculated by averaging the rank assigned to each item by persons with and without medical training to achieve a single rank score. Interestingly, though there is not total agreement between the groups (which is why their rank data needed to be looked at separately), it is quite similar with most elements being ranked relatively the same in terms of high, medium, and low importance (Strauss, 2016). Figures 3, 4, and 5 show the average rank scores for each of the three sets of data. In all cases, the highest rank an item could have is 1.

The main hypothesis being tested here is that quantitative analyses typically used by anthropologists studying cultures can be used to determine what elements should be included in a pictogram, before it is designed, to improve user comprehension. To test this, two different sets of pictograms were designed based on the results of the data collected from participants via freelisting, pilesorting, and ranking. It was decided to divide the domain item samples approximately into fourths as an arbitrary way of creating divisions in the data. To treat each domain equally (because there are different numbers of items in each domain), this made the one-fourth cutoff 5. Therefore, one set of pictograms was created using the five elements with the highest average ranks (more if there was a tie for fifth place). If the hypothesis is correct, this set of pictograms should have high levels of comprehension when tested because they are composed of elements that informants said were important to include in the pictograms for each referent. The other set of pictograms was designed using the same set of data, only they were made using the five (or more in the case of a tie for fifth place) items with the lowest average ranks. This second set of pictograms should have low comprehension when tested because they are composed of items that participants said were the least important elements to be included to convey the meaning of the pictogram. The calculated average rank scores can be seen in Table 2 for all three referents.

The following figures show the pictograms that were designed on the basis of the consensus analysis results. In order to minimize differences in comprehension that could possibly result from the way informants react to different art styles, the pictograms were all designed using the same artistic style. This style was also intentionally designed to look as commonplace as possible. This was done to avoid adding in a confounding element

Figure 3.

Oncology

Items in the cultural domain of oncology that were grouped together at least 70% of the time by study participants. Size and color of circles indicate how highly each item was ranked. Items listed in a column at the far left did not consistently group with others at this level of agreement.

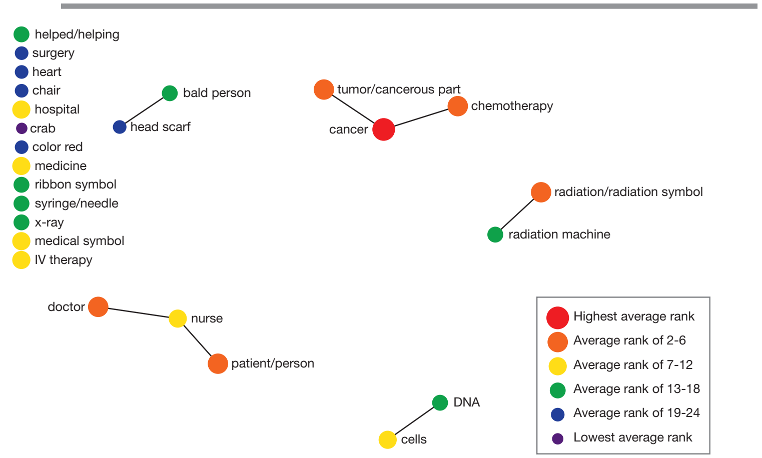


Figure 4.

Outpatient

Items in the cultural domain of outpatient that were grouped together at least 50% of the time by study participants. Size and color of circles indicate how highly each item was ranked. Items listed in a column at the far left did not consistently group with others at this level of agreement.

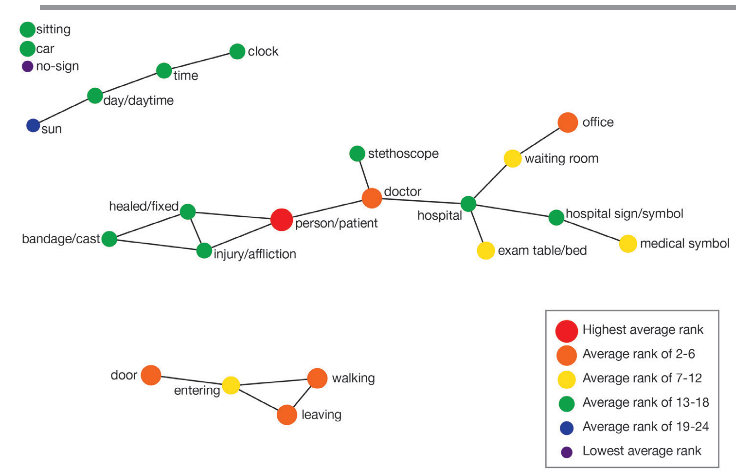


Figure 5.

Psychiatry

Items in the cultural domain of psychiatry that were grouped together at least 70% of the time by study participants. Size and color of circles indicate how highly each item was ranked. Items listed in a column at the far left did not consistently group with others at this level of agreement.

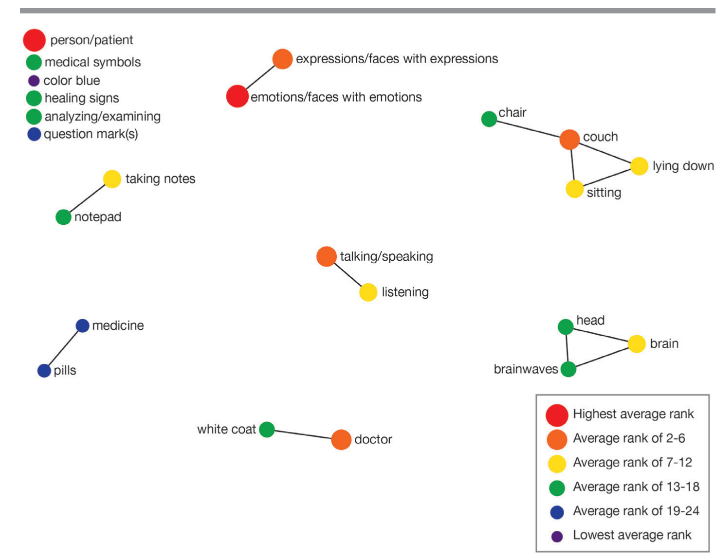


Table 2.

Average rankings for items in the three cultural domains. Items used to make pictograms can be seen in bold. Highest ranked items are at top, lowest at bottom.

Average rankings for cultural domain items

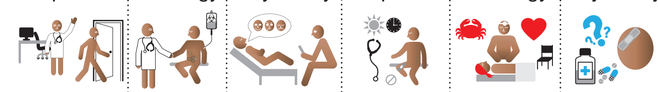
Oncology Rank		Outpatient Rank		Psychiatry Rank	
1	**Cancer**	**1**	**Person/patient**	**3**	**Emotions/faces with emotions**
3.5	**Chemotherapy**	**2.5**	**Walking**	**3**	**Person/patient**
3.5	**Patient/person**	**4**	**Leaving**	**4**	**Talking/speaking**
3.5	**Doctor**	**5**	**Doctor**	**4**	**Doctor**
4	**Tumor/ cancerous part**	**5.5**	**Office**	**6**	**Expressions/faces with expressions**
5.5	Radiation/ radiation sign	**5.5**	**Door**	**6**	**Couch**
9.5	Nurse	7	Entering	8	Lying down
9.5	Cells	10.5	Exam table/bed	8.5	Listening
10.5	IV therapy	10.5	Medical symbol	9	Taking notes
10.5	Medicine	11.5	Waiting room	10	Brain
10.5	Medical symbol	13	Hospital sign/symbol	10.5	Sitting
11	Hospital	13	Hospital	12.5	Chair
12.5	Radiation machine	14	Injury/affliction	12.5	Notepad
14	Ribbon symbol	15	Time	14	Brainwaves
14.5	Helped/helping	15.5	Bandage/cast	14.5	Head
15.5	X-ray	15.5	Car	16	Analyzing/examining
16.5	Syringe/needle	**16.5**	**Stethoscope**	16.5	White coat
17.5	DNA	**16.5**	**Day/daytime**	17.5	Medical symbols
18	Bald person	**16.5**	**Clock**	**18**	**Healing signs**
20	**Head Scarf**	**17.5**	**Sitting**	**19**	**Pills**
20	**Surgery**	**17.5**	**Healed/fixed**	**20**	**Medicine**
23	**Color, red**	**19.5**	**Sun**	**20.5**	**Question mark(s)**
23	**Heart**	**23**	**No-sign**	**23**	**Color, blue**
23.5	**Chair**				
24.5	**Crab**				

that could be created by representing icons in unfamiliar ways. To do this, image research on how others have most commonly depicted people and icons that appear in each icon was conducted. In particular, the Noun Project website, which is a repository of icon and pictogram designs made by designers from around the world ("Noun Project - Icons for Everything," n.d.) and Google image searches were used to find frequently used depictions of icons. Every effort was made to make the somewhat random-seeming set of icons that composed the pictograms made from the lowest ranking items in each cultural domain look like a coherent pictogram. The resulting pictograms can be seen in the following figures (*figures 6-11* next page).

The pictograms were treated as two separate sets with some study participants receiving a set of three pictograms made with the highest ranking symbols and others getting the three pictograms that were made using the lowest ranking symbols. All participants (for total numbers, see Table 3) in the comprehension tests were not participants in any of the previous phases of research. Participants in the comprehension portion of this study included those with and without medical training. The proportion of the study population who took comprehension surveys with medical training ranged between 25-33% for the six icons. Because those with medical training did not have different levels of comprehension compared to those without medical training, the comprehension results discussed here include all participants, regardless of medical training. All informants were asked for each icon to answer the same question: "In a single word or brief phrase, what does the above pictogram mean?" The total number of responses for each pictogram can be seen below in Table 3.

Table 3.

Total number of participant responses to surveys asking for people to tell the meaning of the pictograms in this study.

	Pictograms using highest ranking graphemes and icons			Pictograms using lowest ranking graphemes and icons		
	Outpatient	Oncology	Psychiatry	Outpatient	Oncology	Psychiatry
						
Number of participant responses	56	57	57	50	48	48

It is believed that though approximately equal numbers of surveys asking for responses to pictograms based on high-ranking symbols and low ranking symbols were distributed to participants, the number of responses to the latter is the result of participant frustration. Subjects who received pictograms made based on low-ranking symbols tended to voice frustration at not being able to understand what they were looking at much more frequently than those who received the other pictograms (Strauss, 2016). Because participation is voluntary, informants were told at the beginning of the survey that if they did not wish to participate, they could simply hand back in their blank consent form and survey. No blank consent forms and surveys were returned by those who received the set of pictograms based on high-ranking symbols; six sets of low-ranking pictograms were returned blank. In addition, participants who received high-ranking symbol based pictograms provided meanings for all three of the pictograms. Informants who received sets of pictograms based on low-ranking elements sometimes skipped providing a meaning for one or more of the pictograms in the set. This is again believed to be a result of the frustration that was voiced by participants because they could not understand the pictograms.

Figure 6.

Oncology

Icon designed to mean oncology using the highest ranking items in the cultural domain of oncology. Terms with arrows indicate where/how the domain items were used to make the icon.

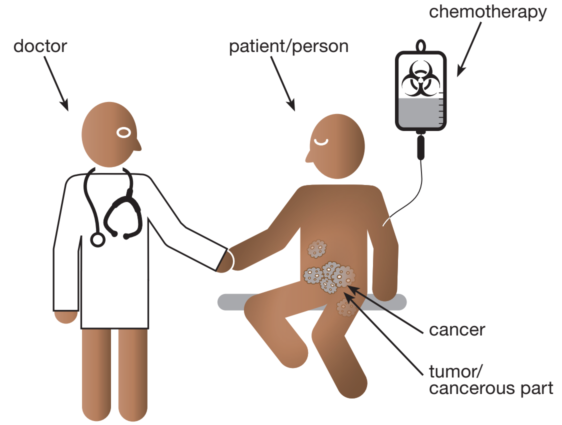


Figure 7.

Outpatient

Icon designed to mean outpatient using the highest ranking items in the cultural domain of outpatient. Terms with arrows indicate where/how the domain items were used to make the icon.

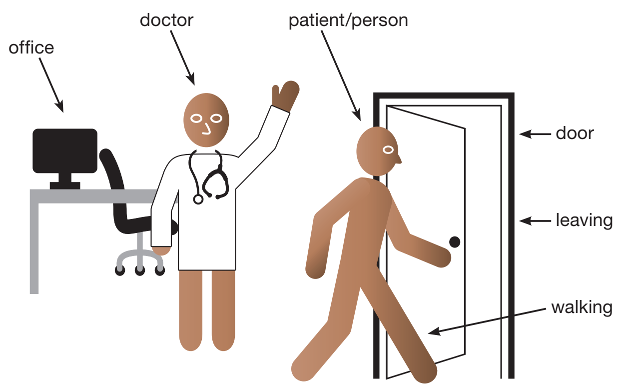


Figure 8.

Psychiatry

Icon designed to mean psychiatry using the highest ranking items in the cultural domain of psychiatry. Terms with arrows indicate where/how the domain items were used to make the icon.

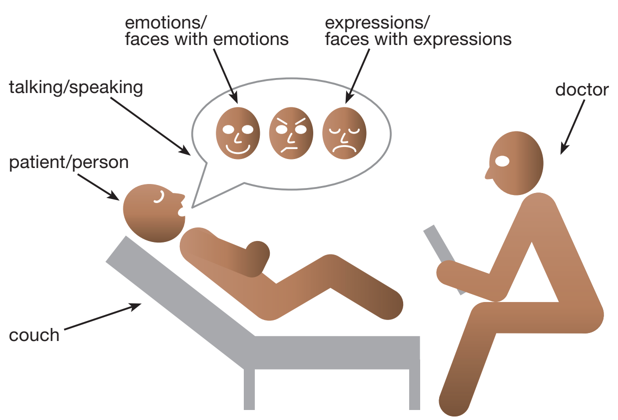


Figure 9.

Oncology

Icon designed to mean oncology using the lowest ranking items in the cultural domain of oncology. Terms with arrows indicate where/how the domain items were used to make the icon.

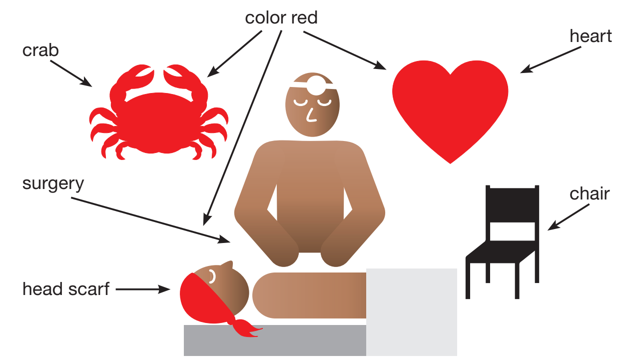


Figure 10.

Outpatient

Icon designed to mean outpatient using the lowest ranking items in the cultural domain of outpatient. Terms with arrows indicate where/how the domain items were used to make the icon.

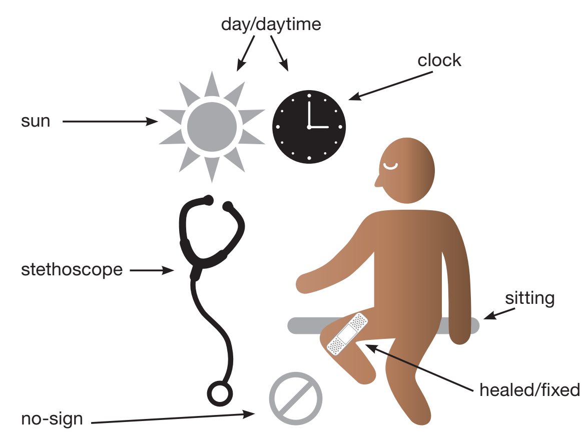
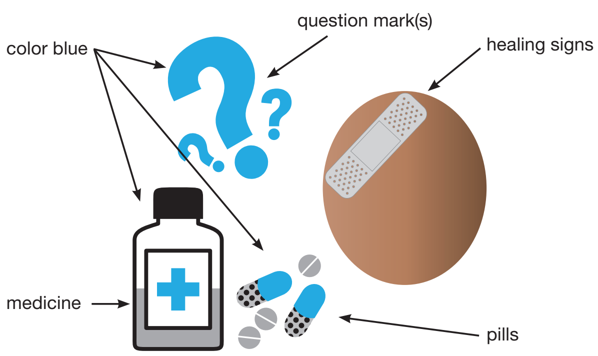


Figure 11.

Psychiatry

Icon designed to mean psychiatry using the lowest ranking items in the cultural domain of psychiatry. Terms with arrows indicate where/how the domain items were used to make the icon.



Results

To determine if consensus analysis is truly a valid way of determining what icons should be included in a pictogram to enhance comprehension, this study did several things. To select referents that were difficult to depict in pictogram form successfully, the three most poorly understood pictograms from Zender and Cassedy's (2014) pictogram comprehension study led to the selection of their three referents, oncology, outpatient, and psychiatry. Clear definitions of each referent were written by combining information from several sources to be used throughout the study (Strauss, 2016). Once freelisting had been used to determine what items were in the cultural domain for each referent, consensus analysis of pilesorting and ranking of those domain items were conducted to determine what symbols should be included in each pictogram. To test if the hypothesis that consensus analysis is a useful tool for improving icon design, two sets of pictograms were made, one using the highest ranking domain items for each referent, and another using the lowest ranking items.

Responses to the comprehension surveys were scored as either correct or incorrect. Responses were deemed correct if the respondent wrote down either the referent word or any word or phrase that was synonymous with the referent. Because the referents for these pictograms were medical in nature, to ensure that participant responses were correctly categorized as correct or incorrect, all responses were reviewed by Eric Warm, MD, Richard W. & Sue P. Vilter Professor of Medicine, Director, Internal Medicine Training Program at the University of Cincinnati, and practicing physician at UC Health. Results of comprehension tests for pictograms from the Zender and Cassedy study, the pictograms made using high-ranking elements, and the pictograms made using low-ranking elements can be seen here (*figures 12-14*).

The International Standards Organization (ISO) recommends a level of 67% comprehension for a pictogram to be considered successful and the American National Standards Institute (ANSI) recommends 85% comprehension for a successful safety pictogram (American National Standards Institute, 1991; International Standards Organization, 1984). Most pictogram comprehension studies aim to achieve the ISO standard of 67% (for examples see Piamonte, et al. 2001; Wolff & Wogalter, 1998; Zwaga & Boersema, 1983). By the ISO standard of 67%, only one pictogram, the one made using high-ranking symbols for the referent psychiatry, was successful with 72% comprehension. This indicates that the items that were ranked as being in the top-ranked quartile were clearly significant symbols needed to depict psychiatry.

Of greater significance here is the improvement to pictogram comprehension made using solely the results from freelisting and consensus analysis of pilesorting and ranking data. As can be seen in Figures 12-14,

Figure 12.

The frequency with which people correctly understood the meaning of pictograms with the intended meaning of "oncology."

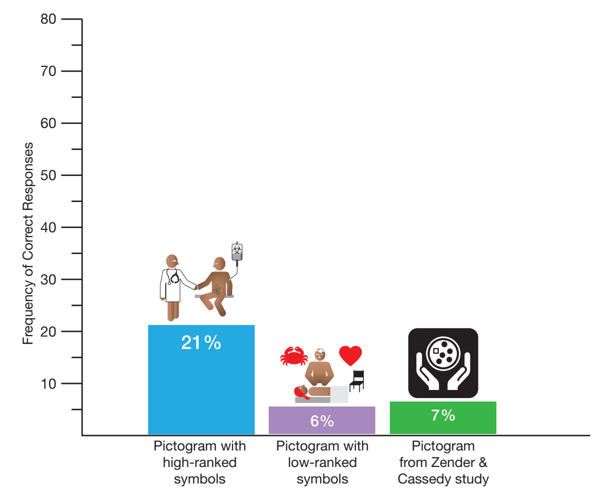


Figure 13.

The frequency with which people correctly understood the meaning of pictograms with the intended meaning of "outpatient."

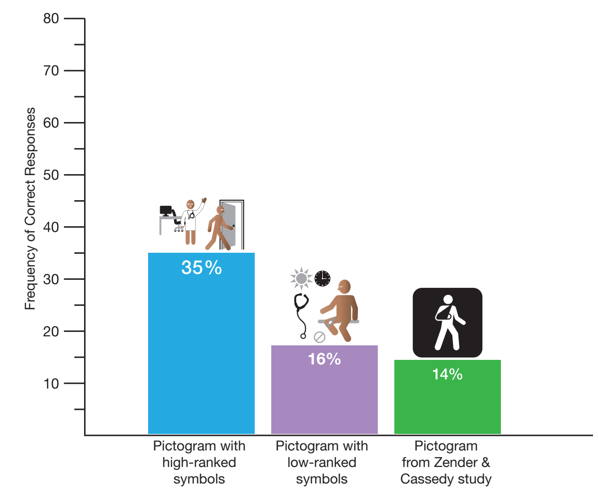
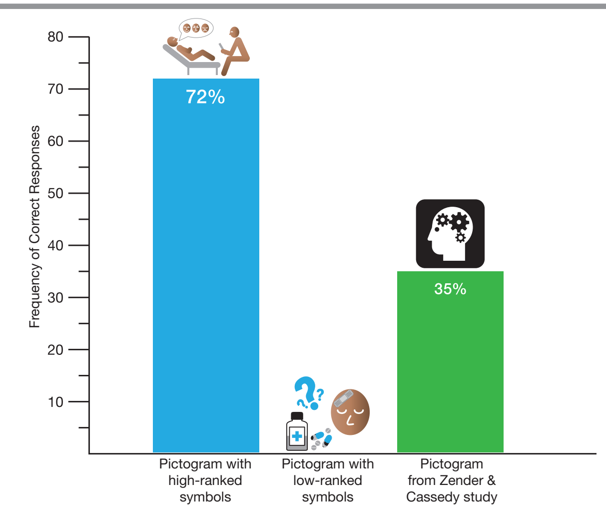


Figure 14.

The frequency with which people correctly understood the meaning of pictograms with the intended meaning of "psychiatry."



comprehension of the pictograms designed using high-ranking symbols determined through consensus analysis was 2.1 to 3 times as great as those designed and tested in Zender and Cassedy's study (2014). This shows that consensus analysis is a useful tool that can aid in the creation of successful pictograms.

In addition to comprehension, those working on designing pictograms also concern themselves with critical confusions. A critical confusion is a response that is the opposite of the intended meaning of the pictogram (Wolff & Wogalter, 1998). The ANSI recommends that for a pictogram to be considered successful, no more than 5% of responses should be critical confusions (American National Standards Institute, 1991). When looking at the pictograms designed using the high-ranking symbols, critical confusion was rarely, if ever, seen. For the referent psychiatry, one response, "patient is manipulative," was far enough away from the intended meaning that it could possibly be considered to be a critical confusion giving a critical confusion level of 2%, however, since it still deals with emotions, it probably is not. For the referent oncology, there is one blatantly incorrect response, "cookie infusion," which would make the critical confusion level 2%, however this response is not the opposite in meaning, it is simply extremely (and most likely intentionally) wrong. Finally, for the referent outpatient, there is no response that can be considered to be an example of a critical confusion. Thus, even though all three referents do not satisfy the ISO comprehension level requirement, the lack of critical confusions indicates that these pictograms are very successful first drafts.

Also interesting to note are the responses for each of the three pictograms made using high-ranking symbols that were not categorized as being correct. For the psychiatry pictogram, 64% of the incorrect responses mentioned moods, emotions, or changes in moods and emotions, all things dealt with in the realm of psychiatry. If those responses were added in to the correct responses, the comprehension level for the psychiatry icon would be 96%, well above both the ISO and ANSI requirements for a successful pictogram. For the outpatient pictogram made using high-ranking symbols, there were four major topics of incorrect responses: 24% mention leaving, 21% say good-bye, 18% say the patient is discharged or the exam is over, and 34% mention the patient is healthy or cured. Many of these are ideas encompassed within the concept of outpatient so combined with the correct responses, comprehension of this pictogram would be 98%, again very high. Oncology was the referent with the lowest comprehension and incorrect responses to this pictogram included some common themes: 27% said treatment, curing, or cure, 25% said it showed disease or infection, 20% said doctor's appointment, and 5% thought it showed a doctor greeting a patient. Because the pictogram does show a disease and a treatment, if those responses were also included as correct responses, comprehension

of the oncology icon would be 63%, almost high enough to be considered successful by ISO standards.

Comprehension of pictograms made using the lowest ranking items in each referent's cultural domain were very low, ranging from 0% to 16%. To compare the actual numbers used to generate the charts in Figures 16-18, please refer to Table 4. Note that value for percent correct for pictograms from the Zender & Cassedy (2014), the comprehension numbers for those with and without medical training in the United States were averaged together. This was done to determine comparable scores; the comprehension surveys done here included Americans with and without medical training.

Table 4.

Raw data on pictogram comprehension for all the pictograms discussed in Figures 14-16.

Icon	Total Number in Sample	Total Correct	Percent Correct
Oncology A	56	12	21%
Oncology B	50	3	6%
Oncology C			7%
Outpatient A	57	20	35%
Outpatient B	48	8	16%
Outpatient C			14%
Psychiatry A	57	41	72%
Psychiatry B	48	0	0%
Psychiatry C			35%

A = Pictogram made using highest ranked symbols
B = Pictogram made using lowest ranked symbols
C = Pictogram from Zender & Cassedy's study (2014)

The significance of the low comprehension rates for the pictograms made using the lowest-ranking icons lies in the fact that all the symbols that participants ranked were actually determined by informants in this study. People defined the cultural domain for each referent by telling what they thought should be included in a pictogram with each given meaning. The ranking of those items and the pictograms made from the lowest-ranked of those items shows that while some icons may be associated with a referent in the minds of people, they are not necessarily needed or helpful in conveying the meaning of the referent.

An examination of the incorrect responses to the pictogram comprehension testing for the pictograms made using the lowest-ranking symbols can give some insight into what made them so ineffective. For the oncology pictogram made with low-ranking symbols, there were four common categories of incorrect responses: 37% said it showed heart problems, heart surgery, CPR, or a full code, 13% mentioned death, dying, or dead, 11% mentioned a shellfish or seafood allergy, and 13% mentioned a pirate.

Clearly, the crab (cancer means crab) confused several people into thinking about shellfish allergies (and also a couple of respondents into the idea that pubic lice were involved). Though the symbols red and headscarf were part of the cultural domain for oncology, together they represented pirate a surprising number of times. Most significantly, the heart, possibly because it is such a clear, frequently seen symbol, dominated incorrect interpretations by causing people to provide meanings having to do with heart problems and procedures.

The outpatient pictogram made with low-ranking symbols seems to have confused participants because there were so many symbols that could not be combined to create coherent meaning. The majority of incorrect answers mentioned an injury (20%) or that someone was waiting for a doctor (15%). Though both of these things may happen in an outpatient setting, they were not correct enough to be included in the count of comprehension. Interestingly, for those incorrect responses that mentioned time, 24% said that the action in the icon was happening during the day and 10% at night. Despite the fact that there is a sun next to the clock, participants may have been influenced into guessing night because the clock face is dark.

The psychiatry pictogram formed from low-ranking icons had the lowest comprehension of all the pictograms, 0%. Though every symbol in the pictogram was determined by the study population to be in the cultural domain of psychiatry, clearly these low-ranking symbols are ancillary at best to the visual definition of the referent psychiatry. The majority of incorrect responses stated that the pictogram depicted either confusion about medications (28%) or medicine taken or prescribed (20%). 14% of respondents said the pictogram showed either concussion or headache and 6% said the pictogram meant questions or confusion.

Overall, the results of comprehension testing for both sets of pictograms, those made with the highest-ranked symbols and those with the lowest-ranked symbols, indicates that consensus analysis of ranking is an important part of this process. Freelisting allowed participants to define the cultural domain for each referent. Pilesorting enabled informants to group symbols together however they thought they should be grouped and consensus analysis of those results showed what icons the group as a whole thought were associated with other symbols. Finally, each participant ranked symbols in the cultural domain of each referent from most to least important to include in a pictogram with that meaning. Consensus analysis of rank data showed that medical and non-medical people ranked differently, but comparison of their aggregate lists showed marked similarity. Because the informants determined the important symbols, showed what symbols were closely associated with one another, and then determined what symbols were the most important to include in each pictogram, it is not surprising that comprehension of those pictograms made using the highest-ranked symbols was higher than both pictograms made using other elements in the cultural domain that were low-ranking and pictograms from a previous comprehension study that were designed without user input at the outset of the project.

Conclusions

Pictograms are used around the world to, ideally, communicate ideas and information to people quickly and effectively. The effectiveness of a pictogram is dependent upon how easily it is understood by those viewing it. While designers have spent many years working on how to better draw pictograms, most attention has been paid to how the pictograms look and then, after the designer is satisfied with its appearance, showing the pictogram to users to see if they understand its intended meaning. This study seeks to add a new item to the pictogram designer's toolkit that will enable them to create more effective, that is, more easily understood, pictograms.

The results of this study indicate that consensus analysis is a useful tool that the designer should add to their repertoire when working to design pictograms (Strauss, 2016). The pictograms designed for the three referents in this study were understood correctly by more than double the percentage of the Zender & Cassedy icon comprehension study. This increase was with first-draft pictograms made without any testing or revision of the icons.

The results also suggest that all means of collecting user input are not equal. The five lowest ranking items were all the result of user input but scored very poorly compared to the top five items. One can envision collecting informal input from a very small number of subjects such as in a focus group that would yield the lower raking items which, as this study shows, would misguide the designer. The larger the sample size, the more accurately the participants surveyed represent the population at large. We recommend never collecting data from fewer than the minimum recommended sample size of 30 (Borgatti & Halgin, 1986; S. Borgatti et al., 2002; Borgatti & Halgin, 1998).

Designing a comprehensible pictogram takes more than the ability to draw well. Designers must know what to draw. While aesthetics make pictograms pleasing to the eye, no pictogram can be considered successful, regardless of how attractive it is, if users cannot correctly understand its meaning. To develop more successful pictograms in the future, it is recommended that designers begin with consensus analysis techniques as demonstrated here as the starting point of the design process. This will allow designers to enter into the design process of designing, testing, and refining at a much more advanced stage because users were consulted before the pictogram was designed to learn what they expect to see in the pictograms.

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