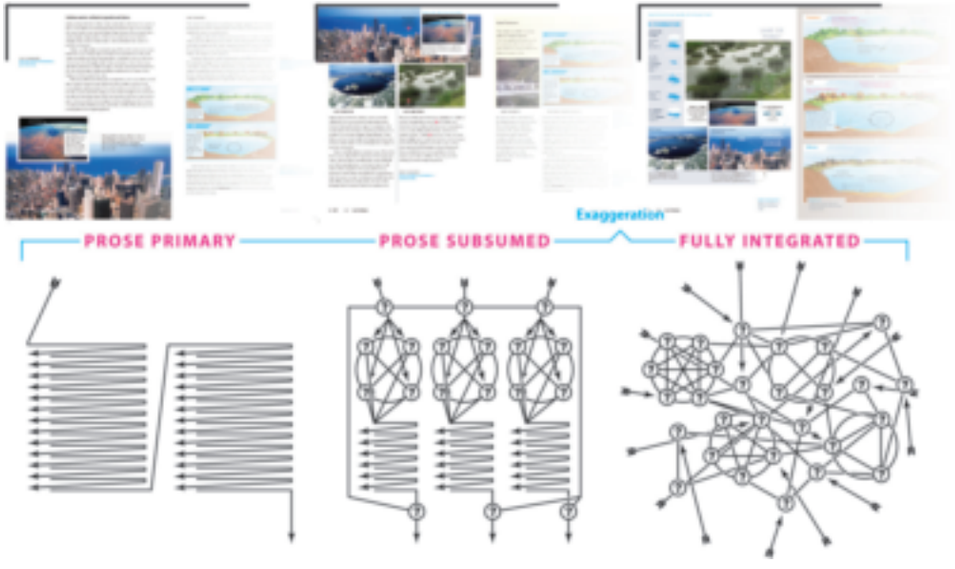
Visible Language

the journal of visual communication research

48 I



THE INTEGRATION OF TEXT AND IMAGE IN MEDIA AND ITS IMPACT ON READER INTEREST

Matthew O. Peterson, Ph.D.

TYPOGRAPHIC LAYOUT AND FIRST IMPRESSIONS

Jeanne-Louise Moys

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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.

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48 I

May 2014

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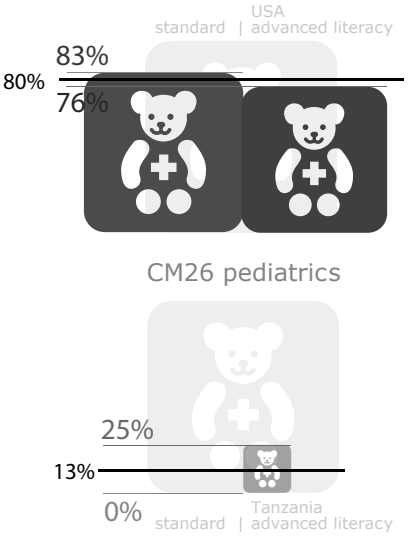
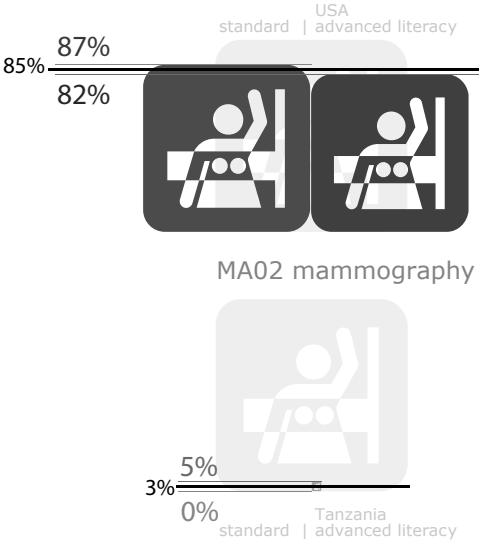
Contents



5 of 47 icons -
10.6% cultural failure



33 of 47 icons -
70.2% knowledge failure

(mis)understanding: icon comprehension in different cultural contexts

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ABSTRACT

Icons are frequently used in contexts where comprehension needs to be consistent across cultural and linguistic barriers. This paper reports on a study comparing the comprehension of 54 universal medical icons in rural Tanzania and the United States of America. It finds that most of the icons were not understood cross-culturally. The premise of the study was that this misunderstanding might have two causes: cultural distinctions and lack of knowledge. To test the premise we studied icon comprehension by those in two different cultures with two levels of medical knowledge: 'standard' and 'advanced'. The results show that most (33 of 47) poorly comprehended icons failed due to lack of medical knowledge or unfamiliarity with technology, while few (5 of 47) poorly comprehended icons failed due to cultural differences. Analysis of icons that failed due to cultural differences suggests that the primary drivers of cultural misunderstanding were the use of culturally sensitive metaphor and the incorporation of learned signs (non-representational symbols such as words) in icon design. Awareness of these causes of poor comprehension across cultures might help designers design effective universal icons by incorporating into the design process research methods that identify disparities of specific knowledge in the target people group and by avoiding use of metaphor and learned signs. These findings empower calls for cultural sensitivity in visual communication with guidance for implementation.

KEYWORDS

icon; pictogram; medical communication; culture; comprehension

INTRODUCTION

Icons are often relied upon to communicate where words fail. They race through Olympic venues, plod through international airports, and glow on smartphones. Icons are useful in these international contexts because they visually represent what they symbolize, bypassing language by connecting with our shared visual experience of the world. Icons can cross cultures and eras. Hieroglyphs in ancient Egyptian tombs still speak without words across accumulated millennia of changing technology and culture.

Icons still speak today, but often unclearly. Recent studies show that contemporary icons may not be as widely understood as we assume. Only 60% of people can correctly identify the tire inflation 'idiot light' icon in cars. (Woodyard, 2010) There are several complicating factors to communicating well with icons. Image-based icons must be designed to connect with familiar objects. Poor drawing, or not drawing an object from the commonly seen point of view such as a tire in Woodyard's example, is one factor that can result in misunderstanding. Another factor is disparity in familiarity with various technologies across the globe. For example, Magnetic Resonance Imaging now seems to be available everywhere in the USA but may not be available anywhere in some African countries. Someone who does not know that an MRI exists will not understand an icon of an MRI, no matter how well drawn. As James Mangan said, "correct interpretation of these signs requires exposure to what they signify." (Mangan, 1978, p. 256) A further factor is the use of metaphor to communicate which may draw upon cultural norms like using children's toys to communicate a children's hospital ward. Such cultural norms differ. What is a toy in one culture may not be a toy in another, leading to failure to understand both the metaphor and the icon based on it.

Some studies verify that cultural differences may impact the ability to correctly comprehend medication instruction icons in Africa, (Knapp, Raynor, Jebar, & Price, 2005), while others find little or no difference across culture but instead find greater difference in comprehension due to educational level. (Kassam, Vaillancourt, & Collins, 2004) The Kassam article, which tested three language people groups living in Canada, exposes the issue of what specific features such as language and praxis should define one cultural from another. Because this paper is in the domain of design rather than anthropology, we defined culture simply following the Merriam-Webster dictionary definition: a particular society that has its own beliefs, ways of life, art, etc.. Applying this simple definition, neither a difference in language nor possession of specialized or technical knowledge will, by itself, define a difference in culture. However, a difference in worldviews, beliefs, and modes of living will indicate a difference in culture. Following this, it is questionable whether the Kassam article truly explored different cultures because although the participants spoke five different languages, all participants lived in Canada, some for more than 10 years. Based on

Knapp et. al., Kassam et. al. and our previous icon studies, we anticipated that some icons would fail cross culturally due to beliefs and ways of life, while others would fail cross culturally due to disparities in knowledge. This study sought to establish that both cultural norms and knowledge acquisition play a role in icon misunderstanding and to define the relative impacts that culture and knowledge had on that failure. One reason we focused on knowledge as a dimension of comprehension is that graphic design as a discipline is equipped to help improve knowledge, while graphic design's ability to change beliefs and ways of life is more challenging due to the large number of factors forming culture and the depth of cultural beliefs. To avoid culture subtlety we chose for our study two very different cultures: the urban United States of Cincinnati, Ohio and the rural African village of Shirati, Tanzania. The cultural difference between USA and Tanzania are illustrated in Figure 1 that shows the laundry area outside the children's ward in Shirati Hospital.

FIGURE 1.

Patient laundry area outside pediatric ward, Shirati hospital, Shirati, Tanzania.

The large rocks were provided so that mothers who stay on an extended basis with their sick children could clean their cloths in the familiar way. The Shirati hospital had a modern laundry facility with commercial laundry machines for washing hospital linens. The rock laundry was for parents and reflects their way of life. We do not claim laundry was the leading indicator of culture, but offer this figure as one example of a very different cultural milieu.

INTERACTION OF SYMBOLS

Understanding the nature of symbols such as icons is prerequisite for understanding their effectiveness in any culture. In general terms, a symbol is anything the stands for something else. This standard'definition is very broad, covering everything from written words to acoustic sounds. In visual communication design, an icon is a visual image that uses symbols to represent not a particular instance of something but a category or concept:

the referent. An icon does this through a highly simplified physical resemblance. Different authors across various domains use different words such as symbol, sign, and pictogram for what we are calling an icon. The following taxonomy clarifies how we will use these words in this paper.

symbol:
A symbol represents something.

sign/glyph:
A sign visually represents without resembling.

icon:
An icon visually represents a category or concept by resembling simply.

picture:
A picture visually represents a specific thing by resembling specifically.

pictogram:
A pictogram combines signs, icons, and pictures to represent a story or data set.

Following this taxonomy, words are signs, smartphone snap shots are pictures, and the green phone symbol on the iPhone is an icon. Because a word has no visual resemblance to its concept its meaning must be wholly learned, whereas a picture or icon visually represents its concept so its meaning typically requires little or no learning. An icon's power to communicate across language and culture comes through simplified resemblance that transcends language so long as the object is known. An image is an icon, or not, based on a combination of simplified drawing that removes the representation from the picture category, making it clear it is not a specific case of an object but an object category, and widespread acceptance of this simplification as a convention of communication. As reported elsewhere, icons are usually combinations of several simply drawn visual symbols that interact to form a collective meaning (Zender, 2006, pp. 188-189). A carefully chosen combination of symbols create a distinct grouping of concepts that together, and in the right context, elicit a specific intended meaning. In fact, two studies have shown that more complex icons containing more symbols that provide more contextual clues are comprehended better than simpler icons with fewer clues. (Lesch, Powell, Horrey, & Wogalter, 2013; Zender & Mejia, 2013) However, in the case of misunderstanding, an icon's combination of symbols breaks down and fails to stimulate the intended meaning. Some possible reasons for the breakdown include poor selection of symbols for the icon, poorly drawn symbols in the icon, well-drawn symbols but of unknown objects or concepts, and well-drawn symbols of known objects or concepts whose meaning varies across cultures. It is the last two cases that this paper investigates. Specifically, the study here investigates the roles knowledge and cultural play in misunderstanding icons. The over arching aim of this and related studies is to discover

how can we do a better job designing icons in particular, and symbols more generally, for more accurate communication.

STUDY

Rather than study proposed icon designs, this study used as the subject matter a recently completed set of universal medical icons for use in health care facilities to communicate in multi-lingual situations.

BACKGROUND

In 2009 the University of Cincinnati joined a five-school consortium brought together by SEGD and Hablamos Juntos to develop 54 universal icons for health care environments. These icons, designed to communicate across language and literacy barriers in hospitals and clinics, were to supplement a previously developed set of health care icons that fit generally within the well-established style of the 1974/1979 AIGA/DOT symbol system. Teams of undergraduate design students at each institution developed candidate health care icons that were tested at four of the five schools using the ISO comprehension estimation protocol. (ISO, 2007) Test subjects spoke five different languages in an attempt to insure universal comprehension. These 54 icons were selected for this study because they had been expertly designed using the latest methods and testing protocols for comprehension, thus theoretically eliminating poor symbol selection and poor drawing as reasons for icon misunderstanding, and enabling the study to use generally well-drawn icons that might fail primarily for reasons that were the focus of the study. These 54 icons became the content for the study.

HYPOTHESIS

The fundamental research question for the study was: will the 54 medical icons designed to work universally in fact be understood in different cultures. The design of a rural health care clinic by architecture colleague Michael Zaretsky and its construction in rural Tanzania supported by the Village Life Outreach Project provided the opportunity to test the icons cross-culturally. We assumed that some icons designed in the United States would not be properly understood in Tanzania, so our secondary research question was to determine why some icons failed to cross cultures while others succeeded.

Based on previous experience designing medical icons, we had observed that some medical icons failed because the viewer was unfamiliar with the medical concept being symbolized. We hypothesized that because the 54 icons had been designed and expertly drawn and tested for comprehension in the United States that remaining reasons for poor comprehension in Tanzania would be either a lack of knowledge or misunderstanding due to cultural differences. Because the knowledge domain of our icons was medicine, we specifically hypothesized that if we could measure miscommunication based on differences in medical literacy (knowledge of medical subject matter), that the remaining

miscommunication would likely be the result of cultural differences. Our research questions then became: could we distinguish between icons that failed to be comprehended correctly due to medical literacy and icons that failed due to cultural perspective, and within that failure, could we identify themes or causes for the respective failures?

STUDY DESIGN + AIM

Our question contained two key issues: 1. medical literacy and 2. cultural perspective. We therefore designed a comparative open-ended comprehension study to be conducted in both Tanzania and in the United States. To evaluate the effect of medical literacy on comprehension the test in each country was divided evenly into two cohorts: those with 'standard' and those with 'advanced' medical literacy. We defined 'standard' medical literacy as anyone without 'advanced' medical training or education, someone who might represent a typical patient. We defined 'advanced' medical literacy as anyone with post-secondary medical training, thus all our 'advanced' subjects had some post-secondary medical training as a doctor or nurse or other health care professional. We reasoned that icons that succeeded in both cohorts in one country and succeeded only the medically literate in the other country had failed in the second country due to lack of medical literacy in the 'standard' medical literacy group, *not* due to cultural differences. Stated the other way, icons that failed *only* with the 'standard' cohort in *only* one country had failed due to medical literacy in that country, not due to cultural difference. We also reasoned that icons that succeeded in both cohorts in one country, but failed in both cohorts in the other country had failed *either* due to lack of knowledge *or* due to cultural differences and that the scores alone may not suggest which. For these we would have to rely on additional analysis of symbol content and text answers to suggest the reason for failure.

METHODS

The study used a comprehension survey procedure based upon the ISO/ANSI Open-ended Comprehension Test (ANSI, 2007). This survey procedure is currently the most reliable instrument for evaluation of icon comprehension. It is a qualitative approach that consists in asking two open-ended questions for each icon: the meaning of the icon and the actions that would be taken in response to the icon. The former probes understanding at the level of abstract concept, the later at concrete action. Taken together, the subject's written responses to the two questions gave an evaluator ample evidence to use to assess subject comprehension. Correct comprehension was defined as a subject writing the intended referent after viewing an icon. A minimum of three subject-area experts used a scoring sheet to independently score completed survey instruments. A sample from the scoring sheet for Medical Library:

Medical Library FA08

response must include:
medical or health or health care or hospital or clinic or doctor's office or care/care center, etc.
plus
library or books or book collection or reading room/area or information place/source, etc.

A subject's written responses to both questions: 'what does it mean…' 'what would you do…' were considered together as a single answer to determine the score to assign to a subject's answer. The experts discussed subjects' answers and used heuristics for decisions. Four scores were available to assign to each subject answer: correct, partially correct, incorrect, fatal. An example of a partially correct response was a subject mention of library or books but *not* also mentioning medical or health care or hospital for Medical Library. An example of a fatal response was the response that an emergency medical kit was in the file drawer for the Medical Records icon FA06. Scoring difficulties discussed elsewhere (Zender, Han, & Fernández, 2011) were largely overcome by using multiple evaluators, discussing conflicting scores, and combining multiple forms of analysis described below.

STUDY

In summer 2010 we surveyed the first two cohorts of 11 'standard' and 9 'advanced' medically literate subjects (total n-20) in Shirati, Tanzania, followed in autumn 2010 by an additional two cohorts of 9 'standard' and 11 'advanced' medically literate subjects (total n-20) also in Shirati, Tanzania, for a sample size of 40 Tanzanian subjects: 20 'standard' and 20 'advanced' medical literacy. In Tanzania local professional translators translated the test instrument (where necessary), administered the survey (under the administrator's supervision), and translated (where necessary) subject answers. In spring 2011 the corresponding USA study involved a similar sample of 31 'standard' (n = 31) and 20 'advanced' medically literate subjects (n = 20) for a grand total of 51 USA subjects. All cohorts were exposed to the same survey instrument consisting of the 54 icons, each icon accompanied by the same two questions: 'what do you think this icon means,' and 'what would you do in response to it?'

Scored subject data was analyzed using a variety of techniques. Two rating systems were used for analysis. In one the percent of each of the three scores: correct, partial, incorrect, fatal was used. In another a numeric scale assigned a value of 1 to correct responses; 0.5 to partially correct responses; and 0.0 to incorrect responses and -0.5 to fatal responses. The numeric scale accounts for different subjects responses by giving a partial credit for a partially correct answer. The numeric approach also accommodates any scoring differences for the three different scorers, of which there were few. Throughout this report the percent correct score is used because it accentuates correctness rather than accommodating incorrectness. In addition to these quantitative means, we used

visualization to analyze the results, (see *figure 2*) and we coded the qualitative verbal answers and analyzed the code quantities and qualities.

In order to understand the distribution of the quantitative data, summary statistics such as simple frequencies and percentages were calculated for each variable in the study. Bivariate analysis was conducted on all icons and overall differences between countries (Tanzania/USA), respondent type (patient/health-care professional), within country differences, as well as within respondent type differences was tested using the Wald's Chi Square statistic ($\chi 2$). An alpha level of less than 0.05 was considered statistically significant. Since this was an exploratory study, there was no attempt to correct for multiple comparisons. Odds Ratios (OR) and 95% Confidence Intervals (CI) were used as a measure of effect size. All analysis was conducted using SAS 9.2©.

Using these combined methods we drew conclusions about differences in comprehension in the cohorts.

RESULTS

Data from the study is visually summarized in Figure 2. Much can be said about this rich data set and while we highlight key findings here, we also invite the reader to review the visualized results in Figure 2 and draw additional conclusions. Much of the discussion below is focused on the percent correct for each icon, in each country, by each cohort. To simplify the text discussion of the icons and of the numbers associated with them, when referring to icon scores we abbreviated the mean percent correct score such as: USA 'standard' 74%, 'standard' plus 'advanced' 78%, 'advanced' 82%, compared to in Tanzania 'standard' 10%, 'standard' plus 'advanced' 30%, 'advanced' 50% thus: USA $_{74}$ 78% $_{82}$ | Tan $_{10}$ 30% $_{50}$. Some of the discussion centered around the total mean of cohorts in the respective countries and is abbreviated thus: USA 78% | Tan 30%.

SUCCEEDING ICONS

Using the ISO/ANSI 'standard' definition of success for safety symbols of 85% or greater correct comprehension, in the USA 22 icons achieved mean comprehension at or above 85%. Four of those icons achieved 100% correct comprehension in the USA:

Dental CM29
Emergence FA01
Ambulance FA02
Radiology X-Ray MA01

and 9 others scored 90% or better in the USA:

Ophthalmology CM15 – 91%
Kidney CM22 – 90%
Cardiology CM23 – 97%
Labor and Delivery CM25 – 97%
Medical Records FA06 – 91%

Chapel FA12 – 97%
Ultrasound MA05 – 96%
MRI MA07 – 96%
CT scan MA09 – 91%.

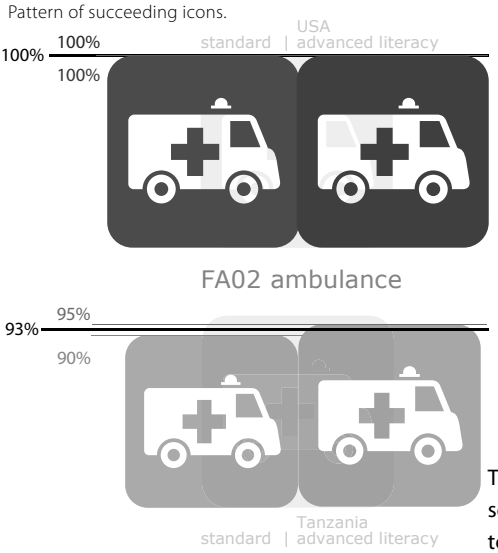
In Tanzania only 3 icons achieved 85% or better:
Immunization CM09 – 88%
Ophthalmology CM15 – 85%
Ambulance FA02 – 93%.

Just 2 of the icons achieved 85% or better in both countries:
Ophthalmology CM15 – USA $_{88}$ 91% $_{94}$ | Tan $_{75}$ 85% $_{95}$;
Ambulance FA02 – USA $_{100}$ 100% $_{100}$ | Tan $_{90}$ 93% $_{95}$.

However, there is more to analysis that just numbers. As suggested in the hypothesis section and elsewhere, the overall pattern of correct is nearly as important for this study as the exact percent correct. The visual pattern for icons succeeding in both countries is shown by icon FA02 in Figure 3.

FIGURE 3.

Pattern of succeeding icons.

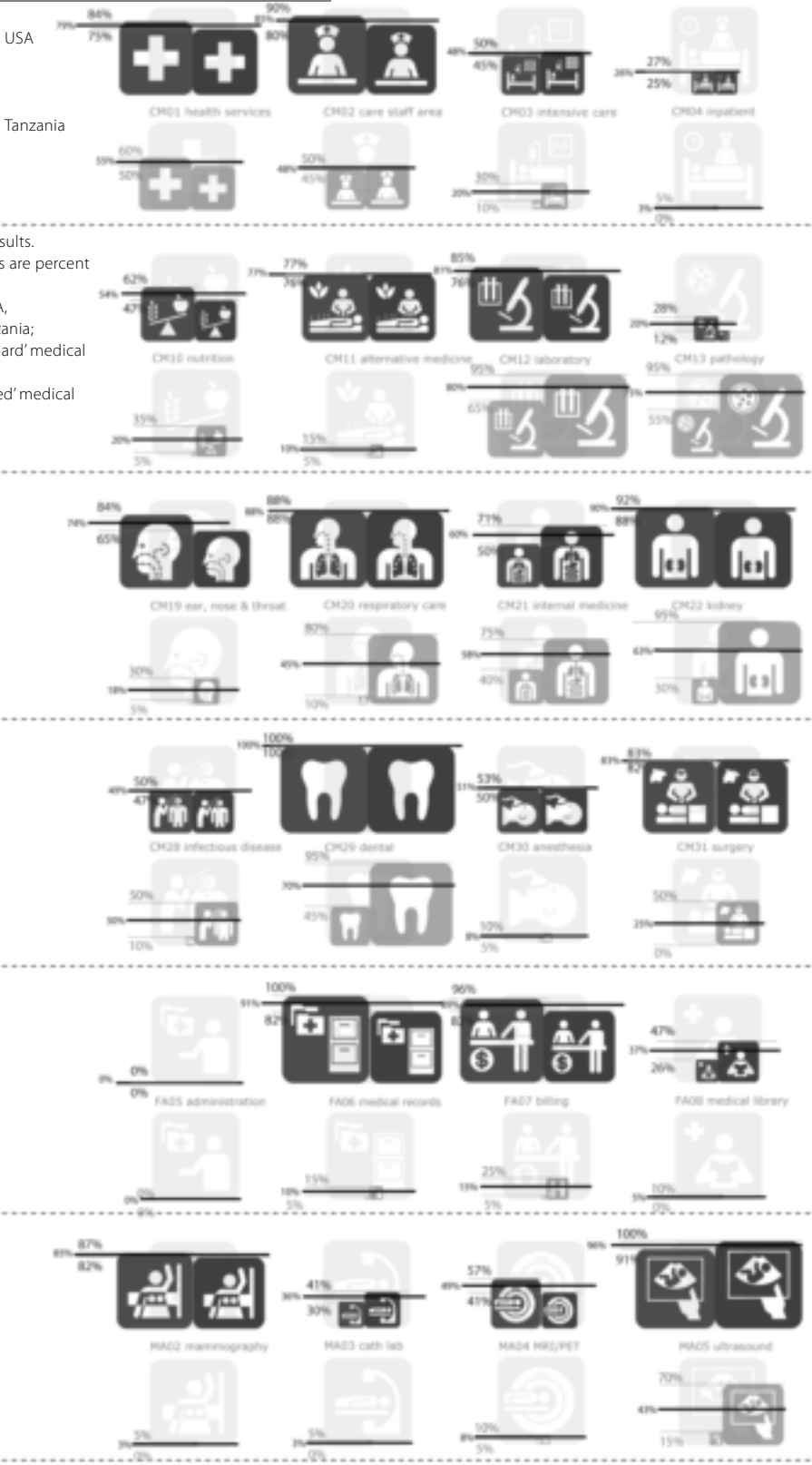


This visualizes icons with similarly high correct scores in both countries. This pattern applied to 7 icons:

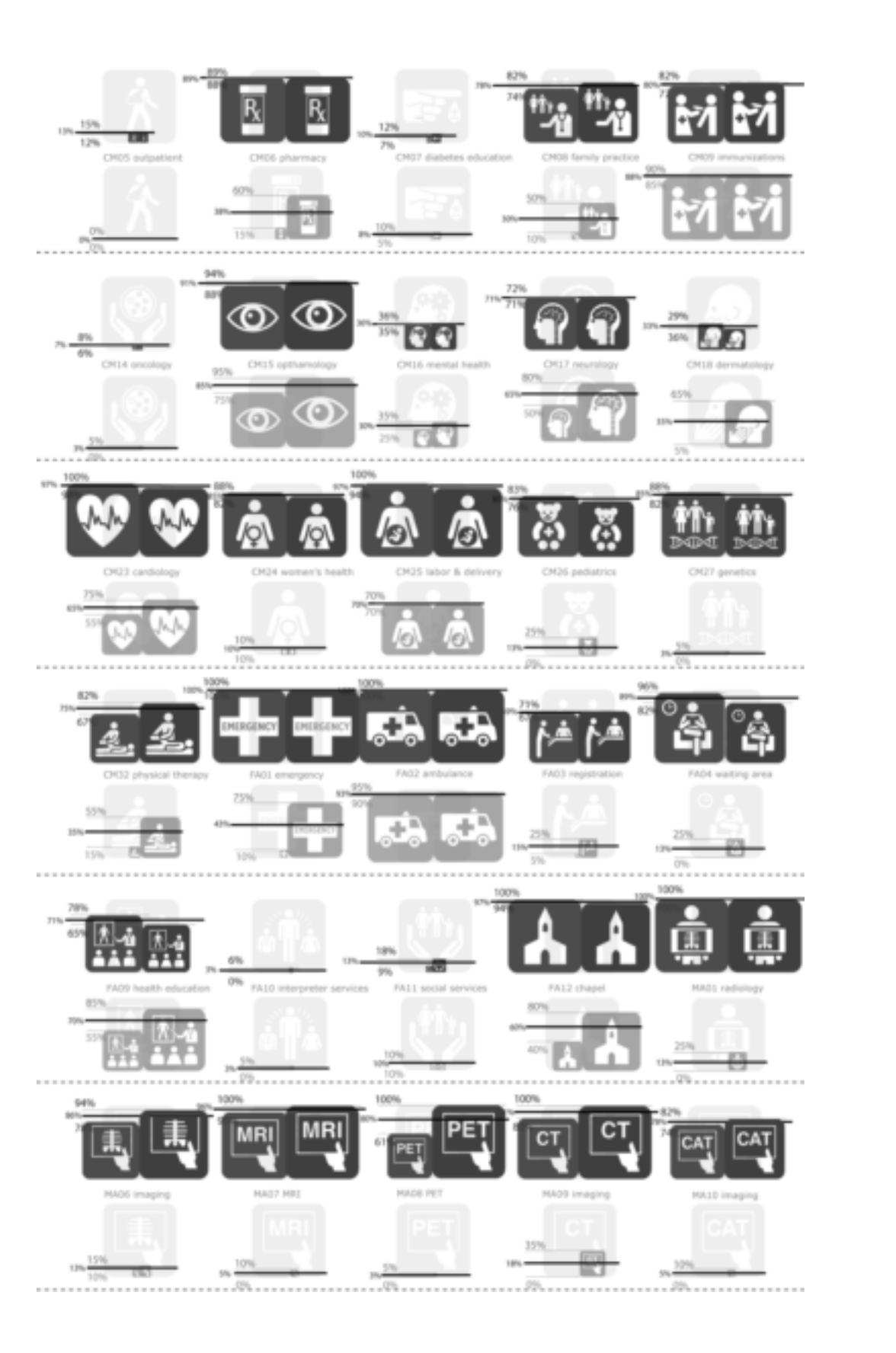
1. Immunization CM09 – USA $_{77}$ 80% $_{82}$ | Tan $_{85}$ 88% $_{90}$
2. Laboratory CM12 – USA $_{76}$ 81% $_{85}$ | Tan $_{65}$ 80% $_{95}$
3. Ophthalmology CM15 – USA $_{88}$ 91% $_{94}$ | Tan $_{75}$ 85% $_{95}$
4. Neurology CM17 – USA $_{71}$ 71% $_{72}$ | Tan $_{50}$ 65% $_{80}$
5. Internal Medicine CM21 – USA 50 $_{60}$% $_{71}$ | Tan $_{40}$ 58% $_{75}$
6. Ambulance FA02 – USA $_{100}$ 100% $_{100}$ | Tan $_{90}$ 93% $_{95}$
7. Health Education FA09 – USA $_{65}$ 71% $_{78}$ | Tan $_{55}$ 70% $_{85}$

Applying this pattern, a total 7 of 54 icons performed well in both cultures.

FIGURE 2.



Summary of results.
All percentages are percent correct.
Upper row USA,
lower row Tanzania;
Left icon 'stnadard' medical literacy;
R icon 'advanced' medical literacy.


CM05 outpatient
CM06 pharmacy
CM07 diabetes education
CM08 family practice
CM09 immunizations
CM14 oncology
CM15 opthamology
CM16 mental health
CM17 neurology
CM18 dermatology
CM23 cardiology
CM24 women's health
CM25 labor & delivery
CM26 pediatrics
CM27 genetics
CM32 physical therapy
FA01 emergency
FA02 ambulance
FA03 registration
FA04 waiting area
FA09 health education
FA10 interpreter services
FA11 social services
FA12 chapel
MA01 radiology
MA06 imaging
MA07 MRI
MA08 PET
MA09 imaging
MA10 imaging

FAILING ICONS

Six of 54 icons achieved 15% or less correct in either the USA or Tanzania:

1. Outpatient CM05 – USA 13% | Tan 0%

2. Diabetes Education CM07 – USA 10% | Tan 8%

3. Oncology CM14 – USA 7% | Tan 3%

4. Administration FA05 – USA 0% | Tan 0%

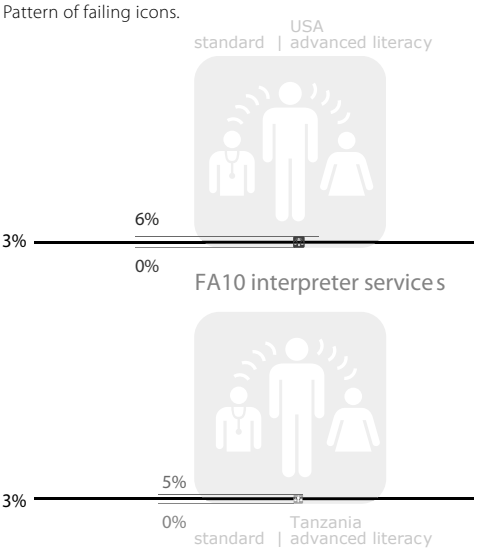
5. Interpreter Services FA10 – USA 3% | Tan 3%

6. Social Services FA11 – USA 13% | Tan 10%.

The visual pattern for failing icons is shown by icon FA10 in Figure 4.

FIGURE 4.

Pattern of failing icons.



This visualizes icons with low correct scores in both countries. Another icon had a similar pattern of low scores in both countries, but higher than 15%:

7. Mental Health CM16 – USA 36% | Tan 30%.

Clearly, these seven icons did not communicate well in either culture. In total, 7 of 54 icons succeeded and 7 of 54 icons failed, leaving 40 icons with misunderstanding either due to knowledge or culture.

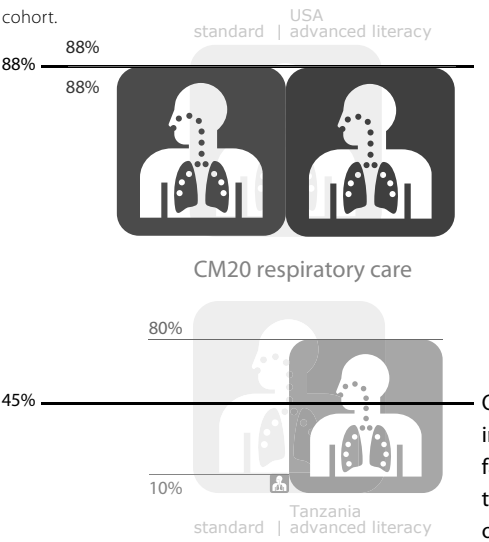
FAILING ONLY IN THE TANZANIAN 'STANDARD' COHORT

Differences in responses by Tanzanian's with 'standard' and 'advanced' literacy seemed to be driving most of the extreme results between countries (see *table 1*) with 'standard' subjects being unable to correctly comprehend many icons. For example, 'advanced' literacy subjects were 44 times more likely to

correctly comprehend the Kidney icon CM22 compared to 'standard' literacy [OR=44.3 (CI=4.8-410.9), $\chi^2 = 11.14$, p=0.0008], and 36 times more likely to understand the Respiratory Care icon CM20 compared to 'standard' literacy [OR=36.0 (CI=5.8-223.5), $\chi^2 = 14.79$, p=0.0001]. The visual pattern for icons succeeding with both cohorts in the USA and with the 'advanced' cohort in Tanzania, but failing with the 'standard' cohort in Tanzania, is shown by icon CM20 in Figure 5.

FIGURE 5.

Pattern of icons failing only in the Tanzanian 'standard' cohort.



Our hypothesis had suggested that the pattern in Figure 5 would be an indicator of an icon that failed due to lack of medical knowledge, not cultural difference. This pattern was seen at the level of significance in 12 of the 54 icons:


1. Pharmacy CM06 – USA 88% 89% | Tan 15% 60%


2. Family Practice CM08 – USA 74% 82% | Tan 10% 50%


3. Nutrition CM10 – USA 47% 62% | Tan 5% 35%


4. Respiratory Care CM20 – USA 88% 88% | Tan 10% 80%


5. Kidney CM22 – USA 88% 92% | Tan 30% 95%


6. Infectious Disease CM28 – USA 47% 50% | Tan 10% 50%


7. Dental CM29 – USA 100% 100% | Tan 45% 95%


8. Surgery CM31 – USA 83% 82% | Tan 0% 50%


9. Physical Therapy CM32 – USA 67% 82% | Tan 15% 55%


10. Emergency FA01 – USA 100% 100% | Tan 10% 75%


11. Chapel FA12 – USA 100% 94% | Tan 40% 80%


12. Ultrasound MA05 – USA 91% 100% | Tan 15% 70%.

The pattern was also apparent, but not to the level of statistical significance, in one additional icon:

13. Cardiology CM23 – USA 94% 100% | Tan 55% 75%

Following our hypothesis, we believe these 13 icons failed due to differences in knowledge, not due to differences in cultural. One disputable icon, Emergency FA01, will be discussed below.

There were 2 icons with an unusual pattern of greater success in Tanzania than the USA:

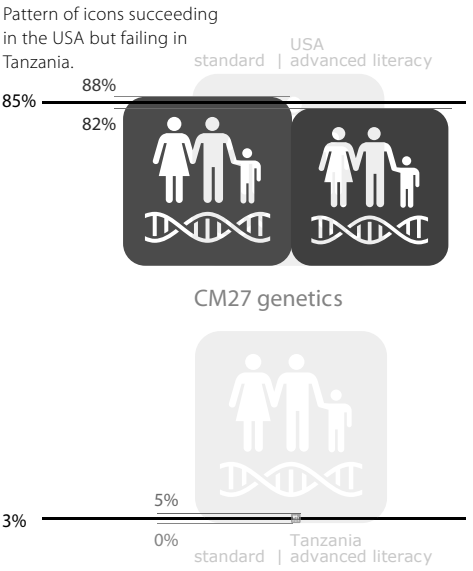
1. Pathology CM13 – USA 12% 28% | Tan 55% 95%
2. Dermatology CM18 – USA 36% 29% | Tan 5% 65%

For the Pathology icon CM13 residents of Tanzania were significantly more likely to comprehend compared to respondents in the US sample [OR=0.09 (CI=<0.001-0.3), $\chi^2 = 20.92$, p=<0.0001]. Due to the great disparity in knowledge in Tanzania, we considered these also to have failed due to knowledge disparity, for a total of 15 failing due to knowledge. In total, 7 icons succeeded, 7 failed, and 15 failed due to knowledge, leaving 25.

SUCCEEDING IN THE USA, FAILING IN TANZANIA

As noted in the hypothesis section, icons that succeeded equally in cohorts with both 'standard' and 'advanced' medical literacy in the USA, but that failed with both cohorts in Tanzania might have failed *either* due to lack of medical knowledge *or* due to cultural differences. Such differences in icon comprehension appeared when data from both 'standard' and 'advanced' medical literacy were pooled together. The visual pattern for icons succeeding in one country but not in the other is shown by icon CM27 in Figure 6.

FIGURE 6.



This pattern visualizes icons succeeding with both cohorts in the USA but failing with both cohorts in Tanzania. Results in Table 2 show the US sample significantly more likely to correctly comprehend icons compared to the Tanzanian sample. Significant differences were found on 38 of the 54 icons. Differences were especially extreme [OR=30 or higher] for 15 of 54 icons. Some of the most extreme examples of this were:

MRI MA07 – USA 96% | Tan 5%

[OR=361.0 (CI=48.3-999.9), $\chi^2 = 32.95$, p<0.0001]

Genetics CM27– USA 85% | Tan 3%

[OR=227.4 (CI=26.1-999.9), $\chi^2 = 24.13$, p<0.0001]

Mammography MA02 – USA 85% | Tan 3%

[OR=220.9 (CI=25.3-999.9), $\chi^2 = 23.90$, p<0.0001].

After removing the 14 icons that either succeeded or failed in both countries, and the 15 icons that failed due to knowledge there remain 25 icons that failed for *either* knowledge *or* cultural reasons:

1. Health Services CM01 – USA 75% 84% | Tan 60% 50%

2. Care Staff Area CM02 – USA 90% 80% | Tan 45% 50%

3. Intensive Care CM03 – USA 45% 50% | Tan 10% 30%

4. Inpatient CM04 – USA 25% 27% | Tan 0% 5%

5. Alternative Medicine CM11 – USA 77% 76% | Tan 5% 15%

6. Ear, Nose, Throat CM19 – USA 84% 65% | Tan 5% 35%

7. Women's Care CM24 – USA 88% 82% | Tan 10% 10%

8. Labor & Delivery CM25 – USA 100% 94% | Tan 70% 70%

9. Pediatrics CM26 – USA 83% 76% | Tan 0% 25%

10. Genetics CM27 – USA 88% 82% | Tan 0% 5%

11. Anesthesia CM30 – USA 50% 53% | Tan 5% 10%

12. Registration FA03 – USA 67% 71% | Tan 5% 25%

13. Waiting Area FA04 – USA 96% 82% | Tan 0% 25%

14. Medical Records FA06 – USA 100% 82% | Tan 5% 15%

15. Billing FA07 – USA 96% 82% | Tan 5% 25%

16. Medical Library FA08 – USA 26% 47% | Tan 0% 10%

17. Radiology MA01 – USA 100% 100% | Tan 0% 25%

18. Mammography MA02 – USA 82% 87% | Tan 0% 5%

19. Cath Lab MA03 – USA 30% 41% | Tan 0% 5%

20. MRI/PET MA04 – USA 41% 57% | Tan 5% 10%

21. Imaging MA06 – USA 78% 94% | Tan 10% 15%

22. MRI MA07 – USA 91% 100% | Tan 0% 10%

23. PET MA08 – USA 61% 100% | Tan 0% 5%

24. CT Imaging MA09 – USA 83% 100% | Tan 0% 35%

25. CAT Imaging MA10 – USA 74% 82% | Tan 0% 10%

TABLE 1. Within Country Differences - Tanzania

	Odds Ratio	Lower 95th CI	Upper 95th CI	chi square	Prob
CM01 (health services)	0.7	0.2	2.3	0.40	0.5257
CM02 (care staff area)	1.2	0.4	4.2	0.10	0.7516
CM03 (intensive care)	3.9	0.7	22.1	2.30	0.1297
CM04 (in-patient)	<0.001	<0.001	>999.9	0.00	0.9594
CM05 (outpatient)					
CM06 (pharmacy)	8.5	1.9	38.8	7.63	0.0058
CM07 (diabetes)	2.1	0.2	25.3	0.35	0.5557
CM08 (family practice)	9.0	1.6	49.4	6.40	0.0115
CM09 (immunization)	1.6	0.2	10.7	0.23	0.6347
CM10 (nutrition)	10.2	1.1	93.3	4.25	0.0393
CM11 (alternative med)	3.4	0.3	35.4	1.01	0.3142
CM12 (laboratory)	10.2	1.1	93.3	4.25	0.0393
CM13 (pathology)	15.5	1.7	139.6	6.00	0.0143
CM14 (oncology)	>999.9	<0.001	>999.9	0.00	0.9594
CM15 (opthamology eye)	6.3	0.7	60.2	2.58	0.1081
CM16 (mental health)	1.6	0.4	6.3	0.47	0.4917
CM17 (neurology)	4.0	1.0	16.3	3.75	0.0528
CM18 (dermatology)	35.3	3.9	321.9	9.98	0.0016
CM19 (eye, ear, nose)	8.1	0.9	75.5	3.41	0.0649
CM20 (respiratory care)	36.0	5.8	223.5	14.79	0.0001
CM21 (internal medicine)	4.5	1.2	17.4	4.76	0.0291
CM22 (kidney)	44.3	4.8	410.9	11.14	0.0008
CM23 (cardiology)	2.5	0.6	9.4	1.72	0.1896
CM24 (women's health)	1.0	0.1	7.9	0.00	1.0000
CM25 (labor & delivery)	1.0	0.3	3.9	0.00	1.0000
CM26 (pediatrics)	>999.9	<0.001	>999.9	0.01	0.9403
CM27 (genetics)	>999.9	<0.001	>999.9	0.00	0.9594
CM28 (infectious disease)	>999.9	<0.001	>999.9	0.00	0.9508
CM29 (dental)	23.2	2.6	208.5	7.88	0.0050
CM30 (anesthesia)	2.1	0.2	25.3	0.35	0.5557
CM31 (surgery)	>999.9	<0.001	>999.9	0.00	0.9452
CM32 (physical therapy)	6.9	1.5	31.4	6.30	0.0121
FA01 (emergency)	27.0	4.6	159.7	13.21	0.0003
FA02 (ambulance)	2.1	0.2	25.3	0.35	0.5557
FA03 (registration)	6.3	0.7	60.2	2.58	0.1081
FA04 (waiting area)	>999.9	<0.001	>999.9	0.01	0.9403
FA05 (administration)					
FA06 (medical records)	3.4	0.3	35.4	1.01	0.3142
FA07 (billing)	6.3	0.7	60.2	2.58	0.1081
FA08 (medical librbay)	>999.9	<0.001	>999.9	0.00	0.9594
FA09 (health edu)	4.6	1.0	21.0	3.96	0.0466
FA10 (interpreter serv)	>999.9	<0.001	>999.9	0.00	0.9594
FA11 (social services)	1.0	0.1	7.9	0.00	1.0000
FA12 (chapel)	6.0	1.5	24.7	6.16	0.0130
MA01 (rdiology X-ray)	>999.9	<0.001	>999.9	0.01	0.9403
MA02 (mammography)	>999.9	<0.001	>999.9	0.00	0.9594
MA03 (cath lab)	>999.9	<0.001	>999.9	0.00	0.9594
MA04 (MRI)	2.1	0.2	25.3	0.35	0.5557
MA05 (untrasound)	13.2	2.8	62.6	10.58	0.0011
MA06 (imaging X-ray)	1.6	0.2	10.7	0.23	0.6347
MA07 (MRI)	>999.9	<0.001	>999.9	0.01	0.9427
MA08 (PET)	>999.9	<0.001	>999.9	0.00	0.9594
MA09 (CT imaging)	>999.9	<0.001	>999.9	0.00	0.9538
MA10 (CAT scan)	>999.9	<0.001	>999.9	0.01	0.9427

In all, 25 of 54 icons fit in the pattern of equal success in cohorts with both 'standard' and 'advanced' medical literacy in the USA, but failure with both cohorts in Tanzania. Additional analysis of icon content below helped determine whether these failed due to lack of medical knowledge or due to cultural differences.

OTHER COMPARISONS

The comparisons above directly inform the hypothesis. To support these, additional comparisons for significance were performed to establish reliability thresholds. Comparisons by respondent type ('standard' vs. 'advanced' medical knowledge) were calculated by pooling data from both countries. While health-care professionals were significantly more likely to identify icons, the number of icons as well as the size of the odds ratios were far less than the country differences seen in Table 2. For example, the icon with the highest odds ratio was for Dental Services CM29 with health-care professionals being 12 times more likely to correctly identify this icon compared to patients in this sample [OR=12.0 (CI=1.5-98.0), χ^2=5.37, p=0.0204]. By comparison, the highest OR in country differences in Table 2 is 361.0 with 26 other icons having an OR higher than 12.0. The reason for the less extreme results may be due to the fact that there were no significant differences between patient and health-care professional in the US sample. These results were used to confirm the significance of differences in the following section.

Between countries contrast were calculated for both 'standard' as well as 'advanced' medical literacy. US 'standard' were more likely to correctly identify most of 'standard' of Care icons compared to their Tanzanian counterparts. No Tanzanian 'standard' literacy subjects correctly identified the icons for Outpatient Services CM05, Pediatrics CM26, and Infectious Disease CM28. Relatedly, US health-care professionals recognized icons at a significantly higher rate than the Tanzanian sample. This was especially apparent in the highly specialized services such as:

Radiology X-ray imaging MA01
[OR=90.7 (CI=8.5-964.0), χ^2=13.97, p=0.0002],
Mammography MA02
[OR=88.7 (CI=8.3-944.8), χ^2 = 13.8, p=0.0002], and
Genetics CM27
[OR=88.7 (CI=8.3-944.8), χ^2 = 13.8, p=0.0002].

Conversely, 'advanced' medical literacy subjects of Tanzania were significantly more likely to correctly identify the:

Pathology icon CM13
[OR=0.007 (CI=<0.001-0.1), χ^2 = 15.19, p=<0.0001]
and the
Dermatology icon CM18
[OR=0.20 (CI=0.1-0.9), χ^2 = 4.44, p=0.0351].

TABLE 2. Country Differences

	Odds Ratio	Lower 95th CI	Upper 95th CI	chi square	Prob
CM01 (health services)	3.4	1.3	8.5	6.50	0.0108
CM02 (care staff area)	6.9	2.5	19.1	14.13	0.0002
CM03 (intensive care)	3.6	1.4	9.2	6.85	0.0089
CM04 (in-patient)	13.7	1.7	110.0	6.07	0.0138
CM05 (outpatient)	>999.9	<0.001	>999.9	0.01	0.9362
CM06 (pharmacy)	13.0	4.2	40.2	19.80	<0.0001
CM07 (diabetes)	1.2	0.3	5.9	0.07	0.7925
CM08 (family practice)	7.9	3.0	21.1	17.26	<0.0001
CM09 (immunization)	0.5	0.2	1.8	1.03	0.3100
CM10 (nutrition)	5.1	1.9	13.5	10.47	0.0012
CM11 (alternative med)	29.7	8.5	103.9	28.18	<0.0001
CM12 (laboratory)	1.1	0.4	3.3	0.03	0.8721
CM13 (pathology)	0.09	0.0	0.3	20.92	<0.0001
CM14 (oncology)	3.0	0.3	30.1	0.87	0.3505
CM15 (opthamology eye)	1.7	0.4	6.4	0.57	0.4522
CM16 (mental health)	1.3	0.5	3.3	0.30	0.5824
CM17 (neurology)	1.3	0.5	3.4	0.39	0.5323
CM18 (dermatology)	0.9	0.4	2.3	0.03	0.8736
CM19 (eye, ear, nose)	15.1	5.1	44.5	24.19	<0.0001
CM20 (respiratory care)	9.0	2.9	27.8	14.78	0.0001
CM21 (internal medicine)	1.0	0.4	2.5	0.01	0.9247
CM22 (kidney)	5.5	1.6	18.7	7.65	0.0057
CM23 (cardiology)	21.5	2.7	173.8	8.30	0.0040
CM24 (women's health)	52.5	13.6	202.1	33.17	<0.0001
CM25 (labor & delivery)	17.1	2.1	139.5	7.06	0.0079
CM26 (pediatrics)	28.9	8.6	97.3	29.46	<0.0001
CM27 (genetics)	227.4	26.1	>999.9	24.13	<0.0001
CM28 (infectious disease)	3.8	1.4	10.2	7.05	0.0079
CM29 (dental)	>999.9	<0.001	>999.9	0.01	0.9389
CM30 (anesthesia)	12.9	3.4	48.8	14.32	0.0002
CM31 (surgery)	14.6	4.9	43.1	23.49	<0.0001
CM32 (physical therapy)	5.1	2.0	13.1	11.20	0.0008
FA01 (emergency)	>999.9	<0.001	>999.9	0.01	0.9457
FA02 (ambulance)	>999.9	<0.001	>999.9	0.004	0.9531
FA03 (registration)	12.2	4.1	36.3	20.27	<0.0001
FA04 (waiting area)	64.7	16.1	260.9	34.40	<0.0001
FA05 (administration)					
FA06 (medical records)	114.0	23.8	545.0	35.19	<0.0001
FA07 (billing)	52.4	13.6	201.8	33.13	<0.0001
FA08 (medical librbay)	21.0	2.6	169.5	8.16	0.0043
FA09 (health edu)	1.1	0.5	3.0	0.06	0.8049
FA10 (interpreter serv)	1.0	0.1	16.6	0.00	1.0000
FA11 (social services)	1.3	0.3	5.2	0.12	0.7240
FA12 (chapel)	26.0	3.2	208.8	9.39	0.0022
MA01 (rdiology X-ray)	>999.9	<0.001	>999.9	0.01	0.9336
MA02 (mammography)	220.9	25.3	>999.9	23.90	<0.0001
MA03 (cath lab)	21.0	2.6	169.5	8.16	0.0043
MA04 (MRI)	12.3	3.2	46.6	13.71	0.0002
MA05 (untrasound)	25.7	5.4	121.6	16.77	<0.0001
MA06 (imaging X-ray)	39.7	11.1	142.3	31.90	<0.0001
MA07 (MRI)	361.0	48.3	>999.9	32.95	<0.0001
MA08 (PET)	134.3	16.1	>999.9	20.50	<0.0001
MA09 (CT imaging)	42.4	11.4	158.2	31.15	<0.0001
MA10 (CAT scan)	65.4	13.2	325.4	26.11	<0.0001

ANALYSIS OF RESULTS

The number and significance of differences in icon comprehension between the US and Tanzania, and differences between cohorts in Tanzania, demonstrated that we were able to distinguish various reasons for icon failure, at least in regards to medical knowledge. As stated earlier, additional analysis was needed to help establish more precisely the causes of various levels of understanding, particularly in icons that succeeded in one country but not in the other.

SUCCEEDING ICONS

As noted, only 3 icons achieved an 85% correct comprehension level in both countries, and only 2 of the same icons achieved 85% success in both countries. So 52 of the 54 icons failed to perform at 85% across cultures. However, 7 of 54 icons fit a *general pattern* of success in both cultures. These 7 icons used familiar objects: a person getting a shot, a microscope, an eye, a brain, bowels, an emergency vehicle, a teacher.

FAILING ICONS

Four of the 7 failing icons were descriptions of a service activities: Diabetes Education CM07; Administration FA05, Interpreter services FA10; Social Services FA11, and one, Mental Health CM16, represented a state of being. We have discussed elsewhere that icons have difficulty communicating actions and states of being (Zender, 2006). This challenge can be overcome by a multi-frame pictogram or an animation, but these approaches were not a part of this icon system.

FAILING ONLY IN THE TANZANIAN 'STANDARD' COHORT: LACK OF KNOWLEDGE

The substantial number of icons (15 of 54) misunderstood due to lack of knowledge confirmed our hypothesis that domain knowledge was a driver of miscommunication across cultures and that this distinction could be identified and measured. Analysis of the referent concepts and the individual symbols used to represent them suggested two broad reasons for misunderstanding.

Eight of the 15 icon referents in this category were related to established medical specialties: Family Practice CM08, Dermatology CM18, Respiratory Care CM20, Kidney CM22, Cardiology CM23, Dental CM29, Surgery CM31 and Physical Therapy CM32. We suspected that because Tanzania had few doctors and hospitals that these medical specialties were not common knowledge but were known to medical professionals. The marginally significant Cardiology icon was instructive in this regard. The difference between 'standard' and 'advanced' literacy for the Cardiology icon was not as pronounced [OR=2.5 (CI=0.6-9.4), x^2=1.72, p=0.1896] as the other specializations such as Kidney [OR=44.3 (CI=4.8-410.9), χ^2=11.14, p=0.0008].

We suspected that Cardiology might be one of the first medical specializations to emerge in a developing medical culture and therefore more widely known than other specializations.

Six of these 15 icon referents were related to concepts that were likely to be part of advanced medical training: Pharmacy CM06, Nutrition CM10, Pathology CM13, Infectious Disease CM28, Emergency FA01, and Ultrasound MA05. More specific analysis of the individual symbols used in the icons revealed that the Pharmacy icon CM06 combined a symbol of a pill bottle with a typographic sign for prescription, the "Rx." This icon was comprehended equally well by those with and without 'advanced' medical knowledge in the USA: 56% and 44% respectively, while in Tanzania there was a significant difference in comprehension: 60% correct by those with 'advanced' medical knowledge but only 15% correct by those with 'standard' medical knowledge. We concluded that in this case Tanzanian 'advanced' medical knowledge subjects understood the Rx sign due to medical training, but that this knowledge was not common for other Tanzanians. Dowse found the same issue with the Rx sign in South Africa (R. Dowse & Ehlers, 2001, p. 91). Detailed analysis of the incorrect text answers was instructive for the Emergency icon FA01 as well. Most of the incorrect answers said simply "cross" but a substantial number elaborated by saying "a cross with some writings (sic)." This suggested a lack of comprehension because the word Emergency was in English leaving non-English speakers out. We believed because the key difference was the word/sign "EMERGENCY" that the icon was understood with 'advanced' medical knowledge subjects not so much because of medical knowledge but because their English reading ability was higher. Hence we did NOT consider it a lack of medical knowledge despite its fit to the pattern and instead counted it as a failure due to reliance on a learned sign: the word "EMERGENCY," which we associated with cultural difference below.

The remaining icon that failed due to knowledge, according to our pattern for interpretation, was Chapel FA12. The majority of the correct answers responded to the question "what does it mean" with the answer "church" which was an acceptable synonym for chapel on the scoring sheet, but for the question 'what actions would you take,' most responded "I don't know." This suggested that 'standard' respondents were familiar with a church but unfamiliar with a church in a medical context. This, we believe, accounted for the number of wrong answers. In summary, 14 of these 15 icons failed due to knowledge disparities.

SUCCEEDING IN THE USA, FAILING IN TANZANIA: KNOWLEDGE OR CULTURE?

As stated previously, additional analysis of icon content helped determine whether the 25 of 54 icons that succeeded in the USA but failed in Tanzania failed due to lack of medical knowledge or due to cultural differences.

Content analysis showed that 18 of the 25 fell into two categories: 9 were 'advanced' technical imaging technologies, 9 were hospital services. Indeed, all but one of the technical imaging related icons, MA01 through MA10, had an odds ratio between 21 and 361, meaning USA respondents were between 21 and 360 times more likely to correctly identify imaging icons: Radiology MA01, Mammography MA02, Cath Lab MA03, MRI/PET MA04, Imaging MA06, MRI MA07, PET MA08, CT MA09, and CAT MA10. Only Ultrasound in this category was not included because it was part of the category of failure only with 'standard' literacy subjects in Tanzania. Ultrasound comprehension could have been influenced by the presence of a portable ultrasound training team in Shirati Hospital at the time of the first survey. We believed the 9 imaging icons (excluding Ultrasound) failed because neither 'standard' nor 'advanced' subjects were familiar with these technologies, not because of cultural misunderstanding.

The other large category comprised 9 hospital services: Health Services CM01, Care Staff Area CM02, Intensive Care CM03, Inpatient CM04, Registration FA03, Waiting Room FA04, Medical Records FA06, Billing FA07, and Medical Library FA08. Content analysis alone was unhelpful so we looked for patterns in the written answers for these icons. The responses for the Health Services icon CM01 showed great consistency around "a cross, a church." In Tanzania a cross was clearly associated more with church than health care. Prevalence and type of with religious practice would qualify this as a cultural difference. For the icon Billing FA07 it was instructive that many people responded "two people standing" but no one specifically responded "dollar" or "money". This suggested that the dollar sign was unfamiliar in Tanzanian culture and the cause of the icon failure. For the Care Staff Area icon CM02 respondents consistently wrote "nurse," which was of course a literal description of the symbol. Apparently care staff areas were not prevalent in Tanzania, a failure of knowledge. For the Registration icon FA03 several people answered "two people writing/talking" or "a patient getting treatment." Because the individual symbols were understood but the combination was not, we interpreted this as a lack of familiarity with this form of registration. For Waiting Room FA04 many respondents answered, "a picture of a person seated reading" or something similar. This suggested to us that sitting and reading were not equivalent to Waiting Room in Tanzanian hospitals. The Medical Records icon FA06 also had many similar wrong answers such as "a first aid box in a file cabinet." The icon for Medical Library FA08 had a similar pattern of wrong answers that were literal descriptions of the individual symbols, "a person reading and a cross," that did not add up to the correct conclusion: Medical Library. We found many cases where incorrect answers described the individual symbols the subjects observed in the icons: "person reading and a cross," but whose individual symbols did not lead to the intended abstract concept. This way of answering was pronounced for the failed Outpatient icon CM05 where most incorrect answers were something like "man walking with broken arm." Answers with

a concrete description instead of an abstract concept may give insight into the icon decoding process. This is corroborated by Beaufils et. al. in their study of cognitive processes used to comprehend icons in that they scored lower – less correct - for participants' answers that gave a concrete (literal) meaning to symbols and scored higher – more correct - for a given abstract meaning. (Beaufils et al., 2014)

Icons for Intensive Care CM03 and Inpatient CM04 were not particularly well understood in either culture and probably should be included in the failing ions category. They were included here because the difference between USA and Tanzanian comprehension was significant.

Two of the icons with extreme differences in comprehension in the USA compared to Tanzania could be considered highly technical, such as Genetics CM27 and Anesthesia CM30, and thus failures due to knowledge. Similarly, Alternative Medicine CM11, Ear, Nose, Throat CM19, Women's Health CM24, Labor & Delivery CM25, and Pediatrics CM26 could be considered medical specializations and failures due to knowledge. However, while Ear Nose &Throat CM19 seemed to be a straightforward example of a medical specialization and thus a knowledge failure, closer analysis of answers suggested a more nuanced explanations for the others. For the Alternative Medicine icon CM11 most answers described the examination of a patient on a bed. The needles were not mentioned. This may suggest that homeopathic or 'alternative' remedies were so familiar in Tanzania they were not labeled alternative! If true, 'alternative' in one culture may not be 'alternative' in another culture. However, the evidence was unclear whether a different view of technology was in play here or not so we left it attributed to knowledge disparity. The Women's Health icon CM24 combined a symbol of a woman with the sign for female (a circle with a plus sign). This icon was well understood by both groups in the USA but was not in Tanzania. Comparing the Women's Health icon to the similar Labor & Delivery icon helped clarify the reason for the miscommunication. The Labor & Delivery icon CM25 combined the same a woman symbol as CM24 but with the symbol of a baby placed in the woman's belly instead of the circle woman sign. The Labor & Delivery icon was comprehended well in Tanzania at 70% correct, compared to Women's Health at 10%. We concluded therefore that the learned sign for woman was the cause of the miscommunication in Women's Health. The Pediatrics icon CM26 answers revealed a different problem. The bear was frequently called a "cat," and never called a "bear." While it was twice called a "toy" and twice called "an idol," it was clear that there were no bears roaming Africa at the time of this study and that stuffed bears were not children's toys. This icon was misunderstood because it used an animal and a metaphor non-existent in Tanzania: a cultural failure.

In summary, of the 25 icons that succeeded in the USA but failed in Tanzania, 9 failed due to imaging knowledge; 5 of 9 hospital services icons failed due to knowledge, 2 failed generally, and 2 failed due to culture; 2 technical icons failed due to knowledge; and 3 of

5 specialization icons failed due knowledge and 2 failed due to culture. In total, 5 of these icons failed due to cultural misunderstanding.

Limitation

The study did not collect educational level other than presence or absence of advanced medical training.

DISCUSSION: SUMMARY OF KEY FINDINGS

The study demonstrated that different causes of cultural icon misunderstanding can be identified: 33 failed due to knowledge, and 5 failed due to culture.

KNOWLEDGE FAILURES

The 33 icons that failed due to knowledge disparities were grouped in three categories: 1. medical technologies including imaging, 2. medical knowledge including practice specializations and training experiences, and 3. medical operations and services. Icons of unknown technologies, medical specializations, and hospital services cannot be effective until the nature and devices associated with those things having first been known.

Others have noted that education level played a role in medical icon comprehension and our study confirmed that. (Ros Dowse & Ehlers, 2003) But whereas Kassam quoting Dowse suggested that education was important to comprehension because it built visual literacy, this study has suggested that more education may be important because it transmits more domain knowledge. This was born out by our findings that for 7 icons using familiar objects, scores in Tanzania were nearly equal for those with standard and advanced levels of knowledge, but for 15 icons of medical specialties or technical objects standard and advanced scores in Tanzania were significantly different. Educational level alone does not account for this. Others have connected level of general education to level of health literacy (Kickbusch, 2001). General skills and knowledge of medical practices, not a special visual literacy, are the likely drivers of improved icon understanding due to education that others have observed. Dowse seemed to suggest this, saying, "Every single respondent with less than 5 years schooling displayed extremely poor comprehension of medication information." (R. Dowse & Ehlers, 2001, p. 91) It is hard to imagine that those with low or no reading literacy, and who are therefore almost totally dependent on reading visual images and symbols for their daily survival, have low visual literacy. Based on interviews with three subjects in Tanzania we would argue that people with low education are highly skilled at reading images and that lack of medical knowledge, not low visual literacy, was the driver of much observed icon misunderstanding.

Others have also observed that both knowledge and culture are two key actors involved in interpretation of icons (Beaufils et al., 2014). This study confirmed that and demonstrated that these two can be distinguished and measured.

Finally, others have noted that one of the key difficulties interpreting symbols was that some have an arbitrary connection to their referent (Beaufils et al., 2014). This paper defined a taxonomy that connected image function to image resemblance: sign = no resemblance; icon = simple resemblance; picture = specific resemblance. The taxonomy noted that signs must be learned. Learned signs are not stable across cultures that use different languages and signs because a sign's meaning is not inherent in its visual form: no resemblance. Our taxonomy is a continuum, not fixed points. An image can move from one category to another as it is used and adapted over time. For example, the cross was originally an icon of Roman capital punishment, then a sign of Christian salvation through Jesus' death, then a medical sign of life saving treatment. It evolved from icon to sign to sign and took on new meanings. We scored a Tanzanian response to a cross sign "incorrect" because the response was "Church" not "Health Services." However, this misunderstanding was as much a statement about intention of the icon designer who intended the cross sign to mean health care not church, as about the respondent who was not privy to the designer's intention. A symbol functioning as an icon is visually related to what it resembles, but a symbol functioning as a sign is fixed only by cultural convention.

CULTURAL FAILURES

Detailed analysis of written answers and symbol content exposed 5 icons that appeared to have failed for identifiable cultural reasons. We grouped these into two general causes: use of metaphor, and use of learned signs.

Use of Metaphor

The Pediatrics icon CM26 combines a symbol of a bear with a cross. The bear symbol was not literally representative of children, but was used as a metaphor for children and combined with the cross sign to represent medical. The Pediatrics icon was comprehended 28 times better in the USA than in Tanzania. In Tanzania not one person with 'standard' medical literacy comprehended this icon correctly. However, medical care for children was a familiar concept in Tanzania. As pictured above, the children's ward was very active with its own laundry space for parents. Yet the Pediatric icon failed. Post survey interviews with subjects confirmed that Tanzanians did not give stuffed bears as toys to their children. We interpreted this as an example of cultural miscommunication based on use of metaphor.

Use of Learned Sign

Introducing a learned sign into the Woman's Health icon CM24 created the potential for miscommunication where the sign had not been learned. This

was similar to the cause of failure in the Billing icon FA07 where the learned dollar sign was not understood, and the Emergency icon FA01 where the word was not understood. For the Health Services icon CM01 the cross sign was (mis)understood as a church, not a hospital.

SIGNIFICANCE

Icons are often misunderstood when applied across cultures. This study has shown that lack of medical domain knowledge was a key driver of this misunderstanding for this icon set. Most (33 of 47) of the icons that failed in this study failed for this reason. Just 5 failed due to broader cultural differences.

Many have called on designers to be more sensitive to the cultural context of their work (Ros Dowse & Ehlers, 2004; Grenier et al., 2011; Kassam et al., 2004). More precise understanding of the causes of cultural misunderstanding is one step in this direction. The following principles for cross-cultural icon design may be use to respond to this.

Learn What They Know

Learn how familiar the target culture is with the concepts to be communicated, particularly where technology and specialized knowledge are involved. Concepts and objects that are absent the cultural consciousness will have to be introduced by scaffolding them onto familiar concepts.

Cultural Metaphor

Recognize when a proposed icon employs metaphor to communicate, and when it does, check to see if the metaphor is present in the target culture.

Learned Signs

Avoid learned signs. This includes words and other learned symbols such as Rx and the sign for female. If signs can't be avoided, they may be disambiguated as part of a system of icons that explains the unfamiliar sign.

Identify and Redesign Icons for Difficult Referents

Use an iterative, participatory design and testing process to improve icons that are simply failures of design.

In 1978 James Mangan articulated a list of steps similar to the one above for creating effective cross-cultural images (Mangan, 1978, pp. 265-266). This study has identified domain knowledge as a dominant reason for cultural (mis)understanding. This knowledge sharpens designers focus onto the main reasons for icon misunderstanding and the suggested means to address it.

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