Nursing Informatics 2016
W. Sermeus et al. (Eds.)

doi:10.3233/978-1-61499-658-3-397

Feasibility of the Rule-Based Approach to Creating Complex Pictograms

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Abstract. To test the effectiveness of the health pictograms created based on the pictogram composite rules, we created 7 new composite pictograms following the composite rules extracted from the USP pictograms. We then tested their understandability by surveying 42 volunteers recruited at a senior wellness center in San Diego, CA. Lower level of comprehension was observed in all 7 new composite pictograms when compared to the USP pictograms with similar styles. No consistent socio-demographic effect on the comprehension of the pictograms was discerned. The major sources of misinterpretations were (1) misunderstanding the main action depicted in the image, (2) ignoring the conditional information, and (3) making an incorrect semantic association between the main information and the conditional information. Design rules from the validated set of pictograms might serve as the starting point for creating a new health pictogram. However, rigorous validation and revision of the initial design should follow.

Keywords. Medication instruction, health pictograms, composite pictograms, patient education, health literacy

1 Introduction

Correct understanding of a health instruction is a prerequisite to achieving positive health outcomes [1–3]. Pictures and images are frequently used to convey various types of health information in an easy-to-understand way. Many studies show that using pictograms could improve health communication, especially with people who have a low level of health literacy [4-7]. For example, United States Pharmacopeial Convention (USP) pictograms are the most widely used and studied pictograms in the healthcare domain [2]. USP is a nonprofit volunteer-led organization that develops standards for various properties of medicines, food ingredients and dietary supplements. The USP pictograms are 81 standardized graphic images developed to help convey medication instructions, precautions, and or warnings to patients and consumers. However, these 81 pictograms by no means address the complete need for graphical representations of medication related information.

Designing a pictogram is also a laborious process that involves multiple iterations of testing and revision. Although no clear step-by-step guideline exists for developing

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2 http://www.usp.org/usp-healthcare-professionals/related-topics-resources/usp-pictograms.

health pictograms, a common process of pictogram creation is observed in many published studies [4-9]. Development of a health pictogram usually starts with an initial design, which is finalized through the iterative process of focus group feedback and revision. Once the initial design of a pictogram is deemed finalized, the pictogram is tested and validated with a larger target audience. Considering the vast amount of health information that can be relevant for pictorial representation, creating a separate pictogram for each piece of health information and ensuring stylistic consistency can be a daunting task, where an automated approach can be helpful.

Pictogram Evaluation and Authoring Collaboration Environment (PEACE) is a web-based tool that supports creating, validating, storing, and reusing health pictograms (http://peace.ucsd.edu) [10]. PEACE was developed to support health communication to facilitate healthcare in the countries with limited resources. The goal of this study was to test the feasibility of composing pictograms based on rules before implementing a semi-automated rule-based pictogram composition module in PEACE.

2. Methods

2.1 Pictogram preparation

Table 1. Sample Demographics

Demographics		N (total 42)
Age	<= 70	28
	> 70	14
Sex	Male	28
	Female	14
Edu	Up to High school	20
	College or more	22
Race	Non-Whites	23
	Whites	19

We first selected the USP pictograms that consist of more than one image, then analyzed their textual instructions and identified granular semantic constructs, such as frequencies, amount, action types (e.g., do or don't, particular sequence), and conditions/situations associated with the actions. We used the USP pictograms as a reference as they are validated and widely used in presenting medication instructions in various settings. We also identified the corresponding pictorial construct for each semantic construct and documented its notable design characteristics such as position, size, repetition, and specific icons/diagrams utilized. This analysis also enabled us to categorize the composite pictograms into 7 types based on the syntactic characteristics of the information that they convey. Through this analysis, we identified 7 pictogram design rules and types.

We manually created 7 new composite pictograms based on the design rules. We tried to utilize the images from the USP pictograms to avoid any potential bias caused by using an image construct that has not been validated. We also selected additional 7 USP pictograms created with the same design rules. This was to test whether the pictogram composite rules were successfully applied to the new pictograms by comparing the comprehension of the two pictograms with the same style.

2.2 Study site and survey conduct

After obtaining approval from the Institutional Review Board, we tested 14 pictograms through one-on-one interviews of the elderly people using a community senior wellness center in San Diego, who volunteered to participate in this study. The interview started by explaining the purpose of this study and the participants' identity would not be collected in this study.

Pictograms were presented as Microsoft power point slides on an i-pad. We adopted open-ended questions "What do you think this picture means?" to avoid any framing effect that pre-defined answer options may cause. The participants were encouraged to take as much time as they needed to understand and explain what they thought the pictograms meant. The interviewer wrote down the answers on a notepad then coded for further analyses (i.e., 0 for incorrect and 1 for correct answers). Nonspecific demographic information was also collected. Data analyses were done using Statistical Analysis System (SAS) version 9.3 (http://www.sas.com).

3. Results

In total, 42 senior center users participated in this study. The demographic distributions of the participants are presented in **Table 1**. The pictogram composite rules we extracted from the USP pictograms, and the USP pictogram and the new pictogram that share a similar design principle are presented side by side in **Table 2** with the correct interpretation rates. The USP pictograms showed higher correct interpretation rates in all 7 pairs. And the differences in correct interpretation rates between the paired pictograms were statistically significant for the pair 2, 3, and 6 when tested with Wilcoxon signed rank sum test. The overall mean correct interpretation rate was 61.56% (*s.d.*=22.41%) for the 7 USP pictograms and 40.48% (*s.d.*=20.67%) for the 7 new pictograms. This difference was also statistically significant ($p < 0.005$) when tested with the Wilcoxon signed rank sum test. Higher mean correct interpretation rates were observed in the participant groups of at least college level of education, male, younger than 70 years old, and Whites. This trend was observed in all 14 pictograms. However, only the mean difference between the two age groups (i.e., age <=70 vs. age >70) was statistically significant when tested with Wilcoxon rank sum test.

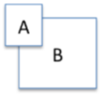
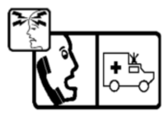
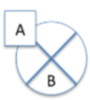
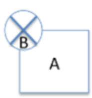
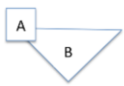
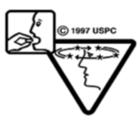
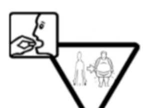
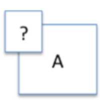
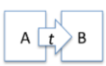
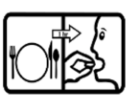
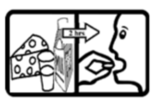
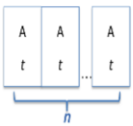
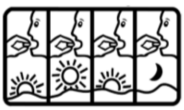
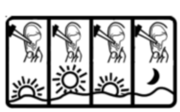
The highest correct response was observed with Type 7, the medication schedule pictograms where no conditional information is attached. Type 4 medication side effect pictograms and Type 5 simple question pictograms were associated with high misinterpretation rates. Relatively complex pictograms with 3 image constructs (i.e., Type 1, 6, 7) tend to show higher correct interpretation rate than simpler pictograms. Most misinterpretations occurred with the image constructs that represent main actions, followed by those that represent the conditional and/or auxiliary information for the main action. Incorrect semantic associations between the main image construct and the conditional image construct were the third most frequent source of misinterpretation. Ignoring the images carrying conditional information was also noted.

4. Discussion

All 7 new pictograms showed lower correct interpretation rates than their USP counter parts. This difference was notable considering that the paired pictograms have the same design style, complexity, and carry the similar types of health information. This study showed important considerations in designing health pictograms. The position of the main information (usually related to an action) and the direction of the information flow need to be carefully coordinated. The participants seemed to read the pictograms from the center, where the main information is represented with a larger image, to the periphery. Then they seemed to try to make an association among the presented pieces of information based on their prior knowledge and beliefs, which occasionally caused ignoring the peripheral images. For example, Type 2 and 3 pictograms deliver the same type of information 'don't [*action*] when [*condition*]' using different design styles. In the former, the action constructs are placed in the center but in the latter they are placed in the left upper corner. In this study, Type 3 showed higher correct interpretation where the conditional information takes the center position. Ignoring the conditional information caused the majority of the misinterpretation in Type 2 pictograms.

Type 4 pictograms, which represent the precautions on medication side effects, are another example that shows the potential effects of the directionality of image reading. Many participants read the images from the center to the periphery and interpreted these pictogram as 'when [*side effect*] happens take this medication to resolve it'. This is quite concerning as it could potentially harm the patients. Finally an image seemingly conveying an apparent piece of information was not always interpreted as such. For example, crossing out an action image with X to indicate prohibition or discouragement of an action, copying an image multiple times to indicate frequencies, and showing sun and moon images to indicate time points of the day were not successful in conveying the intended meaning to many participants. This warrants caution when designing a pictogram with such constructs.

Table 2. Information types, design rules, and the correct response rates in parentheses

Information types	Rules	USP pictograms	New pictograms
1.Simple instruction *Do A if B*		 Call xxx-xxxx for questions on this drug (69.05%)	 Call ambulance if you have headache
2. Conditional instruction (negation as main) *If A don't do B*		 Don't drink while taking this drug (61.09%)	 Don't smoke while using this inhaler (19.05%)
3. Conditional instruction (action as main) *Don't do B if A*		 Don't take this drug if you are pregnant (83.33%)	 Don't take this drug if blood pressure is high (30.95%)
4. Precaution *A may cause B*		 This drug may make you feel dizzy (33.33%)	 This drug may cause you gain weight (28.57%)
5. Question *Is A true?*		 Do you breastfeed? (35.71%)	 Do you drink alcohol? (28.57%)
6. Conditional actions with time interval *If do A then wait for time t then do B*		 Take this drug 1 hr after meal (69.05%)	 Take this drug 2 hrs after eating diary food (42.86%)
7. Medication administration *Take this drug via A at time t for n times per day*		 Take this drug x4/day (78.57%)	 Put this ear drop x4/day (69.05%)

This study was done with a relatively small number of elderly volunteers thus the findings of this study might not be generalized to other populations. Meaningful socio-demographic and/or cultural influence on pictogram interpretation might have been missed due to the small sample size. Relevance of the presented information to the personal situation is an important factor that affects the comprehensibility of the information. A lack of saliency of the presented pictograms to some of the participants might have affected how they interpreted the pictograms. We didn't collect the health status information from the participants as we assumed the majority of the elderly people could relate to health instructions, especially medication instructions. However, it is possible that some participants found the pictograms having little relevance to them. A larger scale study needs to be conducted to confirm the findings of this study.

Pictograms have a high potential to facilitate the communication of complex health information such as medication instructions. However, creating pictograms is a time consuming and laborious process that also requires rigorous validation. This study tested whether leveraging the existing insights on pictogram design can alleviate these challenges. The results of this study showed that applying the design rules extracted from the validated set of pictograms to create a new pictogram is not a straightforward task. A larger scale study needs to be conducted to confirm and better characterize the challenges that we discovered in this study.

5. Acknowledgment

This study is supported in part by the grant U54HL108460 (NIH/NHLBI). More results from this study are available for download[3].

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