"Do Metaphors Influence the Usability of Access Control?": A Gamified Survey.

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ABSTRACT

Metaphors are often considered to be a useful tool in user interface design. They teach a user new mechanics via transferring knowledge from one domain, where the user is experienced, to a new target domain. Specifically, this is helpful in areas with advanced technologies, such as security with its encryption and access control mechanisms. At the same time, some controversy exist on the efficacy of metaphors in user interface design. In this paper, we present our study results on the role of metaphors in a user interface for an access control decision mechanism. We performed our evaluation in a form of a web-based game, obtaining in total 143 responses. The study compared two interface metaphors along with a no-metaphor condition. Our main result suggests that metaphors in user interfaces of security applications can improve user performance, but the observed effect is limited.

CCS CONCEPTS

• **Human-centered computing** → **Usability testing**; **Empirical studies in HCI**.

KEYWORDS

metaphors, user interface, access control, survey

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1 INTRODUCTION

Metaphors are often treated as cross-domain mappings. They allow one to apply user experience from one domain (a source domain) to a new domain (a target domain) in unfamiliar situations [11]. For example, a file-system organization in most of the modern operating systems allows a user to transfer her experience and understand that files are stored in directories. Another example is a "trash bin" metaphor that explains where files go after deletion.

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Problems often occur in the areas where users meet advanced technologies. It is shown that mail encryption can be cumbersome for the common audience. The work of Whitten and Tygar [15] demonstrates the importance of right metaphors for user interfaces. On the one hand, it shows how the usage of the "key" metaphor simplifies understanding of email encryption for novice users, and on the other hand, it demonstrates how metaphors can be confusing in case of usage of different key icons for two versions of an encryption protocol. Good et al. reaffirm that sometimes user interfaces with usability issues can lead to undesirable access control decisions [5]. Thereby, metaphors are not a universal tool, and some concerns exist on whether metaphors are really efficient in transferring new information [4].

In order to clarify the role of metaphors in the design of security mechanisms, in this paper we evaluate the following research question (**RQ**): "What impact do metaphors have on the usability of security mechanisms in user interfaces?"

The following section presents a review of related work. We provide relevant information on metaphors and user-centered design. Section III describes the design of our comparative study, whereas Section IV presents the obtained results. In Section V, we provide a brief discussion of our results. Finally, our conclusions are presented.

2 BACKGROUND

2.1 User-Centered Design

User-centered design can be described as "a design philosophy and approach that places users at the center of the design process from the stages of planning and designing the system requirements to implementing and testing the product" [2]. There exist different methods of user-centered design. Eun-Ok Baek et al. propose User-Centered Design and Development, when users are placed in the center of the design process [2]. The authors distinguish two different types of concepts: rapid prototyping and participatory design. In participatory design, users are actively involved in the design process of a system or product, and in rapid prototyping users participate in iterative series of design tryouts until the product is ready. The authors also reveal two issues of user-centered design: how to effectively incorporate users into the process and how to distribute resources (time, money, tools, and space) for the described activities.

User-centered design can be applied to security as well. Realpe-Muñoz et al. reveal a need for a design process of secure and usable systems [13]. Zurko et al. define the term "user-centered security" as referring to "security models, mechanisms, systems, and software that have usability as a primary motivation or goal" [17]. They focus

their user-centered approach on the security subdomain of access control.

2.2 Metaphors in Design

Metaphors are systematically reviewed in the work of Lackoff and Johnson [7]. They distinguish three main types of metaphors: orientational, ontological and structural. The authors also mention a metonymy as a distinct entity, which has traits similar to those of metaphors.

With *orientational metaphors* Lackoff and Johnson refer to their spatial nature. *Ontological metaphors* have different purposes. They aim to provide a human with an understanding of a new phenomenon in terms of basic experience with physical objects. *Structural metaphors* have a special feature—they can reveal new properties of the target domain referring to a knowledge of a source domain. A *metonymy* is not a metaphor in a strict sense. While metaphors use the understanding of one domain to explain a new phenomenon in another domain, a metonymy uses a part of a concept to refer to the same concept. Barr et al. also distinguish two subtypes of structural metaphors—*process* and *element* and separate them in the following way: "*A process metaphor* is used to explain how some aspect of system functionality works. *An element metaphor* is a perceivable aspect of the user-interface which is designed to aid the user in understanding what process metaphors are applicable" [3].

In the context of security, metaphors play an important role. It is shown that users' security behavior hugely depends on their previous experience and knowledge [6]. Thereby, it would be highly beneficial to have an instrument—metaphor—that could transfer a user's knowledge from one domain to another. An example of such a knowledge-transferring metaphor could be a metaphor of a key for encryption keys in an encryption program [15].

However, there is some controversy around metaphors [4]. A recent work by Windl et al. shows that users have difficulties understanding icons in privacy policies [16]. The authors also note the lack of scientific foundation of using such icons in their field of interest. Given this evidence, we conclude that a deeper investigation is required to understand the role of metaphors in modern user interfaces in the area of security systems.

3 STUDY DESIGN

In our study we follow the user-centered design approach and evaluate metaphors as close as possible to conditions of real-life learning. To achieve this, we developed a game, where a user is asked to make access control decisions, i.e., to set permissions accordingly. Similar to real life, the user is not provided with additional information on how to complete tasks. To address our research question (**RQ**), we formulate the following hypotheses:

- **H1** Metaphoric representations lead to better performance.
- **H2** Metaphoric representations induce a lower cognitive load.
- **H3** Interfaces incorporating metaphors produce higher user satisfaction.

To investigate how metaphors influence learning of new access control mechanics, we chose a simple mechanism to base our game on : "To have an access to an object, a subject should have all the labels that the object has". For example, if the object "file.txt" has labels "label1" and "label2", then a subject accessing this object should also have at least the labels "label1" and "label2". This access control mechanism is based on a category-based access control model [12].

We utilized two metaphors for the developed game: "eye" and "key and lock". The "eye" metaphor is aimed to explain the general access control mechanics—if access is provided, then a requester can "see" a file. The "key and lock" metaphor illustrates how this exact access control system works: in order to get access to a file, you need keys for all the locks the file has. The "eye" metaphor can be classified as being both a metonymy and a structural metaphor, and the "key and lock" can be considered a structural metaphor. This difference is reflected in the game interface: the former metaphor is represented by similar icons of eyes, the latter by two different icons of a key and a lock to better visualize the underlying process structure ("a key *opens* a lock"). We also provided a third game variant without user-interface metaphors. We utilized a between-subject design for the study. In Fig. 1, three variants of the game are shown.

The game itself is structured as follows. Firstly, an introductory screen of the game is presented to a user. It contains the title of the game ("Security Manager"), a link to a user agreement, a start button, and the task:

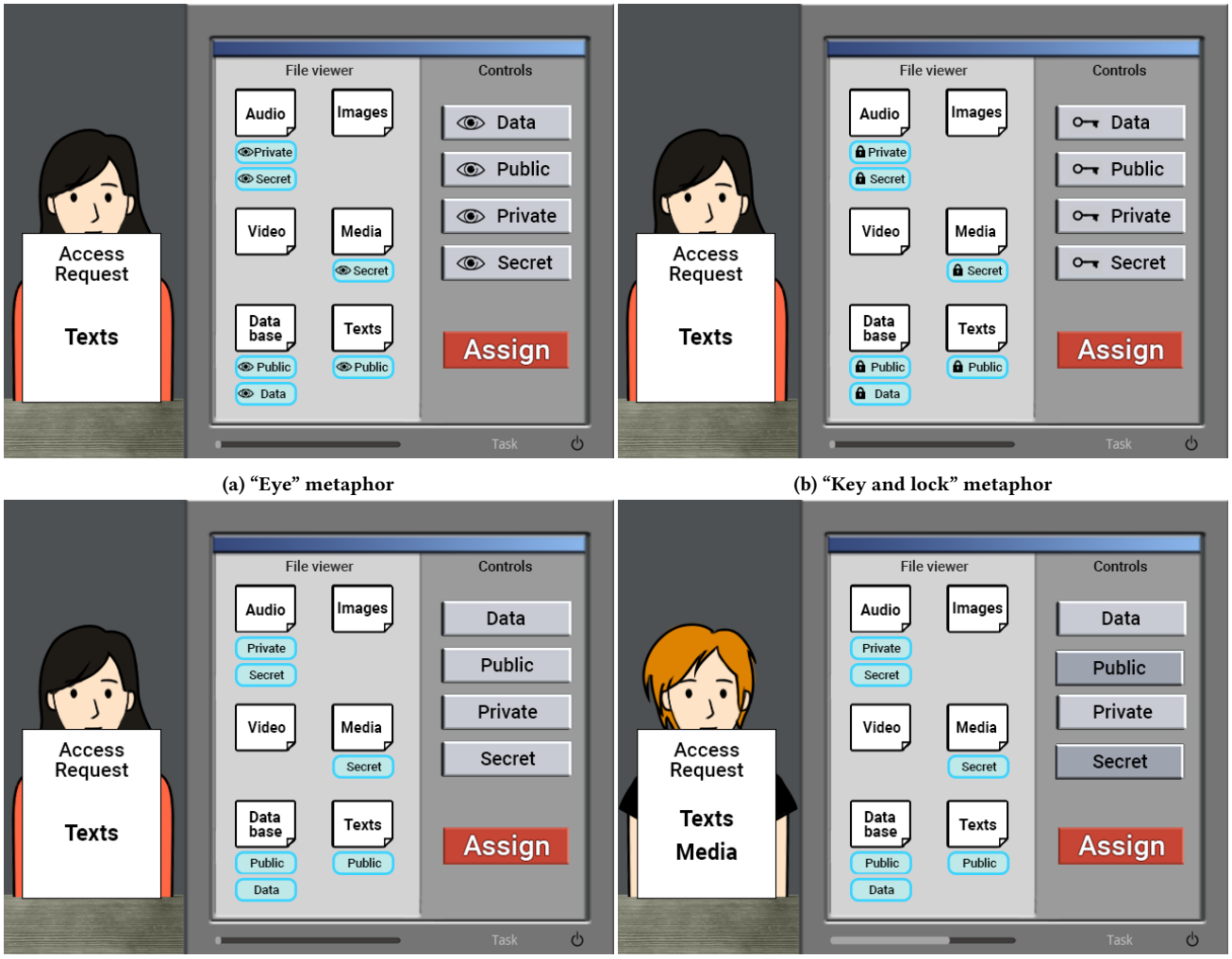
> You are a security manager. Provide access to requested resources, but do not give unnecessary access rights. Use buttons on the right to assign access control labels to requesters.

After hitting the start button, a first slide of the game is presented to the respondent (see Fig. 1). The user should press the desired buttons on the right and click the "Assign" button. To answer correctly, only those controls should be pressed that correspond to blue labels listed below each of the requested resources (see Fig. 1d). The requested resources are listed on the "Access Request" plate on the left-hand side of the screen next to the NPC (non-player character) requester. After hitting the "Assign" button, a green "Right" or a red "Wrong" label appears, corresponding to a right or wrong answer accordingly. Then, the next NPC with a new "Access Request" plate is shown to the user.

After completing all 16 access control requests, a user is asked to fill in the survey. In the survey, we aim to measure the cognitive load and user satisfaction of the three game variants. To measure the perceived difficulty of the task, we used a Single Ease Question (SEQ) [14]. It is shown that unidimensional scales similar to SEQ can be used as a reliable estimation of cognitive load [1]. For measuring usability, we used After-Scenario Questionnaire (ASQ) [8].

4 SURVEY RESULTS

The game and the questionnaire were deployed on the Internet in English and Russian languages and ran for two weeks. The link was distributed on an entertainment website reddit.com (in a group dedicated to surveys) and in a social network vk.com (in groups dedicated to social studies and computer science). For the purposes of analysis of **H2** and **H3**, we aimed to balance the number of respondents who finished the game and answered the questionnaire. It should be noted that the authors could not control to which condition a certain user was assigned, thus a user-condition assignment



(a) "Eye" metaphor

(b) "Key and lock" metaphor

(c) No metaphor

(d) One of the slides with the right controls chosen for the request

Figure 1: Game prototype with different metaphors

was random but not equally distributed among conditions. The survey had a between-subjects design.

After obtaining the results, we performed data clearance. We removed all responses with a median of times per slide less than 5 seconds. These responses demonstrated a clear click-through pattern. We also removed all responses with several attempts to go through the game. Lastly, we removed strong outliers based on the respondents' times per slide. Since we could not be sure whether we deal with distractions or with just a deep thought process, we decided to remove all respondents who took more than one minute per slide (with M_{per_slide} = 9550 ms). In order to avoid a bias caused by outliers, we decided to compare response series' medians instead of means.

After data clearance, we obtained 143 respondents (hereinafter referred to as the "all respondents") who at least opened the first slide of the game. Among them, we received 84 of those, who finished the game (hereinafter referred to as the "game-completer respondents"). And lastly, we got 67 "full" respondents (hereinafter referred to as the "surveyed respondents") who finished the game and filled in the post-hoc questionnaire. In Table 1, it is shown how game variants were distributed among participants.

The gender distribution was not equal among surveyed respondents: 79.1% – male, 16.4% – female, and 4.5% of participants chose another gender or did not provide the answer. The dominant number of male participants might be caused by a higher number of males on platforms where the questionnaire was placed. The age distribution was the following: 18-24 – 32.8%, 25-34 – 41.8%, 35-44 – 11.9%, 45-54 – 2%, and 10.4% did not provide the answer.

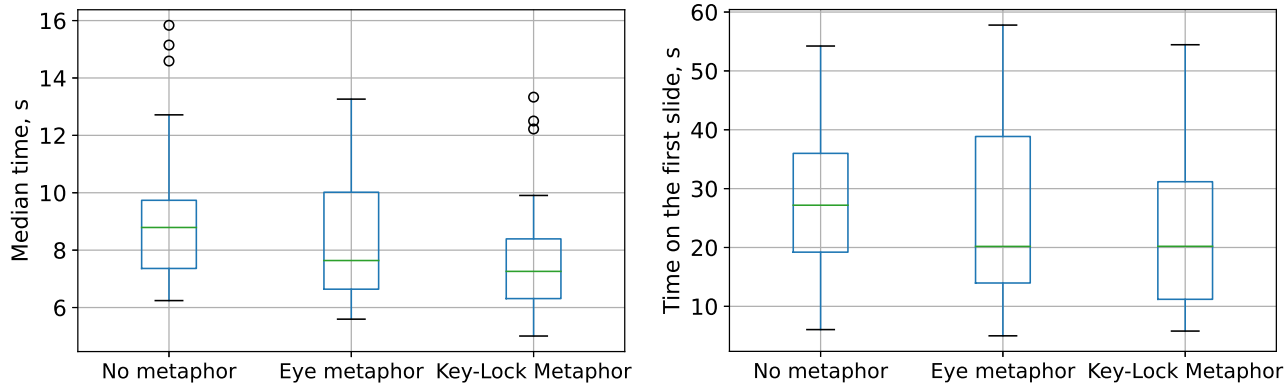
To test the hypothesis **H1** on the difference in performance with or without metaphoric representations, we compared several measures for game-completer respondents. We formulated the following assumptions:

H1.1 The number of respondents passed the last five slides without mistakes is higher among the metaphoric group.

H1.2 The number of correct answers for the first five slides is higher among the metaphoric group.

	All respondents	Game-completer respondents	Surveyed respondents
No metaphor	62	34	26
"Eye" metaphor	35	23	18
"Key and lock" metaphor	46	27	23

Table 1: Distribution of game variants



(a) Medians of times of the first five slides

(b) Time taken to complete the first slide

Figure 2: Participants' performance at the beginning of the game

H1.3 The number of correct consequent answers from the end is higher among the metaphoric group.

H1.4 The learning time at the beginning of the game is less among the metaphoric group.

To test the hypothesis **H1.1**, we used the Chi-squared test. The hypotheses **H1.2** and **H1.3** were tested using the median test. We found no significant evidence to reject the corresponding null hypotheses ($p > 0.2$).

To address **H1.4**, we tested the difference between medians of completion times of the first five slides for metaphoric and non-metaphoric game variants (see Fig. 2a). We assumed that during the first five slides respondents learn how to use the game, so the additional information provided by metaphors will have the highest impact. Since the residuals were not distributed normally, we were not able to perform the ANOVA test. We used the Kruskal-Wallis H-test and found significant differences between samples ($H(2) = 7.67, p = .021$). We performed Dunn's post hoc test using a Bonferroni correction for the p-values and found a significant difference between no-metaphor and "key and lock" metaphor conditions ($p = .017$). Thus, we conclude that metaphors can influence users' performance.

We also compared amounts of time taken by users to complete the first slide (see Fig. 2b). We assumed that during the first slide a more intense learning process is happening. This time the Kruskal-Wallis H-test revealed no significant difference between metaphoric and non-metaphoric representations ($H(2) = 3.35, p > .18$).

Hypotheses **H2** and **H3** were tested by comparing SEQ and ASQ questionnaires results for surveyed respondents. We used Kruskal-Wallis H-test and did not reveal any difference between the metaphoric and non-metaphoric groups (SEQ: $H(2) = 2.2, p > .33$; ASQ: $H(2) = 1.09, p > .58$). To further test hypothesis **H3**, we tested the following assumptions:

H3.1 Number of respondents leaving the game is lower in the metaphoric group.

H3.2 Number of respondents leaving the game right after seeing the first slide is lower in the metaphoric group.

The Chi-squared test for **H3.1** and **H3.2** revealed no evidence to reject the corresponding null hypotheses ($p > .55$).

5 DISCUSSION

Our survey has certain limitations. First, it was distributed via the Internet, so we were not able to control the accuracy of the task understanding or to ensure the absence of respondents' distractions. We tried to compensate the latter factor by using more stable metrics, like a median. Second, we were not able to identify well-established tools for our survey design, thereby we relied on more general methodologies (e.g. LM-GM framework [9]).

Keeping in consideration the aforementioned factors, we can reflect on our main findings. We found a significant improvement of user-learning time with the metaphoric condition "key and lock". At the same time, the "eye" metaphor did not show any significant reduction in learning time. This could happen due to the different nature of the metaphors: "key and lock" was a structural metaphor and better reflected the underlying mechanics.

It should be noted that we did not reveal differences in retention rate, cognitive load, or user satisfaction. Since there is evidence in the literature on metaphors affecting those factors, we conclude that our design was not able to capture the difference. We suggest that a distinct study with a higher degree of interference is required. In that case the usability of metaphors, for example in

terms of cognitive load, can be assessed using gaze-tracking or EEG-measurement [10].

6 CONCLUSION

In this paper, we introduced our work on efficacy assessment of user interface metaphors in the context of access control. We developed a web-based game that asks a user to act as a security manager and assign access control labels to requesters. Users were presented with either a metaphoric or a non-metaphoric variant of the game. After that, participants were asked to fill in the survey.

During our analysis, we found that metaphoric representations can lead to significant improvements in learning of new security mechanisms. At the same time, we were not able to find any significant difference between different metrics of respondents' success and satisfaction. This somewhat contradictory outcome lead us to an interesting conclusion—we still lack an understanding on how to reliably utilize metaphors in user interfaces.

The results of the study reaffirm the claim that metaphors could be inefficient in certain scenarios. Thereby, we draw the conclusion that incorporating metaphors into security interfaces is not a trivial task, and a deeper investigation is required to provide designers with a reliable methodology on the use of metaphors.

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