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Using a New Set of Heuristics in Evaluating Arabic Interfaces

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The Information Technology Sector has been growing rapidly in the Arab world. As a result, Arabic interfaces are now being widely used and developed in the region. However, little existing work has been done that focused on evaluating said systems. In this paper, we propose a new set of heuristics for evaluating the usability of systems that use Arabic interfaces. We focused on formal heuristic evaluation as the usability inspection method for identifying issues in these systems. In order to test the proposed set, we compared the findings of heuristics set by Nielsen with ones reported using the proposed heuristics on three Arabic interfaces. Experimental results show that using our heuristics, evaluators were able to find more severe problems than those who used Nielsen's. Therefore, we believe that heuristic evaluation, when conducted using our proposed heuristics, can be more effective in finding usability issues in Arabic interfaces.

KEYWORDS: Arabic interfaces, HCI, heuristic evaluation, usability, interaction design

1 INTRODUCTION

The design and development of Arabic interface systems is expanding as more companies are recently focusing on systems targeting that market [1] [2]. In fact, Arabic is ranked fifth after Mandarin, Spanish, English, and Hindi in terms of native and total speakers [3]. Arabic is one of the six official languages of the United Nations. However, English is still the dominant language of preference for users in Arab countries; 20-45% of users prefer English interfaces over Arabic ones in seven Arab countries [4]. This percentage is greater in the rest of the Arab countries since the majority of their users prefer English interfaces [4]. Moreover, it has been concluded that methods adopted to evaluate the usability of systems used in Europe or the USA fail in evaluating the usability of their counterparts in countries with different cultures, such as India, China, and Malaysia [5]. Arab countries have different cultures as well, which implies the need to consider such cultures in terms of developing usable software systems.

Although a great amount of Arabic interface systems has been developed, little is done in terms of evaluating these systems or even comparing the usability of two competitive ones. This makes it difficult to determine which system is more usable than the other and why it is usable. Moreover, interaction design of Arabic interfaces has thrown down many challenges to designers and users alike [6] [7] [8], which have not been well explored in the existing literature. This has made evaluating the usability of such systems challenging altogether.

We believe that there is a need in the domain of interface evaluation for an effective and efficient method adapted to the evaluation of Arabic interfaces. Such a method should be also inexpensive and should not require a great amount of learnability to be applied. Heuristic evaluation is widely used, requires less time commitment than other evaluation techniques (such as empirical studies and user testing, ethnography, etc.), and can be less expensive every so often. In fact, user testing is more difficult to conduct than heuristic evaluation [9]. As a result, we believe that heuristic evaluation can be applied to evaluating Arabic interfaces through the modification of Nielsen's original [10] and updated heuristics [11].

This paper aims at adapting heuristic evaluation in identifying the usability issues of Arabic interfaces. Similar to the work presented by Baker et al. as well as Mankoff et al., in which authors applied heuristic evaluation to the domains of computer supported cooperative work and ambient displays, respectively, we believe that modifying Nielsen's heuristics is the way to adapt heuristic evaluation [12] [13]. In this paper we start by exploring the work that have been published in evaluating Arabic interfaces using user testing and satisfactory questionnaire. We also explore the literature and report the work that we have found, which focuses on usability guidelines and challenges in creating Arabic interfaces.

Our research methodology was based on two phases. In the first phase we created a modified set of Nielsen's heuristics with the help of experts in the field. We put this set into practice in the second phase, where an experiment was designed to compare the effectiveness of Nielsen's heuristics with our new set through evaluating three Arabic interfaces. Two websites (www.sharjahairport.ae) (arabiaweather.com) and one desktop application (Smart Soft Pharmacy Information System) were selected for the experiment. It is important to indicate here that although the application is widely used in the region and the two websites have won the UAE App and Web Award and the Pan Arab Web Award, respectively, the focus of this paper is not on the usability of

these interfaces, but rather on the effectiveness of applying our set of heuristics in evaluating such systems. Furthermore, the paper presents our findings of comparing our set of heuristics to Nielsen's in terms of the number of usability issues found by evaluators in each interface as well as the severity level of each issue. After discussing the results, the paper identifies some directions of future work and presents conclusions of the presented work.

2 RELATED WORK

Although current Arabic systems are not being evaluated based on standard criteria, some case studies have been reported in evaluating Arabic interfaces using user testing. In [14], the authors evaluated the design of Arabic websites in order to identify Arab users' preferences. The evaluation was based on a user testing case study where users from Jordan and Lebanon were selected to examine the mapping between the user expectation and Hofstede's cultural dimensions [15]. In another work [16], the authors conducted three user testing experiments to study the behavior of Arabic students in interaction with e-book material. The focus of the study was on the students' preferences of different Arabic typeface styles, font sizes, page layouts and foreground/background color combinations. Another user testing case study of web usability was presented in [17]. Users in this study were tested on three tasks. Their reactions were remotely observed and reported.

Satisfactory questionnaires were also used in evaluating Arabic interfaces. [18] [19] [20]. Although user testing and satisfactory questionnaires may provide interesting insights on the usability of Arabic interfaces, these techniques are often costly, time consuming, and not well adapted for Arabic interface systems.

Several studies have been conducted in identifying usability guidelines in creating Arabic interfaces. If well explored, these guidelines can be used as the bases of heuristics. In [21], for example, the authors introduced a set of 18 guidelines for evaluating the usability of Arabic e-government websites in terms of the website's interface, content, and logic flow. Although these guidelines seem interesting, no evaluation has been reported on the efficiency or effectiveness of applying them in evaluating Arabic websites. Another study [22] has identified eight usability guidelines of creating Arabic e-learning websites. The guidelines were specifically developed for Arabic e-learning websites in higher education. Moreover, the guidelines are directed towards the

design of interface elements, such as color, font size, and use of images, more than the usability of the website as a whole.

Several studies have been conducted in exploring the challenges of designing Arabic interfaces and web technologies. In [23], for example, the authors presented an overview of the use of Arabic digital content along with identifying several challenges that the language faces on the Internet. A relatively similar work has been presented in [24], in which authors presented some of what they find to be important challenges of designing and developing a distributed web crawler for the Arabic search engine. Challenges of designing text mining and query pre-processing tools to efficiently search Arabic web data have been of interest of other researchers, such as in [25]. In [26], the authors investigated the culture-related side of using interactive systems across platforms by conducting a user study that includes some users from Arabic backgrounds. With the findings of their research, they proposed a design model that encompasses the cultural factors to guide the design of international cross-platform services.

Several approaches exist that discuss the usability-related principles as well as the development and validation of usability heuristics [27] [28] [29] [30] [31] [32]. The widest used usability heuristics has been defined by Nielsen [33]: visibility of system status, match between system and the real world, user control and freedom, consistency and standards, error prevention, recognition rather than recall, flexibility and efficiency of use, aesthetics and minimalist design, help users recognize, diagnose and recover from errors, help, and documentation. A checklist for these heuristics has been determined by Pierotti [34] as an aid for the evaluators.

Bastien & Scapin [35] proposed another approach based on evaluating the user interface against ergonomic criteria consisting of 18 elementary criteria grouped into 8 categories (general principles). For each criterion, several usability guidelines are given. Ji et al. [27] developed a usability checklist for mobile phones. The checklist consists of a set of usability principles categorized into five groups: cognition support, information support, interaction support, performance support, and user support. The achieved results show the lack of an explicit mapping between the usability principles and the checklist.

Kamper [36] proposed the Lead, Follow and Get Away (LF&G) heuristics set that could be applied across different technologies, contexts of use, and domains of knowledge. In order to use a formal methodology to develop the usability heuristics Quinones et al. [37] presented several such

methodologies highlighting the importance of a formal usability heuristics development process. Quinones & Rusu [29] surveyed the existing literature on developing usability heuristics. The results of the survey show a plethora of existing heuristics organized around various principles as well as many approaches to validation. Their study reveals a tendency to create and validate in-house heuristics serving specific needs. Several studies proposed various extensions of Nielsen's usability heuristics in order to address specific usability issues [38] [28].

There are many models of culture that are used by researchers and practitioners which can help in studying and designing websites across cultures. To know some relationship between culture and user interface design, and cultural markers [39] that define interface design elements influenced by culture. Authors in [40] in their study on developing UK and Korean cultural markers pointed to the general issues of the cross-cultural web design. To do this, they defined a checklist of relevant design elements which are supposed to be culturally specific design elements, called as the cultural markers [41]. The cultural markers they used included verbal attributes such as language and format (time, date, addresses, currency, printing format and size, units of measurements).

Khusman et al. [42] proposed a model that includes cultural variables, which largely influence the user's acceptance behavior for the e-business websites in Arab countries. The achieved results suggest that e-business websites developed for low power distance, low uncertainty avoidance, high individualism and high masculinity cultures (like the Western cultures) are not optimally suited for Arab cultures which involves high power distance, high collectivism, low masculinity and high uncertainty avoidance.

Research by Aaron Marcus & Associates [43] in the year 2009, discusses issues regarding the influence of culture on Arabic websites. They analyzed three Arab countries, the Jordan, Egypt and the United Arab Emirates. The results points out that Arabic websites need to consider some changes, such as, to add more representative pictures, more multimedia components, more links to the external websites, and more multilingual contents.

A study conducted by Khashman and Large [44] examined the design characteristics of government web interfaces from three Arab countries using Hofstede's cultural dimensions. Organizational and graphical elements from 30 ministry websites from Egypt, Lebanon and Saudi Arabia were examined using content analysis. Element frequency scores were correlated with

Hofstede's dimensions and interpreted based mainly on the model developed by Marcus and Gould. The results suggest that Hofstede's model of culture does not fully reflect the design characteristics of Arabic interfaces.

3 RESEARCH METHODOLOGY

Our research methodology was based on two main phases. In Phase I, we aimed at reviewing Nielsen's updated heuristics [11] to eliminate, update, and add heuristics that are applicable to Arabic Interfaces. The purpose of Phase II was to compare the resulting revised heuristics to Nielsen's while conducting a formal heuristic evaluation of Arabic interfaces. Our methodology of developing the new set of heuristic is similar to that presented by Baker et al. [12] as well as Mankoff et al. [13], in which authors applied their proposed heuristics to the domains of computer supported cooperative work and ambient displays, respectively.

3.1 Phase I: Revision of Heuristics

In this phase three researchers of our group conducted independent reviews of Nielsen's updated heuristics [11] to eliminate any heuristic that is believed inapplicable to Arabic interfaces. In addition, some of Nielsen's heuristics were updated to fit the need of evaluating Arabic interfaces. Some changes were made to the title of the heuristic being reviewed, whereas others to its description. Furthermore, during some brainstorming sessions, there was a clear indication of a necessity to add some heuristics to the updated list that are specifically applicable to Arabic interfaces. After concluding the first round of modification and addition in this phase, a pilot survey was conducted with 12 participants to comment on and discuss the proposed list of heuristics. The participants consisted of five Arabic user interface designers, three experts in heuristic evaluation, two experts of Arabic language and culture, and two graphical user designers. All of the participants' mother tongue Arabic, seven of whom live in Arab countries. The participants' average years of experience working with heuristic evaluation was 5.5 years, whereas it was 6.7 years with Arabic interfaces. They were asked to provide a rating on a Likert scale from 1 to 5 (1 is strongly disagree, 5 is strongly agree, and 3 is neutral) indicating their point of view on the relevance of the updated and/or added heuristics to evaluating Arabic interfaces. Participants were also asked to explain the rationale behind their choices. Table I shows a comparison between

the updated and added heuristics used in the survey, and the final heuristics that resulted from it. Underlined words in the “Suggest Updates/Addition” column of the table indicate an update or an addition to the original heuristic. The table also shows the average rating of the relevance of each heuristic to Arabic interfaces.

Table 1: A Comparison of the suggested updates and additions to each of Nielsen’s heuristic after independent reviews, and the final heuristics derived from the pilot survey. Rel. is the average relevance assigned to each heuristic by pilot survey participants (5 being most relevant)

Suggested Updates/Addition	Rel.	Final Heuristics
Visibility of system status <u>and language mode</u> The system should always keep users informed about what is going on, through appropriate feedback within reasonable time. <u>Users should easily know which language mode they are in</u>	4.7	Visibility of system status and language mode The system should always keep users informed about what is going on, through appropriate feedback within reasonable time. Users should easily know which language mode they are in
Match between system <u>and the Arabic Culture</u> The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.	4.5	<u>Strive for Arabic Cultural Identity</u> <u>The system should clearly adapt to the Arabic culture in its use-of-language, visual designs, concepts, measures, conservativeness, and logical order. Follow Arab-world conventions.</u>
User control and freedom <u>Provide users with a</u> marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo. Also, give the user the ability to modify cultural settings.	4.4	User control and freedom Provide users with a marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo. Also, give the user the ability to modify cultural settings <u>based on their country of preference.</u>
Consistency and standards Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.	4.6	<u>Use Consistent Standards and Unambiguous Translation of Words</u> Follow platform conventions <u>and strive for a consistent translation of words, phrases, and symbols</u>
Combine with Heuristic #9: help users recognize, diagnose, and recover from errors	N/A	N/A
Recognition rather than recall Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.	4.3	Recognition rather than recall Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
Flexibility and efficiency of use <u>Allow users to tailor frequent actions using both Arabic and English accelerators.</u>	4.4	Flexibility and efficiency of use Allow users to tailor frequent actions using accelerators. <u>If letter shortcuts are used, consider both Arabic and English versions with a flexible transition.</u>

Aesthetic and minimalist design Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.	4.5	Aesthetic and minimalist design Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
<u>Help users avoid, recognize, diagnose, and recover from errors</u> <u>The system should constrain actions that make errors, but when an error occurs provide an error message that precisely indicates the problem and provides a solution</u>	4.7	<u>Help users avoid, recognize, diagnose, and recover from errors</u> The system should constrain actions that <u>lead users to</u> make errors, but when one error occurs provide an error message that precisely indicates the problem and provides a solution
<u>Help and documentation</u> <u>Provide users with a searchable documentation of the system in both English and Arabic</u>	4.7	<u>Help and documentation</u> Provide users with a searchable documentation of the system in both English and Arabic
<u>Easy transition of typing modes</u> <u>Most Arabic users use bilingual (usually Arabic and English) interfaces of the same system. The system should provide an easy clearly visible way of transitioning between different typing modes</u>	4.8	<u>Easy and clear transition of typing modes</u> Most Arabic users use both Arabic and English interfaces of the same system. The system should provide an easy way of transitioning between typing modes, <u>with visibility of action and feedback</u>
<u>Aspire to right-to-left</u> <u>An Arabic system should be right-to-left justified in terms of its layout, images, and scrolling</u>	4.8	<u>Aspire to right-to-left layout and navigation</u> An Arabic system should be right-to-left justified in terms of its layout, images, scrolling, <u>hierarchal menus, and navigation.</u>

As shown in Table 1, participants of the pilot survey have strongly agreed on the various addition and/or modification of the heuristics. This was indicated by the average relevance rating of each heuristic, which ranged from 4.2 to 4.8 out of 5 (5 being most relevant). Additionally, some of the heuristics were modified after the pilot survey resulting in eleven final heuristics with their descriptions, as shown in the right column of Table 1. The comments section of the survey provided very good insights and useful data that helped reevaluate the heuristic and/or modify its description in some more specific criteria. For example, several of the participants agreed that a specific heuristic should be clear on having to strive for the Arabic cultural identity instead of just a match between the system and the real world. Another group agreed on altering the description of the Consistency and Standards Heuristic to one that stresses the importance of having consistent translation of words, phrases, and symbols to the overall usability of Arabic interfaces.

3.2 Phase II: Comparison of Heuristics

In this phase, a desktop application and two Arabic websites were tested/evaluated against the modified set of heuristics -listed in the “Final Heuristics” column of Table 1. The purpose of this phase was to compare the effectiveness of the modified heuristics (we will refer to these with Arabic Heuristics) to Nielsen’s Heuristics in conducting a formal heuristic evaluation of Arabic interfaces. The aforementioned comparison of effectiveness was based on the following hypotheses: the number of usability issues reported using the Arabic Heuristics will be greater and more severe than those reported using Nielsen’s heuristics when evaluating Arabic interfaces. Thus, the Arabic Heuristics will prove more useful/valuable to evaluators of Arabic interfaces than Nielsen’s.

To conduct our comparison, we recruited fourteen participants, with a median of 6 years of evaluation experience in general and 5 years of evaluating Arabic interfaces in particular. All fourteen participants were selected carefully to ensure having the least possible variance between them in terms of expertise with Arabic interfaces. We used a between-subjects design where participants were split into two groups of 7. Group A evaluated the three Arabic interfaces using the Arabic Heuristics after learning about the new set of Arabic heuristic, while Group B evaluated the same ones using Nielsen’s. To internally validate the study, the order of the interfaces was randomly assigned to each participant. Although most of the literature and practitioners have reported that five users could find 80-85% of usability issues when conducting a formal heuristic evaluation [10] [45], we included seven participants in each study to address criticism about the sufficiency of five users [46] [47]. Each of the fourteen participants conducted an individual evaluation and was asked to provide a list of usability issues in relation to a heuristic along with the severity rating of each one. Since all participants were familiar with Nielsen’s heuristics but new to the Arabic Heuristics, those who evaluated the interfaces using the Arabic Heuristics were given more time to understand them and their corresponding description. Participants were advised to use a 4-point scale severity level rating used in [10], where 1 is a cosmetic issue that need not be addressed, 2 is a minor issue with low fixing priority, 3 is a major issue that is important to fix, and 4 is a usability catastrophe that must be fixed before the product is released.

4 RESULTS AND DISCUSSION

Table 2 shows a summary of the usability issues in the three Arabic interfaces as reported by the fourteen participants. In essence, the table compares the number of issues reported at each severity level for each interface using Nielsen's heuristics (N) and the Arabic Heuristics (A). Moreover, the table shows the total number of usability issues (T) found in each interface.

Table 2: The number of issues found in each interface based on the severity level using Nielsen's heuristics (N), Arabic Heuristics (A), and the total number of usability issues (T)

Severity Level	Number of Issues in Interface 1			Number of Issues in Interface 2			Number of Issues in Interface 3		
	N	A	T	N	A	T	N	A	T
1	2	3	3	4	4	5	8	9	9
2	3	3	5	5	6	7	9	10	11
3	2	4	5	5	7	8	5	5	5
4	1	2	2	0	1	1	1	2	3

As clearly depicted in Table 2, participants who used the Arabic Heuristics to evaluate the interfaces were able to catch more usability issues than those who used Nielsen's. We believe this happened because all participants were already familiar with Nielsen's heuristics and those who used the Arabic heuristics were trained to use them. This, we believe, gave an advantage to participants who used Arabic heuristics in terms of supporting their knowledge of Nielsen's with a new set of heuristics that are specific to evaluate Arabic interfaces. On the other hand, few of the issues that we found were not reported by either one of the groups. Figure 1 depicts the percentage of the usability issues found by the participants of the two groups for each severity level, combined. As the figure shows, evaluators who used the Arabic Heuristics were able to find 94% of cosmetic issues in the three interfaces, whereas those who used Nielsen's found only 82% of them. The difference was less noticeable in minor issues, where evaluators reported 83% of the issues using the Arabic Heuristics as opposed to 74% using Nielsen's. However, there was a clear difference between the number of major and catastrophic issues reported by each group. Evaluators using the Arabic Heuristics, for example, were able to report 83% of the catastrophic issues found in the interfaces, whereas evaluators using Nielsen's heuristics failed to report more than 33% of the total number of such issues.

Additionally, during our study it was deduced that the percentage of the reported usability issues increases in proportion to the number of participants, as shown in Figure 2. In fact, the figure

shows that 3-5 evaluators were able to find 45-70% of issues using the Arabic Heuristics, which is consistent with the work reported in [10] and [13].

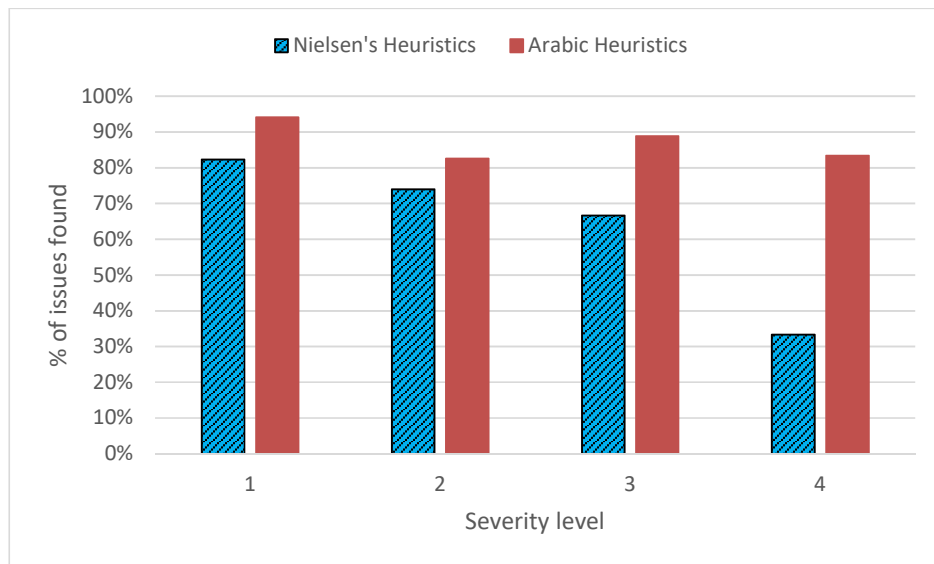


Figure 1: The % of issues found by evaluators using Nielsen’s Heuristics in comparison with Arabic Heuristics (based on the severity level)

The results of our study show that the Arabic Heuristics, discussed and presented in Table 1, were an improvement to Nielsen’s original heuristics in evaluating Arabic interfaces. A single evaluator of an Arabic interface using the Arabic Heuristics is able to find 25% of usability issues on average as opposed to roughly 8% using Nielsen’s. In addition to that, seven evaluators with a median of 5 years of experience in evaluating Arabic interfaces can find up to 88% of issues using the Arabic Heuristics; an increase of 18% to the percentage of issues reported using Nielsen’s. The results also indicate that evaluators who use the Arabic Heuristics are able to find a significantly greater percentage of major and catastrophic usability issues in Arabic interfaces.

Although our experiment shows promising results in using the new set of heuristic to evaluate Arabic interfaces, participants of the experiment were selected to be familiar with Arabic interface as well as have experience in heuristic evaluation. Additionally, participants who evaluated the interfaces using the new heuristics went through some training on the new set before

conducting the experiment. Therefore, we believe the new set of heuristics would be most effective and efficient when the evaluator becomes familiar with them and assuming that he or she has some knowledge of evaluating interfaces using heuristics.

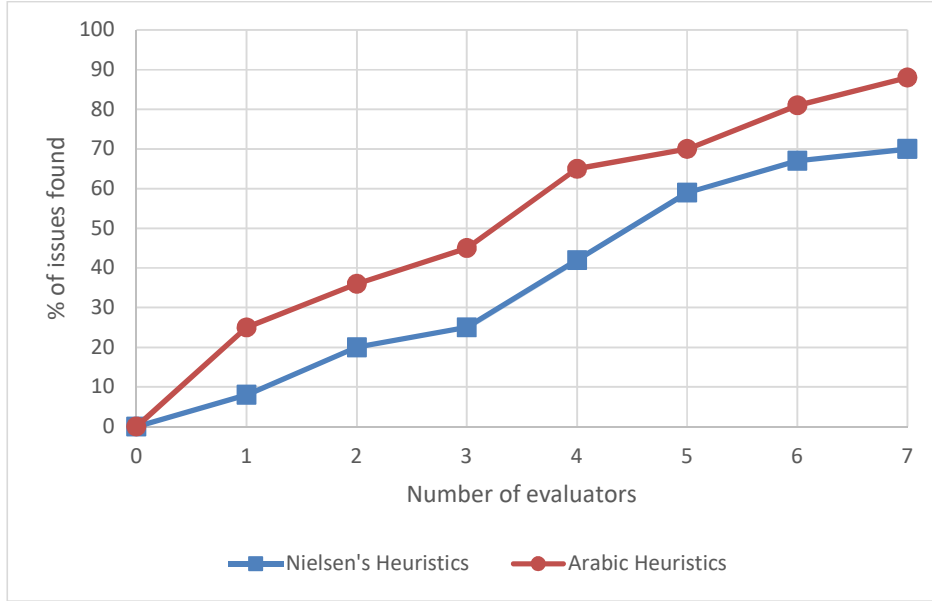


Figure 2: The relationship between the number of evaluators and the percentage of issues found compared between using Nielsen's heuristics and the Arabic Heuristics

5 CONCLUSIONS AND FUTURE WORK

The market is continuously expanding and thus, the number of Arabic-speaking users is expected to further increase over the upcoming years. Although, Arabic is written right-to-left (RTL), it is in fact a Bidirectional language. Therefore, adding support for Arabic does not imply changes to scripts only, but iconography as well. As a result, long-standing rules of thumb were proved, to some extent, insufficient when evaluating Arabic interfaces. Supporting RTL and Bidirectional languages can easily help expand systems to encompass a wider variety of users. However, adding support for such languages can sometimes insinuate bad user experience if not applied properly. In this paper, we presented a new set of Arabic Heuristics-derived from Nielsen's Heuristics- with which the primary focus resides in identifying issues in Arabic interfaces. When

comparing the number of usability issues reported using the Arabic Heuristics to the issues reported using Nielsen's Heuristics, the Arabic Heuristics proved more effective in terms of reporting major and catastrophic issues. These types of issues, if not discovered and addressed properly, can cause large-scale failures and can result in unsatisfactory performance levels.

Although the new set of heuristics show promising results in evaluating Arabic interfaces, directions of future work can be identified in that regard. For example, the presented experiment was conducted on three Arabic interfaces (two websites and a desktop application). We believe that applying the new heuristics on other types of Arabic interfaces, such as mobile apps, might bring interesting results to be studied and discussed. We also believe that a study that includes participants with no solid experience in evaluating interfaces to evaluate Arabic ones using the new set of heuristics would develop some interesting research questions that have not explored yet. For example: would the new set of heuristics be effective for Arabic interface designers with little experience in evaluating interfaces. Some studies showed that Hofstede's model of culture [15] does not fully reflect the design characteristics of Arabic interfaces [44], whereas other studies [14] used Hofstede's model to identify Arab users' preferences. Therefore, we believe there is a future need of further studies that consider Hofstede cultural dimensions such as power distance, masculinity, and uncertainty avoidance in the design and evaluation of Arabic user interfaces. Another direction of future work would be seen in mapping the new set of heuristics into a list of more detailed checklist items. Some work have been reported in such mapping where Nielsen's heuristics were mapped into checklists for several types of interfaces. We believe this might bring interesting results if performed for Arabic Heuristics, making it easier for non-experts to have a preliminary evaluation of Arabic interfaces. We also believe that it is necessary to perform more instances of the proposed experimental study to generalize the presented results. In conclusion, we strongly believe that more work should be done to support and evaluate RTL and Bidirectional Interfaces and the Arabic Heuristics introduced in this paper are means of conducting Heuristic Evaluation on aforementioned interfaces with large probability of catching most usability issues when conducted by a fair number of experts/evaluators.

REFERENCES

- [1] R. Khalaf, "Bridging the Arabic Language Gap on the Web," *The Edge, Qatar Business Magazine*, 2013.
- [2] A. Adel, "ArabNet Summit Sees Growth in Arabic Apps," *Albawaba Business*, 29 March 2012.
- [3] P. M. Lewis, *The Ethnologue: Languages of the World*, 18th ed., SIL International, 2015.
- [4] J. Eltantawy and N. Wiest, "Mediatization in the Arab World: A Cross-Cultural Comparison of New Media Use," *Journal of Communication and Media Technologies*, vol. 5, no. 2, pp. 120-142, 2015.
- [5] T. Clemmensen, "Usability Problem Identification in Culturally Diverse Settings," *Information Systems Journal*, vol. 22, no. 2, pp. 151-175, 2012.
- [6] S. N. Zawati and M. Muhanna, "Arabic Mobile Applications: Challenges of Interaction Design and Development," in *Proceedings of the 9th IEEE International Conference on Wireless Communications and Mobile Computing (IWCMC)*, Nicosia, Cyprus, 2014.
- [7] N. Albalooshi, N. Mohamed and J. Al-Jaroodi, "The Challenges of Arabic Language Use on The Internet," in *Proceedings of the IEEE International Conference on Internet Technology and Secured Transactions*, Abu Dhabi, UAE, 2011.
- [8] H. Hemayssi, E. Sanchez, R. Moll and C. Field, "Designing an Arabic User Interface: Methods and Techniques for Bridging Cultures," *User Experience*, vol. 5, no. 1, pp. 4-9, 2006.
- [9] J. Nielsen, "Noncommand User Interfaces," *Communications of the ACM*, vol. 36, no. 4, pp. 83-99, 1993.
- [10] J. Nielsen and R. Molich, "Heuristic Evaluation of User Interfaces," in *Proceedings of ACM CHI'90 Conference*, Seattle, WA, 1990.
- [11] J. Nielsen, *Usability Inspection Methods*, J. a. M. R. Nielsen, Ed., New York, NY: John Wiley & Sons, 1994.
- [12] K. Baker, S. Greenberg and C. Gutwin, "Empirical Development of a Heuristic Evaluation Methodology for Shared Workspace Groupware," in *Proceedings of the 2002 ACM Conference on Computer Supported Cooperative Work (CSCW'02)*, 2002.

- [13] J. Mankoff, A. K. Dey, G. Hsieh, J. Kientz, S. Lederer and M. Ames, "Heuristic Evaluation of Ambient Displays," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Ft. Lauderdale, FL, 2003.
- [14] N. Khashman, "Intercultural User Evaluation of the Design of Arabic Websites: A Case Study," in *Proceedings of the 9th Annual iConference*, Berlin, Germany, 2014.
- [15] G. Hofstede, *Culture's Consequences: Comparing Values, Behaviours and Organisations Across Nations*, Sage Publications, 2003.
- [16] M. Ramadan, "Evaluating College Students' Performance of Arabic Typeface Style, Font Size, Page Layout and Foreground/Background Color Combinations of E-book Materials," *Elsevier Journal of King Saud University – Engineering Sciences*, vol. 23, no. 1, p. 89–100, 2011.
- [17] A. Almansour, J. Osman and S. Hamido, "Website Usability, Case Study: Shura System," *International Journal of Academic Scientific Research*, vol. 3, no. 4, pp. 1-17, 2015.
- [18] N. Khashman and A. Large, "Arabic Website Design: User Evaluation from a Cultural Perspective," in *Proceedings of the 5th International Conference on Cross-Cultural Design*, Las Vegas, NV, 2013.
- [19] A. Alhussayena, W. Alrasheda and E. Mansora, "Evaluating the User Experience of Playful Interactive Learning," in *Proceedings of the 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015)*, 2015.
- [20] U. T. Alturki, A. Aldraiweesh and A. Kinshuck, "Evaluating The Usability And Accessibility Of LMS "Blackboard" At King Saud University," *Contemporary Issues in Education Research*, vol. 9, no. 1, pp. 33-42, 2016.
- [21] O. Alosaimi and A. Alsumait, "Usability Guidelines for Arab E-Government," *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, vol. 7, no. 12, pp. 3159-3162, 2013.
- [22] M. Benaida, "Developing Arabic Usability Guidelines for E-Learning Websites in Higher Education," University of Salford, Salford, UK, 2014.
- [23] N. Albalooshi, N. Mohamed and J. Al-Jaroodi, "The Challenges of Arabic Language Use on The Internet," in *Proceedings of the IEEE International Conference on Internet Technology*

and Secured Transactions, Abu Dhabi, UAE, 2011.

- [24] M. Abdeen and M. Tolba, "Challenges and Design Issues of an Arabic Web Crawler," in *Proceedings of the 2010 IEEE International Conference on Computer Engineering and Systems*, Cairo, Egypt, 2010.
- [25] A. Yahya and A. Salhi, "Enhancement Tools for Arabic Web Search," in *Proceedings of the IEEE International Conference on Innovations in Information Technology (IIT)*, Abu Dhabi, UAE, 2011.
- [26] K. Majrashi, M. Hamilton and A. Uitdenboger, "Cross-Platform Cross-Cultural User Experience," in *Proceedings of the 30th ACM British Human Computer Interaction Conference*, New York, USA, 2016.
- [27] Y. Ji, J. Park, C. Lee and M.H. Yun, "A usability checklist for the usability evaluation of mobile phone user interface," *International journal of human-computer interaction*, vol. 20, no. 3, pp. 207-231, 2006.
- [28] C. Pribeanu, "A domain-oriented approach in structuring user interface guidelines," in *Proceedings of UIQM Workshop, INTERACT 2005*, Rome, 2005.
- [29] D. Quiñones and C. Rusu, "How to Develop Usability Heuristics: A Systematic Literature Review," *Computer Standards & Interfaces*, vol. 5, no. 2, pp. 89-122, 2017.
- [30] J. Vanderdonckt, "Development milestones towards a tool for working with guidelines," *Interacting with Computers*, vol. 12, no. 2, pp. 81-118, 1999.
- [31] J. Vanderdonckt and C. Farenc, "Tools for working with guidelines," in *International Workshop on Tools for Working with Guidelines*, Biarritz, France, 2000.
- [32] M. Wellie and G. V. d. Veer, "Patterns Languages in Interaction Design: Structure and Organization," in *Ninth IFIP TC13 International Conference on Human-Computer Interaction (INTERACT 2003)*, Zurich, Switzerland, 2003.
- [33] J. Nielsen, "10 usability heuristics for user interface design," NN Group, 1995. [Online]. Available: <https://www.nngroup.com/articles/ten-usability-heuristics/>. [Accessed January 2018].
- [34] D. Pierotti, "Heuristic evaluation-a system checklist," Xerox Corporation, 1995. [Online]. Available: <https://faculty.unlv.edu/thatcher/is485/readings/he-checklist.html>. [Accessed Feb.

2018].

- [35] A. Bastien and D. Scapin, "Ergonomic criteria for the evaluation of human-computer interfaces," INRIA, Roquencourt, France, 1993.
- [36] R. Kamper, "Extending the usability of heuristics for design and evaluation: Lead, follow and get out of the way," *International journal of human-computer interaction*, vol. 14, no. 3, pp. 447-462, 2002.
- [37] D. Quiñones, C. Rusu, S. Roncagliolo, V. Rusu and C. Collazos, "Formalizing the Process of Usability Heuristics Development," in *Information Technology: New Generations*, 2016.
- [38] C. Ling and G. Salvendy, "Extension of heuristic evaluation method: a review and reappraisal," *Ergonomia IJE & HF*, vol. 27, no. 3, pp. 179-197, 2005.
- [39] C. A. Collazos and R. Gil, "Using Cross-cultural Features in Web Design Patterns," in *Eighth International Conference on Information Technology: New Generations (ITNG)*, Las Vegas, USA, 2011.
- [40] R. Juric, I. Kim and J. Kuljis, "Cross cultural web design: an experience of developing UK and Korean cultural markers," in *25th International Conference Information Technology Interfaces*, Cavtat, Croatia, 2003.
- [41] W. Barber and A. N. Badre, "Culturability: The merging of culture and usability," in *4th Conference on Human Factors and the Web*, New Jersey, USA, 1998.
- [42] S. Khushman, A. Todman and S. Amin, "The Relationship between Culture and E-business Acceptance in Arab Countries," in *Second International Conference on Developments in eSystems Engineering (DESE)*, Abu Dhabi, UAE, 2009.
- [43] A. Marcus, "The Impact of Culture on the Design of Arabic Websites," in *HCI International Conference*, San Diego, CA, 2009.
- [44] N. Khashman and A. Large, "Measuring Cultural Markers in Arabic Government Websites Using Hofstede's Cultural Dimensions," *Lecture Notes in Computer Science*, vol. 6770, no. 1, 2011.
- [45] J. Nielsen and T. Landauer, "A Mathematical Model of the Finding of Usability Problems," in *Proceedings of ACM INTERCHI 1993 Conference on Human Factors in Computing Systems*,

1993.

- [46] A. Woolrych and G. Cockton, "Why and When Five Test Users Aren't Enough?," in *Proceedings of IHM-HCI 2001 Conference*, 2001.
- [47] L. Faulkner, "Beyond the Five-User Assumption: Benefits of Increased Sample Sizes in Usability Testing," *Behavior Research Methods, Instruments, and Computers*, vol. 35, no. 3, pp. 379-383, 2003.