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Exploring user experience in digital libraries through questionnaire and eye-tracking data

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ABSTRACT

In the field of digital libraries, research on user experience is sparse, especially in terms of emotions, impressions, and stimulation evoked by interaction with the digital library. Given the many different methods and tools available for assessing user experience, two questionnaires and eye-tracking were explored to see how each can contribute to understanding user experience in digital libraries. An eye-tracking study with 30 participants was carried out using two digital libraries. Analysis of the questionnaires revealed that overall, one digital library was experienced more positively, with the difference most evident in the hedonic quality. The eye-tracking data revealed different gaze patterns in the two digital libraries, with significant difference in measure values particularly on the search boxes. When eye-tracking was combined with the questionnaire data, several correlations were found, indicating that the search box position and the intuitiveness of the homepage had an impact on the user experience.

1. Introduction

The evaluation of digital libraries typically focuses on usability measures, such as effectiveness, efficiency, and satisfaction. However, an important aspect of attracting and retaining users is not only the performance of the digital library, the user friendliness of its interface, and the value of its collections, but also the overall user experience it provides. Encompassing subjective impressions and aspects such as evoked emotions, engagement, and the user's perception of the system, user experience is proving difficult to measure (Schrepp, Hinderks, & Thomaschewski, 2017a). This is probably why these aspects of user experience have not yet been fully investigated in the context of digital libraries or other bibliographic information systems.

User experience has been studied and evaluated more frequently in several other areas of information and computer science (e.g., system and website design, games, mobile apps) and even in relation to physical spaces and services (e.g., retail, museum visits). However, even in these areas, the existing literature shows not only that there are different understandings of the concept of user experience, but also that it can be studied and measured using many different methods and instruments. Reviews of literature (Bargas-Avilla & Hornbaek, 2011; Maia & Furtado, 2016) identified questionnaires as the prevailing method for collecting user experience data, followed by semi-structured interviews and user observations. Several questionnaires have also gone through the process of standardization and have been used repeatedly in various studies of information systems, websites, search engines, etc. (Díaz-Oreiro, López, Quesada, & Guerrero, 2019). As these questionnaires have already gone through the development and testing phase, they represent an interesting option for user experience research also in digital libraries.

In contrast to surveys that collect self-reported experiences after the interaction, there are methods that attempt to capture user experience during the interaction itself, such as the observation of users' psychophysiological feedback (e.g., skin conductance or EEG) or eye movements. These methods represent an interesting approach to studying user experience, as they do not rely on users' reports, but focus on more objective data collected automatically during the user's interaction with the interface. However, there are also some drawbacks that contribute to the less common use of these methods in user experience research; not only do they require specialized equipment and expert knowledge, but the data collected is also difficult to interpret in terms of user experience measures such as evoked emotions, appeal, or perceived ease of use. Despite the potential difficulties, these methods represent an interesting option for gaining a different insight into the user experience compared to questionnaires. This paper aims to explore the potential of one of these methods - eye-tracking, as the authors believe eye-tracking data, such as gaze fixations, dwell time, or time to first fixation could be useful

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in understanding user experience. The study in this paper tests a combination of eye-tracking and questionnaires to examine what can be learned about user experience in digital libraries using the two selected methods. At the same time, it also aims to investigate whether user experience questionnaires can help in the interpretation of the eye-tracking data or vice versa. With the increasing accessibility of eye-trackers and the growing importance of user experience in digital libraries and other bibliographic information systems, the findings could be used by digital library researchers and practitioners to decide which approach is most useful for their needs. The results also contribute to the body of knowledge on user experience in digital libraries and point to some interesting options for future research that can more rigorously examine the interpretation of eye-tracking data in the context of user experience.

2. Problem statement

Understanding user experience is important for improving digital libraries and for attracting and retaining digital library users. To date, few studies have examined user experience in the context of digital libraries or tested how various existing methods or tools for measuring and exploring user experience can be applied to digital libraries. To explore what insights can be gained about user experience in digital libraries through different methods and how the results of these methods correlate, the present study tests two methods: questionnaires as the most used method that captures user perceptions after the interaction, and eye-tracking as a rarely used method that collects data about user experience through observation during the interaction.

To better understand the potential usefulness of questionnaires and eye-tracking data for evaluating user experience in digital libraries, an eye-tracking study was designed in which each participant worked with two digital libraries and completed a standardized user experience questionnaire after each interaction. The analysis sought answers to three main research questions (RQ):

1. How does the user experience in the two digital libraries differ based on questionnaire data and the eye-tracking data?
2. What insights about user experience in digital libraries can be gained from established questionnaires and what from eye-tracking data?
3. Are there correlations between eye-tracking and questionnaire data that could enable better interpretation of user experience in the two digital libraries?

3. Literature review

3.1. The concept of user experience

Based on the use of the term "user experience" in human-computer interaction literature and beyond, there is no single view of what user experience is (Bargas-Avila & Hornbaek, 2011; Bevan, 2009; Rico-Olarte, Lopez, & Kepplinger, 2018). In 2011, Bargas-Avila and Hornbaek (as well as some other authors, e.g., Law, van Schaik, & Roto, 2014) identified two distinct uses of the term user experience:

- As a synonym for interaction, usability, and user-centered design, where research focused on the design and use of user interfaces; or
- As an emerging research movement focusing on non-instrumental needs and user experience in a more complex sense.

A review of the existing literature often reveals this duality also in the unclear distinction between user experience and usability. For some authors user experience is an umbrella term that includes usability measures such as effectiveness and efficiency, some authors see user experience as part of the satisfaction aspect of usability, and some authors view the concept of user experience as distinct from usability, focusing on the user's perceptions and reactions that occur before, during, and after interacting with the system. The latter view is also reflected in the latest version of the standard ISO 9241-210 (*International Organization for Standardization*, 2019), which defines user experience as "person's perceptions and responses that result from the use and/or anticipated use of" a system", where "users' perceptions and responses include the users' emotions, beliefs, preferences, perceptions, comfort, behaviors, and accomplishments that occur before, during and after use" (p. 4). In this paper, a narrower view has been chosen, following the focus in the ISO standard and standpoints of user experience that emerged in the literature over the years and were summed up by Rico-Olarte et al. (2018, p. 547):

- User experience focuses on the "fuzzy quality attributes of experience such as enjoyment, pleasure or fun", thus extending (or exceeding) usability.
- User experience goes beyond task completion and encompasses two main dimensions for measuring it – a pragmatic quality and a hedonic quality.
- User experience emphasizes the user's emotions, motivations, and actions. It is subjective in its nature and focuses on how users feel about the product and their interaction.
- User experience evaluation is of interest for the evaluation of the final product, but also plays an important role in the design phase.

To study and evaluate user experience, it is necessary to first understand the different aspects (also called constructs, dimensions, components) of user experience. Probably most well-known are the models of Hassenzahl (2005) and Thüring and Mahlke (2007), which make a general distinction between the perceived pragmatic (or instrumental) quality of the system (perception of effectiveness, usefulness) and the perceived hedonic (or non-instrumental) qualities (fun, enjoyment, evoked emotions, identification etc.). Both pragmatic and hedonic qualities affect the user's emotional responses (subjective feelings, motor expressions, physiological reactions) and lead to the user's overall judgement and future use of the system. Therefore, to understand user experience in digital libraries, it is necessary to understand how digital library users perceive the pragmatic and especially the hedonic qualities of digital libraries and what emotions result from their interactions.

3.2. Methods for evaluating user experience

As there are many different aspects and contexts of user experience, questions arise about the extent to which it is possible to measure and evaluate user experience (Law et al., 2014) and what methods are best suited to capture the subjective nature of the experience (Partala & Kallinen, 2012). Besides the choice of methods, Maia and Furtado (2016) point out some other considerations in the design of user experience studies such as the use of a single method or a combination of methods, the moment of data collection (before, after, or during the interaction), the type of environment (real world, controlled), and the automation of data collection (manual, automatic, mixed).

While a variety of methods, instruments, and tools have been used and developed in user experience research (Maia & Furtado, 2016; Vermeeren et al., 2010), a systematic review by Díaz-Oreiro et al. (2019) shows a growing trend toward the use of standardized questionnaires as instruments for measuring user experience. The authors found as many as 112 studies using AttrakDiff, UEQ, or meCUE questionnaires in 2018 alone, and a long tail of other methods to complement the user experience questionnaires. However, self-reported or subjective data are often described not only as unreliable (especially for small samples) but also lacking information that is important for understanding user experience (Yao et al., 2014). Research, for example, shows that when interacting with an interface, aesthetic reactions (an important aspect of user experience) are formed within the first 50 milliseconds of viewing a stimulus (Lindgaard & Dudek, 2002). At such a short duration, user's

perceptions happen unconsciously. In fact, Guan, Lee, Cuddihy, and Ramey (2006) reported that when comparing eye-tracking data with self-reported data about what elements users saw on the page, they mentioned only half of the elements they actually looked at. This illustrates that self-reported data can be unreliable and does not necessarily give a complete insight into the user experience. It also suggests that other, more unbiased methods might give a different insight into user experience. In fact, physiological measures, such as galvanic skin response, have already been used in user experience studies as a complementary method to investigate cognitive effort and emotional arousal, and seek correlations with questionnaire data (Yao et al., 2014). Another method that has been used in user experience research (Gerea & Herskovic, 2015; Maia & Furtado, 2016) and provides an interesting contrast to self-reported data and physiological data is eye-tracking. Yao et al. (2014) also suggest using a combination of physiological methods and eye-tracking in user experience research to identify the problems users face in their interaction and how they react to them.

3.3. Eye-tracking and user experience

Compared to physiological methods that are best at detecting emotion and cognitive involvement, eye-tracking technology is typically used to observe what attracts user's attention and examine user's behavior. However, some research has already been done on emotion recognition using eye-tracking data (Lim, Mountstephens, & Teo, 2020). de Lemos, Sadeghnia, Olafsdotir, and Jensen (2008) proposed a system for measuring emotions using pupil size, blink properties, and gaze as cues to detect positive or negative emotions evoked when viewing visual stimuli. Wu, Liu, Tsai, and Yau (2019) combined eye-tracking and electrodermal activity for predicting search satisfaction and found that the horizontally stretched fixations (x axis) imply higher satisfaction with the content being viewed. A few studies also investigated correlations between the state of confusion and eye-tracking measures using machine-learning models. Salminen et al. (2019) tried to predict confusion using fixation quantity, duration, accuracy, and position, while Lalle, Conati, and Carenini (2016) did something similar by measuring gaze patterns, pupil width, head distance from the screen, and mouse events.

But most often, investigation of people's eye movement behavior is used by researchers to gain an understanding of where people look, for how long, and what paths their eyes follow. Because the data is obtained automatically with an eye-tracking device, objectivity is considered one of the biggest advantages of eye-tracking, especially when compared to self-reported data. Schall and Romano Bergstrom (2014) also emphasize the ability of eye-tracking to provide insight into the entire user experience, "even that which users cannot describe" (p. 3). The latter is probably an important limitation of methods such as diary studies (e.g., Salazar, 2016) or concurrent think-aloud, in which participants are asked to describe their experience while interacting with the system. Such user accounts can provide deeper insights into users' perceptions and emotions, but they also interfere with the interaction and thus affect the user experience itself. In that regard, eye-tracking presents a less invasive method to gather data during the interaction itself.

However, a review of the existing literature shows that there have not been many attempts to combine user experience questionnaires with eye-tracking data. Djamasbi, Siegel, Skorinko, and Tullis (2011) used a combination of the two methods and found that users had a significantly higher number of fixations (i.e., cognitive effort) when viewing pages, they rated as less appealing. They also concluded that the least appealing websites all lacked a prominent central focal point. Mahardika, Wibirama, Ferdiana, and Kusumawardani (2018) used a combination of eye-tracking and User Experience Questionnaire (UEQ) (the same questionnaire employed in this study) to overcome the limitations of using only questionnaires and confirm users' self-reported experiences with objective measurements. They analyzed eye-tracking data and the UEQ separately and showed that the results of both methods were consistent. The UEQ questionnaire was also used by Kusumo and Hartono (2019), who were unable to demonstrate correlations between the UEQ and eye-tracking data and suggested further research.

While the literature is rich with studies using eye-tracking, there are also certain limitations to eye-tracking: it remains expensive and time-consuming, it requires appropriate technology and expertise not only to conduct the test but also to analyze and interpret the data, and it can also be considered more intrusive than traditional methods (Sykes et al., 2010). Some authors also point out that the correlations between eye movements and measures such as task performance may not be as straightforward as has often been suggested in the literature (Groen & Noyes, 2010).

3.4. Eye-tracking in digital libraries

Eye-tracking has rarely been used specifically to study digital libraries. Potentially useful in the context of digital libraries are the findings of eye-tracking studies made in the broader field of library and information science, where eye-tracking has been used to identify usability problems and study user behavior in information retrieval (e.g., Athukorala, Glowacka, Jacucci, Oulasvirta, & Vreeken, 2016; Bhattacharya & Gwizdka, 2019; Kules, Capra, Banta, & Sierra, 2009; Liu, Thomas, Bacic, Gedeon, & Li, 2017; Mikkonen & Vakkari, 2016). Also relevant to digital libraries is a study of user behavior in image search result lists, which explored the relationship between fixation duration, relevance judgement, and clicks on an object and concluded that longer examination of the object correlated strongly with relevance of the object (Xie et al., 2017).

Probably the best-known use of eye-tracking in digital libraries is the evaluation of Europeana, where the method has proved valuable for gaining insights into user interactions, search behavior and usability issues (Dobreva et al., 2010; Sykes et al., 2010). Balatsoukas (2012) concludes that eye-tracking could inform the design and development of digital libraries and can be useful as *"it records behavioral data that cannot be captured by other traditional techniques (such as data logs and screen-recording software)"* (p. 102). In addition to the Europeana study, eye-tracking has occasionally been used in other studies of bibliographic information systems to investigate specific parts of the user interface such as faceted navigation (Kemman, Kleppe, & Maarseveen, 2013; Kules & Capra, 2012) and to gain insights into search behavior and metadata use (Carevic, Lusky, Van Hoek, & Mayr, 2018; Vakkari, Luoma, & Pöntinen, 2014). However, in all cases, eye-tracking data was mainly used to identify and understand potential problems with specific parts of the user interface and not from a user experience perspective.

3.5. Digital libraries and user experience

Hedonic qualities and evoked emotions have often been overlooked in the evaluation of digital libraries. Over the past decade, several authors have pointed out that traditional usability metrics such as effectiveness, efficiency, and even satisfaction fail to provide a comprehensive understanding of the user experience needed for digital library development or the assessment of the value of digital libraries (Appleton, 2016; Barifah, Landoni, & Eddakrouri, 2020; Massis, 2018). A promising paper reporting on the development of a Digital Library User Experience Scale (DLues) was published back in 2004 (Toms, Dufour, & Hesemeier, 2004). The scale comprised of nine indicators such as visual appeal, entertainment, escapism, intrinsic enjoyment, excellence, and novelty. However, no further publications followed, and the scale was not published online to be tested by other researchers.

Recently, a study by Barifah et al. (2020) used the user experience framework as a starting point for evaluating digital libraries and compared the insights gained using different user-centered methods. The authors concluded that the user experience framework can be used to design better user experience experiments for digital libraries and suggested the use of tools such as the "pick-a-mood" scale for

investigating emotions before and after the interaction and the "honeycomb" model for evaluating seven user experience dimensions: usefulness, usability, desirability, findability, accessibility, credibility, and value. The authors of this paper continue the work of Barifah et al. (2020) by using the user experience framework to explore emotions, pragmatic and hedonic aspects of user experience, and user behavior in digital libraries using a combination of two methods.

4. Methodology

4.1. Data collection

The study was conducted in May and June 2019, using a convenience sample of 30 participants (16 female and 14 male), all students of different study programs at the Faculty of Arts, University of Ljubljana. All sessions were recorded using Tobii eye tracker to follow participants' gaze patterns and interactions.

Two digital libraries containing a range of cultural heritage objects, from written texts to photographs, were selected for the experiment: Europeana, a well-known international digital library, and dLib, a national digital library. Both are multimedia platforms, providing access to digitized as well as born-digital content, including images, text, maps, audio, and video material. Both also create thematic virtual collections, available for browsing. After inspecting the two digital libraries, the task was selected; participants were to explore the collection and find a photograph of their choice depicting World War I (WWI). At the time of the study, both digital library homepages offered options also for browsing WWI photos. These browsing categories were positioned similarly in both libraries, while other elements, such as the search box, were positioned differently.

The study was designed as a within-subject experiment in which each participant completed the given task using both digital libraries. A counterbalanced measures design was used in which participants were alternately assigned libraries in different orders to compensate for the experience and knowledge bias for the second system used. After completing the task in each system, participants were presented with a questionnaire asking them to report on their user experience with the digital library being tested and to provide information about their previous experience with the system.

Participants took an average of 78 seconds (median 39.5) in Europeana and 89 (median 73) seconds in dLib to complete the search task. Despite the fact that both digital libraries are relatively well-known, this was the first interaction with Europeana for almost all participants (29 out of 30) and the first interaction with dLib for more than half of the participants (17 out of 30).

4.2. Instruments

Since no established questionnaires were found that were specifically tailored to study user experience in digital libraries, it was decided to test existing instruments for interactive products and websites that are general enough to be applicable to digital libraries. Among several questionnaires focusing on user experience, a short version of the User Experience Questionnaire – UEQ-S (Schrepp, Hinderks, & Thomaschewski, 2017b) and the Emotion word prompt list – EWPL (Petrie & Precious, 2010) were selected. A combination of both instruments was used to capture into the core concepts of user experience: hedonic and pragmatic perceptions of the system (UEQ—S) and emotions evoked during and after the interaction (EWPL). Because participants completed the questionnaires after each interaction, the short UEQ version was chosen as the long version could lead to frustration and reduce the quality of participants' responses. The original UEQ scale consists of 26 items, while the short version includes only 8 items: 4 for pragmatic quality and 4 for hedonic quality. Each item represents a pair of terms with opposite meanings (i.e., semantic differentials) and participants rate each item on a 7-point scale, for example:

obstructive	o o o o o o o	supportive
complicated	o o o o o o o	easy

Unlike UEQ, EWPL has not been extensively used. While there are several tools available for eliciting users' emotions, the authors have opted for EWPL as the list has been constructed using emotional think-aloud technique for websites. The EWPL authors suggested that the list could be effectively used as a rating scale after an interaction with a website. The list consists of 16 items or emotion words: 9 with positive valence, 6 with negative valence, and one ambiguous. For each word the user estimates the intensity of the emotion from 1 (low) to 7 (high).

The Tobii pro X3–120 eye tracker was used for the eye-tracking part of the study. The screen resolution was set to 1600 × 900 pixels, the sampling frequency was 60 Hz, and the minimum fixation duration was set to 60 milliseconds.

4.3. Analysis

Analysis of the data collected through questionnaires and statistics on both sets of data was performed using SPSS. Additional analyses of the UEQ-S were performed using a data analysis tool available free of charge at https://www.ueq-online.org/. For eye-tracking data, Tobii Pro Studio software was used to process the data and to create Areas of Interest (AOIs) on specific elements of the digital library (e.g., search box, browsing categories, logo) needed to generate measurements for each element. The following measures have been taken into consideration:

- *Number of users who fixated* is a measure of target findability/noticeability. A higher number indicates a good positioning of the element on the website.
- *Number of fixations before* is an indicator of search efficiency. It indicates the noticeability of the target, but it is recommended to be presented alongside number of users who fixated.
- *Total number of fixations*, where a higher number represents more interest in the stimuli and a bigger amount of information extracted from it.
- *Time to first fixation* (in seconds) is a measure of target noticeability. Faster time shows better attention-grabbing properties of the target.
- *Dwell time* (in seconds) is a duration measure, related to AOIs. Longer times indicate increased cognitive functions triggered by that area and possible difficulty in information processing.
- *Total visit duration* (in seconds) indicates time spent on task. Longer time can indicate difficulties in solving the task.
- *Time to first click* (in seconds) is not an eye-tracking measure, but it is included as it is also a measure of target recognizability in connection to time to first fixation.

The above definitions are based on Bojko (2013), Duchowski (2007), Holmqvist et al. (2011), Poole and Ball (2005).

For RQ1, the researchers compared all questionnaire results and eye-tracking observations for the two digital libraries. Where possible, *Mann-Whitney U* tests, suitable for comparing groups without the assumption of normality, were conducted to test the differences between dLib and Europeana scores. For RQ2, both questionnaires and eye-tracking data were analyzed using descriptive statistics to examine what information their results provide on user experience. For RQ3, Spearman's rank-order correlation coefficient was used to analyze the relationships between the eye-tracking data and the questionnaire results. Here the results for the two digital libraries were merged.

5. Results

5.1. Questionnaire results

The intensity of emotions reported by participants after their

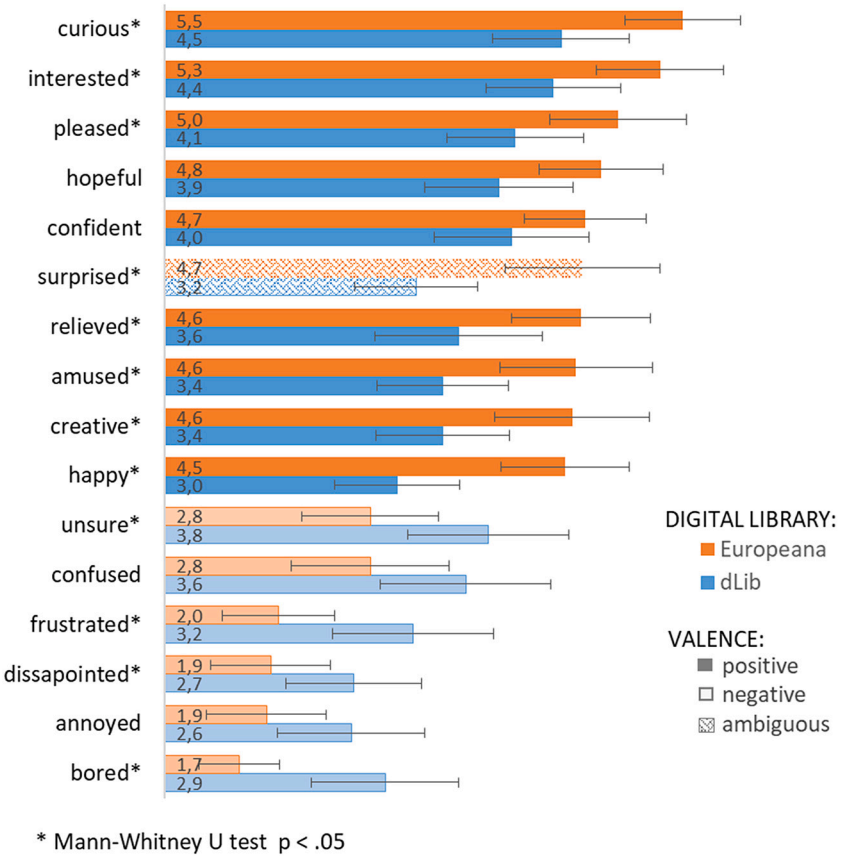

Fig. 1. EWPL mean scores for Europeana and dLib (1 = lowest, 7 = highest intensity).

interaction (Fig. 1) clearly shows that Europeana evoked stronger positive emotions as well as less intense negative emotions. dLib, on the other hand, left participants feeling more frustrated, bored, as well as unsure after their interaction, so much so that some negative emotions were felt more intensely than certain positive emotions. The differences in expressed emotions between the two digital libraries were significant for most of EWPL emotion words, suggesting that Europeana provided a more positive user experience. This is also expressed in the intensity of positive emotions: The mean scores of positive emotion words for dLib barely reach the average intensity at 4.0, while for Europeana the mean scores for all positive emotion words extend well past average intensity. Overall, EWPL results show that participants reported curiosity (M = 5.00, SD = 1.56) and interest (M = 4.87, SD = 4.87) as the most intensely felt emotions when interacting with digital libraries, while negative emotions such as boredom (M = 2.31, SD = 1,45), annoyance (M = 2.28, SD = 1.58), or disappointment (M = 2.29, SD = 1.50) were

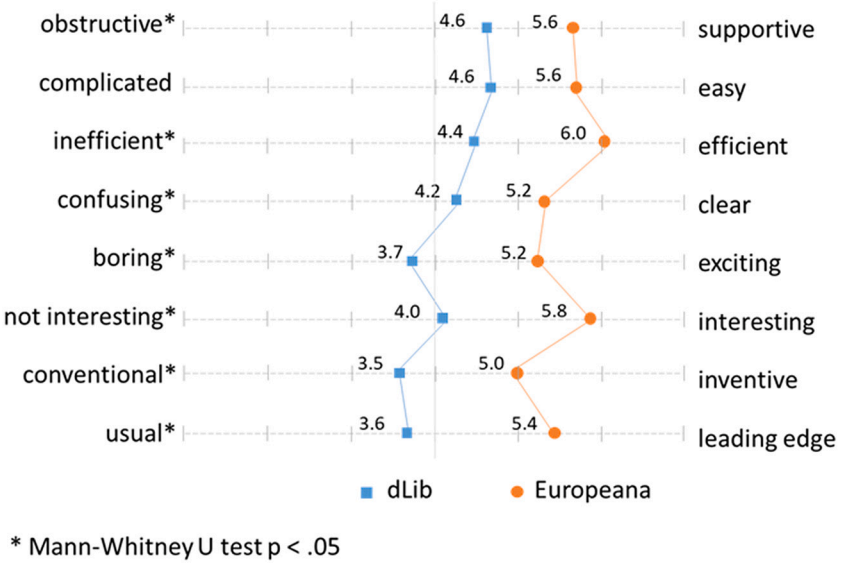

Fig. 2. UEQ-S mean scores for dLib and Europeana.

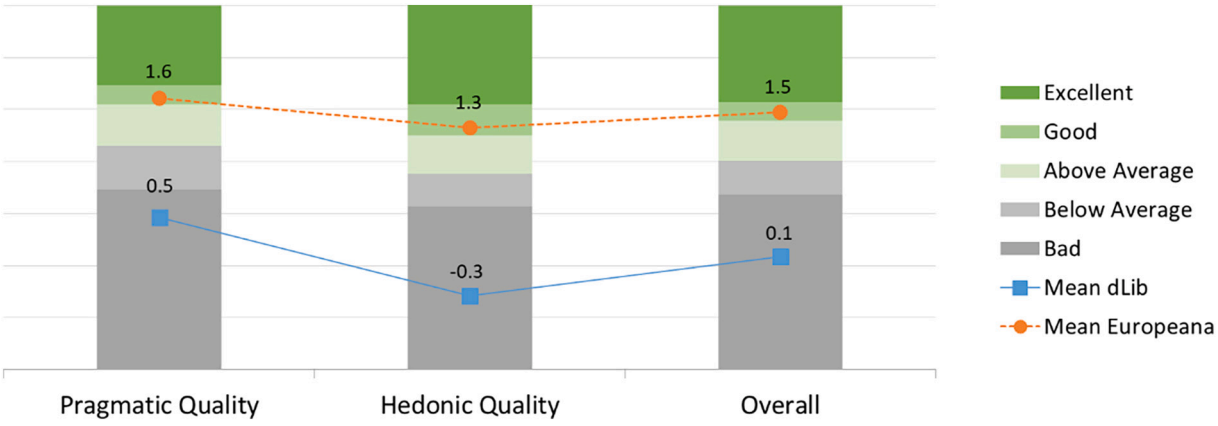

Fig. 3. Benchmark pragmatic and hedonic quality UEQ-S scores for dLib and Europeana.

Table 1
Comparison of UEQ-S mean scores based on the order of interaction.

	order	dLib		Europeana	
	1st	5.3		5.1	
Obstructive – supportive	2nd	3.9	↓	6.1	↑
	1st	4.9		5.6	
Complicated – easy	2nd	4.3	↓	5.7	↑
	1st	4.9		5.7	
Inefficient – efficient	2nd	4.0	↓	6.3	↑
	1st	4.7		4.5	
Confusing – clear	2nd	3.7	↓	5.9	↑
	1st	4.1		4.7	
Boring – exciting	2nd	3.3	↓	5.7	↑
	1st	4.5		5.3	
Not interesting – interesting	2nd	3.5	↓	6.2	↑
	1st	3.3		4.5	
Conventional – inventive	2nd	3.7	↑	5.5	↑
	1st	4.2		5.0	
Usual – leading edge	2nd	3.0	↓	5.7	↑

rated as least intense by participants.

The results of the UEQ-S questionnaire show the perception of the hedonic and the pragmatic qualities. Observing the overall scores, participants recognized digital libraries as relatively efficient (M = 5.20, SD = 1.61), easy to use (M = 5.13, SD = 1.81), and supportive (M = 5.08, SD = 1.63). Also here, significant differences can be observed between the two digital libraries (Fig. 2): dLib was rated quite neutrally, while Europeana received high positive scores in all elements. It stands out that the participants saw Europeana as much more interesting ($U = 170.500$, $p < .001$), leading edge ($U = 208.500$, $p < .001$) and efficient ($U = 213.000$, $p < .001$).

The perceived characteristics of the two systems can also be explored using the UEQ-S analysis tool. It shows that the biggest difference between the two digital libraries according to UEQ-S scores lies in the hedonic qualities of the system (Fig. 3). The tool also provides benchmarking by comparing the two systems to the results of numerous other tests. This puts the results in a broader perspective, rating the Europeana scores as good and above average, while dLib scores as below average and poor.

Further analysis also revealed that interaction with two systems influenced on participants' experiences in a particular way. In both questionnaires, dLib mostly received lower scores when it was interacted with second (after Europeana) than when it was interacted with first (example of scores for UEQ-S in Table 1). In contrast, Europeana received higher scores when it was displayed second (after dLib) than when it was interacted with first. Even at the first interaction, the scores for Europeana were slightly better than scores for dLib, but the differences were not significant. However, for the second interaction, there is a large difference between the scores for dLib and Europeana scores. This finding shows how much the user experience, also in the context of digital libraries, depends on the users' expectations and their previous experiences.

All in all, the results of the two questionnaires show that the participants assessed their interaction and the digital libraries as relatively positive, but the experience was better in Europeana than in dLib.

5.2. *Eye-tracking results*

Being able to quickly navigate the homepage and proceed with the task at hand is one of the most important factors in building positive user experience. Therefore, various eye-tracking measures were considered to assess the intuitiveness of the two digital library homepages. To successfully complete the task, participants could either use a search box or the relevant browsing category. Overall, participants fixated on the relevant browsing categories only in 25 out of 60 interactions, while

Table 2
Comparison of selected eye-tracking measures for Europeana and dLib with results of Mann-Whitney U test.

Eye-tracking measures			Europeana	dLib	*U*	*p*
SEARCH BOX ($n = 48$)	Number of fixations before	Mean	0.8	8.0	134.000	0.001 **
	Time to first fixation (s)	Mean	2.4	5.9	142.500	0.003 **
	Total number of fixations on	Mean	11.3	10.3	267.000	0.672
	Dwell time on (s)	Mean	2.6	2.1	248.500	0.420
	Users who fixated on	Number	25	23	–	–
RELEVANT BROWSING CATEGORY ($n = 25$)	Time to first fixation (s)	Mean	5.7	15.5	35.580	0.757
	Users who fixated on	Number	13	12	–	
HOMEPAGE ($n = 60$)	Time to first click (s)	Mean	6.1	7.3	359.500	0.181
	Total number of fixations	Mean	34.2	38.3	430.500	0.946
OVERALL ($n = 60$)	Total number of fixations	Mean	206.3	245.7	318.000	0.076
	Total visit duration (s)	Mean	78.0	89.1	338.000	0.098
		Median	39.5	73.0		

** Statistically significant at $p < .01$.

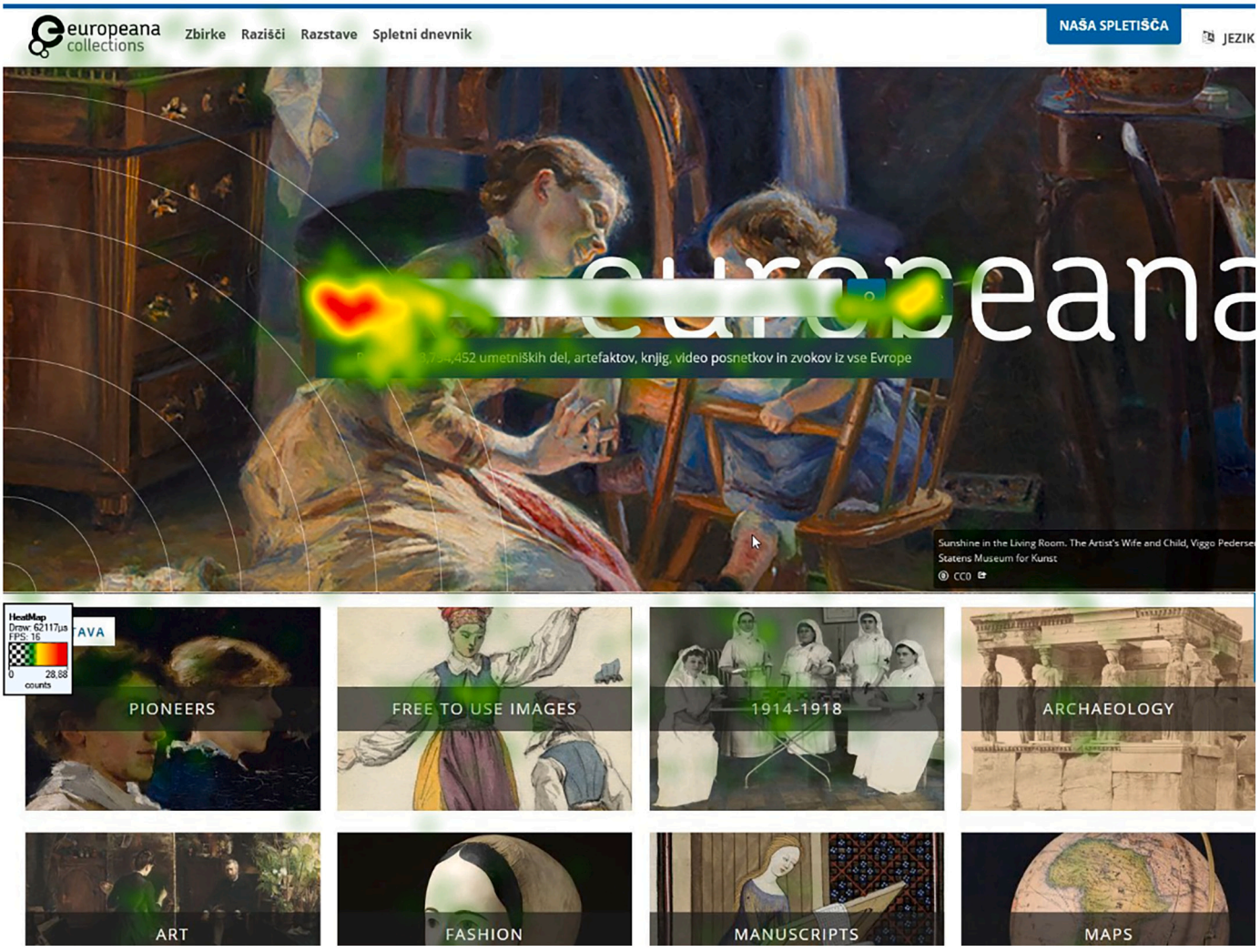

Fig. 4. Heatmap of Europeana homepage.

fixation on the search box was detected in 48 interactions. Comparison of the eye-tracking data in Table 2 shows that statistically significant differences (*Mann-Whitney U* test, $p < .01$) in the interaction with Europeana and dLib happened in the search box area. In Europeana, participants located and fixated on the search box faster. Interestingly, the differences between the two libraries were not significant for the average total number of fixations on the homepage and during the entire task or the average total visit duration. However, a close examination revealed a discrepancy between the median values of total visit duration.

The characteristics of user interaction with the digital libraries are also visible in heatmaps that visualize users' attention based on the number of fixations. Comparison of Figs. 4 and 5 shows that in dLib homepage the gaze was somewhat more distributed among the various elements that the participants inspected, while in Europeana the centrally positioned elements (search box, text, search icon, background image) attracted most of the attention. This information adds to the insights provided by eye-tracking measures in Table 2 and enables a clearer picture of which elements on the homepage were actually inspected by participants. Overall, both heatmaps show that participants paid very little attention to the images displayed on both homepages, which is probably characteristic for an interaction with a specific task at hand.

5.3. Comparison of eye-tracking and questionnaire results

To answer the third research question, researchers explored possible correlations between eye-tracking and self-reported data that could help interpret the results of the two methods in the context of user experience. Using Spearman's correlation coefficient, several weak to moderate correlations were found between the combined data for the two digital libraries (Table 3):

- Users who needed more time to first fixation on the search box felt more confused and unsure, as well as less curious, creative, happy, interested, and pleased according to the EWPL questionnaire. They also rated the system as less interesting and less cutting edge in the UEQ-S questionnaire.
- Among users who focused on the relevant browsing categories, there were moderate correlations between stronger feelings of confusion, disappointment, and uncertainty and the time it took them to make the first fixation on the relevant browsing category. Those who needed more time to do so also felt less curious and perceived the digital library as more difficult to use. Interestingly, a longer dwell time on the relevant browsing categories contributed to higher scores in UEQ-S elements supportive, exciting, and interesting.
- The longer it took users to make their first click on the homepage, the more unsure they felt.

Fig. 5. Heatmap of dLib homepage.

Table 3
Significant correlations between eye-tracking observation and questionnaire data.

Eye-tracking observations	Questionnaires							
	EWPL				UEQ-S			
		n	r_s	*p*		*n*	r_s	*p*
TIME TO FIRST FIXATION on search box ↑	confused↑	48	0.31	0.031*	interesting ↓	48	−0.30	0.038*
	unsure ↑	48	0.29	0.045*	cutting edge ↓	48	−0.29	0.047*
	curious ↓	48	−0.35	0.016*				
	creative ↓	48	−0.34	0.019*				
	happy ↓	45	−0.35	0.018*				
	interested ↓	48	−0.32	0.029*				
	pleased ↓	48	−0.33	0.024*				
TIME TO FIRST FIXATION on relevant browsing element ↑	confused ↑	25	0.41	0.041*	easy ↓	25	−0.50	0.011*
	disappointed ↑	25	0.49	0.014*				
	unsure ↑	25	0.42	0.037*				
	curious ↓	25	−0.44	0.029*				
TOTAL DWELL TIME on relevant browsing element ↑					supportive ↑	25	0.50	0.031*
					exciting ↑	25	0.61	0.005*
					interesting ↑	25	0.50	0.030*
TIME TO FIRST CLICK on homepage ↑	unsure ↑	60	0.29	0.023*				
TOTAL NUMBER OF FIXATIONS ↑	frustrated ↑	57	0.44	0.001*	supportive ↓	60	−0.27	0.039*
	disappointed ↑	57	0.27	0.042*				
TOTAL TASK DURATION ↑	frustrated ↑	58	0.39	0.003*	clear ↓	60	−0.29	0.025*
	unsure ↑	60	0.27	0.038*				

* Correlation is significant at the 0.01 level (two-tailed).

- When the number of total fixations during the task was higher, users reported higher levels of frustration and disappointment. They also perceived the system as less supportive.
- Users who needed more time to complete the task felt more frustrated and unsure and found the system to be less clear.

An interesting observation is that the perceptions of digital libraries that correlate with total task duration fall into the pragmatic aspect of the user experience, while the time to first fixation on the search box and dwell time on browsing elements seem to influence the hedonic aspect of the user experience.

6. Discussion

The first research question focused on comparing the user experience in the two digital libraries using questionnaire results and eye-tracking data. The results of two questionnaires show that one of the two tested digital libraries clearly provided a more positive user experience, which was expressed by stronger positive emotions and less intense negative emotions, as well as more positive perceptions of pragmatic and hedonic quality. A clear indicator of a positive user experience in Europeana were also higher pragmatic and hedonic scores after an interaction with a similar digital library dLib. Eye-tracking data helped identify a more dispersed attention on the homepage of one digital library (dLib), which was probably caused by the (un)intuitiveness of the homepage and especially the position of the search box. Although the participants needed about the same amount of time to complete the task, the eye-tracking results showed that the two digital libraries elicited different interactions, especially in the participants' first steps when they started the search. Comparisons of the eye-tracking data showed that the main differences between the two digital libraries were related to the search box, the time needed to fixate on it and the number of fixations made before that. The results of this analysis have practical implications and show that the tested methods can be useful for comparison of user experience in different digital libraries or versions of the same digital library.

The second research question explored what insights into the user experience in digital libraries each of the tested methods provided. Results of the questionnaires show that participants felt positive about their interaction, but a more interesting finding is that curiosity and interest were the prevailing emotions in both digital libraries. A useful insight was also gained by looking at the intensity of negative emotions, where uncertainty and confusion were highlighted for one digital library that also scored lower in the perception of hedonic and pragmatic qualities of the digital library. Thus, the combination of the two questionnaires revealed the intensity of positive and negative emotions experienced during or after the interaction, as well as users' perceptions of the hedonic and pragmatic qualities of the tested digital libraries. However, questionnaires did not provide an explanation as to why users felt a certain way about the system or what features of the system elicited negative or positive experiences. The eye-tracking data, on the other hand, provided information about user interaction and behavior, but only indirectly gave some indication of their user experience. Heatmaps showed that in one digital library, the attention on the homepage was more dispersed and in the other digital library it was completely focused on the search box. This might be interpreted in different ways, digital libraries might want to encourage users to look at different elements on the homepage and browse and the high number of fixations could be a sign user's interest, but sometimes the dispersion is a sign of confusion as the user is trying to identify the access point needed. Following the findings of previous studies (Djamasbi et al., 2011), a higher fixation count in dLib and the lack of a prominent central focal point revealed in heatmaps could also mean that this digital library is less visually appealing, which is an important factor in the hedonic quality of the user experience. Most of the quantitative eye-tracking measures for selected areas of interest are therefore best interpreted when compared to other collected data.

Connecting the results of the two methods to better interpret the collected data in the context of user experience was the main motivation behind the third research question. Overall, both methods showed some significant differences between the two digital libraries. Both methods were also consistent in the results that highlighted Europeana as the digital library that elicited a more positive user experience. Like a study by Mahardika et al. (2018), the given study found a correlation between higher UEQ scores and users' ability to find visual objects of interest more quickly. However, analysis of the data collected in this study detected some correlations between the eye-tracking data and the questionnaire results that offer potential new insights into user experience in digital libraries and help make interpretations that were not possible with just one method. As demonstrated in Table 3, the interactions associated with the start of the search could have influenced how users felt about and perceived the tested digital libraries. A more detailed analysis further indicated that participant's ability to quickly identify a starting point, especially the search box, and the intuitiveness of the home page were particularly reflected in less positive emotions and stimulation, as well as in the perceptions of the originality of the digital library. Thus, the start of a search seems to have influenced the perceptions of the hedonic, but not the pragmatic qualities of the system, as one might expect. Interestingly, the time needed to complete the task was less influential and these represented the pragmatic (but not the hedonic) dimension of the user experience.

6.1. Limitations

Although the findings of the study provide some insight into the user experience in digital libraries and can have certain practical, theoretical, and methodological implications, there are shortcomings in the design that limit the validity of the results. As this was an exploratory study, participants performed only one task in each system and while they were free to explore the digital libraries, their interaction was short and gave participants limited opportunity to experience the system. The study also has limitations typical of delegated tasks, which improve the comparability of the data but limit the external validity of the results. It can be assumed that some results (e.g., correlation between time to first fixation on search box and negative emotions) apply only to this study due to the nature of the task and need to be tested in future studies. Sample size was determined based on recommendations for eye-tracking studies (Bojko, 2013; Sauro & Lewis, 2012), but was not ideal for statistical analysis of questionnaire data. Considering these limitations, the study outcomes cannot be generalized, and further studies are needed, especially to explore the relationships between eye-tracking and questionnaire results. Future studies could apply such research questions to a larger, more diverse sample and either track users' natural interaction with the system (based on their queries) or use multiple tasks to enable longer interaction and examine repetitive patterns in user behavior and their experience.

7. Conclusion

User experience is an interesting and important area of research, also (or especially) for digital libraries. It can give an insight into how users perceive and experience their interactions with digital libraries and help identify elements that are important to providing a positive user experience that engages and attracts users. This study presents a case study of three tools for evaluating user experience in digital libraries: a questionnaire focusing on users' emotions, a standardized questionnaire for pragmatic and hedonic aspect of user experience, and an eye-tracking technology. Each of the three tools gave some understanding of the user experience. This was particularly evident when the results for the two digital libraries were compared side by side. Combining the eye-tracking data with self-reported data and looking for correlations also showed potential for a better understanding of the user experience in

digital libraries.

Reflecting on the process, it becomes clear that evaluating the user experience in digital libraries through questionnaires is quite practical for gaining a general overview and idea of the user experience. It was found that the combination of the two questionnaires used in the study worked quite well also for digital libraries, even though they were not specifically designed for this type of system. The two questionnaires could, however, be complemented with questions about the perceived aesthetics of the system, an aspect that was missing in the researchers' interpretation of the results. Compared to questionnaires, eye-tracking represented a much more time-consuming and challenging method, especially for evaluating the user experience. It seems that eye-tracking is most useful in identifying specific problems, especially in the development and user experience design of digital libraries. Combined with questionnaires or other types of self-reported data, it also offers many interesting challenges for academic research on user experience in digital libraries, as demonstrated in this exploratory study. This study presents an initial exploration of user experience in digital libraries, but further studies with different types of tasks, different questionnaires and methods are needed to identify those that are most useful in the context of digital libraries.

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References

Appleton, L. (2016). User experience (UX) in libraries: Let's get physical (and digital). *Insights the UKSG Journal, 29*, 224–227.

Athukorala, K., Glowacka, D., Jacucci, G., Oulasvirta, A., & Vreeken, J. (2016). Is exploratory search different? A comparison of information search behaviour for exploratory and lookup tasks. *Journal of the Association for Information Science and Technology, 67*, 2635–2651.

Balatsoukas, P. (2012). An eye-tracking approach to the evaluation of digital libraries. In M. Dobreva, A. O'Dwyer, & P. Feliciati (Eds.), *User studies for digital library development* (pp. 95–104). Facet.

Bargas-Avilla, J. A., & Hornbaek, K. (2011). Old wine in new bottles or novel challenges? A critical analysis of empirical studies of user experience. In *CHI '11: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2689–2698). ACM.

Barifah, M., Landoni, M., & Eddakrouri, A. (2020). Evaluating the user experience in a digital library. *Proceedings of the Association for Information Science and Technology, 57*, Article e280. https://doi.org/10.1002/pra2.280

Bevan, N. (2009). What is the difference between the purpose of usability and user experience evaluation methods? *Proceedings of the Workshop UXEM'09* (Interact 09). Retrieved from https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.460.6252&rep=rep1&type=pdf.

Bhattacharya, N., & Gwizdka, J. (2019). Measuring learning during search: Differences in interactions, eye-gaze and semantic similarity to expert knowledge. In *CHIIR '19: Proceedings of the 2019 Conference on Human Information Interaction and Retrieval* (pp. 63–71). ACM.

Bojko, A. (2013). *Eye tracking the user experience*. Rosenfeld.

Carevic, Z., Lusky, M., Van Hoek, W., & Mayr, P. (2018). Investigating exploratory search activities based on the stratagem level in digital libraries. *International Journal on Digital Libraries, 19*, 231–251.

Díaz-Oreiro, I., López, G., Quesada, L., & Guerrero, L. A. (2019). Standardized questionnaires for user experience evaluation: A systematic literature review. In J. Bravo, & I. Gonzalez (Eds.), *Proceedings of 13th International Conference on Ubiquitous Computing and Ambient Intelligence (UCAml) 2019*. UCAml, 31(1), 14.

Djamasbi, S., Siegel, M., Skorinko, J., & Tullis, T. (2011). Online viewing and aesthetic preferences of generation Y and the baby boom generation: Testing user web site experience through eye-tracking. *International Journal of Electronic Commerce, 15*, 121–157.

Dobreva, M., McCulloch, E., Birrell, D., Feliciati, P., Ruthven, I., Sykes, J., & Ünal, Y. (2010). User and functional testing: Final report. Retrieved February 22, 2019 from https://www.researchgate.net/publication/265627830_User_and_Functional_Testing.

Duchowski, A. T. (2007). *Eye tracking methodology: Theory and practice* (2nd ed.). Springer.

Gerea, C., & Herskovic, V. (2015). Measuring user experience in Latin America: An exploratory survey. In *CLIHC '15: Proceedings of the Latin American Conference on Human Computer Interaction* (pp. 1–4). ACM. article 19.

Groen, M., & Noyes, J. (2010). Using eye-tracking to evaluate usability of user interfaces: Is it warranted? *IFAC Proceedings, 43*, 489–493. https://doi.org/10.3182/20100831-4-FR-2021.00086

Guan, Z., Lee, S., Cuddihy, E., & Ramey, J. (2006). The validity of the stimulated retrospective think-aloud method as measured by eye tracking. In R. Grinter, T. Rodden, P. Aoki, E. Cutrell, R. Jeffries, & G. Olson (Eds.), *Proceedings of the 2006 Conference on Human Factors in Computing Systems* (pp. 1253–1262). ACM.

Hassenzahl, M. (2005). The thing and I: Understanding the relationship between user and product. In M. A. Blythe, K. Overbeeke, A. F. Monk, & P. C. Wright (Eds.), *Funology: From usability to enjoyment* (pp. 31–42). Springer.

Holmqvist, K., Nyström, M., Andersson, R., Dewhurst, R., Jarodzka, H., & van de Weijer, J. (2011). *Eye tracking: A comprehensive guide to methods and measures*. Oxford: University Press.

Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems. (2019). International Organization for Standardization (ISO Standard No. 9241-210:2019).

Kemman, M., Kleppe, M., & Maarseveen, J. (2013). Eye-tracking the use of a collapsible facets panel in a search interface. In T. Aalberg, C. Papatheodorou, M. Dobreva, G. Tsakonas, & C. J. Farrugia (Eds.), *Research and advanced technology for digital libraries. TPDL 2013. Lecture notes in computer science* (pp. 405–408). Springer.

Kules, B., & Capra, R. (2012). Influence of training and stage of search on gaze behavior in a library catalog faceted search interface. *Journal of the American Society for Information Science and Technology, 63*, 114–138. AAAI Press.

Kules, B., Capra, R., Banta, M., & Sierra, T. (2009). What do exploratory searchers look at in a faceted search interface?. In *Proceedings of the 9th ACM/IEEE-CS Joint Conference on Digital Libraries (JCDL 2009)* (pp. 313–322). ACM.

Kusumo, A. H., & Hartono, M. (2019). The evaluation of academic website using eye tracker and UEQ: A case study in a website of xyz. *IOP Conf. Series: Materials Science and Engineering, 703*(012049), 1–7. https://doi.org/10.1088/1757-899X/703/1/012049

Lalle, S., Conati, C., & Carenini, G. (2016). Predicting confusion in information visualization from eye-tracking and interaction data. In S. Kambhampati (Ed.), *IJCAI-16, proceedings of the 25th International Joint Conference on Artificial Intelligence* (pp. 2529–2535). AAAI Press.

Law, E. L.-C., van Schaik, P., & Roto, V. (2014). Attitudes towards user experience (UX) measurement. *International Journal of Human-Computer Studies, 72*, 526–541. https://doi.org/10.1016/j.ijhcs.2013.09.006

de Lemos, J., Sadeghnia, G. R., Olafsdotir, I., & Jensen, O. (2008). Measuring emotions using eye-tracking. In A. Spink, M. R. Ballintijn, N. D. Bogers, F. Grieco, L. W. S. Loijens, L. P. J. J. Noldus, … P. H. Zimmerman (Eds.), *Proceedings of Measuring Behaviour 2008, 6th International Conference on Methods and Techniques in Behavioral Research*. Noldus (pp. 226).

Lim, J. Z., Mountstephens, J., & Teo, J. (2020). Emotion recognition using eye-tracking: Taxonomy, review and current challenges. *Sensors, 20*. https://doi.org/10.3390/s20082384. Article 2384.

Lindgaard, G., & Dudek, C. (2002). User satisfaction, aesthetics and usability: Beyond reductionism. In J. Hammond, T. Gross, & J. Wesson (Eds.), *Proceedings of the IFIP 17th World Computer Congress* (pp. 231–246). Kluwer.

Liu, Y., Thomas, P., Bacic, M., Gedeon, T., & Li, X. (2017). Natural search user interfaces for complex biomedical search: An eye-tracking study. *Journal of the Australian Library and Information Association, 66*, 364–381. https://doi.org/10.1080/24750158.2017.1357915

Mahardika, W., Wibirama, S., Ferdiana, R., & Kusumawardani, S. S. (2018). A novel user experience study of parallax scrolling using eye-tracking and user experience questionnaire. *International Journal on Advanced Science, Engineering and Information Technology, 8*, 1226–1233.

Maia, C., & Furtado, E. (2016). A systematic review about user experience evaluation. In A. Marcus (Ed.), *International Conference of Design, User Experience and Usability: DUXU 2016* (pp. 445–455). Springer.

Massis, B. (2018). The user experience (UX) in libraries. *Information and Learning Science, 119*, 241–244.

Mikkonen, A., & Vakkari, P. (2016). Finding fiction: Search moves and success in two online catalogs. *Library & Information Science Research, 38*, 60–68. https://doi.org/10.1016/j.lisr.2016.01.006

Partala, T., & Kallinen, A. (2012). Understanding the most satisfying and unsatisfying user experience: Emotions, psychological needs, and context. *Interacting with Computers, 24*, 25–34. https://doi.org/10.1016/j.intcom.2011.10.001

Petrie, H., & Precious, J. (2010). Measuring user experience of websites: Think aloud protocols and an emotion word prompt list. In *Proceedings of the 28th International Conference on Human Factors in Computing Systems* (pp. 3673–3678). ACM.

Poole, A., & Ball, L. J. (2005). Eye-tracking in HCI and usability research. In C. Ghaoui (Ed.), *Encyclopedia of human computer interaction* (pp. 211–219). IGI Global.

Rico-Olarte, C., Lopez, D. M., & Kepplinger, S. (2018). Towards a conceptual framework for the objective evaluation of user experience. In A. Marcus, & W. Wang (Eds.), *International Conference of Design, User Experience and Usability: DUXU 2018* (pp. 546–549). Springer.

Salazar, K. (2016). *Diary studies: Understanding long-term user behavior and experiences*. Nielsen Norman Group. Retrieved April 25, 2022 from https://www.nngroup.com/articles/diary-studies/.

Salminen, J., Nagpal, M., Kwak, H., An, J., Jung, S., & Jansen, B. J. (2019). Confusion prediction from eye-tracking data: Experiments with machine learning. In *ICIST 2019, Proceedings of the 9th International Conference on Information Systems and Technologies* (pp. 1–9). ACM.

Sauro, J., & Lewis, J. R. (2012). *Quantifying the user experience: Practical statistics for user research*. Morgan Kaufmann.

Schall, A., & Romano Bergstrom, J. (2014). Introduction to eye-tracking. In A. Schall, & J. Romano Bergstrom (Eds.), *Eye-tracking in user experience design* (pp. 3–26). Morgan Kaufmann.

Schrepp, M., Hinderks, A., & Thomaschewski, J. (2017a). Construction of a benchmark for the user experience questionnaire (UEQ). *International Journal of Interactive Multimedia and Artificial Intelligence, 4*(4), 40–44. https://doi.org/10.9781/ijimai.2017.445

Schrepp, M., Hinderks, A., & Thomaschewski, J. (2017b). Design and evaluation of a short version of the user experience questionnaire (UEQ-S). *International Journal of Interactive Multimedia and Artificial Intelligence, 4*(6), 103–108. https://doi.org/10.9781/ijimai.2017.09.001

Sykes, J., Dobreva, M., Duncan, B., McCulloch, M., Ruthven, I., Ünal, Y., & Feliciati, P. (2010). A new focus on end users: Eye-tracking analysis for digital libraries. In M. Lalmas, J. Jose, A. Rauber, F. Sebastiani, & I. Frommholz (Eds.), *Research and advanced technology for digital libraries, 14th European Conference, ECDL 2010* (pp. 510–513). Springer.

Thüring, M., & Mahlke, S. (2007). Usability, aesthetics and emotions in human-technology interaction. *International Journal of Psychology, 42*, 253–264. https://doi.org/10.1080/00207590701396674

Toms, E. G., Dufour, C., & Hesemeier, S. (2004). Measuring the user's experience with digital libraries. In *Proceedings of the 2004 ACM/IEEE Joint Conference on Digital Libraries* (pp. 51–52). ACM.

Vakkari, P., Luoma, A., & Pöntinen, J. (2014). Books' interest grading and dwell time in metadata in selecting fiction. In D. Elsweiler, & B. Ludwig (Eds.), *Proceedings of the 5th Information Interaction in Context Symposium (IIIX '14)* (pp. 28–37). ACM. https://doi.org/10.1145/2637002.2637008.

Vermeeren, A., Law, E. L., Roto, V., Obrist, M., Hoonhout, J., & Väänänen-Vainio-Mattila, K. (2010). User experience evaluation methods: Current state and development needs. In A. Blandford, J. Gulliksen, E. T. Hvannberg, M. K. Lárusdóttir, E. L.-C. Law, & H. H. Vilhjálmsson (Eds.), *Proceedings of the Sixth Nordic Conference on Human-Computer Interaction* (pp. 521–530). ACM.

Wu, Y., Liu, Y., Tsai, Y. R., & Yau, S. (2019). Investigating the role of eye movements and psychological signals in search satisfaction prediction using geometric analysis. *Journal of the Association for Information Science and Technology, 70*, 981–999.

Xie, X., Liu, Y., Wang, X., Wang, M., Wu, Z., Wu, Y., … Ma, S. (2017). Investigating examination behavior of image search users. In *Proceedings of the 40th International ACM SIGIR Conference on Research and Development in Information Retrieval* (pp. 275–284). ACM.

Yao, L., Liu, Y., Li, W., Zhou, L., Ge, Y., Jing, C., & Sun, X. (2014). Using physiological measures to evaluate user experience on mobile applications. In D. Harris (Ed.), *Engineering Psychology and Cognitive Ergonomics, 11th International Conference* (pp. 301–310). Springer.

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