

An eye-tracking study of website complexity from cognitive load perspective



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ABSTRACT

Online shopping is becoming one of the most popular applications on the Internet. Websites are the important interfaces in HCI (Human–Computer Interaction). Website design significantly affects online shopping behavior. This research used eye-tracker to track the eye-movement process for 42 college students when they were surfing websites with different levels of complexity and completing simple and complex tasks respectively. The study examines how website complexity and task complexity jointly affect users' visual attention and behavior due to different cognitive loads. The study fills a research gap by examining this phenomenon from the cognitive load perspective and taking the moderate effect of task complexity into consideration. The results show that task complexity can moderate the effect of website complexity on users' visual attention and behavior. Specifically, when users conducted a simple task, fixation count and task completion time were at the highest level on the website with high complexity, while fixation duration was not significantly different on the websites with different complexity. However, when users conducted a complex task on a website with medium complexity, task completion time, fixation count, and fixation duration were all at their highest level. The load theory of attention was used to provide the explanation for the results. The findings provide guidelines for website managers and designers to maximize users' visual attention.

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1. Introduction

With the rapid development of Internet technology, online shopping has become more and more popular. According to data from iResearch (<http://ec.iresearch.cn/shopping/20130128/192198.shtml>), the e-commerce market in China reached \$1330 billion in 2012. The economic benefits of e-commerce are self-evident. Thus, how to improve users' web experience has become a major theme in research labs. Website design is considered to be an important factor that influences users' attitudes and behavior when shopping online [24].

The effect of website complexity on users' attitudes and behavior has gained attention from researchers in recent years [1,6,10–13,29,37,39]. However, there have been different findings about website complexity. It is still unclear about the relationship between website complexity and user experience. Some researchers believe that simple websites are

more effective [1,38] while others think that complex websites increase the richness of information presentation and thereby enhance user satisfaction [32] and positively impact approach behavior for experiential users [6]. Furthermore, some studies show an “inverted U relationship” between website complexity and communication effectiveness [11], and between website complexity and user satisfaction for experiential users [29].

While more and more people choose online shopping, online sellers are eager to find out which kinds of website attract users most. However, what bothers many website designers is that an individual can leave a website very easily. The lack of understanding of the major impediments to users' longer website browsing and deeper exploration presents a substantial problem for designers. Exploring the cognitive process of users during web browsing is critical for website designers to understand user behavior. Although previous studies have proposed an implicit link between website/webpage visual complexity and cognitive complexity or cognitive load, normally the cognitive load can only be defined in concert with the user and task at hand [14]. However, little prior research on website complexity has taken task complexity into consideration, which could cause some of the conflicting findings mentioned above. Task complexity is a function of the amount of task-related information an individual has to process when performing a task [40]. The more information to be processed, the more complex

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the task is. Complex tasks require more cognitive work, such as psychological comparison [19]. So we raised our research question: Are there differences in the effects of website complexity on users' behavior under different levels of task complexity? This study fills a research gap by taking the moderate effect of task complexity into consideration while examining the effects of website complexity and provides a new perspective, cognitive load, to better understand the influence of website complexity and task complexity on users' visual attention and behavior.

To better understand users' attention (eye fixations) and how it relates to their cognitive load, we adopt an eye-tracking technique to conduct this study. Among human physiological parameters, eye movement has the most frequent period of update; as a result, eye-tracking can provide a stream of information about the user's mental state in real time [18,26]. At the same time, eye-tracking is an objective method which can reflect cognitive processing through eye-movement metrics [7]. This study reflects objectively the effect of website complexity on the user's visual attention and behavior under different levels of task complexity by using the eye-tracking data to understand the mechanism of website complexity. The findings of this study are of interest to website managers and designers because they provide guidelines for website design to enhance user experience and retain consumers as long as possible on their websites.

The structure of this paper is as follows. In Section 2, we review relevant literature about website complexity and task complexity, eye-tracking and its application to website design, and cognitive load theory. In Section 3, we propose the theoretical hypotheses. The research methodology including measurement and experimental procedure is described in Section 4. Data analysis and results are presented in Section 5. Finally, we conclude with a summary of the results, contributions and limitations, and directions for future research.

2. Theoretical background

2.1. Website complexity and task complexity in online research

Complexity is a function of the amount of variety in a stimulus pattern [2]. Based on this definition, Geissler et al. [10] argued that the complexity of a stimulus depends on three factors: number of elements, the level of dissimilarity between elements, and the level of unity between elements. The definition of website complexity is mainly derived from the definition of stimulus complexity. Huang [16] identified complexity, novelty, and interactivity as important website attributes and mentioned that complexity refers to the amount of information that a site is offering, including elements such as text, hyperlinks, pictures, animations, and video, and the variation in these elements: picture size, arrangement of these attributes, and so on. Consistent with webpage design elements suggested by Geissler et al. [10], Deng and Poole [6] defined webpage visual complexity as composed of two dimensions: (1) visual diversity, which refers to the varieties of design elements, like graphics, text, and links, and (2) visual richness, which refers to the detail of information present in a webpage as measured by the amount complexity of the web content, including the number of design elements, the content of text, number of graphics, and links and layout of a page. Lavie and Tractinsky [23] found that users' perceptions of websites consisted of two main dimensions, classical aesthetics and expressive aesthetics. The classical aesthetics dimension emphasized orderly design and clear design, and the expressive aesthetics emphasized the creativity of designers. In addition, the classical aesthetic perception of websites is similar to the visual complexity of websites.

Extant studies have paid much attention to the determinant factors that influence website complexity. Through manipulating five variables (the length of the homepage, the number of hyperlinks, the number of pictures, the amount of text, and the presence or absence of animation), Geissler et al. [10] found that homepage length, the number of hyperlinks, and the number of pictures have a significant influence on the

perceived homepage complexity. Tuch et al. [37] proposed that compressed file size can be utilized as a reliable, valid, and objective measure for visual complexity. Michailidou et al. [27] verified through experiment a positive, significant, and robust relationship between visual complexity of the page and the number of images, visible links, words, and TLCs (Top Left Corners). In fact, among these potential measures of website complexity, that used in Geissler et al.'s [10] study has been most widely adopted [6,11]. In our study, we use Geissler et al.'s findings for reference.

Extant studies implied that website/webpage complexity affects many user outcomes, such as communication effectiveness [10], usability [37], flow [16], arousal, and pleasantness [6]. Which are better, simple websites or complex websites? Previous studies offered different answers to this question. Agarwal and Venkatesh [1] implied that simple websites are easy to use and effective. However, complex websites can communicate richer information and intrigue consumers [12] and thereby positively impact consumers' arousal [6]. In addition, Geissler et al. [11] put forward an "inverted U relationship" between website homepage complexity and communication effectiveness. For experiential users, Deng and Poole [6] found that webpage complexity positively impacts users' approach behavior, whereas Nadkarni and Gupta [29] suggested an "inverted U relationship" between website complexity and user satisfaction. There is still much to explore about the relationship between website complexity and users' behavior.

In this study, we argue that task complexity can play an important role in determining how website complexity affects users' visual attention and behavior. Based on Wood's [40] frame, task complexity should be the function of three types of complexity: component complexity, coordinative complexity, and dynamic complexity. Task complexity is also linked with the "increase in information load, information diversity, or rate of information change" [4]. A task is more complex, e.g., if there are multiple paths of achieving it or if different paths for desired outcomes conflict with each other [4]. Campbell [4] identified 16 types of tasks and characterized them as simple tasks, decision tasks, judgment tasks, problem tasks, and fuzzy tasks according to the level of task complexity. To simplify the manipulation, we classify online shopping tasks into simple tasks and complex tasks. This classification was adopted by previous studies [15,25]. Compared to a simple task, a complex task requires more cognitive resources, such as psychological comparison [25].

Various studies in the existing literature showed how to manipulate task complexity when conducting an experimental study. According to Miller [28], individuals can hold 7 ± 2 chunks of information in their working memory concurrently. Jiang et al. [17] chose a PDA (personal digital assistant) to represent a condition with a high level of task complexity because a PDA had 17 experiential features, such as address book, note pad, and mail. Accordingly, browsing a watch was considered to be a relatively simple task because a watch only had six experiential features. Leuthold et al. [25] referred to tasks conducted to meet goals with one criterion as simple tasks and tasks conducted to meet goals with several criteria as complex tasks. Both methods were found to be reliable. We apply the method used by Leuthold et al. [25] in this study.

2.2. Eye-tracking research on website design

During recent years, the affective and cognitive aspects of user interface design have received increasing attention [7,34]. Eye-tracking is widely used in HCI (Human–Computer Interaction) studies since eye movement can reflect the visual search mode, which is important in revealing the cognitive processing mechanism.

There are several advantages to using eye-tracking to examine website design. First, eye-tracking removes the subjectivity of self-reporting data [33]. Second, eye-tracking allows us to track users' reactions to webpage elements without affecting the ecological validity and/or "wholeness" of the stimuli and can show which parts of the page captured participants' attention most [3].

The existing research about eye-tracking on website design has several streams. First, there are many studies on website design elements. Schmutz et al. [33] combined an online study and an eye-tracking study to examine the effects of different presentation types (matrix versus list) on cognitive load and consumer decisions. Cyr et al. [5] used a questionnaire, interviews, and eye-tracking methodology to gain insight into how Internet users perceive human images as one element of website design. And Leuthold et al. [25] conducted an eye-tracking laboratory study with 120 participants to compare the influence of different navigation designs (vertical versus dynamic menus) on user performance.

Second, some literature focuses on the fixation behavior of users. Nielsen [31] reported an F-shaped pattern when reading webpages based on an eye-tracking study of 232 users. Using an eye-tracker to collect users' fixation data, Djamasbi et al. [7] proved that members of generation Y (born between 1979 and 1995) favor webpages with a main large picture, pictures of celebrities, a search feature, and little text.

Third, cross-cultural studies can also be found in previous research. For example, Dong and Lee [9] designed a cross-culture (Chinese, Korean, and American) study of webpage design and explained the differences between the three cognitive styles using the different fixation and browsing patterns recorded by the eye-tracking device.

From current literature, we can see that the application of eye-tracking in web design is becoming more and more popular. By combining eye-tracking with the traditional questionnaire survey method, we can better understand users' cognitive process, browsing preference, and interest in using the websites, all of which are very important to designers who wish to optimize website design to cater to the needs of users.

2.3. Cognitive load theory and relevant eye-tracking metrics

Cognitive load theory (CLT) describes the limitations induced by working memory. According to the CLT [35], people's cognitive capacities are so limited that they can process only limited information chunks concurrently. If the information to be processed exceeds a limit, people are overwhelmed. Generally, most extant studies consider that there are three types of cognitive load: intrinsic load, extraneous load, and germane load. According to Sweller [35], intrinsic cognitive load is linked to the material's content, extraneous cognitive load is based on the presentation forms, and germane cognitive load involves information consolidation. Website complexity relates to extraneous cognitive load. Task complexity relates to intrinsic load. Intrinsic cognitive load cannot be altered as it depends on the material or the task itself. Extraneous cognitive load is unnecessary and can be decreased by adequate visual presentation and design of material.

According to the load theory of attention proposed by Lavie et al. [20], there are two mechanisms of selective attention. The first is the perceptual selection mechanism, which means that an individual can ignore irrelevant distractor stimuli when he or she is under situations of high perceptual load [21]. The second mechanism is a more active mechanism of attentional control that is needed for rejecting irrelevant distractors even when these are perceived (in situations of low perceptual load) [20]. Here, perceptual load means either that more information needs to be processed for the same task or that the task is more demanding for the same quantity of information [22]. Based on the literature, we can properly infer that cognitive load can have an influence on users' visual attention and behavior.

This study adopts an eye-tracking technique. We choose the eye-tracking metrics related to users' cognitive activities and visual attention including fixation duration and fixation count. Fixation information can be used to measure the attention that individuals have paid to stimuli [39]. Fixation duration and fixation count are the most commonly used metrics to measure attention allocation [18]. Fixation duration can reflect the degree of digging into the information. Longer fixation duration indicates difficulty in extracting information, or it means that the object is

more engaging in some way [18]. The fixation count shows the total number of fixations on a given object [8]. Task completion time, which is a measure of users' task performance, is taken into account. Less time usually indicates more efficient decision-making and better design interface. However, shopping online is more complicated. Saving time may not be as desirable to online retailers as to consumers. Online retailers want to retain the consumers as long as possible on their websites, exposing them to more product information [15].

3. Hypotheses

If an object is difficult to process, then fixation lasts longer than it would if the object were easy to process [18]. Websites with high levels of complexity provide diverse and numerous information cues that require considerable attention and time to view and comprehend [6]. So a complex website will distract users' attention and trigger more fixations accordingly. But website complexity effects may be sensitive to the existence of other factors such as task complexity.

Compared to simple tasks, complex tasks require more cognitive work, like psychological comparison. Prior research on task complexity indicated that high task complexity can increase information processing requirements and demand more cognitive resources from task executors [19,34]. When sufficient cognitive resources are available, websites with more information grab more attention from consumers, generating enough cognitive resources for users to deal with the possible information overload caused by the webpage itself. When a shopping task is simple, the influence of website complexity on cognitive effort is not too strong so that users continue to stay on the websites. Accordingly, users' attention is likely to spill over to task-irrelative stimuli; as a result, more fixation count, longer fixation duration, and longer task completion time happen when the website complexity increases. The following hypotheses are proposed:

H1. For simple tasks, the higher the website complexity, the higher the fixation count.

H2. For simple tasks, the higher the website complexity, the longer the fixation duration.

H3. For simple tasks, the higher the website complexity, the longer the task completion time.

However, when a shopping task becomes complicated, a website with a lot of information causes conflict between the amount of attention that a task demands and the amount that people's attention resources can afford. The users' cognitive resources are likely to be robbed by a large amount of information presented on the website with high complexity. As a result, users do not have enough available cognitive resources to complete the task and are more likely to be overwhelmed by a lot of information presented on the highly complex websites [17]. According to the load theory of attention [20], when an individual is suffering high perceptual load, there is insufficient capacity for him to process irrelative stimuli, which causes fewer fixation count, shorter fixation duration, and less task completion time. We speculate that a website with moderate complexity which can match users' cognitive load well should be more attractive to users. Therefore, we posit the following hypotheses:

H4. For complex tasks, the user's fixation count on the website with medium complexity will be higher than those on either low- or high-complexity websites.

H5. For complex tasks, the user's fixation duration on a website with medium complexity will be longer than that on either low- or high-complexity websites.

H6. For complex tasks, the user's task completion time on a website with medium complexity will be longer than that on either low-complexity or high-complexity websites.

Table 1
Manipulation of website complexity.

Website complexity	Types of webpages	Page length (number of screens)	Hyperlinks	Pictures	Animation
Low level	Homepage	1	11	2	0
	Display page of relevant products	1	7	7	0
	Display page of a specific product	1	2	2	0
Medium level	Homepage	2	13	11	0
	Display page of relevant products	1.5	13	13	0
	Display page of a specific product	2	2	3	1
High level	Homepage	3	46	23	3
	Display page of relevant products	2	22	16	1
	Display page of a specific product	6	2	8	1

4. Research methods

The hypotheses proposed in this study were tested through a laboratory experiment with a 3×2 design (i.e., 3 levels of website complexity (between-subject) \times 2 levels of task complexity (within-subject)). We manipulated the levels of website complexity by varying the number of design elements on the website, such as pictures, text, and hyperlinks. Task complexity was manipulated by describing the different tasks to the subjects. In the experiment, we collected the eye-tracking data and self-report data about perceived website complexity and perceived task complexity.

4.1. Website stimuli

Following Geissler et al. [11], we manipulated the levels of website complexity mainly by varying page length, the number of pictures and hyperlinks, and the amount of animation. The level of website complexity was determined by the complexity level of all webpages in the website. In our experimental design, we minimized differences among the websites that are not related to the interest of our research to isolate the effects of website complexity as independent variables. Each website in our experiment contains three types of webpages: homepage, display page of relevant products, and display page of a specific product. We used a product-displaying matrix format on the display page of relevant products. This matrix format is to display more than one product on each row, which is widely used on major commercial websites. As the complexity of a particular webpage increases, the page length, the number of hyperlinks and the number of pictures on this webpage will increase accordingly. The specific manipulation rules are presented in Table 1.

We made three websites with three levels of complexity. The three websites used in our experiment were constructed using Macromedia Dreamweaver 8. The materials (like pictures, and product description) were designed based on realistic e-commerce websites while fictitious website names were used to avoid latent brand and reputation effects. Mobile phones and laptops were selected as experimental products in this research because these digital products are popular among college students for making purchases over the Internet. The hyperlinks that have nothing to do with the two products are invalid.

After finishing website design, we conducted a pretest study to check if those designs were appropriate. Fifteen subjects scored the perceived website complexity of three websites; the results showed that there were significant differences ($F = 134.898$, $p = 0.000$) in visual website complexity among sites of high complexity (Mean = 6.400, $SD = 0.6325$), medium complexity (Mean = 4.600, $SD = 0.7368$),

and low complexity (Mean = 2.0667, $SD = 0.7988$), supporting the valid manipulation of website complexity.

4.2. Task complexity manipulation

We divided the online shopping tasks into simple tasks and complex tasks as Leuthold et al. did in their research [25]. We manipulated task complexity by describing different scenarios to the subjects. In the situation of simple shopping tasks, subjects were asked to buy a specific product on the website, for example “Black Nokia 5233”. This scenario represents a situation in real life where individuals know clearly what they will buy before shopping online. Table 2 shows the manipulation of the position of the target product. We consider the manipulation of the position of the target product in the display pages of relevant products from two aspects. First, the length of webpages is directly related to webpage complexity. Target products in display pages with different task complexity were put on different screens in order for subjects to experience different level of complex webpages. For example, simple webpages fit onto one screen with no scrolling required finding the target product. However, subjects in complex websites have to scroll down the webpages to find the target product so that subjects could experience the complexity of the webpage. Second, the relative positions of target products are kept constant across different levels of website complexity, i.e., at the middle positions of the product-displaying matrix. Thus we avoid putting target products at extreme position (for example, first/last column and row) to minimize other extraneous influences of target positions beyond their influences of website complexity on subjects' behaviors. In the situation of complex shopping tasks, subjects were given a series of standards to meet for online shopping such as price, product size, and brand. There are multiple products that match these standards, which forces individuals to make comparisons among different products to find a product that satisfies them most. So the influence of target positions should be less of a concern in complex tasks because, as noted above, subjects are forced to make comparisons and thus very likely to browse through all the presented products.

4.3. Experimental apparatus and experimental procedure

A pilot study was conducted involving six subjects to test the whole experiment procedure, the questions we set, and the experiment materials. For the formal experiment, the sample was comprised of students from a university in southern China who volunteered to participate in this study. A total of 42 students participated in our experiment. All were screened to ensure normal or corrected-to-normal vision.

Table 2
Manipulation of the position of the target product.

Type of webpage	Webpage complexity	The number of screen that the target product locates	The target product position (row, column)
Display page of relevant products	Low level	The 1st screen	(1, 2)
	Medium level	The 1.5th screen	(2, 2)
	High level	The 2nd screen	(3, 2)



Fig. 1. The display page of website with low complexity (simple task).

The eye-tracking device used in this research is the Hi-Speed iView X eye-tracker produced by the German company SMI. Its sampling rate is 500 Hz. An infrared camera was used in the Hi-Speed eye-tracking equipment to capture a video image of each subject's left eye. The experimental websites were presented on a 19-inch monitor with a resolution of 1024×768 pixels. During the experiment, subjects were asked to put their chins on a chin rest, adjust their body to a comfortable sitting position, and keep their head static. The distance between monitor and chin rest was approximately 60 cm. The eye-tracking data from website browsing in the experiment were recorded automatically by the eye-tracker and analyzed using the software BeGaze 2.5¹ matched to the eye-tracker.

Since there is only one eye-tracker in the lab, subjects completed the experiment independently from each other. Before being exposed to the stimulus materials, each subject was instructed about the experiment equipment, procedures, and theme of our study, and signed an informed consent form. Forty-two subjects were randomly assigned to three groups, which used websites with high, medium, and low complexity, respectively. Each subject in each group completed both a simple task and a complex task, which were randomly presented to the subjects.

The experiment was conducted in a laboratory with sound insulation. Subjects were calibrated to the eye-tracker before being exposed to the website stimuli. Calibration took about 2 min on average. Following calibration, subjects started to perform the formal experiment tasks. After one task was completed, subjects were asked to grade perceived website complexity and perceived task complexity (see Appendix A). Then they took a break to rest their eyes. After the next task was completed, subjects were told to grade perceived task complexity and provide personal information such as gender, age, and online shopping experience. There was no time limitation for completing the experiment. The whole experiment process took from 15 to 20 min to complete. Each subject was paid \$5 for participation.

5. Analysis and results

5.1. Background information about the subjects

Among the 42 subjects, 22 were male and 20 were female, with an average age of 22.9. 29 of the subjects were undergraduates and 13

were postgraduates. On average, subjects spent 28.7 h online per week and had 2.77 years of online shopping experience. There are no significant differences in online time ($F = 0.745$, $p = 0.481$) and online shopping experience ($F = 0.748$, $p = 0.480$) among the three experimental groups, which suggest that the random assignment of the subjects to the three experimental conditions is successful. The paired t-tests demonstrate that there are no significant differences ($p = 0.349$) between familiarity with mobile phones (Mean = 3.93, SD = 1.67) and familiarity with laptop computers (Mean = 4.07, SD = 1.83).

5.2. Manipulation check

We conducted manipulation checks using ANOVA and paired t-tests to test the effectiveness of our manipulation of website complexity and task complexity. We used perceived website complexity as a manipulation check for the high, medium, and low website-complexity treatments. The results show a significant difference ($F = 17.998$, $P = 0.000$) in perceived website complexity among sites of high complexity (Mean = 4.259, SD = 1.228), medium complexity (Mean = 3.223, SD = 1.231), and low complexity (Mean = 2.436, SD = 0.937), confirming the successful manipulation of website complexity.

Perceived task complexity was used in the manipulation check for task complexity. The results of paired t-tests show that perceived task complexity is significantly higher ($t = 12.378$, $P = 0.000$) in complex tasks (Mean = 2.949, SD = 1.160) than in simple tasks (Mean = 1.564, SD = 0.803), confirming the successful manipulation of task complexity.

5.3. Heat map analysis

Before our quantitative analysis, we conducted a heat map analysis to reveal qualitatively the effects of website complexity and task complexity on users' visual attention. A heat map, which can be interpreted as the



Fig. 2. The display page of website with medium complexity (simple task).

¹ Please refer to <http://www.smivision.com/en/gaze-and-eye-tracking-systems/products/begaze-analysis-software.html>, last accessed on September 10, 2013.



Fig. 3. The display page of website with high complexity (simple task).

degree of visual attention, provides a more intuitive understanding of fixation results. The cumulative fixation data were translated into a heat map on which colors represent the degree of users' fixations. Red indicates the highest level of fixation, followed by green and yellow. Areas with no color receive no fixation. The red solid diamonds in the heat maps indicate the users' mouse clicks and are irrelevant to fixation analysis.

The heat maps of websites with different complexity when users performed simple tasks are shown in Figs. 1–3. The higher the website complexity, the more fixations the website would get and the larger the fixation areas would be. These findings demonstrate that the higher the website complexity, the more likely users' attention will be distracted. Figs. 4 and 5 show the heat maps of websites with medium complexity when users performed simple tasks and complex tasks, respectively. We find that users performing complex tasks had more and larger fixation areas compared to those performing simple tasks.

5.4. Hypotheses testing

Table 3 shows the means and standard deviations of task completion time, fixation count, and fixation duration when subjects performed

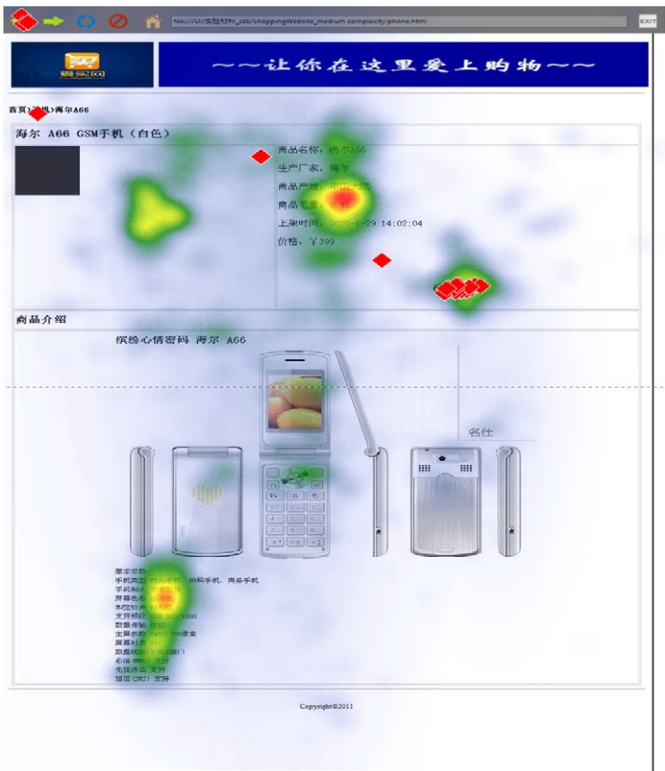


Fig. 4. Display page on website with medium complexity (simple task).

different tasks on websites with different levels of complexity. We used repeated measurements of ANOVA to test the effects of website complexity and task complexity on fixation count, fixation duration,

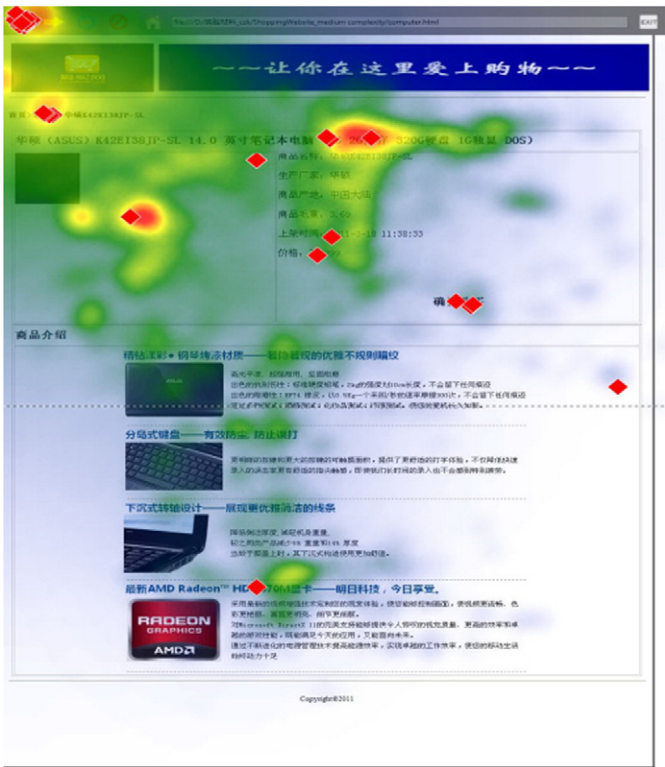


Fig. 5. Display page on website with medium complexity (complex task).

Table 3
Descriptive statistics.

Dependent variable	Task complexity	Website complexity Mean (standard deviation)		
		High	Medium	Low
Task completion time (ms)	Simple	4.3320E4 (14,425.79)	3.6390E4 (17,189.25)	2.4308E4 (12,444.81)
	Complex	1.0763E5 (44,775.8)	1.4292E5 (29,902.9)	4.4991E4 (29,352.5)
Fixation count	Simple	147.93 (44.34)	113.36 (59.63)	94.21 (50.69)
	Complex	353.71 (150.85)	452.21 (102.60)	174.50 (84.57)
Fixation duration (ms)	Simple	3.0911E4 (10,817.44)	2.7242E4 (13,503.37)	2.2479E4 (7449.41)
	Complex	8.0520E4 (32,512.58)	1.0682E5 (22,398.50)	4.1993E4 (21,938.54)

and task completion time (Table 4). We can see that the main effects of website complexity and task complexity are significant ($p < 0.001$), and the interaction effect of website complexity and task complexity is also significant ($p < 0.001$).

Figs. 6–8 shows the estimated marginal means of fixation duration, fixation count, and task completion time in different treatments. Under simple task, we can see that task completion, fixation count, and fixation duration increase while the level of website complexity increases. Under complex task, task completion, fixation count, and fixation duration are higher in medium complexity website than those in low complexity website and high complexity website. The interaction effect between website complexity and task complexity is also shown in Figs. 6–8.

In order to fully understand the interaction effect of website complexity and task complexity, we conducted a main effect analysis of website complexity. For simple tasks, the results of an LSD test show that the fixation count on the website with high complexity is significantly higher than those on the website with low complexity (mean difference (high vs. low) = 53.714, $p = 0.004$) and marginally higher than those on the website with medium complexity (mean difference (high vs. medium) = 34.571, $p = 0.057$). H1 is partly supported. For fixation duration, there are no significant differences among the websites with different levels of complexity (mean difference (high vs. medium) = 2533.886, $p = 0.562$; mean difference (high vs. low) = 7296.943, $p = 0.10$; mean difference (medium vs. low) = 4763.057, $p = 0.279$). H2 is not supported. The task completion time on websites with low complexity is significantly lower than that on the website with high complexity (mean difference (high vs. low) = 19,012.071, $p = 0.002$) and medium complexity (mean difference (medium vs. low) = 12,081.786, $p = 0.037$). H3 is supported.

However, for complex tasks, these indicators are at their highest level when website complexity is medium, followed by those on the websites with high and low complexity. Specifically, task completion time on the medium-complexity website is significantly higher than that on the website with low complexity (mean difference (medium

vs. low) = 97,932.571, $p = 0.000$) and high complexity (mean difference (medium vs. high) = 35,293.214, $p = 0.012$); fixation count on the website with medium complexity is significantly higher than that on the other two websites (mean difference (medium vs. high) = 98.500, $p = 0.031$; mean difference (medium vs. low) = 277.714, $p = 0.000$); and fixation duration on the website with medium complexity is significantly higher than that on the other two websites (mean difference (medium vs. high) = 26,296.121, $p = 0.011$; mean difference (medium vs. low) = 64,823.621, $p = 0.000$). H4, H5, and H6 are all supported. So the results provide empirical evidence of the “inverted U-shape” relating users’ attention and website complexity for complex task situations.

6. Discussion and implications

Based on the results of this study, task complexity moderates the effects of website complexity on the users’ visual attention and behavior. When users perform simple tasks, task completion time on the websites with high complexity and medium complexity is higher than that on the website with low complexity. Further, users’ attention is easily distracted as website complexity increases, which leads to more fixation count. However, there is no significant difference in fixation duration among websites with different levels of complexity. Therefore, although users’ visual attention is distracted by websites with different information amounts, the information on those websites is not explored deeply.

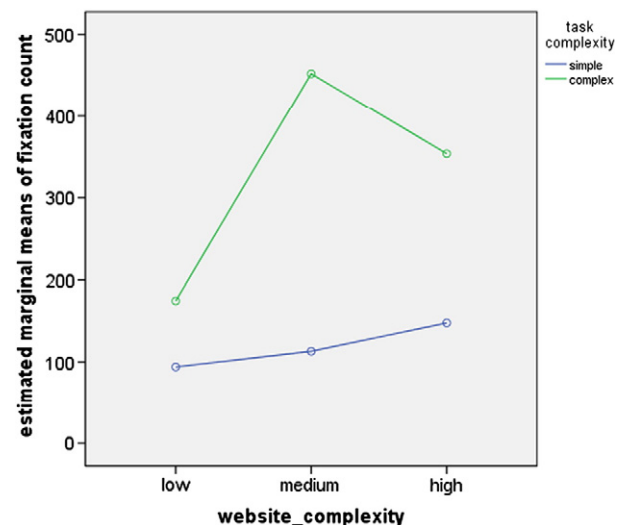


Fig. 6. The marginal means of fixation count.

Table 4
Results of repeated measures of ANOVA.

Independent variable	Dependent variables		
	Task completion time	Fixation count	fixation duration
Task complexity	F = 121.438 p = 0.000***	F = 115.051 p = 0.000***	F = 134.046 p = 0.000***
Website complexity	F = 29.728 p = 0.000***	F = 22.115 p = 0.000***	F = 20.810 p = 0.000***
Website complexity * task complexity	F = 18.302 p = 0.000***	F = 14.777 p = 0.000***	F = 16.163 p = 0.000***

*** $p < 0.001$.

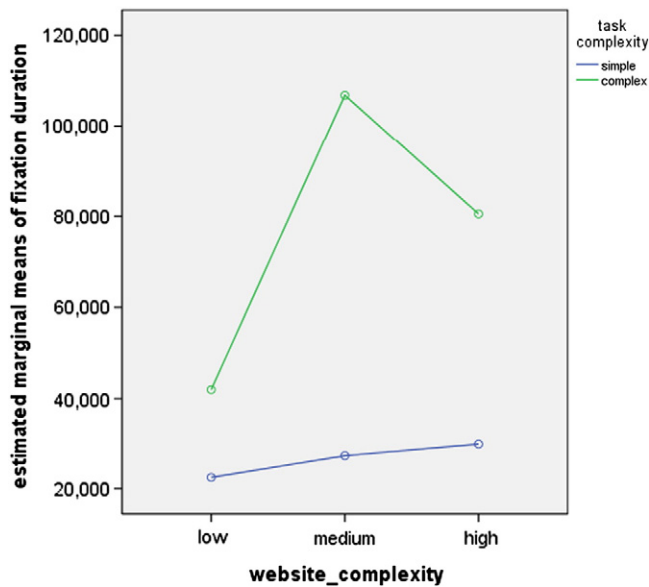


Fig. 7. The marginal means of fixation duration.

This could be explained by the high goal specificity and the low perceptual load for simple tasks. Tam and Ho [36] prove that the higher the specificity of a goal, the more easily the web stimulus can be classified as relevant (or irrelevant) to a goal. There is another active mechanism of attentional control that is needed for rejecting irrelevant distracters even when these are perceived in low perceptual load [21]. Therefore, for simple task situations, complex websites can not only lead to low task efficiency of consumers but also not meet the objectives of online retailers.

When users perform complex tasks, the task completion time, fixation count, and fixation duration of users on websites with medium complexity are at a significantly higher level than on websites with high and low complexity. According to the load theory of attention proposed by Lavie et al. [21], a perceptual selection mechanism exists in the human mind, which means that an individual can ignore irrelevant stimuli when he or she is under circumstances of high perceptual load [19]. When an individual is conducting complex tasks on a website with high complexity, he is suffering high perceptual load, and there is insufficient capacity for him to process irrelevant stimuli. If the load is too high, he might lose interest in exploring further and give up.

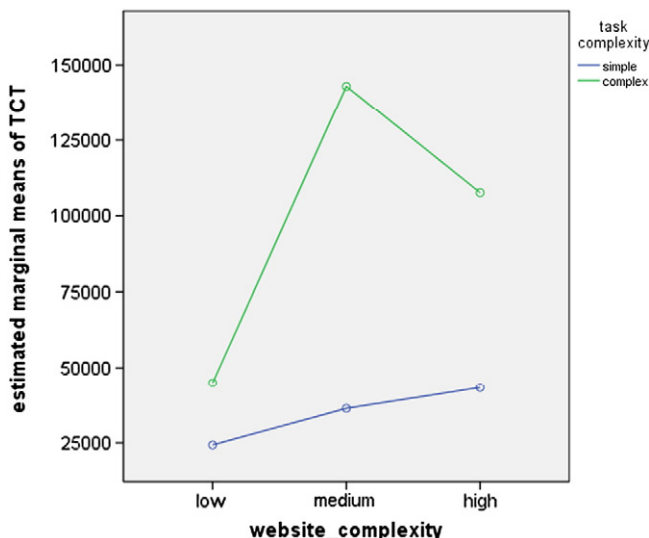


Fig. 8. The marginal means of task completion time (TCT).

Conversely, when an individual is conducting complex tasks on a website with low complexity, he might feel it unnecessary to take time to explore. Compared to websites with high or low complexity, a website with medium complexity is optimal under complex task cases. Users might think that the information on websites with medium complexity is not so complicated to deal with and is sufficient for users to make a wise choice. At the same time, users may be intrigued by the irrelevant stimuli since there is spare cognitive capacity. Users' attention might spill over to the processing of the irrelevant stimuli.

The main contributions of this study are as follows. First, although previous studies investigate the relationship between webpage complexity and user outcomes, such as communication effectiveness [11], usability [37], flow [16], arousal, and pleasantness [6], there is a lack of research taking the moderate effect of task complexity into consideration. Our study examines the interaction effect between website complexity and task complexity and finds task complexity can moderate the effect of website complexity. The relationships between website complexity and users' attention and task completion time are positive for simple task situations. In contrast, the inverted-U relationships exist between them for complex task situations. Compared to a previous study [29] on task goal, perceived website complexity, and user satisfaction, this study resulted in similar findings but focused on objective website complexity, task complexity and user attention. Our results not only enrich knowledge of the role of website complexity, but also provide a possible explanation for the inconsistent conclusions on whether website complexity inhibits [1,38] or improves [6,32] positive user outcomes. Second, we explain the influence of website complexity and task complexity on users' visual attention and behavior from a perspective of cognitive load. We demonstrate that the load theory of attention can be applied in the context of on-line shopping. We find that a more active mechanism of attentional control plays a dominant role when users conduct a simple shopping task, while a passive perceptual selection mechanism plays a dominant role when users conduct a complex task. Third, to explore the influence of website complexity on users' attention this study adopted a physiological measure, eye-tracking, which is more reliable than the self-report method used in Geissler et al. [11]. Compared with previous studies [6,11,29], this study used the eye-tracking method to deeply explore the cognitive processes underlying the website complexity–user outcomes relationships and to better understand how the users' eye fixations related to their cognitive load.

The findings of this research will be of interest to website managers and designers. The results of this study can assist managers as they customize their website design based on the goals of their online visitors. Managers can infer customers' motivations from information about customers' web browsing behaviors and their offerings of products or services. For instance, most users prefer to use a search box to find the specific product they wish to purchase. The search results page can be designed concisely with less complexity to improve the user's efficiency, such as placing fewer advertising words, pictures, and hyperlinks. For users who have no specific purchasing target, the websites should be designed to have moderate complexity, which can lead to longer browsing times and deeper exploration of products; such designs improve the probability of purchase. Further, this study provides examples of websites at different complexity levels and provides general guidelines for website designers to develop websites with an appropriate range of complexity by controlling various design elements. Drawing on the existing literature [10,11], we manipulated website visual complexity by combining different levels of webpage length, number of links, number of pictures, and the amount of animations. Although our treatment of website visual complexity is not exhaustive of all the influencing factors and does not include all possible combinations of different levels of the manipulated design elements, this study shows significant effects on the participants' perceptions of website visual complexity and visual attention. The subjects show different eye-movement characteristics on websites of different levels of complexity, which proves that the two dimensions of websites, the variability of elements and the richness of

There are several limitations and related future research directions. First, our study mainly adopts the perspective of cognitive load to understand the effect of website complexity and task complexity on users' attention and behavior. In future research, we plan to accurately measure users' cognitive load based on existing cognitive load measures. Second, the length of webpages is used to manipulate website complexity in this study. We placed target products in different positions on websites with different complexity so that subjects determine if they need to use the scroll bar to find the product, which aims to let users experience the influence of website complexity. However, the different position of the target product could have interference effect on users' visual mode. In future research, we will reduce the interference by providing various design elements in same size pages. Third, the current study does not consider users' individual differences in online shopping. In future research, we plan to examine cognitive style, using experience in studying the effect of website complexity. Fourth, this study focuses on conducting the relationship tests on website complexity, task complexity, and user behavior outcomes. Prediction of user outcomes such as search time is not considered in this study. In the future research, we plan to create a mathematical model of predicting user outcomes by using a different combination of design elements and including more independent variables. Currently, mobile commerce is booming and changing people's shopping behavior rapidly [30]. One interesting question is how the complexity of webpages which are presented on a small screen affects users' visual attention and behavior. In future research, we would like to conduct experiments of website complexity in online shopping by using mobile applications to better examine this new phenomenon.

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Appendix A. Measures

- (1) Perceived website complexity: 7-point scale (from 1=strongly disagree to 7=strongly agree)
(Adapted from the measurement developed by Geissler et al. in 2001)
- PWC1. The website is complex.
PWC2. The website is crowded.
PWC3. The website is interactive.
PWC4. The website has much variety.

- (2) Perceived task complexity
You think the task that you have just completed is:
- | | | | | | | | |
|-------------|---|---|---|---|---|---|-----------|
| very simple | | | | | | | very hard |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | |

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