Do Cross-Cultural Differences in Visual Attention Patterns Affect Search Efficiency on Websites?

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ABSTRACT

Prior work in cross-cultural psychology and neuroscience has shown robust variations in visual attention patterns. People from East Asian societies, in which a holistic thinking style predominates, have been found to attend to contextual information in scenes more than Westerners, whose tendency to think analytically expresses itself in greater attention to foreground objects. This paper applies these findings to website design, using an online study to evaluate whether Japanese (N=65) remember more and are faster at finding contextual website information than US Americans (N=84). Our results do not support this hypothesis. Instead, Japanese overall took significantly longer to find information than US participants—a difference that was exacerbated by an increase in website complexity—suggesting that Japanese may holistically take in a website before engaging with detailed information. We discuss implications of these findings for website design and cross-cultural research.

CCS CONCEPTS

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

KEYWORDS

visual attention, culture, website search efficiency

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1 INTRODUCTION

A common assumption when designing graphical user interfaces is that end-users will perceive the information provided in the same way. This premise is easily contradicted when looking at an increasingly broad body of research in the fields of psychology and neuroscience showing that a person's cultural background influences visual perception. Culture—defined as shared customs, values, and beliefs of a particular nation, people, or other social group—is thought to affect the extent to which people incorporate contextual information. For example, in various studies using different tasks and stimuli, Western participants have been repeatedly found to focus predominantly on foreground information, while East Asian participants were consistently more sensitive to information provided in the context, or periphery [5, 16, 19, 28, 32–34]. This difference in visual perception is thought to be a result of active participation in a particular culture, which has been found to trigger neural changes in the brain [21]. Neurocognitive researchers have affirmed that humans' visual perception changes due to culturally trained selective attention and memory patterns [10, 12, 20]. For example, US Americans' cultural tendency to emphasize autonomy and independence has been linked to higher activation of their brain regions responsible for object processing relative to people from East Asian societies [12]. In addition, Westerners and people from East Asian societies sometimes prefer different visual information, with Westerners often favoring simpler user interfaces while people from East Asian societies tend to prefer more visually complex ones [13, 43].

While this previous research suggests that attention, memory patterns, and visual preferences differ across countries, little research to date has investigated whether these differences may affect information seeking behavior and recall in the context of websites. Do Westerners indeed attend to website information provided in the foreground more than to contextual information compared to East Asians? Are East Asians faster at finding information in the periphery than Westerners? And does a varying preference for website visual complexity influence their search efficiency and which parts of a website they remember? If the answer to any of these questions is yes, it would provide a strong argument against the current one-size-fits-all approach in website design and for culturally-appropriate adaptations.

To study the phenomena of different visual attention patterns, we conducted an online study with 84 US American and 65 Japanese participants, asking them to search for specific information on a set of website screenshots of varying complexity and testing whether they attended to other parts of a website while engaged in the primary search task. We selected US Americans as our Western sample and Japanese as our East Asian sample to enable comparison to prior findings from psychology (e.g., [19, 27]), in which Japanese have repeatedly been found to focus on contextual information more than US Americans.

Our findings did not confirm that Japanese participants are faster at finding, and better at recalling, contextual information than participants from the US. Instead, both participant groups were faster at finding, and more accurate when recalling, information in a website's main content area than in the periphery. However, Japanese and US Americans significantly differed in recall accuracy and search time, with Japanese taking three times as long to find information on highly complex websites than US Americans. While there are several potential explanations for this, it is most likely that the process of familiarizing with a website differs between Japanese and US Americans, with Japanese spending additional time on understanding webpages before engaging in the primary search task. This finding is consistent with results from eye tracking studies in psychology [6], which have suggested that East Asians have a larger number of rapid, non-focused eye-movements and encode visual information later than US Americans. As a result, East Asians tend to perform less well in object recognition tasks, which is again in line with our results.

We make the following contributions:

- A detailed overview of research in psychology, cognitive science, and neuroscience that has compared visual attention patterns between Westerners and East Asians. We hope the overview may inspire other HCI studies on the effect of varying visual attention patterns on user interface design.
- Empirical results showing that (1) US and Japanese participants are both faster at finding, and better at recalling, information in the main area of a website than in its periphery, (2) Japanese, on average, take significantly longer finding information than US participants and this effect is magnified by website complexity, and (3) despite taking less time to observe websites, US participants had a significantly higher recall accuracy of contextual information on medium and high complexity websites.
- A discussion of these results in light of prior literature to rule out potential confounds and establish a likely explanation for the variation in performance between Japanese and US participants: Japanese seem to holistically take in a website before focusing on the primary task, and hence, are consistently spending more time on search.
- Implications for the design localization of websites, which should clearly highlight related content areas and use consistent layouts for Japanese users, as well as work towards an overall low complexity design for both participant groups. We also discuss implications for future cross-cultural research, which can no longer assume that time is an objective performance measurement across cultures.

2 BACKGROUND AND HYPOTHESIS DEVELOPMENT

Differences in people's abilities, preferences, and behaviors have been repeatedly linked to cultural influences that stem from language, religion, education, social and political norms, and values [23]. Culture has been described as a rich set of meanings, beliefs, practices, symbols, norms, and values prevalent among people in a society [29], making it an intangible and dynamic construct that does not facilitate easy comparison. Researchers have argued that culture cannot be constrained in artificial country boundaries [30]. Instead, a single cultural group can span multiple countries, and one country can often be divided into subcultures (e.g., due to different languages). Humans acquire and shape culture over the course of their lives and may change their culture due to experience [15]. Because of the fluidity and difficulties in defining culture, researchers commonly operationalize the term by comparing two or more national countries while controlling for other variables that shape cultural values and norms. In this paper, we define *culture* as a geographically and demographically coherent group of people: People from a country or region who share similar demographics and the same language. By operationalizing culture this way, we do not assume that all people in a country share a homogeneous set of beliefs, norms, and values. Instead, we attempt to identify tendencies across cultural groups that may shed light on where those groups are similar or different.

One often-confirmed perceptual difference between cultures lies in how people's thinking styles affect visual perception. People exposed to collectivist, group-oriented societies, such as in many East Asian, Latin American, and African countries, tend in general to think more holistically; objects are interpreted along with their contextual content [32]. In contrast, the focus on independent self-concepts in individualist societies leads people to develop more analytical thought patterns and to predominantly perceive objects as independent from their context, as in the US and Western European societies.

These differences in visual perception seem to be robust judging from the high number of studies that have repeatedly confirmed this phenomenon. We list these studies in Table 1 to provide an overview of the breadth of tasks and the relatively consistent results in these prior research endeavours. For example, a memory experiment by Masuda et al. [27] showed participants a 20-second video of an underwater scene and then asked them to report on it. Results suggested that US Americans referred to the fish in the foreground much more often than did Japanese, who were more likely to comment on background objects and the relationship between background and foreground objects. An experiment on attentional breadth by Boduroglu et al. [5] tested whether East Asians (from China, Taiwan, Hong Kong, South Korea, and Japan), have broader attentional foci than US Americans (of non-Asian descent). Participants were asked to respond to color changes when seeing a set of colored squares. The findings concluded that participants in the East Asian group more often detected color changes in a larger

Table 1: Research in Cognitive Science and Psychology, Neuroscience, and HCI that has compared analytic vs. holistic thinking styles and visual attention patterns between Westerners and East Asians.

Field	Task	Westerners	East Asians	Ref.
Psychology	Detect changes in a set of colored blocks	US Americans (N=28 students at University of Michigan (UofM)) were better at detecting changes in the center of the screen	East Asians (N=28 students at UofM, originally were from China, Hong Kong, South Korea, and Japan) were better at detecting color changes in the periphery, suggesting that they allocate their attention more broadly.	[5]
Psychology (Eye-tracking study)	Look at images with realistic complex backgrounds and a single focal object, later recall objects.	US Americans (N=25 students at UofM) had longer fixations of focal objects and a higher recall accuracy of foreground objects even against new backgrounds	Chinese (N=27 at UofM) made more rapid non-focused eye-movements towards the background compared to Americans	[6]
HCI	Freely look at a (translated) webpage without clicking	US Americans (N=9) tended to read websites in sequential order	Chinese (N=9) and Koreans (N=9) tended to scan pages in a circular pattern, and to jump between page contents	[8]
Psychology (Eye-tracking study to replicate the results of [6])	Recall objects from real-world pictures with a focal object on a background	US Americans (N=22 students at the University of Massachusetts, Amherst) looked at focal objects more than the background	Chinese (N=22 students at the University of Massachusetts) also looked at focal objects more than the background	[9]
Neuroscience (fMRI-study)	Look at images with realistic complex backgrounds and a single focal object, later recall objects.	Young US Americans (N=19, mean age=21.7 years) and elderly US Americans (N=19, mean age = 68.1 years)	Young Singaporeans (N=20, mean age=21.3 years) and elderly Singaporeans (N=17, mean age=66.7 years). Elderly Singaporeans showed significantly less adaptation response in the object areas than did elderly Westerners, suggesting that visual experience is affected by culture.	[11]
Neuroscience (EEG and fMRI study)	Look at images with realistic complex backgrounds and a single focal object, later recall objects.	US Americans (N=11) attended to individual objects more as indicated by a corresponding increased activity in the lateral occipital complex, responsible for object recognition.	East Asians (N=11 from Hong Kong and China, recruited in the US) had a greater neural engagement if the background of an image was changed, and this also affected their object memory.	[12]
Psychology	Judge whether a line inside a box is vertical while both the box and the line are turned (Study 3).	US Americans (N=56 students at UofM) made less mistakes, suggesting they were able to ignore the box more.	East Asians (N=42, students at UofM from China, Japan, and South Korea) made more mistakes, suggesting they were incorporating the box when making judgements about the line.	[16]
Psychology	Select two out of three words that are most closely related.	US Americans (N=43 students at UofM) selected words according to their taxonomic classification (monkey and panda)	East Asians (N=119 students from Beijing University and 131 students at UofM from China, Taiwan, Hong Kong, Singapore) selected words based on their relationships to another (monkey and banana)	[17]
Psychology	Replicate the length of a line (1) independent of the size of the frame (absolute condition) or (2) dependent on the size of the frame (relative condition) (Study 1)	US Americans (N=20 students at UofM) were better at the absolute condition	Japanese (N=20 students at the the University of Kyoto) were better at the relative condition	[19]
Psychology (Eye-tracking study and other tasks)	Describe pictures with a focal object in front of a scene background	German children (N=43, mean age = 5.5 years) referred to the background objects more when describing pictures, but in an eye tracking study looked at the object for a similar time.	Japanese children (N=43, mean age = 5.8 years) were less context sensitive when describing pictures, though the eye tracking study did not reveal any difference in focus.	[22]
Psychology (Eye-tracking study)	Focus on a center circle on a screen while contextual information (no background vs. four dots that surround the center circle) was manipulated	Westerners kept their attention on the center circle and were unaffected by the four surrounding circles.	Japanese failed to focus on the center circle when it was presented with four surrounding circles.	[25]
Psychology (Eye-tracking study)	Detect emotions when viewing cartoons of people displaying varying emotions, surrounded by other people expressing the same emotion as the central person or a different one	Western visitors or residents in Japan (N=22 from various anglophone countries) allocated less than 5% of their gaze time to people in the background to detect emotions	Japanese students (N=27) allocated 15% of their gaze time to the background figures	[26]
Psychology	Recall new and old objects from an animated underwater scene and using photographs of wildlife.	US Americans focused more on foreground objects and recognized previously seen objects similarly accurately when objects were displayed in front of the original or a novel background.	Japanese referred to contextual information and relationships more and made more errors when examining previously seen objects with novel backgrounds than with original backgrounds (seemingly finding it difficult to separate objects from their context).	[27]
Cognitive Science	Group an object into a particular target group based on similarity with objects in that group.	Americans (N=61 students at UofM) used rule-based strategies to categorize objects	East Asians (N=28 students at UofM) used family resemblance (i.e., overall looking similar to the target group's objects) more effectively.	[36]
Psychology/HCI	Find a target object on a set of mock-webpages.	European Canadians (N=36 students from the University of Alberta) were faster at finding information on short mock-webpages	East Asians (N=32 students from the University of Alberta) were faster when finding information on long mock-webpages, but similarly fast on shorter mock-webpages (none of which contained text).	[43]

screen region, but more slowly detected changes in the screen's center, than did US Americans. These results were confirmed in an eye tracking study, in which Chinese participants focused more on background elements in a scene, while US Americans focused more quickly and longer on the foreground [6]. The difference in viewing pattern was also corroborated in a performance-based study on attention patterns by Kitayama et al. [19] (known as the "Frame-Line test"), who demonstrated that Japanese were better at incorporating contextual information when making a specific judgment on a foreground object (replicating the length of a given line), while US Americans were better at ignoring the context (the frame of a box in which the line is integrated). Moreover, a number of fMRI and EEG studies confirm these results, as summarized in a review by Han et al. [14].

While few studies have explored how such differences in attention may play out when viewing graphical user interfaces, an eye tracking study by Dong and Lee [8] showed preliminary evidence that variations in viewing patterns may translate to websites. In their study, Chinese and Koreans predominantly scanned websites in a circular manner, whereas US Americans sequentially traversed different screen areas.

In combination, these findings lead us to pose two main hypotheses positing differences in how fast participants will find information and which regions of a webpage they attend to when engaged in such a search task. If East Asians attend to contextual information first before looking at the center, as suggested in the studies by Boduroglu et al. [5], Chua et al. [6], and Dong et al [8], then they should find information in the periphery of a website *faster* than Westerners. Vice versa, if Westerners predominantly focus on foreground objects, then we could assume that they will find information in the main area of a website faster than East Asians. We formulate this hypothesis specific to a comparison between Japanese and US Americans:

H.1(a): There is an interaction effect between website area (foreground vs background) and country (Japan and US) on search speed. Japanese find information in the periphery of a website faster than US Americans and vice versa for a website's main content area.

Our second hypothesis is informed by prior work that suggests an effect of culture on memorization, such as in the work by Dong and Lee [8], in which East Asians were found to traverse a wider area when viewing images and remember contextual objects better than US Americans, who tended to spend more time viewing foreground elements. If this is true for websites, we would expect East Asians to view more objects in a website's periphery. Consequently, they should be better at remembering objects in the periphery than US Americans, who may remember more objects in a website's main area. We hypothesize that this will hold true even if participants are engaged in a primary search task where the target information is randomly placed in the website's main or context area. Our second hypothesis is therefore focused on information recall:

H.2(a): There is an interaction effect between website area (foreground vs background) and country (Japan and US) on information recall in that Japanese more accurately recall information placed in the periphery of a website, while US Americans more accurately recall information placed in the website's foreground.

While our first two hypotheses refer to how fast and well people may find information, both of these factors may be influenced by the visual organization of websites. Visual complexity in user interfaces is thought to negatively influence users' performance [40]. A website's visual complexity, in particular, has been found to negatively affect how people search [4].

While people are (unsurprisingly) faster at finding information, and more accurate at recalling information, on simple user interfaces than on highly complex ones, their visual preferences for certain levels of complexity affect their search efficiency [4] and perception of effort [13]. In other words, user interfaces, such as websites, designed with a visual complexity that does not match someone's preferences will slow down that person when searching for information.

Previous research has been inconclusive as to whether Japanese and US Americans prefer different website designs. For example, when researchers measured visual preferences across countries by having participants rate websites, they found only minor differences between Japan and the US [38]. Japanese and US Americans tended to prefer a similar level of visual complexity (4.15 and 4.08 on a scale of 1=lowest complexity to 9=highest complexity, respectively), and both responded to highly complex websites more negatively than to low complex websites, though Japanese participants were slightly more forgiving of highly complex sites (see peak appeal calculations and Lowess curves in the supplementary materials referenced in [38]). However, Cyr et al. showed that Japanese and US American municipal websites are designed differently [7], and Nordhoff et al. [35] found that Japanese websites usually have a high visual complexity, and a low average saturation of colors, while US websites usually have a medium visual complexity with highly saturated colors. These findings suggest that local designers may cater to divergent design preferences and that Japanese and US Americans might be accustomed to slightly different website designs.

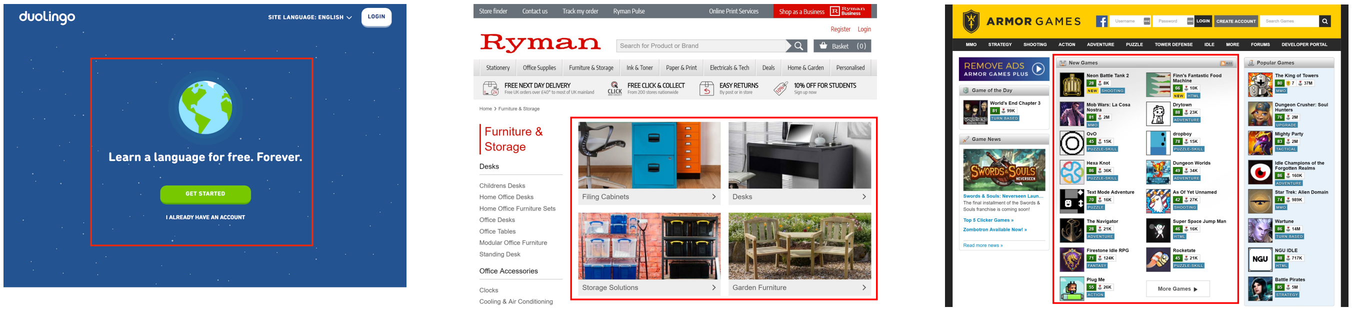
Because Japanese may be used to more complex website designs than US Americans [7, 35], we posit that highly complex websites may have a relatively weaker negative affect on their search time and recall. This is also in line with a finding by Wang et al. whose results indicated that East Asians (unspecified) are faster at finding information on longer (more "information-rich") mock-websites without text than Westerners (Canadian students), while both groups were similarly fast on shorter webpages [43]. We therefore include two additional hypotheses:

H.1(b). Participants will be faster when searching for information on low complexity websites than on high complexity websites independent of country, but this will be modulated by country, with Japanese being relatively faster when searching on high complexity websites than US Americans.

H.2(b). Recall accuracy will be higher with low complexity websites than with high complexity websites independent of country; but this relation will also be modulated by country, with Japanese being relatively more accurate when recalling information from high complexity websites than US Americans.

3 METHODS

To test our hypotheses, we designed an online experiment to assess speed and information recall across foreground and background information on the web between US American and Japanese participants. The experiment was approved by the Institutional Review Board at the University of Washington.



(a) Low complexity (b) Medium complexity (c) High complexity

Figure 1: Three example websites used in the study. Red frames outline the main content area that was defined to constitute the foreground of a page.

3.1 Procedure

The experiment began with a brief overview of the study, a consent form, and a demographics questionnaire. The study was presented in either English or Japanese (including all website screenshots), and the language version shown was selected based on participants' internet browser language. The study itself consisted of six trials, presented in random order, and one practice trial. Each trial presented participants with a scenario, such as "*You want to sign up for a cryptocurrency banking platform. Click the link to create an account.*" These scenarios were designed to represent common search activities on the web. The targets, such as the link to create an account in the example above, were chosen to represent various locations across the website where participants may usually find information, and split equally between main or peripheral placement on the website, as described in the Materials section. Once a participant had read through the scenario, they could proceed to the next page, which showed a website screenshot along with the scenario as a reminder. Importantly, participants were asked to find and click on the target as quickly as possible. Clicks were accepted as correct if they were made within a 5 pixel boundary of the target. If participants clicked outside of this boundary, a red line framed the screenshot and a message to try again was shown below the screenshot. Participants were able to skip a trial if they could not find the target.

Once participants correctly clicked on the target, they were presented with two questions with three answer options per trial to assess information recall (described in more detail in the Materials section). The order of the trials, questions and correct/incorrect answers were randomized. Participants were then given the opportunity to report any technical difficulties and provide comments or questions. The final page showed their average task completion time compared to others. To ensure consistent time measurement for the search tasks, all screenshots were preloaded to minimize any effect of Internet bandwidth. The study took around 10 minutes to complete.

3.2 Materials

Website selection: We selected seven websites (one for a practice trial) from Alexa's top sites ranking [1]. Websites were selected to not have received wide public exposure (an Alexa top site rating of > 100 globally and within country) and represent a variety of topics (finance, games, social network, hobbies, quiz aggregator, retail). We exchanged websites until we had found two websites each with a low, medium, and high complexity, computed using the perceived visual complexity model presented in Reinecke et al. [39]. We only considered perceived visual complexity and popularity of websites when selecting our materials. We did not consider other factors that also may influence website familiarity and performance, such as country of origin, cultural markers, and specific design elements that comprise visual complexity. In the final set of six trial websites (see Figure 1 for three examples), two were by Japanese companies (low and medium complexity), three by US companies (low, high, and high complexity), and one by a UK company (medium complexity). The practice trial website was a global travel website available in Japanese and the US (using the same website design). While the sample of websites is not balanced by country of origin, we remain confident in our selection as the high complexity websites are not common visual designs for either the US or Japan. Additionally, Japanese are among the more frequent visitors to one of our high complexity stimuli (in Fig. 1c) according to Alexa top sites.

Translation: For each website URL, we downloaded the website's source code and translated it into Japanese or English using Google Translate. Members of the research team who are native speakers of Japanese and English checked the resulting translations for any errors. For each website and language version, we took a screenshot at 1024 x 768 pixel resolution.

For the translation of study materials from English into Japanese (including informed consent pages, all instructions, and final results page) we used a professional translator. A native speaker of Japanese again checked the resulting translation for any errors and resolved any discrepancies in meaning.

Assigning Foreground vs. Background Areas: Prior studies in psychology usually defined "foreground" as a primary object (e.g., a fish) set against a larger scene background (e.g., rocks, seaweed, and water bubbles) [27]. To align as closely as possible with this definition, we defined *foreground area* as the *main content* area on a webpage and *background area* as all remaining *peripheral space* on a page. Using this definition, three members of the research team (a US American, a Japanese, and a European) independently marked the main content area(s) of each website by drawing one or more squares on each screenshot (see Figure 1 for examples). All main content areas overlapped and any differences in size were resolved in a discussion among the researchers.

Scenario Generation and Target Selection: To test search time, each website trial included a search scenario and an associated target, such as "*You are interested in booking a hotel for an upcoming trip. Click the link to take you to hotel listings.*" The targets (in this case a link for hotel listings) were chosen from UI elements in the main content area and periphery, with three websites having targets in the main content area and three in the periphery (unknown to the participants).

Question Generation: To test information recall, each website trial included two questions, one referring to a UI element in the main content and one in the background area (shown in random order on the same page). An example question is "*What image is featured next to the quiz?*" Each question had the options of a correct answer ("An anime girl"), an incorrect answer ("A speeding car"), and "I don't know." Questions and answers were iteratively discussed and modified by the research team to ensure a reasonable level of difficulty.

3.3 Metrics

We recorded the following metrics:

Search time was measured as the time between displaying the screenshot and the participant's click on the correct target. Time to read the scenario (presented on the previous page) was not included in the search time.

Errors were recorded as the number of incorrect clicks on the screenshot. Skipping the task was recorded as true (the participant skipped the task) or false (the participant did not skip). Skipped tasks were removed from the search time analysis, but remained for the information recall analysis.

Recall Accuracy was measured using two questions with three answer options (correct, incorrect, "I don't know") to assess how much information on a given website participants perceive while engaging in a primary search task. For analysis, each question was coded as either answered correctly (1) or not (0). "I don't know" answers were coded as incorrect.

We additionally recorded participant demographics that have been shown in prior literature to impact people's visual preferences (such as age, gender, education level [18, 38]) or that could be potential confounds for performance, including hours spent on a computer and input device.

3.4 Participants

Participants were volunteers recruited through LabintheWild.org, an online experiment platform, on which we advertised the study with the slogan "How fast can you scan websites?" Altogether 302 people from the US and Japan completed the study, from which 194 were left after removing those who indicated they had previously completed the study, experienced technical difficulties, or cheated in any way. In order to create a demographically balanced sample, we removed participants from the US under the age of 20. The final number of participants included in the following analyses was 149 (Japan=65, US=84).

Table 2: Overview of participant demographics per country.

Demographic variable	Japan	United States	Statistical Difference
n	**65**	**84**	–
Age (mean (SD))	31 (10.5)	29.6 (11)	$t = .79$ $p = .43$
Gender = Female (n (%))	27 (40)	46 (54.8)	$X^2 = 3.20$ $p = .07$
Hours on Computer Daily (mean (SD))	5.8 (3.5)	6.7 (3.6)	$t = -1.47$ $p = .14$
Language Proficiency (n (%))			$X^2 = 7.20$
Limited knowledge	1 (1.5)	1 (1.2)	$p = .13$
Conversational	2 (3.1)	0 (0.0)	
Proficient	3 (4.6)	0 (0.0)	
Fluent	1 (1.5)	3 (3.6)	
Native	58 (89.2)	80 (95.2)	
Input Device (n (%))			$X^2 = 4.94$
Finger	4 (6.1)	7 (8.3)	$p = .18$
Mouse	40 (61.5)	41 (48.8)	
Trackball Mouse	3 (4.6)	1 (1.2)	
Trackpad	18 (27.7)	35 (41.7)	

Participants were between 16 and 62 years old ($M = 30.2, SD = 10.7$), and the gender distribution was 51.7% men and 48.3% women (no participant identified as non-binary). 93% of participants reported native language proficiency in their respective languages as measured on a 5-option scale labeled with limited knowledge, conversational, proficient, fluent, and native. Participants spent 6.3 hours on a computer per day on average ($SD = 3.7$), with a majority of them (54%) using a mouse as an input device, followed by a track pad (36%). See Table 2 for a demographic breakdown of participants across Japan and the US.

3.5 Analysis and Data Set

The analysis was conducted using R [37]. For each hypothesis, we ran mixed-effects linear regression models using the R package *lme4* [3] and package *emmeans* [24] for post-hoc tests. For our hypotheses on search time, the dependent variable *time* was log transformed because the residuals of a linear mixed effects model for time were not normally distributed. We also analyzed errors participants made when searching and used a mixed-effects negative binomial regression models, as this data comprised overdispersed counts. The two hypotheses on recall accuracy were tested using mixed-effects logistic regression models as it is adequate when modeling the probability of binary events such as correctly answering our recall questions.

All post-hoc tests were adjusted for multiple hypothesis testing using the Tukey method. Post-hoc comparisons were done using t-tests for linear regression models and z-tests for the negative binomial and logistic regression models. We report the Cohen's d as an effect size. For the logistic regression models, we report both the odds ratio (the most common effect size for probabilistic models) and its transformation to Cohen's d following Borenstein et. al. [31] for easy comparison to other results in this work.

4 RESULTS

H.1(a): Do Japanese find information in the periphery of a website faster than US Americans, and vice versa for a website's main content area?

To test our first hypothesis, we ran a linear mixed effect model with log-transformed search time as a dependent variable, participant ID as a random variable, and country [US | Japan], target area [main | periphery], age, and input device as independent variables. We also included an interaction effect of country and target area.

The results do not support H.1(a). While country, age, and the target area significantly affected how quickly participants clicked on a target, we did not find a significant interaction effect between target area and country (see Table 3a for statistical results). Instead, all participants were slightly faster at finding information in the main area of a page than in the periphery, as shown in Figure 2 and supported by the model results with 'target area' as a significant factor.

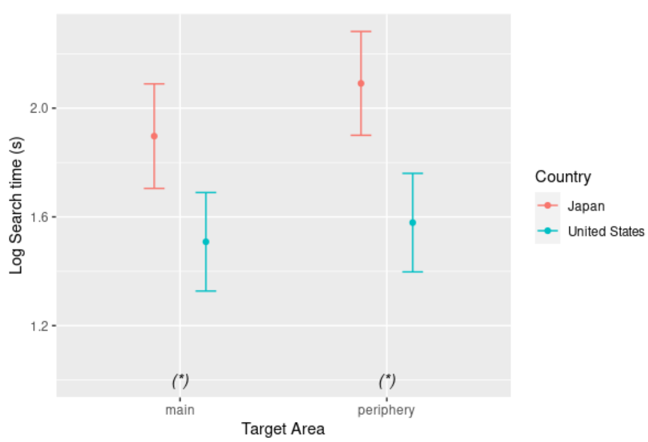


Figure 2: H.1(a): The marginal means of log-transformed search time versus task type show no significant interaction effect between country and target area (disconfirming H.1(a)). US Americans were significantly faster than Japanese participants when finding information in the periphery. Bars show confidence intervals at 95% and asterisks indicate significant differences with p<.001.

The model also showed a significant main effect of country: Overall, US American participants were significantly faster at finding information on webpages than Japanese. The difference was significant for both websites where the target was in the main content area ($t = 3.86, p < .001$ and Cohen's d=.52) and where the target was in the periphery ($t = 5.14, p < .0001$ and Cohen's d=.68).

While participants made no errors in 89% of trials, our error analysis indicated that Japanese participants made more mistakes searching for peripheral than the main content ($\chi^2(1, N = 829) = 5.57, p < .05; Z = 2.95, p < .05$). There was a borderline significant result of Japanese making more errors than US Americans, but only when both were searching for peripheral content ($\chi^2(1, N = 829) = 3.91, p < .05; Z = 2.43, p = .07$).

Table 3: Results of ANOVAs performed on two linear regression models to test the interaction effect of country and target area on search time (H.1(a)) and the interaction effect of country and website complexity on search time (H.1(b)).

	F-statistc	p-value
(Intercept)	67.67	<.001
Country	14.88	<.001
Target area	5.49	<.05
Age	8.88	<.01
Input device	0.49	n.s.
Country x Target area	1.34	n.s.

(a) Results for H.1(a) show no significant interaction effect between country and target area on search time, disconfirming H.1(a).

	F-statistc	p-value
(Intercept)	82.84	<.001
Country	31.84	<.001
Target area	2.91	<.1
Website complexity	146.54	<.001
Age	11.89	<.001
Input device	0.62	n.s.
Country x Target area	0.33	n.s.
Country x Website complexity	37.18	<.001

(b) Results partially confirm H.1(b) with a significant interaction effect between country and website complexity on search time.

H.1(b): Does website complexity affect search time and moderate its relationship with country?

To test whether website complexity positively correlates with search time and whether website complexity moderates the relationship between search time and country, we added an interaction effect between country and website complexity to the model used to test H.1(a).

The results partially confirm H.1(b). As shown in Figure 3, there is a positive correlation between website complexity and search time: The more complex a webpage, the more time participants took to find information. This corroborates prior results with an effect of similar magnitude [4].

A significant interaction effect of website complexity and country on search time additionally supports our assumption that website complexity affects the two participant groups differently (see Table 3b). However, contrary to our expectations, Japanese are more negatively affected by highly complex websites than US participants. While US participants were significantly faster with low complexity websites than Japanese ($t = 3.29$, $p = .014$, Cohen's d=.56 when combining main and periphery conditions), this performance gap between the two groups increased dramatically for high complexity websites ($t = 10.12, p < .0001$, Cohen's d=1.86). Japanese took three times longer (18.6 seconds) than US participants (6.1 seconds) to find information.

It is also worth pointing out differences between our model predicting search time (H.1(a), Table 3a) and the present model in Table 3b. Website complexity has overtaken the significance of the

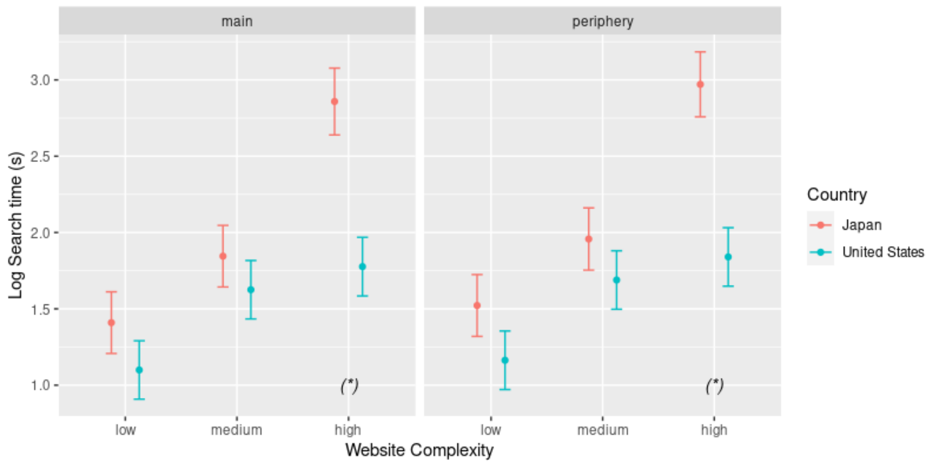


Figure 3: H.1(b): Search time increases with website complexity. Country and website complexity significantly interact with Japanese being significantly slower when searching for information in high complexity websites. Bars show confidence intervals at 95% and asterisks indicate significant differences with p<.0001.

target area that we found in the analysis for H.1(a), and increased the significance of participants' country. In other words, we can see a trend that both Japanese and US participants are slightly faster finding information in the main content area than in the periphery ($F = 2.91, p < .1$), but it is the difference between the two countries in search time that plays a larger role ($F = 31.84, p < .001$).

Our error analysis revealed that Japanese made significantly more errors on high complexity websites compared to low or medium complexity, both when searching for main and peripheral content ($\chi^2(2, N = 829) = 17.49, p < .001$). Japanese participants also made significantly more errors than US Americans, but only when searching for peripheral content at high complexity ($\chi^2(2, N = 829) = 10.00, p < .01; Z = 3.50, p < .05$).

H.2(a): Do Japanese participants recall contextual information more accurately than US American participants, and vice versa for a website's main content area?

To test this second hypothesis, we used a binomial-logistic linear regression analysis to model the probability of correctly answering a recall question as a dependent variable and participant ID as a random variable. Country [US | Japan] and question type [main | periphery] were modeled as an interaction effect, while age and log-transformed search time served as control variables.

The results did not support H.2(a). Although the model results presented in Table 4a show statistical significance for all independent variables but age, including a significant interaction effect between country and question type, the results were again contrary to our expectations. Both participant groups had a higher probability of recalling information (i.e., correctly answering questions) from the main content area of a website than from the periphery (see Figure 4). Post-hoc tests showed that Japanese had a slightly higher probability (56% on average) when recalling information only from the main content area of a website than US participants (45%, $z = 2.49, p = .06$, odds ratio=1.54, Cohen's d=.85). This is

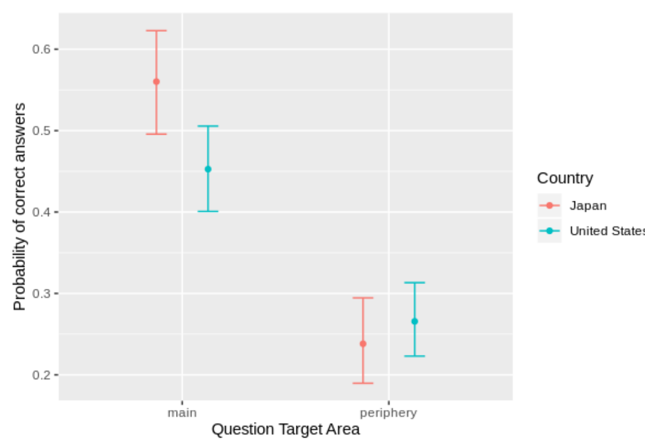


Figure 4: H.2(a): Marginal means of recall accuracy versus question type shows a tendency for peripheral information to be harder to find by both groups of participants. Japanese tend to be more accurate in recalling information from the main region than US Americans (p=.061). Bars show confidence intervals at 95%.

contrary to what we would expect to see. There was no significant difference between the countries when recalling information from the periphery of a webpage.

What is also apparent from Figure 4 is that the higher recall accuracy of information from the main content area vs. the periphery is especially pronounced for Japanese participants. In other words, the effect size between recalling information from the main vs. peripheral content area is larger for Japanese participants ($z = 7.96, p < .0001$, odds ratio=4.07, Cohen's d=2.25) than it is for US Americans ($z = 5.99, p < .0001$, odds ratio=2.29, Cohen's d=1.26).

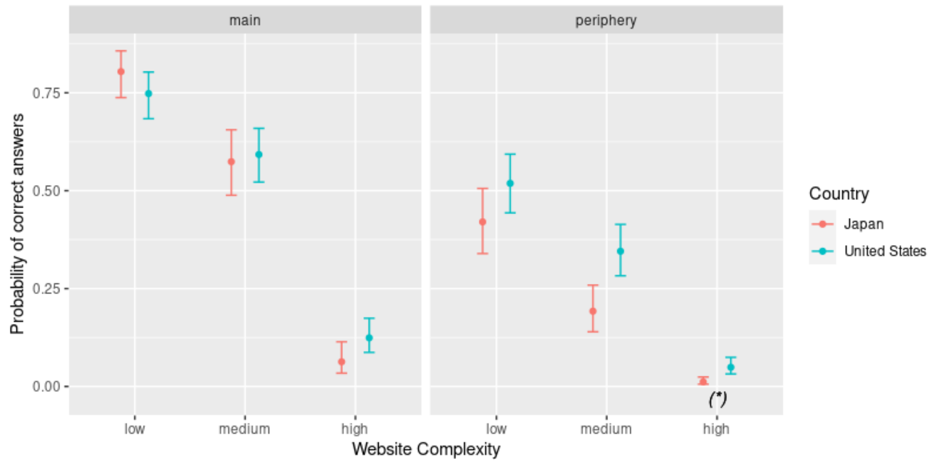


Figure 5: H.2(b): Recall accuracy decreases with website complexity. Country and website complexity significantly interact: US participants were more accurate than Japanese participants when recalling information in the periphery on medium (p=.05) and high complexity webpages (p<.05). Bars show confidence intervals at 95%.

H.2(b) Does website complexity negatively affect search time and recall accuracy differently between countries? We continued with an analysis of the impact of visual complexity on recall accuracy (H.2(b)), again adding an interaction effect between country and stimulus complexity to the previous model.

Partially confirming H.2(b), we found a significant negative correlation between website complexity and recall accuracy. Figure 5 illustrates this relationship: The more visually complex a website is, the less likely our participants were to remember information when asked about it.

The results of this analysis also show a significant interaction effect between country and website complexity on recall (Table 4b). This interaction effect reflects changes in the slope of the correlation between website complexity and recall in the periphery (see right side of Figure 5). Post-hoc tests revealed that, compared to Japanese participants, US participants had a significantly higher recall accuracy for medium complexity websites ($z = -3.25, p = .05$, odds ratio=.45, Cohen's d=.25) and high complexity websites ($z = -3.49$, $p < .05$, odds ratio=.23, Cohen's d=.13) when answering questions about elements in the periphery of a websites.

Independent of this, both Japanese and US Americans are significantly more likely to remember information from the main content area of a webpage than from the periphery. As discussed before, this is contrary to our assumption that Japanese would remember more contextual information.

Table 4: Results of ANOVAs performed on two linear regression model to test the interaction effect of country and question type on recall (H.2(a)) and the effect of country and website complexity on recall (H.2(b)).

	Chisq	p-value
(Intercept)	6.75	<.01
Country	6.21	<.05
Question Type	63.44	<.001
Search Time	12.13	<.001
Age	0	n.s.
Country x Question Type	6.75	<.01

(a) Results for H.2(a) show a significant interaction effect of country and question type on recall accuracy, albeit in the opposite direction of what we hypothesized.

	Chisq	p-value
(Intercept)	8.05	<.01
Country	0.70	n.s.
Question Type	73.67	<.001
Website Complexity	120.45	<.001
Search Time	35.01	<.001
Age	3.94	<.05
Country x Question Type	8.19	<.01
Country x Website Complexity	7.17	<.05

(b) Results for H.2(b) show a significant interaction effect of country and website complexity, partially confirming H.2(b).

5 DISCUSSION

Visual attention patterns are commonly assumed to be universal. However, this assumption has been contested by researchers in psychology and neuroscience, who have shown that culture affects where people focus their attention, and, as a result, which parts of an image or scene they may remember. In this work, we set out to test whether such differences in visual attention patterns may affect search efficiency and recall in websites.

Our two main hypotheses, positing significant interaction effects between participant country and website content area, were mostly disconfirmed: While we found significant differences between Japanese and US participants, we did not see that Japanese were faster at finding contextual information than US Americans, as we hypothesized considering East Asians were previously found to scan websites in a circular manner [8]. We also did not find that Japanese were better at remembering information in the periphery, which we expected to be the case since much work has demonstrated their focus on contextual elements (e.g., [6, 27]). Instead, both US and Japanese participants were slightly faster at finding, and significantly more accurate when recalling, information in the main content area of a website than in the periphery of the website.

In line with our follow-up hypotheses, we found a positive correlation between search time and website complexity (both groups were faster at finding information in low complexity websites than in high complexity websites), and a negative correlation between information recall and website complexity (both groups were better at recalling information from low complexity websites than from high complexity websites). However, the hypotheses were only partially confirmed: Instead of seeing Japanese participants performing better with highly visually complex websites (which we would expect given Japanese participants' preference and experience with highly visually complex websites), we found that they were much more negatively affected by the visual complexity than US Americans, both in terms of their search time and information recall accuracy.

The results revealed an unexpected variation in search efficiency and recall between our US American and Japanese participants: US Americans tended to be faster at finding information in both the main content area and in the periphery than Japanese, but this difference was especially striking for highly complex websites, where US Americans were three times as fast. This finding, while not directly comparable, contradicts prior work that has shown East Asians (country not specified in the paper) to be faster at finding information on longer mock-websites (without textual information) than Westerners, while both participant groups were similarly fast on shorter websites [43].

There are several potential explanations for this finding. First, website familiarity might have played a role since Japanese websites have previously been found to differ from US American websites [7, 35]. Websites are not culturally neutral and familiarizing oneself with websites from another country and culture might necessitate additional time if it contradicts previously established mental models. However, two out of six of the websites in our experiment were originally Japanese websites (at low and medium complexity), for which we saw the same trend of Japanese consistently taking longer to find information than US Americans. Additionally, prior works from Alexander et al. [2] shows a tendency for websites from high-contextual societies (such as Japan) to include more links, one-level menus, and images. Both our high complexity stimuli have many links and images, which suggests that those high complexity websites should be more familiar to our Japanese participants than to those from the US. Familiarity as the sole cause of this discrepancy is therefore unlikely.

As a second explanation, we considered a variation in aesthetic preferences between the two groups, which has been shown to affect search efficiency [4]. We ruled out this explanation for the same reason as described above, and because Japanese and US Americans have been found to prefer similar websites [38] (at least based on the most powerful predictors of website preferences, a website's colorfulness and complexity [39]).

A third reason for the discrepancy in search time could be the writing script (Japanese script for Japanese, and Latin script for US American participants), which was the only difference between the websites both participant groups interacted with. Indeed, prior work has found that it takes longer to read words written in Japanese script than Latin script, with Japanese readers reading 193 words-per-minute on average ($sd = 30$) and English readers reading 228 ($sd = 30$) words-per-minute [41]. If reading speed is indeed cause for the delay in finding information in Japanese participants, one would have to assume that both participant groups find information at roughly the same speed on low complexity websites, which have very little text. In contrast, our results showed that, on average, Japanese take significantly longer to find information even for the most simple websites. Nevertheless, reading speed may play a role, since the difference in performance between US and Japanese participants increases with more text-heavy websites.

While our study cannot fully determine the reason for the difference in search time between Japanese and US Americans, prior eye-tracking studies in psychology provide a plausible explanation: In these prior studies, US Americans fixated sooner and longer on specific objects, while East Asians were engaging in rapid non-targeted eye movements (saccades), presumably to understand the relationship between objects [6, 25]. The extra time Japanese spent before encoding visual information is also thought to explain why US Americans were slightly more accurate in recognizing objects [6] – which is again in line with our results. Hence, it is likely that Japanese participants in our study spent more time understanding the website *before* starting to retrieve information.

This also suggests that the rapid eye saccades between different content areas of a page do not serve information uptake as such, but rather enable Japanese to create an internal map of various elements and their relationship. During this time, they may not focus on the primary task of finding and remembering information, but rather at the structure of the site and the relationship between its various parts.

It is important to emphasize that our findings do not disprove prior work in psychology, cognitive science, and neuroscience, where findings pointing to cross-cultural differences in visual attention to foreground objects and contextual information have been fairly robust across a number of tasks and studies (see [9] for an exception). While we did not find that Japanese were more accurate at recalling information from the periphery than from websites' main content areas, this may be due to the fact that websites do not depict components in 3D, with clearly assignable foreground and background objects as real-world scenes do. Hence, people may process websites differently than real-world scenes, which could explain why our hypotheses were partly disconfirmed.

5.1 Implications for Design and Cross-Cultural Research

Contrary to our expectations, US and Japanese were both faster at finding, and better at recalling, information in the main content area of a website than in its periphery. While websites do not always have an obvious focal area, this result does suggest that information placed in or near the center of the screen will be found first and also most remembered. Whereas this in itself is nothing new, our results indicate that for both US and Japanese users, website designs should offer the most commonly needed information and most commonly required functionality in this main content area.

We also found that Japanese took significantly longer to find information than US participants and discussed that one possible explanation is that they may need additional time to make sense of a website, in line with research that has found a higher amount of eye saccades between foreground and background areas of a scene. Websites should better guide this process of sense-making and taking in the overall structure of a website. For example, it may be more important for Japanese than for US Americans to have consistent layouts that correspond to their mental model of a website. It may also be more important to clearly indicate different content areas and, for example, highlight related areas with the use of color.

Moreover, the finding has implications for future cross-cultural studies that use time as a main measurement. Because we found that Japanese take longer to find information, independent of whether or not a website was designed in Japan or elsewhere, time can no longer be assumed to be an objective performance measurement across cultures. Instead, researchers may need to normalize time across cultures. They should also rely on different, or at least include additional, performance metrics such as task success, errors, or learnability.

Finally, our study findings imply that despite a plethora of relatively robust findings in psychology that show variations in visual attention patterns between East Asians and Westerners, we are still only beginning to understand how this may translate to graphical user interfaces. In other words, there is much room for future work, which we discuss next.

6 LIMITATIONS AND FUTURE WORK

One important difference between previous studies and ours is that we attempted to translate findings from psychology—which often involved visual scenes with clearly identifiable foreground objects—to websites for which the classification into foreground and background is less clear. In user interfaces, attention to focal objects is often determined by UI elements that stand out from others, such as images, diverging fonts and font sizes, or by having contrasting or highly saturated colors. Unlike real-world scenes, websites rarely have a 3D perspective where a foreground object clearly sits on top of a larger background area. Hence, mapping prior results from visual attention studies to websites was challenging; our international team went through multiple iterations to approximate what we believe was closest to the definition of foreground and periphery in those prior studies. In the end, we believe that slight changes in defining foreground and background elements would not change our results. However, unlike most stimuli used in prior studies in psychology, websites do not solely consist of visual objects but additionally include text, which takes additional processing and sense making. This introduces a need for future research to explore the effects of language in addition to cultural background on website searching and recall. Our study did not separate the influence of language and culture, and rather defined culture in a way to include language. An exciting follow-up to our work is to construct a set of websites where the text is either replaced by simple geographic objects or replaced by dummy text. This would remove the influence of language and text processing and could shed light on whether the differences in search time that we found between US and Japanese participants still hold.

Another important consideration for future work is the impact of design origin and cultural markers on participant task speed. Prior works have shown that prototypicality of websites, or how familiar their appearance is, in combination with visual complexity, affect aesthetic perception [42]. Although such considerations were out of scope for our study on visual complexity and information placement, our materials did not include a balanced and representative set of design elements and origins from the populations we studied. Our experiment only included six websites to limit study times with our volunteers, and thus, may not generalize to significantly different website designs. Therefore, we also recommend that future work should conduct similar studies with a larger and more diverse set of websites. Systematically evaluating the influence of more diverse website designs to test the importance of familiarity, such as by including websites from more countries or many different websites from only the countries of interest, will be an important step to validate the robustness of our findings.

Last but not least, our study design was not suitable for inferring what may have caused the difference in search time between Japanese and US participants. For this first experiment, we decided against using an eye tracking study in favor of a larger number of participants; however, future work could replicate our study while recording participants' gaze behavior with an eye tracker to explain the origin of the variations in search that we saw.

7 CONCLUSION

In this paper, we asked whether repeated findings of cross-cultural differences in visual attention patterns may also affect search efficiency on websites. We answered this question by conducting an online study with Japanese and US Americans who were asked to complete several search and recall tasks with information being provided either in the main content area of a page or in the periphery. The results clearly showed that Japanese and US Americans approach websites differently: while US Americans seek out information as fast as they can, Japanese seem to be taking the extra step of holistically making sense of a website before engaging in a primary search task. According to our results, this additional step does not appear to contribute to searching a website and remembering information, but is instead a separate sense-making step that US Americans do not have, or at least not to the same extent. Our work underlines the need for design localization to support these different approaches in searching for information between Japanese and US Americans.

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8 DATASET AND MATERIALS

Our website stimuli, the dataset, and code used for analysis are available for download under the supplemental materials.

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