# READ BETWEEN THE EYES: COGNITIVE STYLE DIFFERENCE BETWEEN AMERICANS AND CHINESE IN A DUAL-DISPLAY SETTING

by Dai Tang

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# READ BETWEEN THE EYES: COGNITIVE STYLE DIFFERENCE BETWEEN AMERICANS AND CHINESE IN A DUAL-DISPLAY SETTING

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ABSTRACT

Based on previous literature comparing Westerners' analytic cognitive style and Easterners' holistic cognitive style, we conducted a laboratory study to examine the attention allocation and information reception differences between Americans and Chinese in a foreground-background display setting. Consistent with previous findings, the results suggested that Chinese were better at getting information from the background display, which was located in the periphery of their visual field. In addition, as the visual complexity of the background display went up, Chinese were more likely to redistribute their attention accordingly whereas Americans were less subjected to the change. The findings extended the existing cross-cultural cognitive style research in a novel display setting and a larger physical space. It also generated design implications for systems support multitasking especially background information processing used in an international setting.

## BIOGRAPHICAL SKETCH

Dai Tang was born on December 7th, 1985, in Changsha, China. She received her bachelor's degree in Digital Media Arts from Beijing University of Posts and Telecommunications, Beijing, China, in June 2008. Soon after graduating, she joined Cornell University's communication department in August 2008, to pursue a master's degree in communication and media studies.

Dai Tang received teaching assistantship and research assistantship from the communication department. She became a part of Collaboration Technology Lab in 2009. She has a passion for the interplay between traditional communication theories and new technology. Her interests are in the field of computer supported collaborative works, human-computer interaction and cross-cultural studies. Her major achievements include presenting at the poster session of CHI 2010 (28th ACM Conference on Human Factors in Computing Systems).

After graduation, Dai Tang will be moving to Redwood Shore, California, where she will be working as a usability specialist in the usability lab in Oracle corp.

献给我最亲爱的爷爷，外婆，奶奶，嗲嗲，爸爸和妈妈

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# INTRODUCTION

For centuries, people of different cultural backgrounds have lived in comparatively isolated environment due to barriers such as geographic distance and language differences. Advanced telecommunication technologies (Cummings & Kiesler, 2005) and transportation systems (Janelle & Beuthe, 1997) have given rise to unprecedented collaboration and contact among people from a wide array of cultural backgrounds and nationalities. The trend toward globalization has also resulted in increased homogeneity in consumer goods and experiences available to people all over the world (Friedman, 2006). Furthermore, the majority of today's globalization influences have originated from western culture. When people from Eastern cultural backgrounds are using electronics that were predominately produced using western standards, watching movies and television programs tailored to western audience's tastes, we cannot help but to ask, how can we compensate the cultural differences in today's world?

In the current study, using a novel display setting, we tried to understand how people from Western and Eastern cultural backgrounds are different in their attention allocation pattern, so as to further generate design implications for displays and system interface that will be used in an international setting.

The Western and Eastern cognitive style difference is one of the emerging areas of cultural comparison research. As defined by Riding and Rayner (1998), cognitive style is "an individual's preferred and habitual approach of organizing and representing information" (p.8). In a few empirical studies (Nisbett & Miyamoto, 2005), Asian participants were found to have a holistic cognitive style, that is, a tendency to pay attention to the entire visual field and to the relationships between different objects in a scene. In comparison, European and North American participants tend to have an analytic cognitive style, that is, a tendency to primarily pay attention to the focal objects (Masuda & Nisbett, 2001). This interesting divide in cognitive style has been further supported by more recent eye tracking studies (Chua et al., 2005) and brain imaging studies (Hedden et al., 2008).

Cognitive style influences how individuals allocate their attention and further cast effects on how they receive and process information from the world. Information presented in a same format may be interpreted differently by people from different cultural backgrounds. In other words, information needs to be displayed differently to compensate the analytic or holistic cognitive preferences of diverse cultural groups.

Most previous research in this area uses still images displayed on a computer monitor to test how people allocate their attention to foreground and background objects placed in a same scene. However, in a real world environment, people usually receive dynamically changing information in a broader physical scope. In the current study, we used a lab experiment to test if the analytic and holistic cognitive style difference still holds in a dual-display setting. Participants were asked to react to dynamic information presented on a foreground and a background display. The fact that the cognitive style difference did influence people's attention allocation in such novel display setting speaks the importance of considering the cognitive style difference between cultures in future system design.

## LITERATURE REVIEW

In this section, we first review previous research findings on Eastern and Western cognitive style differences. We then review major approaches in the field of Human Computer-Interaction (HCI) to leverage people's ability in managing the foreground-background information processing.

### Holistic-Analytic Cognitive Style

The research comparing the cognitive style between people from Eastern and Western culture backgrounds is one of the latest and emerging areas in cultural comparison research. Anthropological and psychological studies of general cognitive processes suggest that culture is one key factor that correlates with cognitive styles (Nisbett et al., 2001; Riding & Rayner, 1998).

Holistic cognitive style implies a context-dependent way of processing information and a tendency to pay attention to the entire visual field. Analytic cognitive style means paying attention to a focal object and understanding its behavior using rules and formal logic (e.g., Nisbett et al., 2001). An early study conducted by Abel and Hsu (1949) provided evidence that Asian Americans are more likely to use a holistic approach to process information whereas the tendency to emphasize parts or single aspects of an object is more predominant in European Americans. In Ji et al. (2000)'s study, participants from Eastern Asian countries and the United States were shown pairs of pictures with no correlations. The study shows that Eastern Asian participants had a tendency to draw associations between those pairs of pictures and had a harder time decoupling foreground objects with the background scene in the pictures compared to Americans. In another experimental study (Masuda & Nisbett, 2001), Japanese and American participants were first shown a set of underwater scenes. They were then asked to recall what they had seen. The Japanese and Americans provided equal numbers of statements about which of the fish (the focal object in the scene) were larger than others, but the Japanese participants made about 70 percent more statements about the general environment, or the field surrounding the fish, and twice as many statements describing relationships between the fish and the background than the Americans did. This study thus revealed differences between Easterners and Westerners, that is, Easterners focused more on the field and on relationships, whereas Westerners are more focused on objects and tend to detach objects from the field. In addition, the results Masuda and Nisbett (2006) obtained from a set of change blindness tests also showed that American participants were better at detecting changes in foreground objects whereas Japanese participants performed better in detecting changes in context and environment. Studies exploring the cultural variations between Eastern Asian and American aesthetics also yielded interesting results that traditional art and photography in Eastern Asia has predominantly context-inclusive styles, whereas object-focused styles are more often appreciated in Western art (Masuda et al., 2008). The culturally shaped aesthetic orientations have been maintained in most contemporary art works (Masuda et al., 2008).

The aforementioned research all points to this interesting cognitive style divide between Easterners and Westerners, in which Easterners tend to engage in "context-dependent and holistic perceptual processes" by attending to the relationships between objects, whereas Westerners prefer a "context-independent and analytic perceptual process" by focusing on a small number of salient focal objects (Nisbett & Miyamoto, 2005, p. 469). In Nisbett and Norenzayan (2002)'s paper "Culture and Cognition," they tried to tie Easterners' holistic cognitive processes and Westerners' analytic cognitive processes to the different socio-economic structure and physical environment that people grew up in. As shown in Illustration 1, the American street scene on the left is wider, less crowded, and has less objects (e.g., stores, signboards) compared to the Japanese street scene on the right. The crowded Asian street scene may lead people to keep allocating part of their attention to their periphery either consciously or unconsciously, whereas the simple American street scene gives people fewer distractions. People thus are more used to focusing on foreground and focal objects. The comparison indicates that the cognitive style differences may be generated from the way people construct and make assumptions of the social and physical settings surround them.

Illustration 3 The comparison between an American street view (left) and a Japanese street view (right) (Nisbett & Miyamoto, 2005)

More recent studies used eye tracking to examine whether the cognitive style difference is reflected in fundamental levels of cognition and attention allocation. Chua et al. (2005) measured the eye movements of American and Chinese participants when they were viewing photographs with a focal object on a complex background. The study found that the Americans fixated more on focal objects than did the Chinese. The Chinese also made more saccades to the background than did the Americans. In Dong and Lee's study (2008), Korean, Chinese and American participants were asked to look at a webpage. Researchers divided the webpage into several designated areas. The eye tracking data suggests that within a certain amount of time, Asian participants switched significantly more frequently between different areas than American participants. Their study further confirmed Easterners' more holistic or global viewing pattern and Westerners' more analytic viewing approach. It also provided design guidelines for systems used by holistically-minded and analytically-minded people.

Recently, cultural neuroscience, an interdisciplinary field of psychology, anthropology, neuroscience and genetics has been established to investigate the interplay between culture and biology using a theoretical and empirical approach (Chiao & Ambady, 2007). The findings in this field using brain imaging studies are in accordance with the proposition that Westerners are inclined to an analytic cognitive style whereas Easterners tend to have a holistic cognitive style. For instance, in Hedden et al. (2008)'s study, they assessed the functional magnetic resonance imaging (fMRI) responses of Chinese and Americans when they were performing absolute judgmental tasks (ignoring visual context) or relative judgmental tasks (taking visual context into account). As frontal and parietal brain regions are known to be associated with attention control (Wager & Smith, 2003), activation in these regions was greater when American participants were performing relative judgmental task and when Chinese participants were performing absolute judgmental task. They interpreted the result as more activation appears when people perform tasks that they are less culturally prepared. Therefore, Americans were shown to have a more absolute processing mode whereas Chinese people were shown to have a more relative processing mode. Moreover, within each group, activation differences in these regions significantly correlated with scores on questionnaires measuring individual differences in culture-typical identity.

**Foreground and Background Information Processing**

In transferring the cognitive style divide from scene perception to a more realistic setting, we are interested in a scenario in which people have to attend to multiple activities in parallel. We wonder if the preferred holistic or analytic processing mode would influence how they distribute their attention in such scenario. In this section, we mainly review people's foreground-background parallel processing behavior and systems that support such multitasking.

People are capable of dealing with the co-presence of foreground and background information. For instance, in an open office working environment, one's primary work task is often displayed on a large monitor in foreground. The monitor however only covers about 10% of our visual field (Grudin, 2001). The rest 90% is usually filled with background information such as other colleagues, documents, etc. Previous research on workplace awareness (MacIntyre et al., 2001; Wisneski et al., 1998) suggested that while focusing on their work station, people are peripherally monitoring the rest 90% of their visual field to arrange their next task and implicitly communicate with other colleagues about each other's availability.

A recent focus in HCI community is thus to help people leverage their dual processing ability and to better distribute their attention between an ongoing foreground activity and intermittent background activities (e.g., Bailey & Iqbal, 2008). Systems such as Tickertape (Fitzpatrick et al., 1998) and adjusting windows (Bailey et al., 2000) help people be aware of the information (e.g., incoming communication requests, news) via lightweight and highly tailorable message window located on the peripheral areas of the computer screen. Other studies used peripheral visual stimulus such as moving icons to test people's background awareness (Bartram et al., 2001). Most of these studies have generated positive findings that people are capable of and can make better use of the cognitive resources by attending to multiple activities. However, very little research has been done to discern how culturally nurtured cognitive style might influence people's use of those systems.

Furthermore, as the amount of accessible information is rapidly overloading traditional displays (Grudin, 2001), researchers resorted to the area beyond traditional desktop monitor to display information. For instance, Grudin (2001) found that adding a second monitor improves work efficiency by helping people maintain the flow of their thoughts and better arrange their primary and secondary tasks. MacIntyre et al. (2001) devised an interactive peripheral projected display – Kimura. Using Kimura, while engaging in a foreground activity on the desktop monitor, users are able to glance at the projected display on which background working contexts (e.g., related documents, communication with other colleagues) are visualized as a montage of images. More recent approaches involve using large screen, head-mounted display device which present background information in the periphery of people's visual field (Buxton & Fitzmaurice, 1998). Ambient display systems further explore the boundary of people's background processing. Systems such as AmbientROOM display information though subtle cues of sound light or motion naturally embedded in users' physical surroundings. Through displaying information at the periphery of users' perception (Wisneski et al., 1998), users can thus process the background information "at the periphery of perception" (Wisneski et al., 1998, p. 25). In Andrews et al.'s study (2010), a workstation of eight combined high-resolution LCD panels significantly increased the amount of external information that one can access while conducting cognitively demanding sense-making tasks. However, all of these studies have been done in the Western cultural environment, without considering how the holistic tendency might change the way Eastern people attend to the background information in their periphery.

# CURRENT STUDY

## Motivations

First, despite that we are processing information from multiple displays and sources every day, very few study has been done discerning how the analytic and holistic cognitive style influence how people selectively attend to information on different displays, especially when information is arranged in a foreground and background order.

Second, in real life people are dealing with constantly changing information whereas in previous studies researchers often used still images or texts to test people's attention allocation pattern (e.g., Nisbett & Miyamoto, 2005). Furthermore, the dynamic process of people reacting and redistributing their attention according to the change of information in the background has not been compared between cultures. Whether changes in a same complexity level in the background may lead to people of different cognitive style to redistribute their attention differently is yet to be examined.

Third, to what extent people pay attention to the entire visual field was usually determined by content recall tests in previous studies. How much one remembers about the focal and the background objects in a scene might not be the most direct representation of people's attention allocation. Individual's memory ability and familiarity with the scene may vary. Moreover, it fails to capture people's real time response to different visual stimulus, when and how they focus on different parts of their visual field. Therefore, in the current study, we used eye tracking to record participants' real-time attention focus.

## Research Questions

We wonder if culture plays a key role in determining how people attend to different activities in a multi-display setting. Will people who are more habituated to a holistic cognitive style be more likely to allocate their attention to the background display whereas people who tend to process information in an analytic way be more likely to focus on the foreground display?

**Experiment Set-up**

We built a dual-display system. Two different tasks involved different dynamic visual stimulus were shown on the two displays (see (1) in Illustration 2).

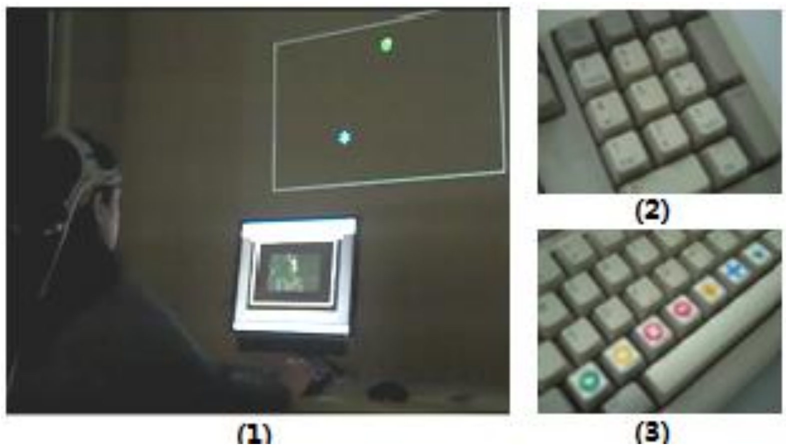



Illustration 4 Dual-display setting. (1): participant sitting in front of the dual-display setting; (2): number pad for number task; (3): buttons for icon task.

*Foreground Display*: A computer monitor was placed in front of participants. The center of the computer screen was approximately 20 inches away from participant's eyes. We considered it as our foreground display as it covered participants' focal visual field when they sat down and looked slightly below their eye level. It also fits well with most people's habit of working on their primary task on desktop or laptop computers.

*Video Task*: To constantly engage participants' attention on the foreground display, short videos were shown with numbers appeared briefly (for .5 seconds each, 36 numbers for a 3-minute long video) at random intervals. Participants had to use the number pad on keyboard to input as many of these numbers as they saw (see (2) in

Illustration 2). The design was borrowed from Tang and Birnholtz's study (2010) in which such videos were shown to be cognitively engaging[1].

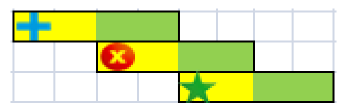
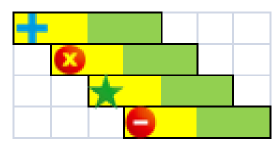
*Background Display*: The background display was projected on the wall behind and above the monitor. The center of the background display was approximately 40 inches away from participants' eyes. It covered part of participants' peripheral visual field when they looked at the foreground display.

*Icon Task*: Icons varied in shape and color appeared on the background display at certain times (18 icons in total for a 3-minute long segment) in parallel with the videos. Each icon appeared, stayed still for 5 seconds and moved in different motion paths for another 5 seconds before they disappeared. Participants used the buttons on the keyboard which were marked with the icons (see (3) in Illustration 2) to input the icons they noticed.

To test how people of different cognitive style react to the visual complexity change in the background, we designed four visual complexity levels on the background display (see Table 1). In level 1, the background display remained dark, as no icon was shown. In level 2, two icons appeared successively without overlapping each other. In level 3, a new icon appeared every 5 seconds. Therefore, two icons were overlapping during half of the time. In level 4, a new icon appeared every 2.5 seconds. There were times when two, three or four icons showed simultaneously on the background display. The icon task was switching from one complexity level to another based on a pre-set script. Each level took approximately an equal amount of time in each 3-minute experiment segment.

[1] The task load was measured with the NASA Task Load Index in the study. On a 20-point scale with the higher end indicating a higher difficulty, participants across conditions have rated the task load to be 12.49 (*SD*=3.49).

Table 1 Visual complexity levels of the background display.

| Level | Icon Interval | Maximum Overlapping icons | Sample Script |
|---|---|---|---|
| **1** | N/A | N/A | N/A |
| **2** | 10s | 0 |  |
| **3** | 5s | 2 |  |
| **4** | 2.5s | 4 |  |

Participants were asked to work on both tasks displayed in the foreground and the background. While participants were mostly engaged in the video task shown in the foreground, once they noticed a new icon in the background, they needed to record the icon using the icon buttons.

**Hypotheses**

We used task performance as our first measurement of participants' attention allocation. As Western people were more likely to be paying more attention to foreground objects whereas Eastern people have the tendency to pay more attention to objects in the entire visual field, we hypothesized that there would be a difference in how well they notice the visual stimulus on the two displays. In particular, we hypothesized that:

*H1a:* Easterners will notice more icons appear on the background display than Westerners.

*H1b:* Westerners will notice more numbers appear on the foreground display than Easterners.

The next two sets of hypotheses both used the eye tracking data to measure the attention allocation. As the more time people spend actively looking a certain display implies the more attention they pay to that display (Liversedge & Findlay, 2000), we used eye gaze duration, that is, the amount of time people spend in looking at certain display, as a way to examine people's attention allocation pattern to the two displays. According to the analytic and holistic cognitive style divide, we hypothesized that:

*H2a*: Easterners will have longer eye gaze duration on the foreground display.

*H2b*: Westerners will have longer eye gaze duration on the background display.

Moreover, we believe as the visual complexity level of a display goes up, it is likely to attract more attention from individuals. If Easterners are paying more attention to the background display, they will be more likely to notice and respond to the variation of the visual complexity level of that display. We used fixation frequency to measure participants' response to the visual complexity. According to relevant perception literature, fixation is the maintenance of visual gaze on a single location for 100msec or longer. Eye fixations induce the firing of visual neurons' and indicate that the brain is processing visual information (Martinez-Conde et al., 2004).

*H3*: Easterners' eye fixation frequency on the background display will be more likely correlated with the changing visual complexity of the background display.

Last but not least, we used a post-experimental questionnaire to assess how difficult participants would perceive the task to be. Since we believe Westerners are less culturally prepared to pay attention to the entire visual field, we hypothesized that they would feel working in the dual-display setting to be more difficult compared to Chinese:

*H4*: Westerners will perceive the cognitive load of the dual-display task setting to be higher.

# METHODS

## Participants & Recruitment

We chose Chinese as representatives for Eastern culture group and Americans as representatives for Western culture group in our study. Samples from the two nationality groups are shown in previous studies to have different cognitive styles (Hedden et al., 2008). The use of Americans and Chinese in cultural comparison research is common in studies of this nature. All participants were graduate students at a large US university. They were recruited through campus online mailing lists.

## Experiment Design

A 2 by 2 mixed design was used with nationality as an independent variable varied between subjects and two task conditions either with or without the background display as the other independent variable, which was varied within subjects. We call the condition in which information was displayed on both displays the dual-display condition. The other condition in which participants only had to focus on the number task on the foreground display is called single-display condition. We included the single-display condition to set a baseline for participants' number task performance. Each condition was consisted of two 3-minute long segments. The data from the two segments were then averaged. The task complexity of the peripheral task was classified into four levels which also varied within subjects.

## Eye Tracking Apparatus and Measures

An ASL H6 head-mounted eye tracker was used to record participants' eye gaze data. We specified the foreground display and the background display as the two areas of interest in our study. Based on the videos recorded by a head-mounted camera, when the eye tracker detected neither display, participants were mostly looking at the keyboard to press either icon or number buttons.

As mentioned in the hypotheses section, we used two forms of data generated by the eye tracker: eye gaze duration (how long one has spent looking at a display) and fixation frequency (how frequently one fixated on a display). The start and end time of each fixation was time stamped. It's enabled us to examine the fixation frequency during different visual complexity level period.

**Procedure**

Upon participants' arrival to the laboratory, they put on the eye tracker. To calibrate the eye tracker, they were instructed to look at a series of dots on both displays to verify proper tracking and calibration.

After the calibration, participants were given one practice segment to get familiar with the experiment setting. They then proceeded to two segments in dual-display condition and two segments in single-display condition. The segment order was randomized. At the end of the experiment, participants completed a post-experimental questionnaire. We used the 5-item NASA task load index (Hart & Staveland, 1988) to assess participants' perceived task difficulty. The whole experiment took about an hour.

## RESULTS

We recruited 29 students ($M_{AGE}$=24.62, $SD_{AGE}$=1.74) who passed the nationality and cultural background check for our study. All 29 participants' questionnaire data was used to test our fourth set of hypotheses. Since 7 participants' eye gaze data was invalid[2], we used the rest 22 participants ($M_{AGE}$ =23.78, $SD_{AGE}$ =1.56)' task performance and eye data. 12 participants are Americans born and raised in the U.S. The remaining 10 participants are Chinese born in mainland China or Taiwan (7%) and have been to the U.S. for less than 3 years. All participants speak fluent English.

### Foreground vs. Background Task Performance

According to H1a and H1b, Chinese would notice more icons on the background display, whereas Americans would notice more numbers on the foreground display. We ran a mixed model ANOVA using nationality as a between-subjects variable and the number or icon task score as within-subjects variables. As shown in Table 2, we found that Chinese performed significantly better in the icon task, $F(1, 63)=5.24$, $p<.05$, which lent clear support to H1a. H1b was not fully supported as we did not find any statistically significant difference between Chinese and Americans' number task performance, $F(1, 63)=1.17$, $p=.28$.

The results from the single-display condition showed that Chinese performed marginally better in the number task than Americans, $F(1, 63)=3.87$, $p<.05$. The data suggested that the foreground task needs to be better designed to avoid any possible advantages from either of the two nationality groups.

[2] The data was invalid either due to participants' eyes were untrackable or the room we used to run the study was not completely dark. Light would interfere with the eye tracking process.

Table 2 Participants' task performance. All task scores were standardized on a 100-point scale.

| | | American | | Chinese | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| **Dual-Display** | **Number Task** | 61.69 | 3.88 | 64.27 | 3.37 |
| | **Icon Task** | 90.51 | 9.72 | 95.96 | 4.18 |
| **Single-display** | **Number Task** | 91.78 | 2.66 | 96.46 | 6.66 |

**Eye Gaze Duration**

According to our second set of hypotheses, Chinese will spend longer time looking at the background display and Americans will spend longer time looking at the foreground display. As aforementioned, the dwell data was used here as the measurement for participants' eye gaze duration on each display. We conducted a mixed model ANOVA using viewing area (foreground display, background display, and keyboard) as a within-subjects factor. As shown in Table 3, no significant differences were found in terms of eye gaze duration on all three viewing areas.

Table 3 Participants' eye gaze duration

| | Americans | | Chinese | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| **Foreground display** | 121.96 | 26.55 | 117.89 | 23.22 |
| **Background display** | 9.05 | 10.40 | 8.62 | 5.60 |
| **Keyboard** | 20.06 | 12.64 | 18.00 | 19.40 |

**Foreground-to-Background Glances**

In our experiment, participants were mostly engaged in capturing the foreground number task. They quickly glanced at the background icon task when necessary. We suspect the reason why we did not see any significant difference in terms of the gaze duration data was due to each glance was very short in time ($M$=.33s, $SD$=.71s). Besides the duration of these "glances", we believe how many times they switched from the foreground display to the background display to "glanced" also indicates how much attention they paid to the background[3].

We conducted a one-way ANOVA to compare the amount of such glance between the two groups. The results showed that Chinese participants ($Mc$=25.85, $SD$c=8.86) had marginally more such glance than American participants ($M_A$=18.42, $SD_A$=8.84), $F(1, 20)$=3.65, $p$=.07. Realizing there were only 18 icons that appeared on the background display in each experiment session, we interpreted from the data that Chinese participants were not necessarily more likely to sense the changes in the background. Instead, Chinese were being more watchful in checking the background display even when no new icon appeared.

**Fixation Frequency**

H3 predicted that the fixation frequency of Chinese participants would more likely to be correlated with the visual complexity of the background display, which indicates that the fixation frequency of American participants would more likely to be independent from the visual complexity change.

First, we conducted a repeated measures test on participants' fixation frequency on the background display using nationality as a between-subjects variable and the complexity level was used as a within-subjects variable. The results suggested that the visual complexity had a main effect on the eye gaze intensity of both Chinese ($F(3, 27)$=9.19, $p$<.05) and American ($F(1.71, 18.82)$=4.14, $p$<.05) participants, that is, both groups have fixated more frequently on the background display as the visual

[3] We did not include the times when participants switched from the keyboard to the background display. Based on our experiment observations, those "glances" were more likely used by participants to confirm they had chosen to input the correct icon.

complexity level went up. However, an interaction effect was found between visual complexity and nationality, $F(2.10, 42.04)$[4] $=4.43$, $p<.05$. The data suggested that Americans and Chinese reacted differently to the visual complexity change on the background display (see Figure 1).

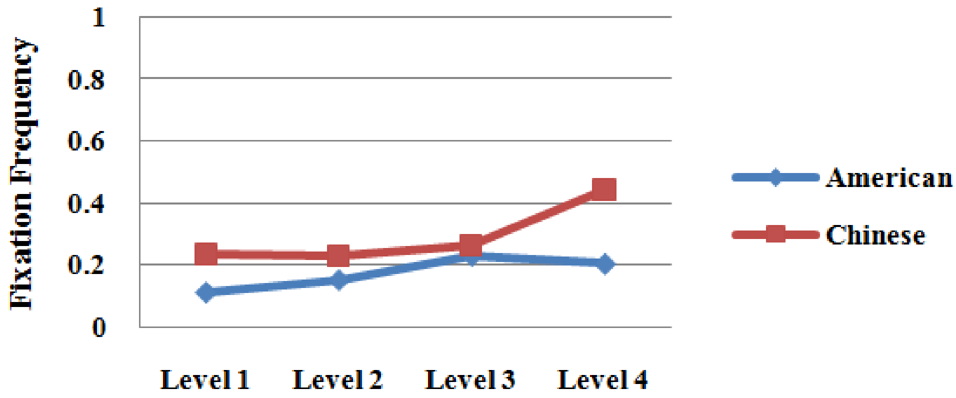



Figure 3 Fixation frequency on the background display

To further analyze how the two groups differed on each complexity level, we then ran a mixed model ANOVA on fixation frequency data using the visual complexity level as within-subjects variables and nationality as a between-subjects variable. The pairwise comparison suggested that when the background visual complexity was the highest (level 4), Chinese participants had a significantly higher fixation frequency on the background display than Americans, $F(1, 240)=3.91$, $p<.05$, which to some extent explains the significant interaction effect between nationality and the complexity level in the repeated measures test. H3 was partially supported as both groups positively responded to the visual complexity change. However, Chinese participants had a significantly higher fixation frequency compared to American participants in the highest complexity level.

[4] Mauchy's test indicated that the assumption of sphericity had been violated, $\chi 2(5)=13.301$, $p<.05$. Degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon=.570$).

Table 4 Eye fixation frequency on each viewing area with the visual complexity level specified. For instance, the data in the first row indicates American participants fixated on the background display for .11 times (*SD*=.11) per second during level 1.

| Viewing Area | Level | American | | Chinese | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| Background Display | 1 | .11 | .11 | .23 | .20 |
| | 2 | .15 | .11 | .23 | .18 |
| | 3 | .23 | .17 | .26 | .17 |
| | 4 | .20 | .18 | .44 | .20 |
| Foreground Display | 1 | 1.75 | .21 | 1.61 | .39 |
| | 2 | 1.65 | .32 | 1.60 | .40 |
| | 3 | 1.50 | .34 | 1.52 | .42 |
| | 4 | 1.40 | .27 | 1.35 | .37 |
| Keyboard | 1 | .26 | .25 | .27 | .26 |
| | 2 | .38 | .23 | .30 | .34 |
| | 3 | .43 | .29 | .41 | .38 |
| | 4 | .53 | .31 | .52 | .48 |

The changes in participants' fixation frequency in corresponding to the visual complexity of the background task inspired us to connect the performance data with the fixation frequency data. To find out whether Chinese participants' significantly higher gaze intensity on the background display in level 4 has resulted in better performance in the icon task, we divided the task performance according to the four complexity levels. We ran a mixed-model ANOVA test with the task complexity as the within-subject variable and the icon task performance as the dependent variable. The pairwise comparison showed that Chinese ($M_C$=97.73, $SD_C$=5.07) performed significantly better than Americans ($M_A$=86.46, $SD_A$=11.25) when the complexity level was the highest, $F(1,63)=9.15$, $p<.005$. No significant difference was found in the other two lower complexity levels (Level 2, $F(1,63)=.66$, $p=.42$; Level 3: $F(1,63)=.21$, $p=.65$).

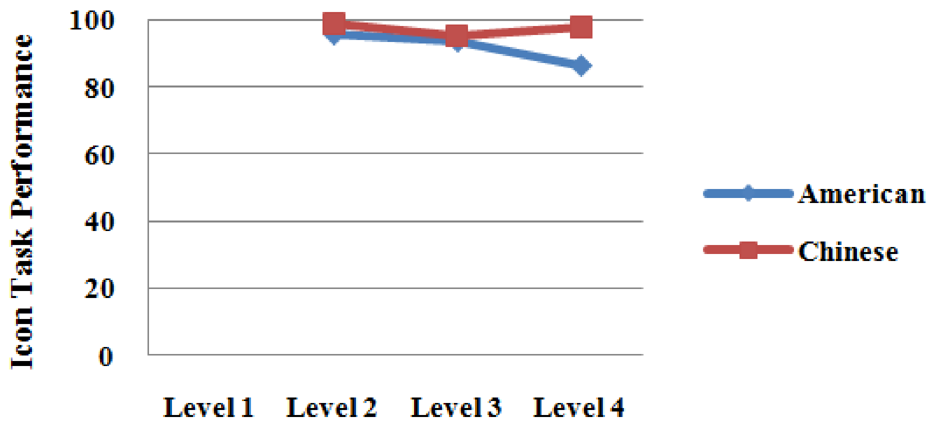



Figure 4 Icon task performance with the task complexity specified. No data was shown in the first row since no icon appeared during the level 1 period.

We conducted similar repeated measures tests on the other two viewing areas: the foreground display and the keyboard area. Along with the increasing complexity level, both groups linearly decreased their fixation frequency on the foreground display (linear component: $F(1, 20)=12.58$, $p<.05$) and linearly increased on the keyboard area (linear component: $F(1, 20)=21.17$, $p<.05$). No interaction effect between nationality and the complexity level of the background display was found. According to the pairwise comparison in Table 4, no significant difference was found on all four complexity levels in both viewing areas. We interpreted the results as when more icons appeared on the background display, participants needed to input more icons via the keyboard and thus allocated less attention to the foreground display. We also did not find any significant differences in participants' number task performance on all four complexity levels.

**Task Difficulty & Comfort Level**

After all items were reverse coded and aggregated, we found that the overall average scores from Chinese participants ($M_C$=4.73, $SD_C$=.43) was significantly higher than American participants' average rating ($M_A$=4.35, $SD_A$=.32), $F(1, 27)$=2.65, $p$<.05. To correct for this difference, we centered the questionnaire data from each nationality group by subtracting each item from the grand mean of that group (Harkness et al., 2003). We believe the centering has helped us avoid the positive rating tendency of Chinese participants (After centering: $F(1, 27)$=.00, $p$=1.00).

H4 suggests that Chinese participants will perceive the cognitive load of such dual-task setting to be lower compared to American participants. We used the 5-item NASA task load index to assess participants' perceived task difficulty (Cronbach's α =.739). H4 is supported as the rating was significantly higher among American participants ($M_A$=1.34[5], $SD_A$=1.06) as opposed to Chinese participants ($M_C$=.20, $SD_C$=1.07), F(1, 27)=8.44, $p$<.05.

We also included several items assessing participants' comfort level with the foreground and the background task. Five questions were asked about participants' experience in completing the number task in the dual-display condition (Cronbach's α=.737). We expected American participants to report a higher comfort level as the task was located in the foreground. The results showed that Chinese participants actually had a marginally higher comfort level with the number task ($M_A$ =-.22, $SD_A$ =1.00, $M_C$=.36, $SD_C$=.71, $F(1, 27)$=3.14, $p$<.05). Another set of 3 questions were asked (Cronbach's α=.641) about participants' experience with the icon task as well. We expected Chinese participants to be more comfortable working on the icon task as it was located in the background. The results showed that American participants ($M_A$ =-1.09, $SD_A$=1.01) did rate allocating their attention to the background display to be more difficult compared to Chinese participants' ratings ($M_C$=-.11, $SD_C$=1.24), $F(1, 27)$=5.44, $p$<.05.

[5] We reported the after centering questionnaire means here.

The questionnaire data suggested that participants from the two nationality groups not only differed in the quantitative evaluations of their task performance and gaze data, but also had different subjective evaluation of their experience working in the dual-display setting.

## DISCUSSION

In this section, we further discuss the cognitive style differences. We also stress the importance that future system design needs to be tailored to different cultural groups' preferred attention allocation style.

**Attention Allocation in the Dual-display Setting**

The task performance data suggested that Chinese were better than Americans at noticing visual changes in the background. Although Chinese did not spend significantly more time looking at the background display, they did switch from the foreground task to glance at the background display slightly more frequently than American participants. The finding can be interpreted in two ways. First, Chinese participants were possibly more sensitive to the visual changes in the background. Whenever a new icon appeared, they were more likely to switch their visual focus to the background display. Second, Chinese participants were more watchful of the possible changes in the background. They were used to frequently looking at the background display to monitor the possible new icons. Given that there were only 18 new icons in each 3-minute icon task and Chinese participants had on average 25.85 times (*SD*=8.86) of foreground-to-background visual sequences whereas American participants had on average 18.42 times (*SD*=8.84), the second interpretation of the dwell data seemed to be better supported. Chinese participants were not necessarily more sensitive than American participants in terms of sensing the background changes, but they were more alert to the background and constantly checking even when no new icon appeared.

As for the attention allocation to the foreground activity, neither the task performance nor the dwell duration was different between Americans and Chinese. One possible explanation is the number task was not difficult enough for us to observe any culture-related performance difference. Given that Chinese actually performed marginally better than Americans in the number task when they did not have any background interferences, Chinese might even have certain advantages in performing the number task which made it even more difficult for Americans to outperform Chinese in the dual task condition.  However, the fact that the marginal performance difference in the number task disappeared in the dual task condition indicated that it might have cost Chinese participants more effort to monitor the background, so that they could not maintain their better performance in the foreground task.  Taking the glance analysis into consideration, the more effort was perhaps that they were being overly watchful of the changes in the background.

The different impact casted by adding the background activity on Chinese and American participants implies that, in real life, scenarios or systems that demand foreground-background multitasking might be more distracting to people from an Eastern cultural background.  The fact that they are more watchful of the background can be both an advantage and a disadvantage in that it disperses their focal attention more.  If the foreground task is more important and demands constant concentration, designers should avoid the unnecessary distractions from the background activity for holistically-minded people.

**Response to the Background Complexity Change**

Along with the increase of the visual complexity in the background complexity, we found similar trend of correlations between the visual complexity and the fixation frequency in both nationality groups.  Only on the background display we found a slightly different fixation frequency level between the two groups: Chinese participants had a significantly higher fixation frequency compared to American participants when the background activity reached its highest complexity level.  The same pattern was found in participants' background task performance as well: Chinese participants only significantly outperformed American participants when the complexity level of the background task was the highest.

Existing literature has not compared Easterners and Westerners' attention allocation when the complexity of the display varies. The current study identified that the attention allocation difference between Americans and Chinese became salient only when the background activity reached a certain complexity threshold. When the background complexity was low, the difference between Chinese participants' and American participants' fixation frequency were not significantly different and it did not result in any task performance differences. The findings discerned the attention allocation pattern on a more detailed level and revealed that it might not exist throughout people's cognition process.

Designers should keep in mind when designing systems that present important information in the background, visual stimulus of a certain complexity level might attract Easterners and Westerners at different levels. Especially when it comes to warning or alert systems, the discrepancies might lead to significant consequences.

**Comfort Level with the Dual Task Setting**

Participants' self-reported attention allocation experience was mostly in line with the task performance in that Americans did rate the overall task difficulty to be lower and report feeling less comfortable allocating their attention to the background task. The data implies how satisfactory and how cognitively demanding they felt about the dual-display setting. Users' satisfaction with the system has always been a very important component in usability evaluation metrics (e.g., Chin et al., 1988). The fact Chinese and American participants even had differences in their subjective evaluation of the system stress the importance of tailoring HCI system design to different cultural groups.

# LIMITATIONS

There are a few limitations in our current study. First, as there was a marginally significant difference in participants' task performance in the single task condition, the number task might engage American and Chinese participants' attention in foreground differently. Also, the number task might not be difficult enough. As it might not exceed the foreground attention capacity of Eastern people, the distinction in attention allocation might not be salient enough to lead to a performance difference.

Second, as the eye tracker works better in a dark environment so as to capture the eye data, except for the light from both displays, we tried avoiding other light sources to keep the laboratory dark throughout the whole experiment. Although no evidence so far has shown limited lighting would affect Easterners and Westerners' attention allocation differently, we cannot rule out the possibility that this might change how people normally allocate their attention in an environment with normal lighting.

Last but not least, our research has been focused on the individual level of cognition so far. As most of the information processing we encounter everyday are embedded in certain social contexts. How individual level of cognition influence and interact with the way individual communicate and process social information might be an interesting direction to explore in future studies. It has long been identified that Easterners and Westerners have different self-construal in a group context (Markus & Kitayama, 1991). The concept of power dynamics, work and interpersonal relationships, etc. are also different between Eastern and Western culture. Assuming the background information was not merely icons, but meaningful messages with different focus (e.g., individual-oriented, group-oriented, etc.), studies can be conducted to discern will people react differently to same message content, and would the message content modifies people's preferred way of allocating their attention?

## CONCLUSION

Based on previous findings on Easterners' holistic cognitive style and Westerners' analytic cognitive style, the current study suggested that the cognitive style difference was also reflected in how Easterners and Westerners allocate their attention and process information in a foreground-background dual-display setting. In particular, the difference became salient when the visual complexity of the background activity reached a certain threshold. In addition, two groups were different in their perceived comfort level receiving information from the foreground and the background display.

The culture difference on the cognition and attention allocation level is especially important in that it determines how people receive information and make sense of the world. As the digital revolution further breaks down the geographic and linguistic boundaries between different cultures, the current study emphasizes the need to include this cognitive style cultural difference as a system or interface design guideline as opposed to hastily enforcing the global standards which are usually originally set in a western cultural environment.

Furthermore, with the overwhelming amount of information people are dealing with everyday, more and more large screen display or peripheral display system have been used in today's workplace to enable foreground-background information processing. As the physical scope of the display is enlarging, the current study is among the first few that investigate the cultural difference in attention allocation pattern and information reception capacities in such dual processing setting. We hope when designing systems for international organizations or cross-cultural collaborations, designers can take into consideration the cognitive style difference between different cultures. Information can be displayed in a way that is tailored to the attention allocation preference of holistic-minded people and analytic-minded people.

APPENDIX

**Post-experimental Questionnaire**

**Part 1: Central Viewing Area (Computer Screen)**

Please indicate the extent to which you agree or disagree with the following statements based on your experience recording the numbers when watching the movie trailers. All items in this part need to be rated on a 7-point scale with 1 being "strongly disagree" and 7 being "strongly agree."

1. I was mostly watching the movie trailers on the computer screen.
2. I was able to record the numbers effectively.
3. I had trouble recording numbers from the movie trailers.
4. I think I missed a lot of numbers from the movie trailers.
5. I could do a better job in recording those numbers if I was not required to also pay attention to the icons pop out on the wall.
6. I think I got most of the numbers from the movie trailers.
7. I paid attention to the content of the videos (movie trailers) showing on screen.
8. Those movie trailers interested me a lot.

**Part 2: Peripheral Viewing Area (Projected Display)**

Please indicate the extent to which you agree or disagree with the following statements based on your experience noticing the icons displayed on the wall. All items in this part need to be rated on a 7-point scale with 1 being "strongly disagree" and 7 being "strongly agree."

1. It felt natural for me to pay attention to the wall while working on the computer.
2. I adjusted quickly to the process of working on the computer and paying attention to the projected display.
3. I spent a lot of time monitoring what was showing on the projected display.

4. I frequently looked at the wall even when there was no icon appearing.

5. I only looked at the wall when I felt an icon might have appeared.

6. I was seriously distracted by the icons appearing and moving on the wall when recording numbers from the movie trailers.

7. It was easy for me to notice those icons when they first appeared on the wall.

8. I only noticed the icons when they started to move.

9. I think I missed a lot of times when icons first appeared on the wall.

10. I had trouble figuring out what icons were displayed on the wall.

**Part 3: Task Difficulty**

Please evaluate the task we asked you to accomplish in this experiment (i.e.: recording numbers in the movie trailers while pressing matching buttons on the keyboard). All questions in this part need to be rated on a 20-point scale with 1 being "low" and 20 being "high".

1. How mentally demanding was the task?

2. How hurried or rushed was the pace of the task?

3. How successful were you in accomplishing what you were asked to do?

4. How hard did you have to work to accomplish your level of performance?

5. How insecure, discouraged, irritated, stressed, and annoyed were you?

**Part 4: Demographics**

Please answer the following questions regarding your demographic information.

1. Gender:

□ Female □ Male

2. Occupation

□ Undergraduate □ Graduate □ Staff □ Others: (please specify) ______

3. Are you fluent in English?

□ Yes □ No

4. What is your native language? ___________

5. What is your country of birth? ___________

6. In which country did you live for the majority of your childhood? ___________

7. How many years have you been in the U.S. or Canada? __________

8. Citizenship: ___________

9. Ethnicity

□ American Indian/Alaska Native

□ Asian

□ Black/African-American

□ Hispanic/Latino

□ Native Hawaiian or Other Pacific Islander

□ White/Caucasion

□ Others: (please specify) ______

10. With what ethnic group do you identify the most? (optional)

□ American Indian/Alaska Native

□ Asian

□ Black/African-American

□ Hispanic/Latino

□ Native Hawaiian or Other Pacific Islander

□ White/Caucasion

□ Others: (please specify) ______

11. What is your height? ____________

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