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Reducing Inattentional Blindness Using Subliminal Cueing in Visual Performance Tasks

Deepti Pappusetty, Hari Kalva; Florida Atlantic University; Boca Raton, Florida/ USA

Abstract

Not all the visual information acquired by the eyes is processed by the human visual system. Human visual attention selects information most relevant to the task being attended. Unexpected objects get overlooked when we are busy attending something else. Inattentional blindness is a psychological phenomenon where a visual stimulus goes unnoticed by the observer. This paper presents a research study on using subliminal cues to cause subliminal attention shift in a video scene showcasing inattentional blindness. The goal of this work is to develop and optimize video processing systems for applications such as surveillance and driving safety. Preliminary results indicated that subliminal visual cueing helped in making aware of other objects or events happening in a scene other than the prime task.

Introduction

Inattentional Blindness

There are several occasions when we do not see things even if they are right in front of our eyes. Sometimes things are in plain sight but we still miss them. This is often termed as *Looking without Seeing*. It is either because one is so absorbed in their deep thoughts or are concentrating on something else. This psychological lack of attention is called *Inattentional blindness* [1]. Inattentional blindness is not a vision defect and most of us experience it at one time or the other.

One of the first well known studies on inattentional blindness was conducted by Neisser [2]. In his experiment, two different activities were shown in an overlapped visual field and the viewers were asked to pay attention to a specific action in one of the activities. An unexpected event in the unattended activity often got missed by the viewer.

Simons et al. extended Neisser's experiment [3] and designed the "Invisible Gorilla" experiment [4]. The video had two teams of three players each. One team wore white and another in black. Players in each team passed an orange basketball to each other within their respective teams. The participants were asked to count the number of times players wearing white passed the balls. The second variation of the experiment was to count number of times black team passed the balls to each other. What many participants missed was a gorilla walking through in the middle of the scene. Similarity of the gorilla to the attended objects had some effect on whether or not the participants noticed the event.

Objective results using eye tracker [5] for inattentional blindness on the "Invisible Gorilla" video have also shown that even though the target is in plain sight and crosses the fovea, many miss the unexpected event. Another essential conclusion from the research was that there were no fixations in the region on interest (ROI) and the ROI was instead observed with peripheral vision.

Subliminal Cueing

Subliminal means perceiving something without being aware of it. A subliminal cue is a visual stimulus which is processed below the threshold of consciousness. It is shown for a very short time and is removed before a human can process it fully. Subliminal stimuli studies have shown its effects on human choice responses and decision making [6]. Chen et al. experimented on attention shift in images [7]. A short-duration visual stimulus was flashed before presenting the image and an eye tracker recorded the saccades before and after the visual cue. The experiment results showed that a dim blob shown for as short as 50ms duration, object cue for 100ms and a face cue for 200ms duration, were able to guide viewer's attention unconsciously to the cued hemi field.

Motivation

The much discussed area where inattentional blindness leads to fatal results are during driving. Looked-but-failed-to-see-errors (LBFS) during driving lead to serious misfortunes [8]. LBFS is a term used to describe the types of accidents where it looks as if the car drivers actually have been looking in the direction where other parties were, but have not perceived their presence. In other cases, such as video surveillance, research has demonstrated how easily people miss blatant security threats like a knife when they are focused on some other primary task [9].

Given a target/threat that is potentially missed because of inattentional blindness, can a subliminal cue on target object be used to make the user/viewer aware of its presence, at the same time not distracting them from the actual task at hand? Application specific object detectors can be used to detect objects that are likely to go unseen because of inattentional blindness (IB). Focus of this project is on understanding whether we can induce attentional shift of a viewer to an ROI in a video scene susceptible to inattentional blindness. Experiments were designed to answer the following questions: 1) Can adding visual cues increase the detectability of regions that go unseen because of inattentional blindness? 2) Does the type of visual cue (a geometrical or a face cue) affect the detectability of ROI, 3) Does cue duration (E.g. 33ms or 67ms) affect the detectability of ROI, 4) Does addition of visual cues reduce main task performance? In the studies reported here, we attempt to examine each of these factors.

As per the Invisible gorilla experiment by Simons et al. [4], the gorilla is likely to go unseen due to inattentional blindness. We used two different visual cues, each with two different durations to see its role in attention shift. We determine the effectiveness of using visual cues by comparing the results with a baseline case of a video without any visual cues. Visual cues are effective in reducing inattentional blindness if more subjects notice the gorilla in videos with visual cues.

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Experiment

The Simon's video clip comprises of two teams of three participants each passing basketball (one basketball per team) to each other [4]. A person dressed in gorilla suit walks in to the scene at approximately 15 seconds. When walking across, it pauses in the middle and beats its chest and walks off the screen for about 5 seconds. The ROI here is the person in the gorilla suit. Gorilla is the object that is likely to go unseen because of inattentional blindness and our aim for this study is to understand whether a subliminal cue helps reduce incidences of inattentional blindness.

Different types of cues were overlaid on gorilla's face when the gorilla pauses in the middle of the scene and thumps its chest (Figure 1) [11]. A video editing tool "Corel Video Studio" was used to alter the "Invisible Gorilla Video" to add the cues.

Fig. 1. Screenshot of the gorilla from the video originally used by Simons et al. (1999)

Fig. 2. Cue 1, white spot covering gorilla's face

Fig. 3. Cue 2, Famous actor/celebrity Brad Pitt's face on gorilla's face

Fig. 4. Cue 3, Focus on gorilla's face

The first cue was a simple geometric stimuli, a white oval, covering the gorilla's face (Figure 2). Simons *et al.* reported that the gorilla was seen more when the counting task was done with players in black rather than the players in white because of similarity of a black gorilla to players in black [4]. Since the task was to count the balls passed by the white team, the similarity of white spot with the attended player's features was an interesting factor to note. The likelihood of seeing an object is higher if its features (color in this case) are similar to the objects subjects are attending [4]. We expect that a white spot, which is of the same color as the shirts worn by players that subjects are instructed to observe, would pop out and attract subjects' attention.

The second cue had the gorilla's face brightened (Figure 3) and remaining background darkened. This cue puts focus on the target object. For third cue, since studies have shown that human faces always attract visual attention, we chose a famous actor/celebrity "Brad Pitt" face to see if it led to attention shift. Familiarity of a face could be an influencing factor. Significance of this factor needs to be studied by varying trials with different human faces such as a random face, familiar faces, and celebrities.

The cues of varying durations were overlaid on gorilla's face. The video was coded at 30 frames per second and the cues were added for 4 different durations (1 frame = 33ms, 2 Frames = 67ms, 3 Frames = 100ms, 4 Frames = 133ms) leading to 12 test videos in total as shown in Figure 5.

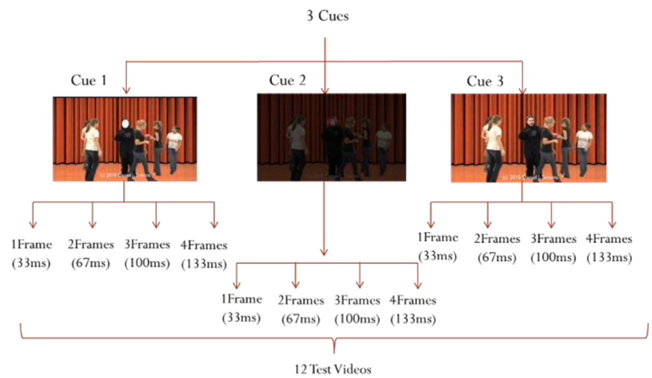

Fig. 5. Three cues: White Blob Cue, Gorilla Focused Cue and Face Cue. Cues were shown in the video for 4 different durations: 33ms, 67ms, 100ms, and 133ms as per preliminary experiment [1]

In the initial trials [11], three subjects were chosen to view each video. Therefore, 3 * 12 = 36 different members participated in the experiment. The experiment was conducted with one subject at a time. Only one video was shown to each subject and was shown only once. All the participants saw the video on their personal laptops or desktops which varied in sizes and screen resolutions. All the questions were asked orally.

In the preliminary experiments [11], percentage of identification of gorilla increased from 42% (from base case of original Simon's experiment) to 67%. This motivated our current experiment with more subjects (at least 12 test takers in each case) to validate the results. In this paper, we present results from our second set of experiments to understand the influence of cueing.

Experiment Design and Reliability Checks

We created a website to conduct the tests online. All the participants where provided with the website link. The experiment setup was free viewing in natural conditions and no controlled lighting was used. The experimental setup reflects real world scenarios such as surveillance and driving where IB could be a problem. The website contained all the required instructions, test video, and post-test questions. Results were stored into our database.

The first page of the website asks for demographic information (age, gender, location, type of device, and monitor size). It was made sure that the test was taken on a laptop or a desktop, and not on mobile device. The system rejected any survey attempts from a mobile device. The second page then gives instructions on the task to be performed when watching the video. The participants were instructed to count the number of times the players in white passed the ball. The video starts playing when play button is pressed and redirects to the questions page automatically once the video playback ends. All other play controls were disabled and subjects

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are prevented from replaying the video. Attempts to refresh the browser were detected and results were not stored in the database. The five questions were asked sequentially one after the other and not on the same page. The time taken to play the video is an indication of the bandwidth availability at the test takers end. Long playback duration is indicative of interrupted playback and the results were discarded.

Before showing the video, all the members were instructed to count the number of passes conducted by players in white. This was the prime task which required attention and made the users unaware of the actual motive for the experiment. After the video was shown, participant's questionnaire consisted of the following questions:
(i) Which of the following pictures is from the video you just saw?
- The options consisted of still images of similar sport from three different videos. Test taker had to select out of the radio button options. The intention for this question was to determine whether the viewer paid attention to video.
(ii) Have you seen the video before?
- The results for the subject were rejected if they answered "yes" for this question. The format was radio button options.
(iii) How many times did the players wearing White Pass the ball?
- This question was intended to assess if the cues inserted distracted the subject and affected the primary task performance (Correct count for passing of balls was 16). The format for answers was a drop down list of numbers from 0- 100.
(iv) Did you notice anyone else other than the players passing the ball? If yes, describe what you saw. If no, say no.
- This question was intended to assess if the viewer witnessed the unexpected event which is the Gorilla.
(v) Do you remember seeing any of the following cues in the middle of the scene as shown below? If No, please choose last option.
- This question showed the images of different cues hinting at gorilla's face and also some false options to see how accurately the viewer identified the cue. There were totally six radio button options for this question. Three actual cues used in the experiments, a false cue with white arrow pointing gorilla's face, a false cue with a red cross on gorilla's face and one option with no cue.
(vi) Any comments if viewer wanted to give about the experiment.

Subjects were from Mechanical Turk and volunteer subjects from high school and university students (undergraduate and graduate). Most of the results were obtained from Amazon Mechanical Turk. All the participants were provided with the website link. No instructions or questions were conveyed orally. The participant pool was diverse and comprised of different ages, locations, and background. We made sure that participants took the test only once. Amazon Mechanical Turk's features were used to block participants who already took the test.

We chose only the five videos for our present study:
Case 1. No Cue (Control Case),
Case 2. Gorilla with Brad's face (1frame duration),
Case 3. Gorilla with Brad's face (2 frames duration),
Case 4. Gorilla with white spot (1 frame duration),
Case 5. Gorilla with white spot (2 frames duration).

Results

In the original "Invisible Gorilla" experiment around 42% of the subjects reported seeing gorilla (the opaque/white/easy task from [4]). The original video of Simon's with no cues was used as the control case.

Overall 174 subjects participated in the experiments. A total of 75 subjects were filtered out leaving 99 valid responses. The valid responses were from 43 female participants and 56 male participants with ages ranging from 15 to 61 years. Data on monitor sizes were also collected as input from viewers and it varied from 10 inches to 26 inches. Of the 99 results, 29 valid results were obtained from high school students, 57 valid results from workers of amazon mechanical Turk and 13 valid results from the remaining set (99 valid results in total).

Data from many subjects were discarded for the following reasons: (i) the observer already knew about the phenomenon or has previously seen the original Simon's video. (ii) The count was either too low (less than 7) or was either too high (greater than 25). Significantly differing counts are indicative of a subject not performing the task as instructed. (iii) Since the experiment was conducted online, bandwidth connection at viewers end was one of the concerns as any pausing or buffering video could have resulted in a subject noticing the gorilla. Especially we observed majority of the participants from Asian countries and had low bandwidth connection. Due to these reasons, totally 75 results were rejected. 48 results were rejected due to low bandwidth connection (3 from high school samples and 45 from MTurk samples); 19 samples were due to the participant already familiar with the experiment (9 from high school, 9 from MTurk and 1 from FAU samples); 7 results were rejected due to invalid counts (1 from high school, 3 from MTurk and 3 from FAU samples); finally one sample was rejected due to vague and unclear answer (1 sample from high school). After filtering invalid views, we got 26 valid results for Case 1, 15 valid results for Case 2, 21 valid results for Case 3, 18 valid results for Case 4, and 20 valid results for Case 5. Table 1 shows the results for each of the five conditions.

Effect of visual cues

In the original Simons experiment, around 42% detected the gorilla [CITE]. HOW MANY DETECTED IN OUR CONTROLLED CASE. In our experiment with cues, around 67% of the subjects identified the gorilla when Brad face was shown for 1 frame duration (33ms) than in the control case (50%); $\chi^2 = 11.56$, $df = 1$, $p < 0.0005$. Table 1 shows the results of identification of the unexpected event and the cue for all the five different cases. With Brad Face and two frame duration, the identification of gorilla is not though significant but increased to 57%. With white spot 1 frame duration the identification is not effected much but with 2 frame duration it makes an impact.

Type of cue and its visibility

We also noted whether the subjects noticed the cues. Very few accurately identified cue when the duration was 33ms, for both Brad face and white spot (1 out of 15 for brad face, 3 out of 18 for white spot). But when duration is increased to 2 frames, the cues starts getting identified (4 out of 21 for brad face, 8 out of 20 for white spot). It is interesting to note that very few could remember the cues but still were subliminally getting diverted to the intended targeted location. Another interesting point to note here is even though very few accurately identified the face cue when compared to white spot, it attracted the attention more than a white spot. The results indicate that familiarity of the cue (human face) is an influencing factor (67% detection).

Cue duration

One can expect that with increase in cue duration, the identification of gorilla must increase. We see an increase in identification for gorilla with a white spot from 50% to 63%. But

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the pattern is opposite in case of a face cue. The identification decreases from 67% to 57%. There is an ambiguity seen in this case. In both the cases, identification of the cue increased with increase in duration of the cue. Although, geometric cue was identified more than the face cue.

Table 1: Results for identification of unexpected event and the cues for the five different videos

Videos	Saw Gorilla	Did not see gorilla	P value	Accurately identified cue
Original Simon's Experiment (White/Easy/Opaque)	42%	58%	-	-NA- 12 Observers
Case1: No Cue (Control case)	50%	50%	-	-NA- 22/26 saw no cue
Case2: Brad Face (1Frame 33ms)	67%	33%	<0.0005	7% 1/15 Observers
Case3: Brad Face (2Frames 67ms)	57%	43%	<0.15	19% 4/21 Observers
Case4: White Spot (1Frame 33ms)	50%	50%	=0.99	17% 3/18 Observers
Case5: White Spot (2Frames 67ms)	63%	37%	<0.005	37% 7/19 Observers

Effect of cue on main task performance

Though the cues were observed, it did not distract them from the task at hand. Table 2 shows that the mean and standard deviation when adding the cue and with no cue are all close to mean of 15.

Discussion & Conclusion

We conducted a research study focusing on understanding subliminal attention shift to an ROI (Region of Interest) in a video scene showcasing inattentional blindness using cues. The "Invisible Gorilla" video by Simon et al [4] was used to evaluate the proposed method for reducing Inattentional blindness. As reported by Simon et al the gorilla is likely to go unseen due to inattentional blindness. By varying the duration and types of the cues, we saw its role in attention shift. Results indicated that visual cueing helped in making aware of other objects or events happening in a scene other than the prime task.

Table 2: Mean of the "counts of number of times players in white passed the ball", as reported by the viewers from each of the video categories

Videos	Mean	Standard Deviation
No Cue (Control case)	15.03	2.21
Brad Face (1Frame 33ms)	14.6 p>0.05	2.4
Brad Face (2Frames 67ms)	14.9 p>0.05	1.59
White Spot (1Frame 33ms)	14.9 p>0.05	2.36
White Spot (2Frames 67ms)	15.6 p>0.05	1.24

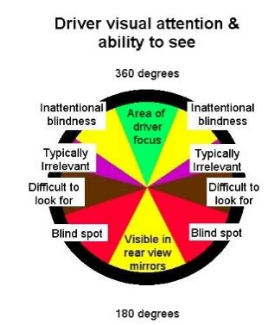

Fig. 6. Schubert's 180 degree graphic display of driver's visual attention and ability to see

An example of a potential use case: A system can be conceived which determines the primary task at hand. The primary task for example can be a driving task or a video surveillance by a security personnel. Based on the context, it then infers unimportant events or unattended regions and cues to such locations. The cueing hence makes the observer aware of other unattended regions and alerts them of any threat or unexpected occurrences. For example, Figure 6 shows the Schubert's 180 degree graphic display of driver's visual attention and ability to see [12]. Inattentional blindness spots usually fall outside of the driver's focus of attention. A visual cue can be shown to the targeted area most likely to be missed or towards unattended area on a head-up display (HUD) of a car in the area of Inattentional blindness of a drivers view.

As said earlier, there have been various awareness campaigns but not much work has been done to help reduce inattentional blindness. Also, there has been no study on the effect of subliminal cueing on Inattentional Blindness. Cueing, based on the current results, seems to be an effective way to divert the attention of the viewer to the inattentional blindness object by a machine. Applications are not just limited to surveillance and driving safety as mentioned elsewhere in the paper. Inattentional blindness phenomenon leads to missing important events in visual performance tasks performed by airport screeners, border guards, building security personnel, radiologists reading CT scans, and pathologists looking for cancer in biopsy slides etc. Automatically inserting visual cues could be an effective way to help reduce the mistakes and threats caused by inattentional blindness and change blindness.

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Author Biography

Deepti Pappusetty received her BS in Computer Science and Engineering from Jawaharlal Nehru Technological University (2008), India, and her Masters in Bioengineering (2011) from Florida Atlantic University. She has around two years of experience as a Software Developer in Oracle Pvt. Ltd. She is currently pursuing her PhD in Computer Science from FAU. Her work is focused on exploring ways to apply models of human perception and cognition to video processing. Applications of this research include new approaches to video compression, analysis, quality evaluation and visual search.

Hari Kalva is a Professor, Associate Chair, and the Director of the Multimedia Lab in the Department of Computer & Electrical Engineering and Computer Science at Florida Atlantic University (FAU).

Dr. Kalva has over 20 years of experience in multimedia research, development, and standardization. He has made key contributions to technologies that are now part of MPEG-4 standards. His current research focuses on understanding and applying human visual perception, cognition, and social context to optimize visual information processing.

Dr. Kalva received a Ph.D. and an M.Phil. in Electrical Engineering from Columbia University in 2000 and 1999 respectively. He received an M.S. in Computer Engineering from Florida Atlantic University in 1994, and a B. Tech. in Electronics and Communications Engineering from N.B.K.R. Institute of Science and Technology, S.V. University, Tirupati, India in 1991.