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Examining the Influence of Ambient Sounds on Visual Attention and Search Performance

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Abstract:

In sports competitions, ambient sounds, such as audience cheering and booing, can influence athletes' performance, either positively or negatively. Cheering is typically seen as supportive and performance-enhancing, while booing is perceived as depressing. This study investigates the effects of cheering and booing on attention and performance. Visual observation is crucial in many sports, where athletes assess situations and make decisions. This process demands increased attention and significantly impacts the outcome of the game. The study uses different levels of visual search tasks to simulate the observational phase of sports, with an eye-tracker to record participants' gaze behaviors. Three sound environments were established: positive cheering, negative booing, and silence. Analysis of Time to First Fixation indicated that in both high-difficulty and low-difficulty tasks, participants' search speeds were significantly slower in the cheering and booing conditions compared to silence. Moreover, in high-difficulty tasks, positive cheering disrupted performance more than negative booing. Further analysis of Average Fixation Duration revealed no significant difference between cheering and booing in terms of cognitive load on participants, suggesting that the interference caused by sound is due to attention disruption rather than cognitive overload. The study's findings provide quantitative and precise data via eye-tracking technology. These results offer scientific insights for enhancing training and competition environments to help athletes perform better. Additionally, the findings suggest that audiences should minimize their interference with athletes by refraining from making noise during moments requiring high concentration in the game.

Keywords: Sports, Ambient sound, Visual search, Eye tracking, Cognitive load, Attention

1. Introduction

In sports competitions, environmental factors, such as temperature, humidity, and audience noise, can significantly affect athletes' psychological states and physiological performance. While temperature and humidity can be managed with technology, audience-generated sounds are more challenging to control. Sounds generated by the audience, such as cheering and booing, can impact an athlete's concentration and decision-making abilities (Smith et al., 2016). These sounds can either enhance performance or increase psychological stress, thereby affecting the competition's outcome (Jones et al., 2007). Hatzigeorgiadis (2011) found that negative social evaluations, such as booing, can increase athletes' psychological stress, leading to distractions and fatigue. However, Tucker (2012) noted that negative feedbacks can motivate athletes to perform better. Some research suggests that positive cheering can lead to excessive excitement and mistakes (Zillmann & Bryant, 2001), while other studies show it can boost confidence and motivation, leading to higher performance levels (Smith, 2007). Understanding the effects of audience noise on athletic performance is essential for improving the environment of sports competitions and training.

Some studies have used reaction time techniques to assess the impact of noise on athletes' performance (Brooks, 2017; Smith, 2019). Reaction time could reveal direct behavioral outcomes. In contrast, the eye-tracking technology offers more detailed insights into attention and information processing, allowing for a deeper analysis of cognitive mechanisms. Moreover, most previous studies have focused on investigating the effect of one single sound stimuli, i.e. either cheering or booing. Few research makes comprehensive comparisons among various ambient sounds (Brooks, 2017; Smith, 2019). This study investigated three environments including cheering, booing, and silence, which provides a more holistic view of the ambient sounds. Observation is a key phase during the competition, i.e. in ball games, fencing, curling, requiring a high level of concentration. Athletes would analyze the current situation or the opponents' reactions to make tactics accordingly. Visual search tasks are used to simulate the observation phase in the present study. Moreover, an eye-tracker is used to record participants' eye gaze behaviors under these conditions. The eye-tracking results could provide accurate and quantified data to evaluate the impacts of different ambient sounds. The aim is to provide scientific evidence for optimizing training and competition environments to enhance athletes' performance and guide audience behavior during sports games.

2. Method

2.1 Participants

In this study, a sample of 26 individuals were recruited randomly from a shopping mall in Shanghai, China. The average age of the participants was 34.44 years, with a standard deviation of 11.75 years. The participants were evenly and randomly assigned to one of three groups: Group A, Group B, and Group C. Prior to the experiment, all participants were briefed on the procedure and any potential risks associated with the eye-tracker. Consent was obtained from all participants, who agreed to participate in the experiment on a voluntary basis.

2.2 Stimulus

The experiment investigates three different sound environments: positive cheering sounds, negative booing sounds, and silence. Group A participants are exposed to positive cheering sounds, while Group B participants are subjected to negative booing sounds. Group C participants perform the experiment in a silent environment. Visual search tasks are utilized to mimic the conditions of observation and intense concentration. A total of six visual search tasks are presented in the form of images, consisting of three high-difficulty tasks and three low-difficulty tasks. The objective of these tasks is to find out the target object in the images. High-difficulty images have more distracting elements, whereas low-difficulty images contain fewer distracting elements.

2.3 Procedure

The experiment employed a mixed design. The three sound environments serve as the between-group variable and the high-load versus low-load task as the within-group variable. Participants were randomly assigned to one of the three groups. After reading and signing the informed consent form, they voluntarily agreed to participate in the study.

Participants were led to sit in front of a monitor, with an eye-tracking device (Tobii 4C pro) positioned below the screen. Before the experiment officially started, staff played the audio in advance for each group using noise-canceling headphones to ensure the influence is successfully exerted. Following a five-point calibration, the experiment officially started. Six visual search images were presented in a random sequence, and participants were asked to locate the position of the target element on the screen and responding by pressing a designated key. Upon response, the screen would automatically advance to the next image. Throughout the experiment, audio con-

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tinued to play through the headphones, and the eye-tracker recorded participants' gaze patterns.

Each participant received a dessert after the trial. The target stimulus in each image was defined as the area of interest (AOI). Once all participants had completed the experiment, the eye gaze data for the AOI, including Time to First Fixation (TFF) and Average Fixation Duration (AFD), were extracted for further analysis.

2.4 Data analysis

In order to compare the impact of various auditory conditions on participants' performance in visual search tasks, one-way ANOVA and independent samples T-tests analyses were conducted to evaluate Time to First Fixation (TFF) and Average Fixation Duration (AFD) across the three subject groups. Furthermore, to identify the influence of task difficulty on visual search performance, paired samples T-tests were applied to analyze the TFF and AFD of participants when comparing high-difficulty and low-difficulty tasks within each group.

3. Result

3.1 Single-factor ANOVA analysis and T-tests for AFD

As presented in Table 1, the single-factor ANOVA and between-group T-tests indicated no significant difference in AFD among the three subject groups ($p > 0.05$). Additionally, the comparison of AFD between high-difficulty and low- difficulty tasks within each group did not yield any statistically significant differences ($p > 0.05$).

3.2 Single-factor ANOVA analysis and T-tests for TFF

As presented in Table 1, the single-factor ANOVA revealed no significant difference in TFF among the three groups for the low- difficulty task ($p > 0.05$). While there is a significant difference observed for the high- difficulty task ($F = 3.40, p < 0.05$).

For the low- difficulty tasks, a two-sample T-test indicated that the TFF of subjects in Group A ($M = 3.91, SD = 2.81$) was significantly higher than that of Group C ($M = 2.24, SD = 1.79; t = 1.61, p < 0.05$). The TFF of subjects in Group B ($M = 3.29, SD = 3.94$) was higher than that of Group C, but this difference was not statistically significant ($t = 0.75, p = 0.08$).

In the high- difficulty tasks, the TFF of both Group A ($M = 6.78, SD = 3.92$) and Group B ($M = 4.58, SD = 2.91$) was significantly higher than that of Group C ($M = 2.00, SD = 2.17$; $t = 2.89, p < 0.05$ *for Group A*; $t = 1.43, p < 0.05$ *for Group B*). A between-groups T-test also found that the TFF of Group A was significantly higher than that of Group B ($t = 1.48, p < 0.05$).

Table1: AFD and TFF of Group A, B and C in High- difficulty and Low- difficulty tasks

	High- difficulty task			Low- difficulty task		
	Group A	Group B	Group C	Group A	Group B	Group C
AFD(s)	0.22	0.21	0.20	0.21	0.21	0.21
TFF(s)	6.78	4.58	2.00	3.91	3.29	3.12

4. Discussion

This study explored the impacts of different environmental sounds on people's visual search behaviors which simulated athletes' observation status in sports competitions. Background sounds (positive cheering, negative booing, and silence) and visual search tasks of different difficulty levels were manipulated as independent variables. Participants' gazing behaviors served as the dependent variables. Average Fixation Duration (AFD) was used to measure the cognitive load during the search process, and Time to First Fixation (TFF) was employed to assess the speed at which participants located the target in the visual search task. The data analysis indicated no significant differences in AFD across the three sound conditions, nor between the high and low difficulty tasks. This suggests that neither task difficulty nor environmental sounds had a significant impact on participants' cognitive load in the experiment. The analysis of TFF revealed that both the positive cheering and negative booing groups had longer TFFs compared to the silent group in both high and low difficulty tasks. In the high difficulty task, the positive cheering group exhibited an even longer TFF than the negative booing group. This indicates that both positive cheering and negative booing interfered with participants' search speed, prolonging the time taken to locate the target. When the task gets more complicated, cheering has a more negative effects than booing.

The data analysis showed that cheering didn't boost the search performance. Instead, both positive cheering and negative booing resulted in extended search duration compared to the no-sound condition. This indicates a higher social inhibition effect on participants. This is consistent with the competitive model of emotional activation (Mather, 2011). Emotional activation leads to changes in attentional resource allocation. Typically, during visual search, individuals focus on task-relevant targets. However, the occurrence of external sounds, i.e. positive cheering or negative booing, triggers an emotional response. Positive cheering may lead to overexcitement and negative booing may lead to stress or frustration. These emotional responses could cause a redistribution of resources in information processing, particularly in terms of focus and distraction of attention. Participants receiving emotional signals reallocate their attentional resources, which slow their reactions during visual search. Since they need to balance their emotions and the search tasks. This phenomenon has been observed in previous studies (Schaefer, 2010; Schmitz, 2011). Whereas such emotional changes did not lead to changes in subjects' cognitive load in the experiment. Emotional activation mainly affects the allocation of attention and does not directly increase the burden of information processing (Isen, 2000; Basso, 2004).

A between-group comparison of Time to First Fixation (TFF) between the positive cheering group and the negative booing group revealed that positive cheering had a greater disruptive effect on subjects during the search task than negative booing in the high-difficulty task. From the perspective of emotional psychology (Cohen, 2013), positive cheers are likely to elicit stronger emotional reactions than negative booing, especially when task difficulty is high and participants are highly motivated. As a form of positive social feedback, cheers activate the individual's reward system which potentially lead to raised emotional states. This activation can cause a shift in attention resources away from the task and towards emotional responses, especially when the task is more complicated. This is the potential reason why positive external distractions, such as cheering, can excessively divert attention in this experiment.

In sports competitions, positive cheering typically occurs in a public, collective context, which usually has high level of uniformity and intensity. Negative booing, in contrast, is usually lower in sound frequency and amplitude. When positive cheers occur from a large, coordinated crowd, their volume and consistency can lead to sensory overload. According to Wegner's (2002) social psychology research, extreme group emotional expressions, such as cheering, may cause individuals' information overload. Hence their performance would be affected. This is also a potential reason why the positive cheering group performed significantly lower than the negative booing group when doing the more difficult search task.

This study has some limitations that should be addressed in future research. Firstly, the study used visual search tasks to simulate the observation stages in sports competitions, which may not fully replicate real competition scenarios. Future studies could bridge this gap by conducting experiments in actual sports competitions. Additionally, in real-world scenarios, audience cheering or booing may target specific players by calling their names, potentially leading to a stronger emotional response and yield different results. This also could be further explored in future studies.

5. Conclusion

In this study, different ambient sounds and task difficulties were utilized as independent variables to investigate the impacts of cheering and booing in sports competitions. An eye-tracker was used to record the participants' gazing process during the search task. Data analysis revealed that participants' search speeds under positive cheering and negative booing conditions were significantly lower than those in a quiet environment, regardless of task difficulty. Furthermore, in the high-difficulty task, positive cheering sounds caused even increased interference for participants compared to negative booing sounds. The findings also indicated that neither the sounds nor the task difficulty affected participants' cognitive load. This suggests that the primary cause of noise interference with participants' attention is attentional distraction rather than psychological overload, which provides valuable insights for future research. These results suggest that audiences should remain quiet during critical phases, especially when players need to maintain focus. This approach could create a better training and competition environment for athletes.

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