The Effects of Lighting Quality on Visual Perception at Sports Events: A Managerial Perspective

Chin-Hsien Hsu
National Chin-Yi University of Technology

This study examines the effects lighting quality on spectator visual perception, based on the principles of sports lighting and environmental psychology. The subjects of this study were 260 spectators of the World Games in-line hockey competition (aged 15-60). According to the study results from stage 1, the lighting of the in-line hockey rink at I-Shou University (the World Games 2009 venue for in-line hockey) did not meet international standards. Additionally, an analysis of the structural equation modeling in stage 2 showed that poor lighting quality impaired the quality of the visual perceptions of spectators. Implications of the results for managers improving lighting at sports events to enhance the potential enjoyment of spectators are developed

Introduction

The quality and quantity of lighting at sporting venues affects competition as well as the safety of both the athletes and spectators. Moreover, the design and quality of lighting at sporting venues may have an effect on the country's image when that country hosts international events. For instance, one of the events of the FIFA Futsal World Championship, Taipei, 2004, was suspended for half an hour due to a circuit breaker that was tripped at the National Taiwan University, an event which resulted in negative media feedback. Thus, lighting is a key element in the construction of sporting venues. It should conform to international standards in order to meet the requirements of safety, technical specification, economy, and energy conservation (Tsai Chang-Chi, 1983).

Well-designed lighting can relieve strain on the eyes, speed up the recognition of objects, lengthen visual durability, improve sporting quality, and prevent injuries and accidents during exercises or competitions (Tung Chih-Kang1993). Therefore, sporting venues with comprehensive lighting quality can ensure the physical safety of athletes and spectators. This analyzes the lighting quality of sporting facilities and its effects on spectator visual perception in order to suggest practical steps managers can take to improve the situation

The purpose of designing lighting is to provide appropriate illuminance, color temperature, and lighting to meet the physical and psychological requirements of the user's vision. Different lighting conditions result in varying different visual psychological perceptions that can affect the 'atmosphere' at sports events (Sung Ping-Sheng, 2001). The lighting of a facility is a key issue for research conducted into the dimensions and peripheral equipment of sporting venues. Proper design aims to control the brightness and illuminance of a subject (a ball or person) to create an optimum lighting environment where the subject is presented clearly in front of both the live spectators and television viewer (Shanghai Sports, 2000). A number of specific aspects for of lighting research have been suggested (Tung Chih-Kang, 1993), such as the angle and height of sports lighting, the lluminance of sports lighting, the uniformity of sports lighting, the intensity of sport lighting, and finally the selection of lighting for sports events.

Before examining visual perception, environmental perception needs to be understood first, given that the former is an instance of the latter. The perception process is at the core of environmental behavior as it is the source of all environmental messages. The environment may stimulate the senses and provide more messages to individuals than they can process effectively. Belk (1975) pointed out that it is difficult to 'separate' individuals from their environment during the perception process because they are interactive and the perception of individuals is affected by their environment. In perception studies, psychologists tend to focus on object perception instead of perception as regards the general environment and its importance to individuals, which some argue is more obvious and important (Mehrabian & Russell, 1974). Space perception is a physiological process whereby an individual perceives the surrounding space, objects, and situation based on their senses. In three-dimensional space, an individual must make judgments on distance, height, and direction, in time and in any place. Otherwise, one might encounter difficulties or dangers (Areni & Kim, 1994). Space perception comprises visual space perception and aural space perception. Visual space perception refers to depth perception, specifically, three-dimensional perception or distance perception. Obviously, depth perception is based on vision. With visual stimuli and previous experiences, individuals are able to understand and judge the situations.

There are a number of stages that characterize the interaction between people and their environment. First, people must be stimulated by their environment, only then does perception and cognition occur, as well as an evaluation of their physical environmental. These stages overlap, so it is not easy to separate them clearly. The environmental perception process covers both senses and perception. Sense is more like a physiological process, whereas perception is mainly based on the psychological process and is organized differently. The evaluation of a particular physical environment, such as that encountered at a sports event, depends on previous experience and the current psychological state of the subject (Mehrabian & Russell, 1974). Within a competitive sporting venue, spectators' visual perceptions are naturally created while observing the competition. One key factor which might impact on spectators' visual perception is lighting (Tai Hsia-Ling, 2008; Chan Ching-Hsuan, 1991). If lighting uniformity at sporting venues is poor, the human eye, specifically the pupil, must constantly adjust causing eye fatigue. Adequate lighting can strengthen the ability of the retina to identify tiny objects so as to improve the perception of both near and distant objects. With appropriate miosis, the image on the retina will be much clearer. Thus, a well-designed lighting environment can make the object outlines crisp and clear thereby helping to avoid eye fatigue because of straining (Chan Ching-Hsuan, 1991).

This study aims to investigate the quality of lighting at a specific sports event from this perspective and to test its impact on the visual perceptions of spectators at the event. The investigation can be divided in to a number of stages

Stage 1

This stage of the research was conducted at the in-line hockey rink at I-Shou University (the World Games 2009 venue for in-line hockey competition) on July 3, 2009. During the survey, all of the lamps in the rink were turned on and the survey was conducted in accordance with the international illuminance standard for in-line hockey. 49 measurement spots were empirically measured and the measuring values were recorded and analyzed.

The following tools were used to measure the lighting quality of the rink: (1) Illuminance meter: digital illuminance meters (TES-1335 vertical illuminance meter and LI-250 horizontal illuminance meter) were used as the primary tools. The DPI was 0.01Lux~0.1kLux/0.01fc~0.01kfc and its degree of measurement accuracy was ±3% rdg± 0.5% f.s. The illuminance meter was used to survey the distribution of illuminance in the in-line hockey rink. (2) Laser distance meter: handheld distance meter Trimble HD-150 was used to measure the height of the lampposts and the measurement spots. Its average degree of accuracy: (0.3~30m/1~100ft) ±2mm (±3/32in), maximum: (0.3~30m/1~100ft) ±3mms (±1/8in). The next stage comprised the measurement process: There were three tasks here. The number of lampposts and lamps was confirmed. Then the height of the lampposts was measured using the laser distance meter. Finally, a measuring tape was employed to measure relevant locations of the lampposts and the surface of the rink. The measurement spot was then located. The regulations set by CIE (International Commission on Illumination) were adopted in this research. This involved installing installing the illuminance meter on a one-meter high stand and aiming the sensory center right above the measurement spot, then fine tuning the horizontal position of the stand. When the tool was in a state of stillness for about 10 to 15 seconds, the vertical illuminance and horizontal illuminance values were calculated from four directions and the average and stable value taken as the illuminance value. Finally, the third step was repeated for at all measurement spots and recorded.

This investigation produced the following results: (1) Condition of the indoor in-line hockey rink at I-Shou University and its lighting. The floor material, number of spectator seats, type of lamp-shade, height of lamp poles, and lighting wattage at I-Shou University are presented in Table 1.

Illuminance of the indoor in-line hockey rink at I-Shou University: The mean horizontal illuminance, mean vertical illuminance, maximum-to- minimum illuminance, maximum-to-minimum illuminance ratio, and variance of the indoor in-line hockey rink at I-Shou University are presented in Table 2.

Table 1: Condition of the indoor in-line hockey rink at I-Shou University

Flooring	Lamp-shade	Lamp pole height	Lighting wattage (per lamp)	Number of seats
Maple flooring	Diffusion lamp- shape	10 meters	1000 watt	3942

The horizontal illuminance of the indoor in-line hockey rink at I-Shou University was 135 Lux and did not meet the standard; the vertical illuminance was only 72 Lux. The speed variation range of objects, i.e., balls, in different sports is great and the smaller the ball used in a sport, the faster the sport is and the greater demand for high illuminance level (Hsu Lung-Chih, 2009). The ratio between horizontal illuminance and vertical illuminance will noticeably influence the lighting system. As such, low illumination levels result in players' inability to make accurate judgments regarding distance, negatively influencing performance. (Huang Wen-Liang, Hsiao Ying-Chang, 1993; He Shu-Hsin, 1991) Liu Tien-Hsiu (2007) also indicated that the illuminance level should be enhanced to improve spectators' visual perception depending on the number spectators and scale of spectator seats. The In-line Hockey competition during the World Games in Kaohsiung was an international event, yet the mean horizontal illuminance of the official venue failed to meet international standards, and the vertical illuminance only reached 72 Lux. The result did not meet the standard for holding international events by 750~1,500 Lux, thus it can be argued negatively influencing the in-line hockey players' performances and spectators' visual perceptions during World Games 2009.

In addition, the maximum-to-minimum illuminance ratio of the indoor in-line hockey rink at I-Shou University was 12, while the variance was 0.39, both of which fell short of international competition standards. In large-scale sporting venues like in-line hockey rinks, the illuminance uniformity will impact the players' and spectators' vision in locating the ball as well as determining its speed (He Shu-Hsin, 1991; Wen Yen-Chih, Liu Tien-Hsiu, Hsu Lung-Chih, 2004). The maximum-to-minimum illuminance ratio and the variance of the indoor in-line hockey rink at I-Shou University also did not meet standards causing the players' and spectators' parallax, with a likely negative impact on the quality of the competition and the quality of the spectators perceptions of the event.

Table 2: Results of the analysis of the indoor in-line hockey rink at I-Shou University

Measuring items	Illumination
mean horizontal illuminance	135 lux
mean vertical illuminance (east/south/west/north)	72 lux
maximum/minimum illuminance (horizontal illuminance)	215 lux/ 18 lux
maximum/minimum illuminance (vertical illuminance)	118 lux/ 14 lux
maximum/minimum illuminance ratio	12
Variance	0.39

Stage 2

This stage of the research was conducted with relevance to the World Games, which was held in Kaohsiung County in July 22nd to July 26, 2009. The testing location was the indoor in-line hockey rink at I-Shou University, the venue for the In-line Hockey Competition of the World Games 2009. Consequently, the spectators were invited to be the subjects of the research. The survey was conducted personally by the researcher at the venue. All of the subjects agreed to respond to the survey after the research purpose had been explained. The number of questionnaires for this research totaled 400, with the number of collected questionnaires being 280. After eliminating incomplete questionnaires, 260 questionnaires were considered to be valid, giving a response rate of 87%.

The spectator visual perception scale used in this research was adapted from the Spectator Visual Perception Scale of Sport and Leisure Environments (Wakefield & Blodgett, 1996; Hsu Lung-Chih, 2009). Three experts were asked to examine invited to the questionnaire and offer opinions. After modifying the questionnaire to satisfy these views and ideas the final questionnaire was developed and designated "Questionnaire for Spectator Visual Perception at the In-line Hockey Rink". The questionnaire comprised three dimensions (14 questions), which focused on illuminance, illuminance variance, and visual clarity. Statements such as: "during the game, the light illuminance in the defensive zone of this rink was quite bright", and: "during the game, the light illuminance in the rear area of the goalkeeper defensive zone of this rink was quite bright" were evaluated with a five-level Likert scale, and scores were given in according to the level of agreement: "strongly disagree" (1 point), "disagree" (2 points), "neither agree nor disagree" (3 points), "agree" (4 points), and "strongly agree" (5 points). A confirmatory factor analysis was conducted in the scale. The fit indices of the overall model of the spectator visual perception scale were as follows: $\chi2$ (74, n=260,) =172.17, $p < .01$, GFI=0.93, RMSEA=0.060, SRMR=0.044, CFI=0.98, NNFI=0.97, CN=192.25, $\chi2/df$=2.33. According to Hu and Bentler (1999) for a particular fit index, if GFI, CFI, and NNFI 0.90, then RMSEA is less than 0.80, and SRMR less than 0.50. They argue that if $\chi2/ df$ is less than 5, and CN exceeds 150, then the model has a good degree of fit. Given these figures, the model tested in the present research had a 'good degree' of fit. In terms of reliability, Cronbach's α for the consistency of the scale was 0.77 to 0.88, which suggests that the In-line Hockey Spectator Visual Perception Scale is highly reliable.

Datum were processed and analyzed by the statistical software SPSS14.0 and LISREL 8.7. (1) Descriptive statistics: descriptive statistics (frequency, percentage, and average) were adopted to obtain information about the subjects. (2) Linear structural equation model: the linear structural equation model was used to analyze spectators' influence on visual perception regarding the lighting of in-line hockey rinks.

The larger portion of the spectators was male (141 people, 54.2%); most of the people answered *no* to the question asking whether or not they used to be an in-line hockey player (160 people, 61.5%); most subjects had obtained associate degrees or bachelor's degrees

(169 people, 65%); as for the age, subjects under 20-year olds were in the majority (118 people, 45.4%), whereas subjects aged 21-30 were second (90 people, 34.6 %).

Model identification was conducted before the formal analysis in order to verify whether there was a unique solution in the theoretical model. According to Bollen's t-Rule (1989): (p+q) (p+q+1) / 2, p refers to the number of exogenous variables while q denotes the number of latent endogenous variables. Based on this formula, there was 1 exogenous variable and 14 endogenous variables. As a result, the formula was (1+14) (1+14+1) / 2 = 120. This means that 32 parameters had to be verified to test the theoretical model underlying this research. If the number of parameters is less then that required, the theoretical model of this research can be regarded as having sufficient identification. The subjects of this study totaled 260, the estimated parameters amounted to 33, so the ratios between the number of subjects and parameters were 8.12:1, higher than that required, according to Bentler and Chou (1980).

The SEM assumption data was tested to see if it conforms to normality assumption (normal distribution of univariate and multivariate). The kurtosis and skewness of the 14 observed variables were ±2 which conformed to the standard of normal distribution (Mardia, 1985).

This study used standardized loading as an index of measuring model evaluation. The results are presented in Table 4. The obtained t value indicates showed that all the standardized loadings of the index are such as to suggest that the associated path coefficients do not exist. The highest standardized coefficient of each index was 0.88, which did not exceed 1(≧0.95), suggesting that it did not go beyond estimation. (Huang Fang-Ming, 2002)

Table 3: Sample Statistics

Info	Number of People	Percentage	Info	Number of people	Percentage
Sex			**Age**		
Male	141	54.2%	Under 20	118	45.4%
Female	119	45.8%	21-30	90	34.6%
Player eligibility			31-40	25	9.6%
Yes	100	38.5%	41-50	18	6.9%
No	160	61.5%	Over 51	9	3.5%
Education					
Senior High and Vocational School Graduate (or lower)	65	25%			
Bachelor's Degree/Associate Degree from College	169	65%			
Graduate or Professional Degree	26	10%			

The structural model of this research is shown in figure 1. The latent variables in stage 1 are: a- illuminance, b- illuminance variance, c- visual clarity; the latent variable in stage 2 is: d- visual perception; b1 refers to whether the spectators were in-line hockey players.

Table 4: Table of Parameter Evaluation of Spectator Visual Perception Model

Parameter	Standardized Parameter	t value
λ_1	0.68	11.02
λ_2	0.82	13.68
λ_3	0.71	12.13
λ_4	0.84	16.62
λ_5	0.81	16.09
λ_6	0.63	11.36
λ_7	0.83	16.67
λ_8	0.88	18.17
λ_9	0.86	17.63
λ_{10}	0.72	13.44
λ_{11}	0.65	11.84
λ_{12}	0.62	10.32
λ_{13}	0.81	14.02
λ_{14}	0.76	13.00
δ_1	0.53	10.60
δ_2	0.43	9.96
δ_3	0.48	10.34
δ_4	0.30	8.58
δ_5	0.33	8.99
δ_6	0.60	10.89
δ_7	0.31	9.17
δ_8	0.22	7.78
δ_9	0.25	8.36
δ_{10}	0.48	10.60
δ_{11}	0.57	10.97
δ_{12}	0.62	9.98
δ_{13}	0.34	5.88
δ_{14}	0.42	7.39

This stage constructed the paths for the relationships based on the theoretical model. Estimates of the extent to which the model correctly identified or fitted, the dataare given by the model indices, which were: $\chi 2$（87, n=260）=188.90, $p < .01$, GFI=0.91, RMSEA=0.057, SRMR=0.070, CFI=0.98, NNFI=0.97, CN=195.01, $\chi 2/df=2.17$. The indices showed that the covariance matrix of the assumed model conformed to the empirical data. The analysis of the overall paths is presented in Table 5. γ 1 is the path coefficient pertaining to whether the spectators were players and their visual perception; β 1 is the path coefficient regarding visual perception and illuminance; β 2 pertains to visual perception and illuminance variance; β 3 pertains to visual perception and visual clarity.

Discussion

This study focused on constructing and testing a spectator visual perception model. The model measured the visual perception and psychological impact of the lighting for spectators (subjects) whilst watching the games. A scale or measure was developed for this research to test the three-dimensional spectator visual perception model that was developed . The model was constructed with three latent variables and 14 observed variables. The latent variables include: illuminance (5 questions), illuminance variances (6 questions), and visual clarity (3 questions). The definitions of the three variables are as follows: Illuminance is defined in terms of the visual tolerance level of spectators

Figure 1

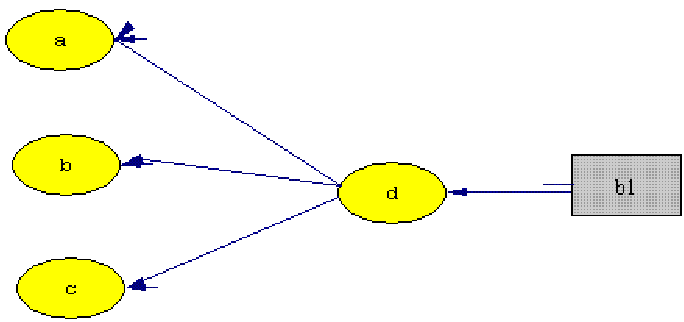

Table 5: coefficient of model parameter

Parameter	Standardized parameter	Standard error	t value
$\gamma 1$	0.16	0.06	2.39*
$\beta 1$	0.68	0.08	9.11*
$\beta 2$	0.49	0.07	4.40*
$\beta 3$	0.97	0.09	9.33*

Note: *p<.05

with regard to the lighting intensity at the rinks. The illuminance variance is the visual interference of lighting distribution to spectators. Visual clarity is mainly based on how color rendering influences spectators' vision during a competition. According to the model developed, these three variables will directly impact spectators' visual perceptions while watching a game.

Human identification of the surrounding environment such as a sport event depends on lighting illuminance, which stimulates a user's vision and elicits different psychological perceptions (Areni & Kim, 1994; Knez & Kers, 2000). The intensity and distribution of light determines the quality of the perceived environment as well as influencing the behavior of spectators. Insufficient illuminance reduces their recognition capability and negatively impacts their psychological perceptions. On the other hand, the enhancement of illuminance improves will the recognition as well as psychological perception. However, "the higher the better" is not a rule of illuminance. Various factors should also be considered such as physical adaptability and economic efficiency. Illuminance uniformity gives the 'impression' of brightness and influences the external appearance of things as well as internal psychological perceptions. Improper lighting, inctrrect projection angles, and poor illuminance distribution all result in glare, whereas greater illuminance difference produces, sharper contrast and makes it easier the easier to emphasize visual focus. Thus, lighting distributions with sharper illuminance contrast are commonly used to emphasize specific features of the environment, such as a sport event, as well as to relieve eye fatigue (Park & Farr, 2007a, 2007b). A lighting source with high color rendering is able to present or indicate the original colors of object surfaces, whereas low color rendering tens to cause color aberration. The color rendering of a light source in turn influences visual perception of the colors of the surfaces of objects.

One aim of the structural model of this was to investigate whether spectators visual perceptions were affected by them being hockey players or not, and to find out how this could impact on their view of the lighting provided at the hockey game. Whether the spectators had been hockey players or not is a categorical question, which has two options: yes and no. The results of the study showed that this factor—having played hockey-- had a positive impact on overall visual perception, suggesting that the design of lighting does influence spectators' visual perception while watching hockey competitions. The results showed that the spectators who were or had been players had higher sensitivity to the lighting than general spectators. Perhaps this is because players as competitors are or had been subject to the effects of such lighting before. However, it should be noted that whether or not spectators used to hockey players has a positive impact on the visual perception of lighting, its 'influential power' only reached 16%.

Conclusions

The first stage of the results showed that the lighting quality at this sports arena did not meet international standards, despite it being one the venues of World Games 2009. Further improvement is needed. To address the question spectators will be affected directly by this poor lighting while watching competitions, in the second stage of the research, illuminance, illuminance variance, and visual clarity were measured separately and their effects on different aspect of spectator visual perception assessed. The question as to whether spectators who were players would be more sensitive to lighting quality than general spectators was also investigated. Stage 2 results showed that conformed that the inferior lighting quality at the venue had a negative impact on the quality of spectators' visual perceptions.

The fact horizontal illuminance and vertical illuminance were found not to meet international standards probably affects players or competitor as well as spectators. With poor lighting it is more difficult for players to locate the ball and make judgment about its likely movements, thus influencing player performance negatively and perhaps even causing injuries. This provides another reason for managers to improve both kinds of lighting at venues for hockey.

From the findings we also suggest that the distribution and angle of the lighting be adjusted and vertical illuminance especially be strengthened to prevent glare. Regular maintenance and cleaning are also important key elements of lighting concerns. The quality of the illuminance of sporting facilities is determined not only by the number and watts of lights but also by the angle of the light source. It is found in this research that the light sources were not installed at a proper angle so they produced apparent differences in brightness. This question of the impact of different lighting angles on the overall quality of lighting needs to be examined in future research. To extend the applicability of the present findings, this study should be repeated with spectators at different sport events at which the importance of lighting is likely to vary.

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