Int. j. racket sports sci. vol. 5(1), 2023, xx eISSN: 2695-4508
Original Investigation DOI: 10.30827/---

Hearing the roar: Spectator noise and umpires stress in major badminton tournaments

Hearing the roar: Spectator noise and umpires stress in major badminton tournaments

Fredrik Sjödin [1], Hanno Felder [2], Stefan Holmström [1] and Martin Fahlström [3]

1 Department of Psychology, Umeå University, Sweden.
2 Olympic Training Center, Department of Biomechanics, Saarbrücken, Germany
3 Department of Clinical Sciences, Umeå University, Sweden.

Received: 10-11-2023

Accepted: 13-03-2024

Abstract

This study investigates the effects of spectator noise on umpire stress levels during major badminton tournaments. Previous research has shown that spectator noise can affect performance and decision-making in sports, including badminton. However, there is limited understanding of how this phenomenon explicitly affects umpires, who play a crucial role in officiating matches. Nine experienced umpires from the 24th Badminton World Federation (BWF) World Championships participated in the study. Heart rate variability (HRV) was used to measure stress levels objectively. In addition, subjective noise sensitivity and general stress levels were assessed using validated questionnaires. Noise levels were recorded on court using stationary sound level meters, and individual noise exposure was measured using personal carried noise dosimeters. The results showed a statistically significant correlation between spectator noise level and stress, mainly when umpires were working as service judge. Umpires with a higher subjective sensitivity to noise and higher general stress levels showed a stronger correlation between noise levels and stress during matches. The findings suggest that spectator noise may be a factor to consider in efforts to support umpire performance and well-being in stressful environments. Further research is needed to investigate the potential impact of this association on decision-making processes.

Keywords: *Spectator noise, stress, badminton, umpires.*

Resumen

Este estudio investiga los efectos del ruido de los espectadores en los niveles de estrés de los árbitros durante los torneos más importantes de bádminton. Investigaciones anteriores han demostrado que el ruido de los espectadores puede afectar el rendimiento y la toma de decisiones en los deportes, incluido el bádminton. Sin embargo, no se sabe muy bien cómo afecta explícitamente este fenómeno a los árbitros, quienes desempeñan un papel crucial en el arbitraje de los partidos. En el estudio participaron nueve árbitros con amplia experiencia que estuvieron en el 24.o Campeonato Mundial Bádminton organizado por la Federación Mundial de Bádminton (BWF). Se utilizó la variabilidad de la frecuencia cardiaca (VFC) para medir objetivamente los niveles de estrés. Además, se evaluaron la sensibilidad subjetiva al ruido y los niveles generales de estrés mediante cuestionarios validados. Los niveles de ruido se registraron en el campo mediante sonómetros fijos y la exposición individual al ruido se midió con dosímetros de ruido personales. Los resultados mostraron una correlación estadísticamente significativa entre el nivel de ruido de los espectadores y el estrés, principalmente cuando los árbitros trabajaban como jueces de servicio. Los árbitros con una mayor sensibilidad subjetiva al ruido y mayores niveles generales de estrés mostraron una mayor correlación entre los niveles de ruido y el estrés durante los partidos. Los resultados sugieren que el ruido de los espectadores puede ser un factor a tener en cuenta en las iniciativas

Corresponding author: Fredrik Sjödin, fredrik.sjodin@umu.se

Cite this article as:
Sjödin, F., Felder, H., Holmström, S., & Fahlström, M. (2023). Hearing the roar: Spectator noise and umpires stress in major badminton tournaments. *International Journal of Racket Sports Science, 5*(1), x-xx.

para apoyar el rendimiento y el bienestar de los árbitros en entornos estresantes. Es necesario seguir investigando el impacto potencial de esta asociación en los procesos de toma de decisiones.

Palabras clave: *ruido de los espectadores, estrés, bádminton, árbitro.*

BACKGROUND

Spectator noise is a common factor at most major sporting events, and spectator noise has been shown to affect the performance of athletes and technical officials in terms of performance and decision-making (Myers & Balmer, 2012; Nevill et al., 2002; F. Sors et al., 2019; Starcke & Brand, 2012; Unkelbach & Memmert, 2010).

Badminton is no exception, and high spectator noise levels are common at badminton championships (Sjödin & Fahlström, 2018). Research has shown that spectator noise can affect referees' decision-making in football (Nevill et al., 2002; Sors et al., 2021). However, the reason for this effect can vary from person to person (Nevill et al., 2017) but also that that the decisions of referees with high anxiety might be more easily influenced by external factors like spectator noise (Sors et al., 2019).

High noise levels may in itself be perceived as unpleasant and thus cause stress and secondly, especially in a sports context, make it challenging to perform the work task and thus cause stress (Burns et al., 2016; Goyal et al., 2010; Sors et al., 2019). In a sports context, with spectator noise as the primary noise source, noise exposure is also more variable and subject to less control for technical officials such as umpires. Lower control of the noise source has been shown to be associated with lower cognitive performance (Belojevic et al., 2003; Paunović et al., 2009; Sobotova et al., 2010; Wright et al., 2016).

It is also likely that the vast media and spectator interest is putting additional pressure on the technical officials at the various venues. The time they spend working in the noise is also of great importance. Longer exposure time has been shown to increase fatigue (Ackerman et al., 2010).

During high-attention work at a high level of competition, cognitive resources can become depleted. It is argued that this affective experience of exhaustion can place additional cognitive demands on the individual as they attempt to maintain attention levels. If this continues during work, performance may decline to an unacceptable level (Beal et al., 2005). This is thought to harm our ability to maintain our attention on the work task, especially if we have had fluctuations in performance during a workday. It is suggested that this may harm our ability to maintain our attention on the work task, especially if we have previously had challenging tasks during a previous workday (Trougakos & Hideg, 2009). Working with a high cognitive load, pressure from spectators, and a high noise level that strains working memory (Baddeley, 2001) can lead to cognitive fatigue, so referees tend to make more mistakes over time (Nevill et al., 2002; Nevill et al., 2017).

The physiological explanation for the stress response due to noise is that a physical and mental imbalance caused by noise triggers a stress response to maintain homeostasis. The sympathetic nervous system becomes hyperactivated with chronic stress, leading to physical, psychological, and behavioral abnormalities. Studies have shown that noise exposure in the workplace can lead to hormonal changes through the release of cortisol (Ising & Kruppa, 2004; Ising & Prasher, 2000; MIKI et al., 1998). Measuring stress in an objective, non-intrusive way is difficult, especially in sports. As mentioned earlier, stress can be measured by taking cortisol samples, but this method is time-consuming, costly, and challenging to conduct during an activity. Questionnaires can also be used but do not measure the stress experienced during the activity. Heart rate variability (HRV) is another way to measure stress and has been used as an objective measure of stress in several studies (Jiménez Morgan & Molina Mora, 2017; Pagaduan et al., 2020).

It has been reported (Dimitriev & Saperova, 2015) that psychological stress increased predictability, regularity of RR (R waves) intervals, and reduced complexity. This reflects a shift towards more stable and periodic HR (heart rate) behavior under stress. The results of (Sim et al., 2015) showed the impact of different types of noise on HRV parameters. Reductions in HRV were observed during noise exposure: After adjusting for noise frequency, during low-frequency noise exposure, HF was reduced (a reduction of 32%, 34%, and 16%, respectively), and during high-frequency noise exposure was found to reduce LF (low frequency) by 21% compared to no noise exposure (Walker et al., 2016). The most commonly reported factor associated with variations in HRV variables was low parasympathetic activity, characterized by a decrease in the high-frequency band and an increase in the low-frequency band. Neuroimaging studies suggest that HRV may be associated with cortical regions (e.g., ventromedial prefrontal cortex) involved in stress appraisal; recent neurobiological evidence suggests that HRV is influenced by stress and supports its use for objective assessment of stress (Kim et al., 2018).

Considering the complexity of working as an umpire in badminton, which requires quick decision-making, it is interesting to investigate to what extent spectator noise can influence the umpire's experience of stress. In badminton, the umpires have two functions during matches: the main umpire and the service judge. The main umpire sits above the court and is responsible for all decisions on and around the court. The umpire ensures that the game is played according to the badminton rules. The main umpire makes calls regarding service errors and other errors or omissions of the players. The umpire keeps the score during the match and records all incidents of misconduct. The umpire's jurisdiction extends from entering the court before the match until leaving the court after the match. The second function is the service judge, whose task is to judge the technical execution of the player's serve and to assist the main umpire in making a decision in case of uncertainty. The service judge sits on the floor next to the net to fulfill these tasks. The two different roles are of particular interest due to their difference in cognitive load during matches. There is a lack of studies investigating the effects of noise on stress, especially in a sports context, using objective data on stress levels in an ecologically valid setting.

AIM

The study aims to use HRV data from umpires at a major badminton tournament to investigate whether there is an associationbetween audience noise and stress reactions and whether this possible association is also related to subjective noise sensitivity.

Secondly, the study also aims to investigate whether a possible association between spectator noise and stress differs depending on the officiating role (i.e., a main umpire and service umpire).

METHODS

Participants

All umpires (n = 16) who participated in the 24th Total Badminton World Federation (BWF) World Championship, 2020, in Basel, Switzerland, were invited to participate in this study. A total of nine umpires participated in this study (M age = 46 years, SD = 3.9 years). All umpires were BWF-certified, which is the highest level of umpiring. During the BWF World Championships, each umpire officiated an average of 5.2 (SD = 2.3) matches and 5. 1 (SD = 3.9) as a service umpire.

Procedure

This study was conducted in collaboration with the BWF and, the ethical review board in Sweden approved the study in Sweden, dnr 2019-06424.

Prior to the BFW World Championships, all referees were informed of the study's aims by a research team member at a meeting. In particular, information about the purpose of the study, the use of their information and data would be used, and the voluntary nature and confidentiality of the study were discussed. At this stage, participants had the opportunity to ask questions about the study before giving their consent to participate.

On the tournament's first day, all on-site umpires were on location, asked by a project team member to participate in the study, which took place over the seven days of the championships. Umpires that accepted to participate were again informed about the aim of the study. Information also included that their participation was strictly voluntary and that they could end their participation at any time without the need for an explanation. All participants were also informed that all data would be presented anonymously. All participating umpires gave their written consent to participate in the study.

The first day of the tournament was used as a pilot to test all settings on the equipment and to answer a multi-section questionnaire asking for demographic information and various health and stress-related questions (see section Questionnaires).

From the second day and throughout the tournament, all participants were fitted with heart rate variability sensors before deployment. They were required to wear them throughout their shift, including rest periods between matches. The stationary sound level meters, which measure the noise of spectators near the courts, were also put into operation before the start of the day's first match.

The time for each umpire, whether they were umpiring or serving, and the rest periods were recorded by the project group using a log.

After each work shift, all umpires removed the heart rate variability equipment and the personal noise dosimeter. The sound level measurements near the courts were also completed at the end of the day. This procedure was repeated on all days of the tournament. As only three heart rate variability devices were available, not all umpires could be monitored daily.

MEASURES

Questionnaires

All participating umpires answered a questionnaire with demographic questions concerning age, gender, and hearing-related health at the tournament's beginning. Weinstein's Noise Sensitivity Scale (NSS-11) (Weinstein, 1978) was used to measure the participants subjective sensitivity to noise. The scale is composed of 21 items addressing affective reactions and attitudes to general noise and everyday environmental sounds. For every statement, participants indicate their agreement on a 6-point likert scale, which ranges from 1(disagree strongly) to 6 (agree strongly). Items include "Sometimes noises get on my nerves, and I get irritated" and "I am good at concentrating no matter what is going on around me". Individual sensitivity is seen as lying on a continuum ranging from high to low. The scale has been used across several contexts and has strong psychometric properties of validity and reliability (Nordin et al., 2013).

Questions were also asked regarding their hearing status using the question, "How is your hearing?". The participants were asked to grade their hearing using a 1-3 Likert scale ranging from 1 = Good, no problem, 2= slightly reduced, and 3 = strongly reduced. Experience of tinnitus was also asked using the question "Do you experience tinnitus?" using the following grading 1 = No, 2 = Yes in both ears, 3 = Yes, only in the left ear, 5 = other. Participants who experienced tinnitus were also asked to rate the frequency of experiencing their tinnitus and its severity.

Subjective stress was measured using the Perceived Stress Scale 10 (PSS-10) (Cohen et al., 1983; Cohen & Williamson, 1988). The PSS-10 has been shown to have high internal reliability and good construct validity in domains such as anxiety, depression and mental or physical exhaustion (Nordin & Nordin, 2013). The questions are rated on a four-point Likert scale ranging from 0=never to 4=very often. All questions are summarized into a total score, with higher scores corresponding to higher perceived stress.

Sound level measurements

During the tournament (seven days), sound level measurements were measured between the four courts using two Class 1 stationary sound level meters (Svantek 979, Svantek 977). The sound level meters were positioned in the center between two courts each.

Both sound level meters were set to log dB(A)Leq, dB(C) peak, dB(A)max with the range set to 30 to 137 dB for Leq and 70-140 for Cpeak, 10 times per second. One-third octave band data was also collected for all measurements. The microphones compensation filters were set to diffuse field. All sound level meters were calibrated each day using a Svantek SV35A Class 1 acoustic calibrator.

The sound level measurements were started before the first match and stopped after the last match each day. Sound levels for each day were analyzed using the Svantek PC++ software. The sound level data collected were recalculated into 1-minute logging values to match the heart rate variability data.

Heart rate variability measurement

Three kits of eMotion Faros 180 model for heart rate variability were used in the present study. The kits were mounted on the participating umpires in the morning before their first match every day of the tournament. Due to the limited number of kits available, all matches could not be measured for all umpires. The kits were evenly distributed among the participating umpires during the whole tournament. After the umpires last match of the day, the equipment was removed. If other participating umpires, not wearing a kit, had more matches the same day, the kit was mounted on that umpire to maximize the number of measurement hours.

The ECG signals were recorded (1000 Hz) offline over a defined period of time (day, hours), events (breaks, umpire-times etc.) were logged, and after review transferred to KUBIOS-HRV-Software. This is a full-featured hear-rate-variability analysis software: it was used for accurate QRS and pulse wave detection, automatic artifact correction algorithms, automatic analysis sample generation, the calculation for all commonly used time-domain, frequency-domain and nonlinear HRV analysis parameters and for time-varying.

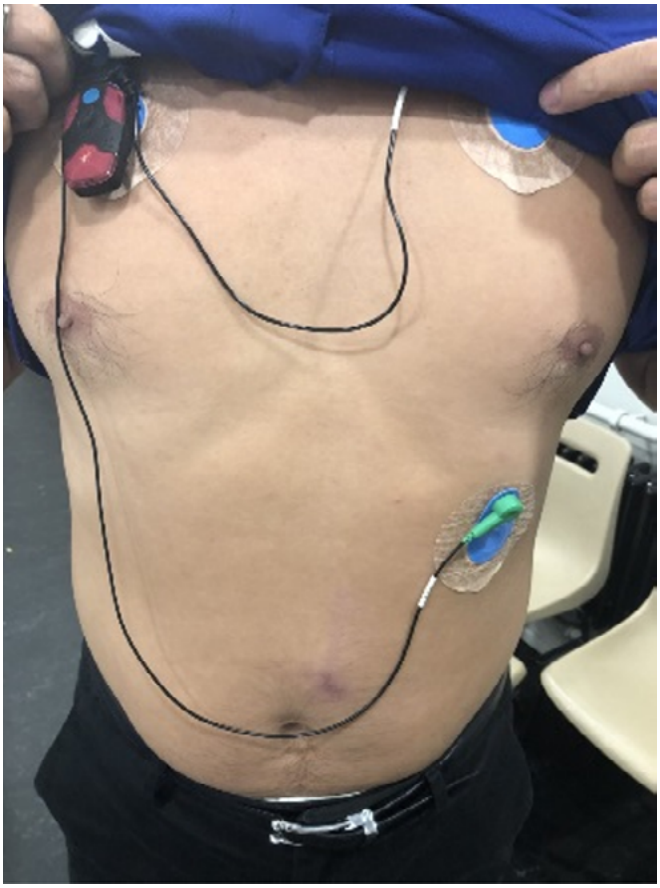

Figure 1. Positioning of the ECG-electrodes and the recorder on the trunk

STATISTICAL ANALYSES

All analyses were made using the Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows, Version 28.0; Armonk, NY). All correlations were analyzed using Pearson's correlation coefficient with the level of significance set to α 0.01. Differences in correlation strengths were analyzed using Fischer's R to Z transformation. The stress variable as well as all noise level variables were analyzed for kurtosis and skewness. Range range for kurtosis varied between .57 to -.06, and for skewness .55 to -.41.The data was assessd as normally distrubited. Non parametric tests were used to analyze the subjective reported data that was not normally distributed.

RESULTS

In Table 1 are the descriptive data regarding heart rate variability data (PNS = parasympathetic nervous system, SNS = Sympathetic nervous system, Stress = software calculation generating a stress value based on the relation between PNS and SNS) as well as the subjective noise sensitivity (NSS-11) and subjective stress (PSS-10) presented.

The correlations in Table 2 show that there is a statistically significant correlation between measured stress using heart rate variability and LaFMax (A weighted maximum sound level) and when working as an umpire r(1314) = .08, p = .006 and as a service umpire r(1058) = 0.27, p = .001. A similar result was also observed regarding dBALeq (A weighted equivalent sound level) and stress when working as an umpire r(1314) = .17, p = .001, and stress when working as a service umpire r(1058) = .029, p = .001. A statistically significant correlation was also observed for stress and Cpeak (C weighted impulse sound) when working as a service umpire r(1058) = .023, p = .001. However, no statistically significant correlation was observed for Cpeak when working as an umpire.

Table 1
Heart rate variability data and subjective noise sensitivity and stress.

	N	*M*	*SD*
PNS	1314	-21963.0	9135.2
SNS	1313	34823.4	16822.8
Stress	1316	162465.6	53349.8
NSS-11	7	35.1	8.4
PSS-10	7	13.7	3.0

Table 2
Correlations for stress (value and stationary sound levels when working as umpire and service umpire

	LaF_{Max}		dBA_{Leq}		C_{peak}	
Stress umpire	0.08	**	0.17	**	0.04	
Stress service umpire	0.28	**	0.25	**	0.23	**

The difference in strengths of the correlations for umpires and service umpires was tested using Fischer's r to z transform the R values, presented in Table 2. By comparing the Z scores, the analyses revealed that there is a statistical difference, $P <$ .05, for Laf_{Max}, Zobserved = -4.8, dBA_{Leq}, $Z_{observed}$ = -3.1, and C_{peak}, $Z_{observed}$ = -3.5 between the two groups. The results show that when working as a service umpire, there is a stronger association between noise levels and stress than when working as an umpire.

Correlations at an individual level for working as an umpire or a service umpire are presented in Table 3. As can be observed, some individuals, especially when working as a service umpire, show a stronger correlation between noise levels and stress. As can be observed for Umpire 1, the stress levels increased when exposed to higher LafMax noise levels as well as equivalent dBA noise levels when working as a service umpire. A similar result was observed for Umpire 5. Umpire 4 showed no statistically significant correlations between noise and stress levels.

Table 3
Correlations for stress value and stationary sound levels when working as Umpire and Service umpire at for Umpire 1 to 9

		LafMax		dBALeq		Cpeak	
Umpire 1	Stress Umpire	0.05		0.18	**	0.01	
	Stress Service Umpire	0.27	**	0.29	**	0.08	
Umpire 2	Stress Umpire	0.10		0.18		0.03	
	Stress Service Umpire	-0.15		-0.29	*	0.13	
Umpire 3	Stress Umpire	-0.14	*	0.00		-0.07	
	Stress Service Umpire	0.12	*	0.10		-0.01	
Umpire 4	Stress Umpire	-0.07		0.00		0.04	
	Stress Service Umpire	0.05		0.20		-0.28	
Umpire 5	Stress Umpire	0.17	**	0.27	**	-0.06	
	Stress Service Umpire	0.07		0.22	**	0.11	
Umpire 6	Stress Umpire	-0.09		-0.14		-0.21	
	Stress Service Umpire	-0.10		-0.26		0.02	
Umpire 7	Stress Umpire	-0.11		0.37	**	-0.10	
	Stress Service Umpire	0.07		-0.18	*	0.23	**
Umpire 8	Stress Umpire	0.24	*	0.06		0.08	
	Stress Service Umpire	n/a		n/a		n/a	
Umpire 9	Stress Umpire	0.00		0.04		0.05	
	Stress Service Umpire	-0.02		0.30	**	0.03	

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

Based on the individual results in Table 2, a Mann-Whitney U test was used to analyze whether umpires have an association between noise exposure (dBALeq) and stress (HRV) during matches working as a service umpire (Umpire 1, 2, 5, 7, 9) differed regarding their rated noise sensitivity and general stress different compared to umpires (Umpire 4, 6) not having this association. Noise sensitivity data is missing for umpire 3 and 8. Umpires with an association between noise and stress during matches reported higher subjective noise sensitive (*Mdn* = 36.0, *n* = 5) compared to the non-association group (*Md* = 27.5, *n* = 2), *U* = 3.5, *z*= -0.61, *p* >.05, however; the difference was not statistically significant.

When comparing the same groups regarding general experienced stress, the results showed that umpires with an association also reported their general stress as higher (*Mdn* = 15.0, *n* = 5) compared to the non-association group (*Mdn*=11.5, *n* = 2), *U* = 1.5, *z*= -1.37, *p* >.05, however; the difference was not statistically significant.

DISCUSSION

The aim of this study was to investigate whether there is an association between spectator noise during matches in a major badminton tournament and stress in the form of heart rate variability changes among the umpires. The results indicate a weak to moderate correlation between spectator noise and stress during matches for some umpires during the tournament studied.

The result of the present study suggests that the association between noise and stress was stronger when the umpires worked as service umpires compared to umpiring. A result that may be explained by the difference in cognitive load and stress, as umpires have to give their full attention throughout the match, while the service umpire focuses mainly on the players' serve. Since more decisions have to be made during a match, the stress level is likely to be higher according to most physiological stress theories, such as Lazarus' transactional stress model (Lazarus, 1966) and McEvans' model of allostatic load (Juster et al., 2010). For most participating umpires, it is likely that the stress level when umpiring may have reached levels that spectator noise cannot further influence the often-called ceiling effect.

This study did not investigate whether the association between noise and stress found in this study has a negative or positive impact on the umpire's decision-making. The increased stress due to spectator noise likely has a positive effect on some umpires' decision-making and a negative effect on others. Research suggests that the effects of stress on decision-making follow a U-curve, where too little or too much stress can lead to underperformance in correct decision-making (Starcke & Brand, 2012), and this most likely varies from person to person. Therefore, the individual differences observed in the present study are of particular interest. When controlling for self-reported general noise sensitivity and self-reported general stress, the results showed that the umpires who showed a stronger association between noise and stress during matches also reported being more sensitive to noise in general and reporting higher general stress levels. This group difference was not statistically significant, probably due to the limited number of participants in this study. The result shows that umpires who enter the court with a subjective sensitivity to noise are also more stressed during matches when working as service umpires. The results of the current study are consistent with previous studies (Nordin et al., 2013), showing that individuals with higher noise sensitivity are often associated with higher stress levels. Individuals with higher noise sensitivity have also been shown to be more impaired by noise, both in terms of overall performance and in mental tasks during noise exposure (Glass et al., 1973; Miedema & Vos, 2003). The results of this study have shown that some umpires are more affected by noise than others, which in turn may affect their performance during matches. The implications of these findings and the extent to which this may affect decision-making and performance need to be investigated in future studies.

Due to the limited number of participants in the present study, the results should be interpreted cautiously. Therefore, the statistical analyses of the subjectively reported data were not statistically significant. Furthermore, the correlation analyses were mostly weak to moderate and the actual psychological experience of this noise-induced change in stress level needs further investigation. The study does also not take into account that other variables such as actions on or off court may affect the stress level.

CONCLUSIONS

In conclusion, this study shows that umpires heart rate variability and stress can be affected by noise levels during badminton matches at major tournaments. The effects vary from person to person and from work tasks, and therefore, spectator noise must be considered as a factor that can affect the umpire's performance during matches. Noise is probably only one of many factors that can affect stress levels; further studies are needed in this area of research.

ACKNOWLEDGEMENTS

BWF supported this project.

The authors declare no conflicts of interest.

REFERENCES

Ackerman, P. L., Kanfer, R., Shapiro, S. W., Newton, S., & Beier, M. E. (2010). Cognitive Fatigue During Testing: An Examination of Trait, Time-on-Task, and Strategy Influences. *Human Performance, 23*(5), 381-402. https://doi.org/10.1080/08959285.2010.517720

Baddeley, A. D. (2001). Is working memory still working? *American Psychologist, 56*(11), 851-864. https://doi.org/10.1037/0003-066X.56.11.851

Beal, D. J., Weiss, H. M., Barros, E., & MacDermid, S. M. (2005). An Episodic Process Model of Affective Influences on Performance. *Journal of Applied Psychology, 90*(6), 1054-1068. https://doi.org/10.1037/0021-9010.90.6.1054

Belojevic, G., Jakovljevic, B., & Slepcevic, V. (2003). Noise and mental performance: personality attributes and noise sensitivity. *Noise Health, 6*(21), 77-89. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=14965455

Burns, K. N., Sun, K., Fobil, J. N., & Neitzel, R. L. (2016). Heart Rate, Stress, and Occupational Noise Exposure among Electronic Waste Recycling Workers. *International Journal of Environmental Research and Public Health, 13*(1), 140. https://doi.org/10.3390/ijerph13010140

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *J Health Soc Behav, 24*(4), 385-396. https://www.ncbi.nlm.nih.gov/pubmed/6668417

Cohen, S., & Williamson, G. (1988). Perceived stress in a probability sample of the United States. In S. Spacapam & S. Oskamp (Eds.), *The social psychology of health: Claremont Symposium on applied social psychology*. Sage.

Dimitriev, D. A., & Saperova, E. V. (2015). [Heart rate variability and blood pressure during mental stress]. *Ross Fiziol Zh Im I M Sechenova, 101*(1), 98-107.

Glass, D. C., Singer, J. E., Leonard, H. S., Krantz, D., Cohen, S., & Cummings, H. (1973). Perceived control of aversive stimulation and the reduction of stress responses. *J Pers, 41*(4), 577-595. https://doi.org/10.1111/j.1467-6494.1973.tb00112.x

Goyal, S., Gupta, V., & Walia, L. (2010). Effect of noise stress on autonomic function tests. *Noise Health, 12*(48), 182-186. https://doi.org/10.4103/1463-1741.64976

Ising, H., & Kruppa, B. (2004). *Health effects caused by noise : Evidence in the literature from the past 25 years* (Vol. 6). http://www.noiseandhealth.org/article.asp?issn=1463-1741;year=2004;volume=6;issue=22;spage=5;epage=13;aulast=Isi ng

Ising, H., & Prasher, D. (2000). Noise as a stressor and its impact on health. *Noise Health, 2*(7), 5-6. https://www.ncbi.nlm.nih.gov/pubmed/12689467

Jiménez Morgan, S., & Molina Mora, J. A. (2017). Effect of Heart Rate Variability Biofeedback on Sport Performance, a Systematic Review. *Appl Psychophysiol Biofeedback, 42*(3), 235-245. https://doi.org/10.1007/s10484-017-9364-2

Juster, R. P., McEwen, B. S., & Lupien, S. J. (2010). Allostatic load biomarkers of chronic stress and impact on health and cognition. *Neurosci Biobehav Rev, 35*(1), 2-16. https://doi.org/10.1016/j.neubiorev.2009.10.002

Kim, H. G., Cheon, E. J., Bai, D. S., Lee, Y. H., & Koo, B. H. (2018). Stress and Heart Rate Variability: A Meta-Analysis and Review of the Literature. *Psychiatry Investig, 15*(3), 235-245. https://doi.org/10.30773/pi.2017.08.17

Lazarus, R. S. (1966). *Psychological stress and the coping process*. McGraw-Hill.

Miedema, H. M., & Vos, H. (2003). Noise sensitivity and reactions to noise and other environmental conditions. *J Acoust Soc Am, 113*(3), 1492-1504. https://doi.org/10.1121/1.1547437

Miki, K., Kawamorita, K., Araga, Y., Musha, T., & Sudo, A. (1998). Urinary and Salivary Stress Hormone Levels While Performing Arithmetic Calculation in a Noisy Environment. *Industrial Health, 36*(1), 66-69.

Myers, T., & Balmer, N. (2012). The Impact of Crowd Noise on Officiating in Muay Thai: Achieving External Validity in an Experimental Setting. *Frontiers in Psychology, 3*. https://doi.org/10.3389/fpsyg.2012.00346

Nevill, A. M., Balmer, N. J., & Mark Williams, A. (2002). The influence of crowd noise and experience upon refereeing decisions in football. *Psychology of Sport and Exercise, 3*(4), 261-272. https://doi.org/10.1016/S1469-0292(01)00033-4

Nevill, A. M., Hemingway, A., Greaves, R., Dallaway, A., & Devonport, T. J. (2017). Inconsistency of decision-making, the Achilles heel of referees. *Journal of Sports Sciences, 35*(22), 2257-2261. https://doi.org/10.1080/02640414.2016.1265143

Nordin, M., & Nordin, S. (2013). Psychometric evaluation and normative data of the Swedish version of the 10-item perceived stress scale. *Scand J Psychol, 54*(6), 502-507. https://doi.org/10.1111/sjop.12071

Nordin, S., Ljungberg, J., Claeson, A.-S., & Neely, G. (2013). Stress and odor sensitivity in persons with noise sensitivity. *Noise and Health, 15*(64), 173-177. https://doi.org/10.4103/1463-1741.112366

Nordin, S., Palmquist, E., & Claeson, A. S. (2013). Metric properties and normative data for brief noise and electromagnetic field sensitivity scales. *Scand J Public Health, 41*(3), 293-301. https://doi.org/10.1177/1403494813475532

Pagaduan, J. C., Chen, Y. S., Fell, J. W., & Wu, S. S. X. (2020). Can Heart Rate Variability Biofeedback Improve Athletic Performance? A Systematic Review. *J Hum Kinet, 73*, 103-114. https://doi.org/10.2478/hukin-2020-0004

Paunović, K., Jakovljević, B., & Belojević, G. (2009). Predictors of noise annoyance in noisy and quiet urban streets. *Science of The Total Environment, 407*(12), 3707-3711. https://doi.org/10.1016/j.scitotenv.2009.02.033

Sim, C. S., Sung, J. H., Cheon, S. H., Lee, J. M., Lee, J. W., & Lee, J. (2015). The effects of different noise types on heart rate variability in men. *Yonsei Med J, 56*(1), 235-243. https://doi.org/10.3349/ymj.2015.56.1.235

Sjödin, F., & Fahlström, M. (2018). Noise Exposure and Hearing Related Risks for Technical Officials during a Major Badminton Tournament. *Jacobs Journal of Physical Rehabilitation Medicine*, 4(1), 1-11. https://umu.diva-portal.org/smash/record.jsf?pid=diva2%3A1248554&dswid=-7753

Sobotova, L., Jurkovicova, J., Stefanikova, Z., Sevcikova, L., & Aghova, L. (2010). Community response to environmental noise and the impact on cardiovascular risk score. *Sci Total Environ, 408*(6), 1264-1270. https://doi.org/10.1016/j.scitotenv.2009.12.033

Sors, F., Grassi, M., Agostini, T., & Murgia, M. (2021). The sound of silence in association football: Home advantage and referee bias decrease in matches played without spectators. *European Journal of Sport Science, 21*(12), 1597-1605. https://doi.org/10.1080/17461391.2020.1845814

Sors, F., Tomé Lourido, D., Parisi, V., Santoro, I., Galmonte, A., Agostini, T., & Murgia, M. (2019). Pressing Crowd Noise Impairs the Ability of Anxious Basketball Referees to Discriminate Fouls. *Front Psychol, 10*, 2380. https://doi.org/10.3389/fpsyg.2019.02380

Sors, F., Tomé Lourido, D., Parisi, V., Santoro, I., Galmonte, A., Agostini, T., & Murgia, M. (2019). Pressing Crowd Noise Impairs the Ability of Anxious Basketball Referees to Discriminate Fouls [Original Research]. *Frontiers in Psychology, 10*(2380). https://doi.org/10.3389/fpsyg.2019.02380

Starcke, K., & Brand, M. (2012). Decision making under stress: A selective review. *Neuroscience & Biobehavioral Reviews, 36*(4), 1228-1248. https://doi.org/10.1016/j.neubiorev.2012.02.003

Trougakos, J. P., & Hideg, I. (2009). Momentary work recovery: The role of within-day work breaks. In *Current perspectives on job-stress recovery.* (pp. 37-84). JAI Press/Emerald Group Publishing. https://doi.org/10.1108/S1479-3555(2009)0000007005

Unkelbach, C., & Memmert, D. (2010). Crowd noise as a cue in referee decisions contributes to the home advantage. *J Sport Exerc Psychol, 32*(4), 483-498. https://doi.org/10.1123/jsep.32.4.483

Walker, E. D., Brammer, A., Cherniack, M. G., Laden, F., & Cavallari, J. M. (2016). Cardiovascular and stress responses to short-term noise exposures-A panel study in healthy males. *Environ Res, 150*, 391-397. https://doi.org/10.1016/j.envres.2016.06.016

Weinstein, N. D. (1978). Individual Differences in Reactions to Noise: A Longitudinal Study in a College Dormitory [Article]. *Journal of Applied Psychology, 63*(4), 458-466. http://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=5111358&site=ehost-live&scope=site

Wright, B. A., Peters, E. R., Ettinger, U., Kuipers, E., & Kumari, V. (2016). Moderators of noise-induced cognitive change in healthy adults. *Noise Health, 18*(82), 117-132. https://doi.org/10.4103/1463-1741.181995