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Selected visual parameters related to the working conditions of musicians

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Professional musicians are required to practice playing instruments for long hours, which often exerts significant impact on their health. Attention should be given to the specificity of playing each instrument, including uncomfortable and sustained body position and repetitive movements causing long-term strain of certain parts of the body.

The aim of this study was to evaluate the impact of long-term playing wind and string instruments on the visual system. Ninety male and female subjects aged 15 to 30 years were included in the study and divided into two groups: musicians (Msc) and non-musicians (nMsc).

Significantly less subjects in the Msc group had properly corrected vision, wore optical prescription recommended by an ophthalmologist/optometrist, and/or underwent any eye examination at all in their lifetime, even though more subjects in this group experienced certain asthenopic symptoms. Also, accommodative amplitude got statistically worse under dim illumination conditions, accommodative facility was significantly different between musicians and non-musicians, although there were no differences between the groups when tested in bright illumination. None of the music stands used by the study subjects met the respective standards concerning uniform illumination rates.

Playing string and wind instruments is a challenge for the visual system due to the forced body and head positions, and asymmetry between the visual plane and the plane of regard as well as non-uniform illumination in the working environment. However, conditions such as correct working distance and proper tilt of the music stand may be beneficial to the visual system. It is the role of optometrists to properly educate their patients about the importance of appropriate vision correction, especially in dim light and under adverse working conditions and to communicate the impact of such conditions on the visual system.

Keywords: musicians, visual parameters, working conditions.

1. Introduction

Playing instruments every day for a number of years affects the general health status of musicians. Researchers tend to focus particularly on the musculoskeletal problems potentially arising from playing a particular instrument. The reported incidence of musculoskeletal disorders varies from 73.4 to 87.7 percent of examined musicians. There are two main causes of muscle strain. The first one is forced body position required in order to keep the instrument properly, which leads to prolonged and sustained muscle tension that may result in chronic myofascial pain. The other cause is related to the specific and precise movement pattern necessary to bring out the sound of the instrument, which results in tendon pain as well as other symptoms, which was found in string players [1]. There is a great diversity of muscle and tendon pain locations, starting from the temporomandibular joint shown in wind instruments players [2], through the cervix, upper limbs, the wrists, the thumb supporting the instrument to back pain. Current management strategies include administration of pain relief medication, physiotherapy, surgical interventions and even discontinuation of professional career in music [3–5].

Studies investigating the influence of playing instruments on the visual system, especially in the field of visual function, are quite scarce. However, research has shown that visual complaints may be relatively common among musicians and that more attention should be given to illumination and proper optical prescription adapted to the specific visual tasks in this patient group [6]. There are studies concerning ophthalmic problems such as glaucoma [7] or the differences between musicians and non-musicians on the neuronal level [8], sensitivity to spatial frequency of the visual stimulus [9] and even differences in the size of corpus callosum [10] and brain architecture [11, 12]. There are also differences regarding multisensory integration between musicians and non-musicians [13]. Musicians are considered a perfect group for comparative research due to long-term and repetitive practice under uniform conditions.

It seems interesting to investigate whether adaptation mechanisms, similar to those confirming brain plasticity, can be found on the functional level. The relation between the body position and the visual system is bi-directional. On the one hand, body movement pattern is reflected by eye movement in order to keep the image in focus, which requires maintaining it on the fovea [14]. Additionally, visual information [15], as well as information from the extraocular muscles (proprioceptive), can impact body balance [16], while cervix and neck tension can influence dynamic retinoscopy results [17]. Additionally, Harmon found that changes in illumination and ergonomics in classroom significantly reduced visual problems, postural problems and chronic fatigue [17]. Forrest [18, 19] also described changes in astigmatism resulting from the changes in the visual environment and visual scanning. He also created a model of functional astigmatism which was further investigated by Harris [20] in his case study of seven musicians playing in an orchestra.

Another relation may be found in the impact of visual problems on body position. Von Noorden states that in most cases head tilt is caused by hypertropia or cyclotropia, the elimination of which resulted in proper head position [21]. Also, modifications of the accommodation/convergence ratio can influence the activity of trapezius rectus muscle [22]. According to Zetterberg *et al*. [23], it can be the cause of neck and arms discomfort related to near work. The position in an orchestra is different for every musician playing a specific instrument and usually cannot be changed. This implicates differences between musicians in convergence stimulus (distance as well as symmetry), accommodation facility and eye movements factor when looking at the conductor. Looking at music stands requires an unnatural eye position since a single stand is oftentimes shared by two musicians. There are also certain requirements resulting from the design of the instrument, so visual challenges may be affected by a number of different factors. Accommodation can be also influenced by illumination of the workplace which is inseparably connected to the specificity of any musician's work. Even though it may be possible to maintain proper illumination in a music classroom, it is not always feasible during a music performance as it depends on the musician's role in the show. If musicians are the main element of the performance (*e.g*. in a philharmonics), the conditions will differ dramatically from a situation when they are just the "background" for an opera or ballet show. In the latter circumstances, musicians are hidden in the lower area in front of the stage (the orchestra pit) which oftentimes is small and improperly illuminated. One has to remember that the specificity of musician's work differs from other professions because the artistic effect oftentimes outweighs pragmacy, ergonomics and norms. Głowacka *et al*. found that some of the musicians experiencing issues with their occlusion did not want any orthodontic intervention because they were afraid of losing their specific sound [24]. Many of them also reported problems connected to visual demands but they did not even try to look for solutions considering their issues to be normal. What is more, they were not educated enough to know how to manage them.

The aim of this study was to investigate how long-term music practice affects the visual parameters in musicians playing wind and string instruments as well as to perform illumination measurements at the Poznań Opera House.

2. Materials and methods

2.1. Participants

Ninety subjects who participated in the study were students of the Academy of Music in Poznań, two Musical High Schools in Poznań and the Poznan University of Medical Sciences. All subjects gave their informed consent prior to the study and the study design was approved by the Institutional Review Board at the Poznan University of Medical Sciences (Resolutions No. 622/12 and 802/12). The study subjects were divided into two groups: musicians (Msc) and non-musicians (nMsc). The Msc group consisted of 50 subjects (mean age = 20.36 years, SD = 2.9) who had played their instruments longer than 4 years and for more than 4 hours a week. The nMsc group consisted of 40 subjects (mean age = 23.40 years, SD = 4.02) who have not played any musical instruments at the time of the study or in the past.

2.2. Procedures

Full history of each case was taken, followed by a complete optometric evaluation. The optometric evaluation included: taking visual acuities in the subjects' habitual prescription (if any), pupillary distance measurement using an automatic refractor (Tomey RC-4000) and subjective refraction. After the refractive error has been established, visual acuity was measured again and followed by a set of tests with the subjects wearing prescription that helped them achieve BCVA. The set of tests included: Worth test, horizontal and vertical phoria measurements at distance and near using von Graeffe method, horizontal and vertical vergence ranges for distance and for near using von Graeffe method, near point of convergence, accommodative amplitude, positive and negative relative accommodation, accommodative facility and a questionnaire. All the photometric measurements were taken with Reichert phoroptor (model 11625W) and Huvitz CCP-3100 chart projector. Accommodative facility was measured under two different illumination and distance conditions: 300 lux at 40 cm and 5 lux at 80 cm, which was considered by the subjects to be the standard distance between a musician and a music stand. Additionally, the level of illumination in the orchestra pit in the Grand Theatre in Poznań was assessed in order to evaluate the working conditions in the theatre and to compare them with the European standards for workplaces. The measurements were taken using Elsec 7650 UV and a light monitor.

2.3. Analysis

The statistical data was used for comparative analysis between the groups of musicians (Msc) and non-musicians (nMsc). Statistical analysis was conducted using Statistica Software (ver. 10, Stastoft, Inc.) and normal distribution of data was verified using the Kolmogorov–Smirnov test. The mean values of the assessed statistical features (for values expressed using quantitative scales) between the groups have been verified using a test of statistical significance (t-test for unrelated variables, large sample model). Structural indicators (percentages) of the studied statistical features (for values expressed in qualitative scales) between the groups have been created using a test of difference in significance for two structural indicators tests. The interrelations between the analysed statistical features were assessed using Pearson's correlation coefficient r in order to establish the strength and direction of correlation (if both of the analysed features were expressed using quantitative scales). Statistical tests have been performed for a significance level of 0.05 as statistical significance occurs for p-values below 0.05.

2.4. Results

The Table shows that illumination ratios for music stands vary from 0.17 to 0.26. Current European norms (EN12464-1:2001) recommend balanced illuminance and reflectance. The level of illumination for visual tasks should be uniform and the area of regard together with its immediate surrounding (*i.e.* 0.5 m around the area of regard) should have an illumination ratio of 0.4. The illumination ratio of the background area (which

T a b l e. Illumination ratios on music stands in the Grand Theatre in Poznań.

Instrument	Maximum illuminance [lux]	Minimum illuminance [lux]	Illumination ratio
Violin (first)	340	90	0.26
Violin (second)	500	95	0.19
Violin (second row)	380	80	0.21
Clarinet	340	70	0.21
Trombone	550	100	0.18
Trumpet	300	70	0.23
French horn	550	95	0.17
Cello	480	110	0.23

is 3 m around the area of regard) should be 0.1. Noticeably, the illumination ratios for the area of regard (music stands) do not even meet the lower standards for the immediate surrounding.

It seems evident that the working conditions are far from perfect since the visual system has to readapt numerous times to meet the conditions at the top and the bottom of a music stand. It seems obvious that if our visual environment is challenging and certain conditions are beyond our control, we should take every step to modify the conditions which are within our control. Definitely, eye care professionals are able to provide appropriate correction of refractive errors. However, it was observed that only a minority of Msc wearing prescriptions had properly corrected refractive errors (46% in OD and 31% in OS). For nMsc the ratios were 56% and 63% respectively. Therefore, the number of nMsc with properly corrected refractive errors was significantly higher than the number of properly corrected Msc. Among the Msc subjects not wearing correction (19% OD and 8% OS) benefited from VA improvement when their refractive errors were corrected. The effect of prescription was similar for nMsc subjects who did not wear prescription prior to the study (4% OD and 8% OS). The lowest VA levels in the Msc group wearing prescription were as follows 20/32 OD, 20/50 OS and 20/25 OU while in the group not wearing prescription the values were 20/100 OD, 20/50 OS and 20/25 OU. It should be mentioned that sufficient visual acuity is required to allow the accommodation system to function properly.

In this study the authors intended to check how low illumination levels affect the amplitude of accommodation and accommodative facility as those parameters may affect the quality of work and sometimes even make the work impossible. As could be expected, normal accommodative amplitude decreased dramatically when illumination was reduced from 300 to 5 lux, which was observed both in the Msc and the nMsc groups. The results are shown in Fig. 1.

The percentage of subjects within normal limits for accommodative amplitude decreased dramatically from 32% in full illumination to 6% in dim illumination for right eye in the Msc group ($p = 0.0005$) and from 36% to 10% for left eye in Msc group ($p = 0.0010$) and also from 33% to 8% for right eye in the nMsc group ($p = 0.0026$) and from 43% to 10% for the left eye in nMsc group ($p = 0.0005$). It should be em-

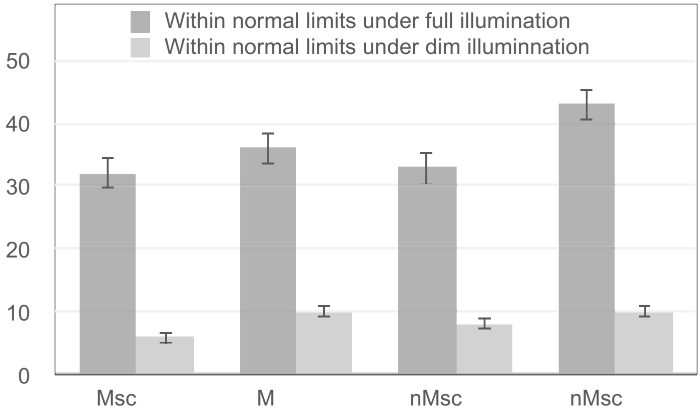

Fig. 1. Percentage of subjects within normal limits for accommodative amplitude.

phasised that the number of subjects within normal limits for accommodation levels was lower in the Msc group already at baseline.

Interestingly, a significantly higher number of participants in the nMsc group was unable to complete the accommodative facility tests with the OD ($p = 0.0013$), OS ($p = 0.0001$) and OU ($p = 0.0025$) in dim illumination (Fig. 2). This might have possibly been the result of extensive practice in the Msc group (switching between the music stand and the conductor) or some additional psychological factors. The accommodative facility test was the last element in the testing sequence (the total duration of all tests was approximately 1.5 hours) and the nMsc subjects might have lost their motivation to complete the examination, as opposed to Msc subjects who are used to long hours of practice and commitment.

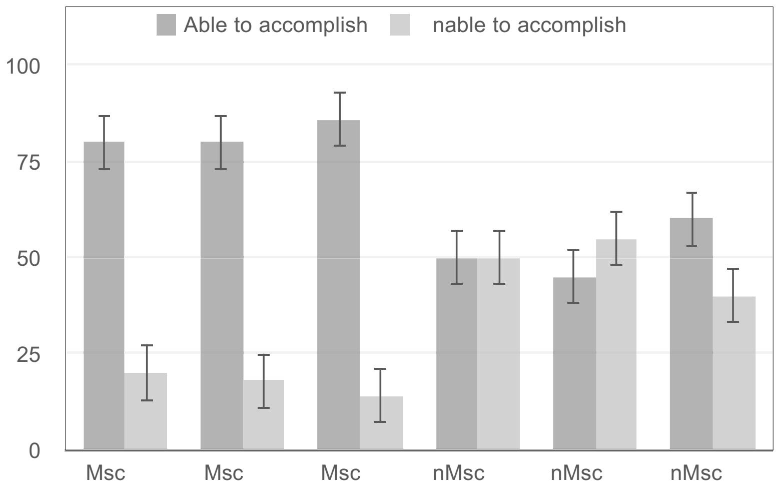

Fig. 2. Percentage of subjects able to accomplish ±1.00 flipper test at 80 cm in dim illumination.

Similarly, the number of cycles completed with a ±1.00 flipper was significantly higher in the Msc group than in the nMsc group for OD ($p < 0.0003$), OS ($p < 0.0003$) and OU ($p < 0.0058$).

Subjects in the nMsc group had difficulties clearing the image through the +1.00 lens in the flipper which indicates a problem with releasing accommodation under such conditions. In the Msc group only 18% of subjects had a problem with the plus lens (*vs*. 53% in the nMsc group; $p = 0.0003$), which shows that the Msc subjects had a better ability to relax accommodation under the test conditions (illumination and distance, see Fig. 3).

In the study survey, statistically more Msc subjects with normal VA levels reported blurry vision ($p = 0.0113$) as well as issues related to skipping/re-reading lines, as com-

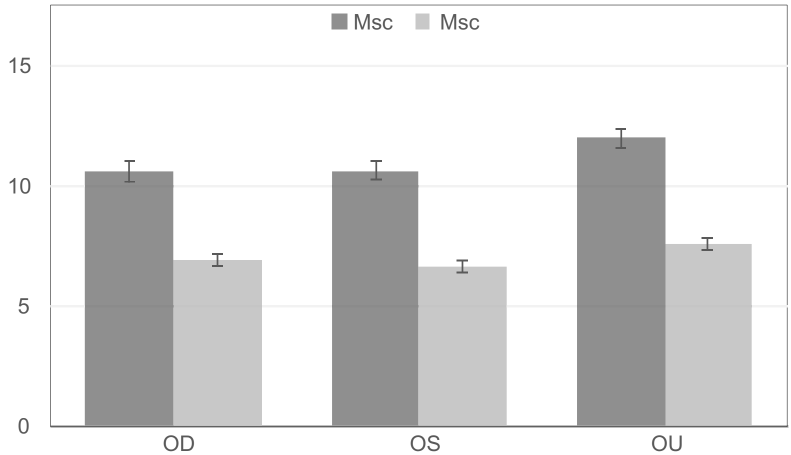

Fig. 3. The number of cycles completed with a ±1.00 flipper at 80 cm in dim illumination for the Msc and the nMsc groups.

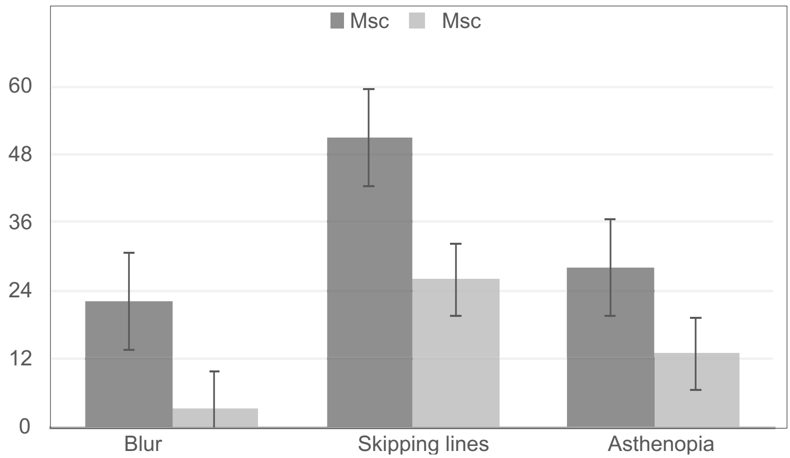

Fig. 4. Percentage of subjects showing visual symptoms at near.

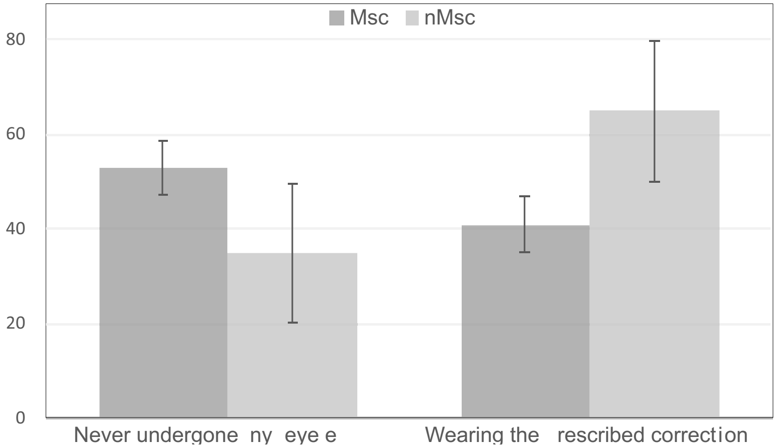

Fig. 5. Percentages of subjects who have never undergone an eye exam and subjects who wore the prescribed correction.

pared to the nMsc group. Also, more Msc subjects showed asthenopic symptoms ($p = 0.0013$) such as headaches, sore, burning, itchy and/or watery eyes (Fig. 4)

Considering the above results, both the visual conditions and the reported symptoms, it seems that significantly more Msc subjects ($p = 0.0419$) have never undergone eye examination. What is more, a high number Msc subjects with prescribed vision correction did not even wear it ($p = 0.0078$) (Fig. 5).

The causes of the aforementioned circumstances should be studied and certain ways of overcoming them should be suggested.

3. Discussion

Working as a musician influences numerous aspects of health. A number of studies reported an increased risk of performance-related musculoskeletal disorders (PRMDs) [25–27] and noise-induced hearing loss [28]. What is more, the quality of performance is oftentimes considered more important by musicians than their health status. Although 83% of musicians playing brass instruments are aware of potential hearing loss, they often do not use earplugs fearing a potential decrease of performance [28]. Similar concerns were reported in Głowacka's work on stomatognathic system disorders in musicians [24]. Special programs have been designed worldwide, such as Health Promotions in Schools of Music [29], to educate musicians in the field of health and to promote healthy behaviours, which is another confirmation that the health burden in this group is enormous.

In the BECKERS *et al.* study, professional musicians reported visual problems (35%), experienced fatigue (33%) and considered that adverse visual conditions prevented them from achieving the desired level of performance [6]. Their complaints referred mainly to poor illumination, problems with reading music in small font, blurry vision, fatigue, eyes itching and burning. The observations are in line with the results of the questionnaire administered by the present authors during their study. Blurry vision and asthenopia were reported more often in Msc group and even though, less subjects from this group underwent eye examination and wore prescribed glasses. It could be due to belief that these symptoms can be caused by difficult illumination conditions, reported by musicians, and so other aspects, including proper correction, is neglected by them. During the present study, the illumination ratios were measured in the Poznań Philharmonics orchestra (music stands) and the results were between 0.17 and 0.26. Polish standards (PN-EN 12464-1: 2001) concerning illumination levels in workplaces define the minimum illumination ratio in public buildings (which includes theatres, concert halls, cinemas, *etc*.) as 0.6. Thus, none of the music stands met the legal requirements. What is more, the area immediately surrounding the stand should have an illumination ratio of 0.4 while for the more distant areas (more than 3 meters from the stand) the ratio should be 0.1. The intensity of illumination should be at least 300 lux as per the Polish standards but none of the stands met this requirement in its lower portions. The quality of illumination also depends on the number of musicians playing during the same performance. A higher number of music stands connected to the power supply line may change the voltage values for each stand, which may reduce the intensity of illumination. Moreover, the notes are printed on sheets with different colours, which impacts the amount of light reflected by the sheets and produced varied levels of contrast. This means that the visual system is forced to make a constant effort to readapt to the changing light conditions in the area of regard in order to be able to read the notes. Also, the musicians need to switch their vision between the music stand and the conductor.

Considering the above data concerning the working conditions of musicians, it may be expected that their functional visual acuity will be reduced together with their accommodative parameters as the accommodative reflex is a response to blurry retinal image. Accommodation is influenced by spatial resolution of the target, its luminance and contrast level. Accommodative dysfunctions may „cause a number of visual symptoms which reduce working efficiency" [30]. Theoretically, even stable accommodation shows minor fluctuations with an amplitude of approximately 0.1 D [31]. In the present study, accommodative amplitude was measured under full and dim illumination and it decreased significantly in dim illumination in both groups. Even though the drop in the amplitude was expected by the authors it was not expected to be so significant. And it might have serious consequences in terms of near work. The problem will particularly affect presbyopic subjects whose accommodative amplitude is physiologically reduced, even under sufficient illumination.

Also Hiraoka *et al*. presented extremely interesting results concerning functional VA [32], which was compared under photopic and mesopic conditions. The term functional visual acuity (FVA), which was first suggested by Goto [33], has been introduced following the finding that long-term observation of objects during daily activities results in reduced VA levels, as compared to VA measured traditionally by reading single letters from a Snellen chart. Significant differences between the traditional values of VA and FVA may occur particularly in subjects functioning under mesopic conditions [34].

The authors have found that all the studied values were reduced under such conditions. The average VA level declined from 1.25 to 0.4; FVA was reduced from 1.1 to 0.3; the best VA dropped from 1.4 to 0.5; while the maximum VA level changed from 0.9 to 0.16. The authors suggested that in low luminance the VA level is impacted by non-refractive factors and the cause of VA drop is a lower amount of light reaching the retina. Hiraoka *et al.* [32] concluded that visual fluctuations were more pronounced under mesopic conditions and the visual maintenance ratio (VMR, *i.e.* the ratio of baseline VA to FVA) was significantly lower. Therefore, the subjects' visual functions were less stable which suggests that it is hard for the human eye to maintain a constant VA level under mesopic conditions. This observation is in agreement with the report of Charman describing accommodative micro fluctuations [31]. Therefore, particular attention should be given to the appropriate prescription powers for musicians working in dim illumination. As many as 10% of musicians participating in the present study failed to achieve the standard VA level (1.0) in their habitual prescriptions. This means that their FVA in dim illumination may be even lower than the FVA of subjects from the Hiraoka study [32]. It should be emphasized that only proper correction allows to achieve best possible visual acuity, which requires eye examination and wearing prescribed corrective glasses or contact lenses. In the present study eye examinations and compliance were both neglected by Msc group as opposed to nMsc group.

Apart from illumination level, another condition affecting the visual function of musicians is their location within the orchestra. The parameter is beyond their control as their location depends on the instrument they play. It is noticeable that the locations of musicians are at different distances and angles from the conductor, which results in varied convergence stimuli (working distance and symmetry of gaze) and different requirements for accommodation facility. Studies have confirmed that appropriate training may improve visual parameters [35] and the measured levels may serve as a reliable predictor of potential visual discomfort [36]. Therefore, certain working conditions may lead to improvement of some visual parameters, which was confirmed by the present study in relation to accommodative amplitude in low illumination, which was significantly better in Msc group compared to nMsc group. It is quite interesting however which plays bigger role, constant shifting from near (music stand) to far (conductor) or maybe psychological and motivational aspects distinguishing Msc and nMsc group. It should be emphasised, however, that the study subjects were non-presbyopic. Over time, reduced accommodative amplitude will require finding applicable solutions in this age group.

The widely described musculoskeletal problems may also be related to variable light intensities, found in present study, which is confirmed by the aforementioned study by Harmon [17]. He claimed that illumination imbalance impacted body posture while modifying illumination and adapting the workstation to the subject's height reduced visual symptoms by 65%, postural issues by 25% and chronic fatigue by 55%. Therefore, the location of a music stand creates a challenge for the visual system as it oftentimes requires gaze direction to the left or right as the same stand is shared by several musicians playing the same type of instrument (violins, violas, *etc.*) or its position may be due to the design of the instrument (*e.g.* trombone), which does not allow for primary gaze. According to Charman [37], such conditions may promote the development of myopia due to variable convergence as the accommodative stimuli are not equal. The study showed that the level of accommodative response will be proportional to the lower visual stimuli. Therefore, at least one eye will see a blurry image and the level of blur increases the further the direction of gaze is from the body midline and the closer the object of regard is. The usual distance of a music stand from a musician is 80 cm. Thus, the difference between the dark-focus condition and the distance to the stimuli is only 0.25 D. This might potentially reduce the accommodative problems related to traditional near work where the working distance is 40 cm, *i.e.* 1 D more than the dark-focus. During the present study, the authors have not observed anisometropia resulting from aniso-accommodation, which has been reported in literature. The difference between the accommodative stimuli in either eye is reduced with increased distance to the object of regard. Therefore, the phenomenon is influenced also by the working distance.

The result of the authors' survey administered among musicians indicated that the percentage of musicians who ever underwent an eye exam was statistically lower as compared to controls. Moreover, even if optical prescription was recommended, significantly less musicians wore them. It seems reasonable to initiate education in the field of visual hygiene when subjects start to learn playing an instrument. The process should also involve the parents as at the initial stage of music education they may significantly contribute to developing health-promoting habits and appropriate layout of musician's workplace.

Longitudinal studies starting on the first days of music education and monitoring the development of the visual system over the years of career in music might produce extremely interesting results. Such research should analyse the impact of each environmental factor on the visual systems of musicians and extend to the age when the subjects are affected by presbyopic changes. It would also be interesting to compare the visual parameters of professional musicians performing in low illumination (*e.g.* those performing daily in an orchestra pit *vs*. philharmonic hall), especially in presbyopic subjects as their accommodative problems may be exacerbated at this age. It seems worthwhile to verify whether better accommodative facility is impacted solely by training (*i.e.* switching vision between the music stand and the conductor) or whether there is an additional psychological aspect involved.

4. Conclusions

Musicians should work together closely with optometrists in order to ensure visual comfort, improve their quality of life and working conditions as playing musical instruments creates a burden to the visual system. Another field of collaboration between the two groups should be education in order to explore the mechanisms which might impact the health status and working comfort of musicians. Further examinations of musicians could help eye care practitioners explore the mechanisms impacting the visual system and thus such collaboration could be beneficial to both communities.

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