VISUAL FUNCTIONS IN PEDIATRICS, ADULTS AND ELDERLY IN BANDAR INDERA MAHKOTA, KUANTAN, PAHANG: A COMPARISON STUDY

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ABSTRACT

Introduction: The purpose of this paper is to investigate the comparison of visual acuity, color discrimination ability, stereopsis and pupil responses in pediatrics, adults and elderly.
Methodology: Fifteen pediatrics (mean age: 7.40 ± 1.99 years old), fifteen adults (22.67 ± 1.03) and fifteen elderly (64.20 ± 3.35) that live in Bandar Indera Mahkota, Kuantan were enrolled in this study. Their visual acuity, color discrimination and stereopsis were assessed using logMAR chart, Farnsworth D-15 (percentage of correct caps arrangement) and TNO stereo test respectively. Their pupil reflexes (mm) in both photopic and scotopic condition, and rates of pupil responses which are velocity from mydriasis to miosis (mm/s) were measured using Oculus Keratograph 5M.
Results: There are significant reduction in visual acuity, color discrimination ability and stereopsis in elderly group ($p < 0.05$). It is also revealed that elderly had diminished pupil reflexes in scotopic condition and reduced pupil velocity compared to adults and pediatrics ($p < 0.05$). However, for pupil reflexes in photopic condition (miosis), there are no significant difference between pediatrics, adults and elderly ($p > 0.05$).
Conclusion: This study indicates that visual acuity, color discrimination ability and stereopsis are inversely proportional to increase of age which might be due to physiological lenticular deterioration and changes in cortical activity which induced by changes in levels of neurotransmitters. Diminished pupil responses in old age might be caused by senile miosis which mediated by reduction in sympathetic input. These age-related physiological changes will cause reduction in quality of life of elderly and affect their mobility.

KEYWORDS: visual acuity, D15, stereopsis, pupil response, pupil reflexes, photopic, scotopic, pediatrics, adults, elderly.

INTRODUCTION

Comprehensive program of research is highlighting how increasing in age or age differences may affect various aspects of visual functioning. Most common visual functions that have been investigated are visual acuity, stereopsis and color vision. Ageing may also affect pupil size and it could give effect to these visual functions (Bitsios et. al., 1996). According to the National Institute of Aging, vision and aging per se is more concerned by many scientists rather than emphasizing on eye disorders and diseases only (Owsley, 2010).

Each visual function shows how the visual system is working up. It includes many visual structures started from the retina up until lateral geniculate nucleus (LGN), and later the stimulus is received by striate cortex before being interpreted by the brain. Visual system and functions is more admissible to be researched on as it presents responses at certain levels which can be recorded quantitatively. By giving specific visual stimulation, specific neurons can be assessed and it is possible to carry out quantitative studies precisely rather than other system (Spear, 1993). Different age levels may show different responses due to physiological or pathological changes of the structures itself (Andersen, 2012).

Theoretically, people would expect that visual functioning in children and adults are better than elderly provided that there are no significant congenital or acquired ocular diseases that may disrupt the vision early. When the age increase, there are many components in the eye that will start to degrade and loss their function gradually such as sphincter and dilator muscle, crystalline lens and vitreous gel. Dilator muscle is closely related to the pupil size while increase in lens density will contribute to loss of lens transparency. On the other hand, vitreous gel will constantly lack its regular arrangement and break down as the time pass which later causes the eyeball fail to maintain its integrity (Remmington, 2012). The downturn of visual functions related to age makes important to rule out either the deterioration can be treated or not (Cunha, 2017).

Thus, current experiment is emphasizing on looking at the comparison of visual functions between different age group which are pediatrics, adults and elderly. Specifically, this research was done to determine the relationship between visual acuity, depth perception, colour vision and pupils size with age in population.

MATERIALS AND METHODS

2.1 Subjects

A total of 45 healthy volunteers including males and females consist of fifteen pediatrics (mean age: 7.40 ± 1.99 years), fifteen adults (22.67 ± 1.03) and fifteen elderly (64.20 ± 3.35) that live in Bandar Indera Mahkota, Kuantan were enrolled in this study. Sample size was calculated using Software PS – Power and Sample Size Calculation version 3.1.2 with $\alpha = 0.05$ for 95% CI and power = 0.8. Calculation was made based on mean of the outcome variables taken from previous study by Bohr and Read (2013).

2.2 Study Procedure

Participants selection were conducted based on the inclusion and exclusion criteria and this research adhered to the tenets of Declaration of Helsinki. Each participant was explained about the procedure from the beginning and consent form then collected. Ethical approval has been obtained from Kuliyyah of Allied Health Sciences (KAHS) Ethics Committee (IIUM/310/G/13/4/4/KAHS 81/18) and this research is under grant code: RIGS16-128-0292. Visual acuity was tested monocularly using logMAR chart at 4 meter. The finest and smallest recognition of letters that participants could see was recorded and calculated in logMAR unit using following formula:

VA = 0.1 + LogMAR value of the best line read – 0.02 X (number of letters read)

Second, color vision testing. This test was done using Farnsworth D-15 at distance of 40cm. Monocularly, participants were asked to arrange the color caps according to color similarity within 2 minutes per eye. The results then were recorded in percentage based on the color caps that been arranged at correct position over total caps.

For stereopsis, participant was instructed to wear habitual near correction and a red-green goggle was placed on top of the correction. TNO booklet was presented at about 40cm and participants were asked to identify the sector of the circles that are missing in each of the plates in page V to VII. The results of stereoacuity were recorded in arc second based on the last plate that they could identify the missing sector.

Last step was measuring the pupil size, rate of pupil responses (velocity) and horizontal visible iris diameter (HVID) using pupillometer in Oculus Keratograph 5M. Test was done in fully dark room. For first 10 seconds, the pupillometer measured size of pupil in scotopic condition,then white light was projected about 2-3 seconds to measure the size of pupil in photopic condition. The test was automatically repeated in 1 minute so that there were 3 readings for scotopic and photopic condition. The average reading was automatically calculated. Maximum pupil size represents the size of pupil (mm) in scotopic condition while the minimun one was for the photopic condition. Rate of pupil responses (mm/s) and HVID (mm) were then measured. Ratio of pupil size to HVID (pupil reflexes) was manually calculated and the results were recorded in 3 decimals place.

2.3 Statistical Analysis

All data were analyzed using Statistical Package for Social Science (SPSS) version 12.0.1 for Windows. Data normality was tested prior to statistical analysis. If the data was normally distributed, One Way ANOVA was used to evaluate the data of each variable. For non-normal distribution, the data was evaluated using Kruskal-Wallis Test. *P*-value of 0.05 or less was considered statistically significant throughout the study.

RESULTS

Fifteen pediatrics (mean age: 7.40 ± 1.99 years), fifteen adults (22.67 ± 1.03 years) and fifteen elderly (64.20 ± 3.35 years) were recruited. The means and standard deviation of all measured parameters were calculated for each statistical method, given in Table 1 and Table 2. For visual acuity, color discrimination and pupil reflexes in scotopic condition, One Way Anova was used to analyse the data since it was normally distributed and equal variance assumption was met (Levene's test, $p > 0.05$). Post hoc test was done using Bonferroni multiple comparison to find which pairs of group had significant results (refer Table 3). Meanwhile for stereopsis, pupil size in photopic condition and rates of pupil responses, data were analysed using Kruskal-Wallis since it were not normally distributed, and follow-up Mann-Whitney test was used as post hoc equivalent to Bonferroni factor (refer Table 3).

It was statistically showed that there were significant reduction in visual acuity, color discrimination ability and stereopsis in elderly group compared to pediatrics and adults ($p < 0.05$). The pattern of reduction was shown in Figure 1.

Table 1 Visual acuity, color discrimination ability and stereopsis of pediatric, adult and elderly.

Parameters (unit)	**Materials**	**Pediatrics**	**Adults**	**Elderly**	***P*-value**
Visual acuity (logMAR)	LogMAR chart at 4m	0.08 ± 0.17	-0.10 ± 0.12	0.07 ± 0.12	$p < 0.05$ (Anova)
Color discrimination (% of correct responses)	Farnsworth D-15	92.22 ± 9.70	100.00 ± 0.00	75.79 ± 25.52	$p < 0.05$ (Anova)
Stereopsis (arc seconds)	TNO Stereo test	168.00 ± 72.43	57.00 ± 22.82	244 ± 180.67	$p < 0.05$ (Kruskal-Wallis)

Table 2 and Figure 2 revealed that elderly had diminished pupil reflexes in scotopic condition (One Way Anova: $p < 0.05$) and had reduced pupil velocity compared to adults and pediatrics (Kruskal-Wallis: $p < 0.05$). However, for pupil reflexes in photopic condition, there are no significant difference between pediatrics, adults and elderly (Kruskal-Wallis: $p < 0.05$).

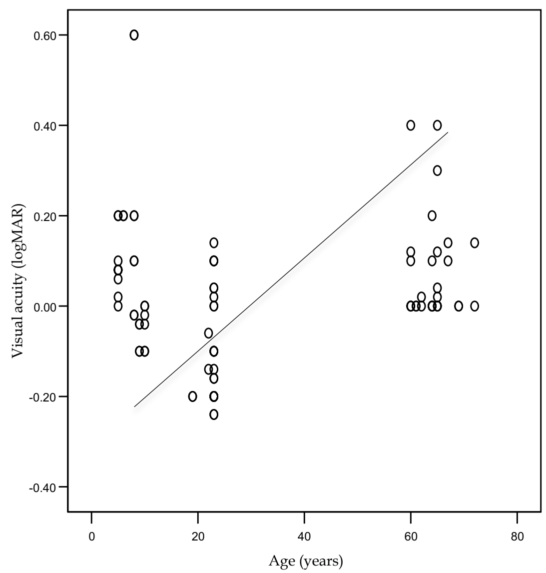
Table 2 Pupil reflexes in both photopic and scotopic condition and rates of pupil responses for all groups.

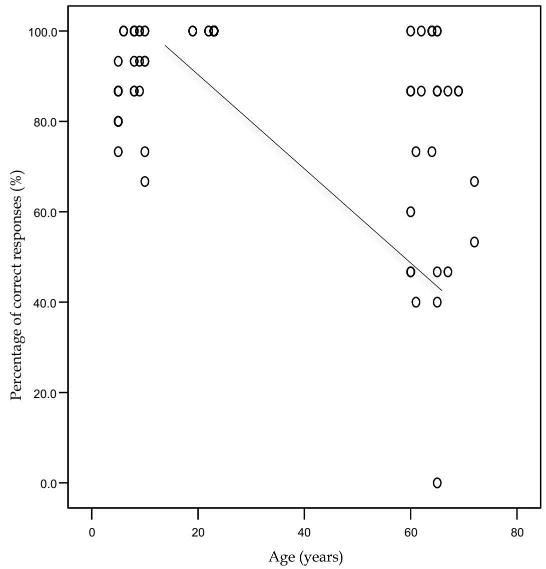
Parameters (unit)	**Materials**	**Pediatrics**	**Adults**	**Elderly**	***P*-value**
Pupil reflexes		0.20 ± 0.09	0.18 ± 0.11	0.12 ± 0.06	$p > 0.05$

in photopic condition (mm)				(Kruskal-Wallis)
Pupil reflexes in scotopic condition (mm)	0.57 ± 0.06	0.55 ± 0.04	0.46 ± 0.05	$p < 0.05$ (Anova)
Pupil response (mm/s)	-0.08 ± 0.09	-0.03 ± 0.01	-0.09 ± 0.11	$p < 0.05$ (Kruskal-Wallis)

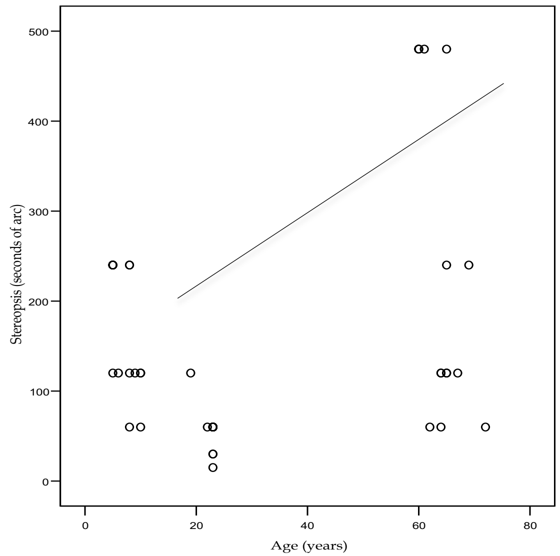
Table 3 *P*-value between age groups for each parameter. Statistically significant difference with Bonferroni multiple comparison or follow up Mann-Whitney test ($p < 0.05$).

Parameters (unit)	Pediatrics versus adults	Pediatrics versus elderly	Adults versus elderly
Visual acuity (logMAR)	$p < 0.05$	$p > 0.05$	$p < 0.05$
Color discrimination (% of correct responses)	$p < 0.05$	$p < 0.05$	$p < 0.05$
Stereopsis (arc seconds)	$p < 0.05$	$p > 0.05$	$p < 0.05$
Pupil reflexes in scotopic condition (mm)	$p > 0.05$	$p < 0.05$	$p < 0.05$
Pupil response (mm/s)	$p < 0.05$	$p > 0.05$	$p < 0.05$



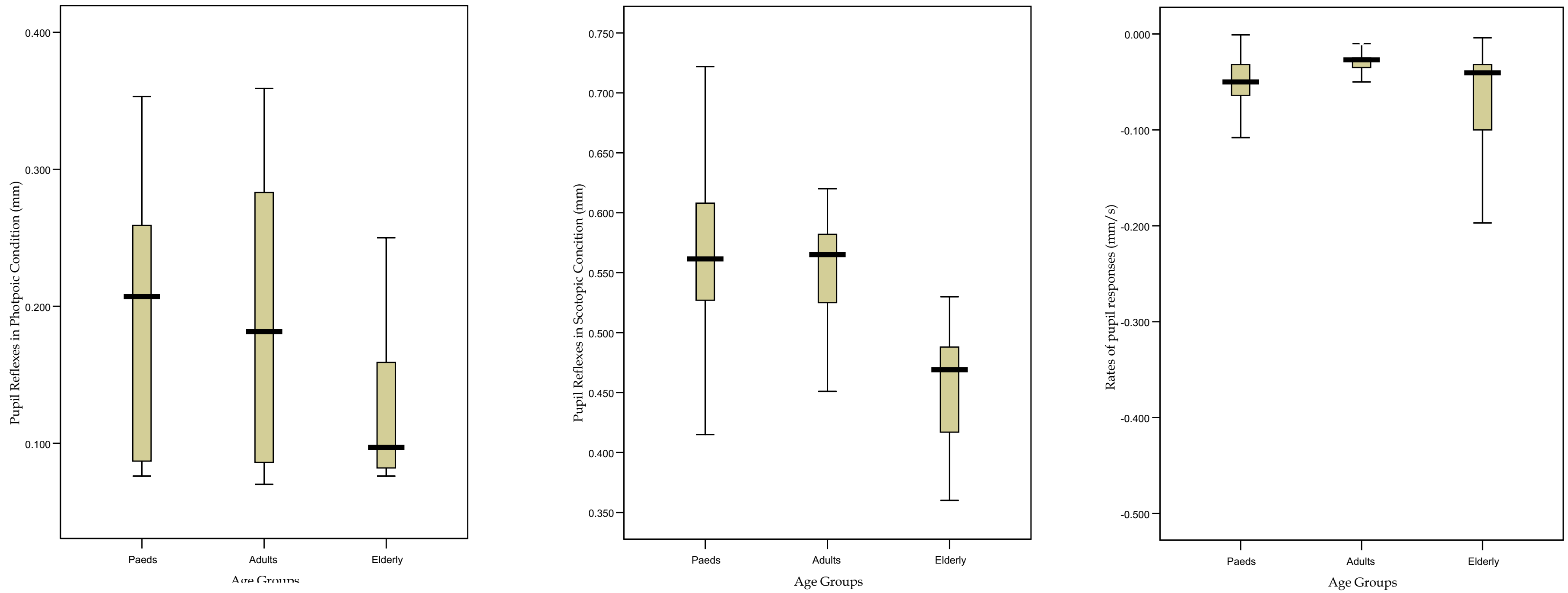


b) Color discrimination ability in different age groups



c) Stereopsis in different age groups

Figure 1 Scatter plots for each parameters for all three age groups: a) visual acuity (logMAR unit), b) color discrimination ability (percentages of correct responses), c) stereopsis value (seconds of arc). The patterns showed reduction in visual function as the age increases.



a) Pupil reflexes in photopic condition in different age groups

b) Pupil reflexes in scotopic condition in differen age groups

c) Rates of pupil responses in different age groups

Figure 2 Pupil reflexes (mm) in both photopic and scotopic conditions (a and b respectively) and rates of pupil responses (c). The black horizontal lines were group means, the 'boxes' were SD, The 'whiskers' were extreme values in each groups. Elderly had diminished pupil reflexes (ratio of pupil size to HVID) in scotopic condition and reduced pupil velocity compared to adults and paediatrics (p <0.05).

DISCUSSION

4.1 Visual functions

This study shows, in agreement with previous reports that elderly had reduced visual functions compared to adults and pediatrics. Visual functioning is inversely proportional to ageing (Spear, 1993) and the responses given by older person to a specific visual stimulation is different due to physiological changes of the eye (Andersen, 2012). Visual acuity mainly can be affected by the length of eyeball or the transparency of crystalline lens (Bainter, 2015). Decrements in visual acuity in elderly (refer Table 1) might be due to physiological lenticular deterioration that prompted lack of clarity in vision. Average lens density increase from 1.386 to 1.394 in elderly as well as the lens thickness (0.050mm/D to 0.024mm/D), which suggest the difference of acuity achieved between elderly compared to adults and pediatrics are statistically significant (Brown, 1990; Garner et al, 1998). This change of lens shape showed that older age have index gradient that was flatter at centre while steeper at peripheral, inducing more light scattered which later produce out of focus image (Hemenger, 1995). Meanwhile in pediatrics, their optical system is still developing and in process of emmetropization. Their eyeball are typically short at early age and making them low hyperopic, yet as they grow up, the eyeball continue to elongate due to hyperopic defocus stimulation, and become emmetropised as the light fall on to the retina (Bainter, 2015).

Denser and brunescent lens has transforming growth factor (TGF-β) which responses to mechanical stress. It undergoes trans-differentiation, producing alpha-actin-2 and collagen type 1 and 3 (Duncan, 1997) Collagen 1 and 3 are insoluble proteins which encounter 56 to 64 percent of total lens protein. Its compositions affect the absorption spectrum and alter the light transmittance which induces spectral variations (Duncan, 1997; Zigman et al, 1979). This process disrupts the absorption of short wavelength chroma such as blue and induces changes in spectral sensitivity; yellowish appearance to some objects (Mercer et al, 2013). This answered why elderly had reduced percentage of correct responses for color discrimination in this study (refer Table 1). Meanwhile, younger infant tend to failed color vision test especially with red or green target due to lack of visual system immaturity and confusion axis distance for red and green plate in International Commission of Illumination (CIE) vector has very small gap (Mercer et al, 2013).

Changes in absorption spectrum by the lens which may be due to brunescence also induce phototoxic reaction to retina since it allows absorption of longer wavelength (Zigman et al, 1979). This reaction later promote damaged to retinal ganglion cells specifically M-cells because they are more susceptible to physiological ageing process (Wright, 1992). The damaged will disrupt the receptive fields and disturb spatial summation at higher level of visual processing (V2). In other words, it will abolish the retinal disparity and cause declines in spatial integration which later reduced performance of visual acuity as well as 3-dimensional shape perception (Wright, 1992; Bohr and Read, 2013). In addition, the depth perception decrements are likely due to change in cortical activity which instigated by changes in levels of neurotransmitters as people get older (Andersen, 2012). In pediatrics, stereopsis value is reduced since they are still in visual developing stage. Stereo acuity started to mature at the age of ten years old as the lateral geniculate nucleus and visual cortex now involved in higher level visual processing (Bohr and Read, 2013). In this study, most of pediatrics subjects were between five to eight years old, hence, that is the reason why they have significant stereo acuity reduction compared to adults.

4.2 Pupil reflexes and responses

Pupil size is one of the most recognized clinical characteristics of normal ageing. Study by Bitsios et al (1996) found that resting pupil diameter was significantly smaller in elderly group in both scotopic and photopic condition, and they also found that dark and light reflexes were slower in older age. In this clinical study, there are some correlations with previous study where it is revealed that elderly had diminished pupil reflexes in scotopic condition and reduced pupil velocity (rates of pupil responses) compared to adults and pediatrics.

Scotopic, mesopic and photopic pupil diameter decrease with age and the shape of the pupil also towards irregular as one got older due to alterations in autonomic functions (Kasthurirangan and Glasser, 2006). Decline in pupil diameter is due to iris rigidity as a result of senile iris degenerations in senior groups (Telek et al, 2018). This condition is also known as senile miosis which happen due to reduction in sympathetic input (reduce in adrenergic dilator influence on dilator muscle) in pupillary pathway of geriatric population. Theoretically, it slows down the pupil reflexes and velocity of older age in any rates of illumination (Bitsios et al, 1996; Telek et al, 2018). This diminished pupillary response will induce slower dark adaptation and reduce in scotopic luminance since the pupil is constricted in elderly group (Bitsios et al, 1996). Thus, in low luminance condition, elderly will face difficulty in recognition task as their pupils were small, allowing only small amount of light to pass through.

4.3 Relationship between mobility and reduced visual performance of old age community

Reduced visual functioning in elderly might affect their daily lives such as increase risks of falls, difficulty in driving and poor night vision (Gleeson et al, 2014; Johnson, 2013; National Institute for Rehabilitation Engineering (NIRE), 2002). Morbidity and mortality in older people are highly caused by falls (Gleeson et al, 2014); a type of harm that can be prevented. 33 percent of worldwide elderly and 60 percent or geriatric home residents experience falls at least once per year (Andrew et al, 2017) and the risk of falls increases even more if they have visual impairments such as age-related macular degeneration, cataract and retinitis pigmentosa (RP) (Kitchin et al 2007). Firmingham Eye Study reveals that 1.6 percent of those 52 to 64 years old and 27.9 percent of those 75 to 85 years old suffer from age-related macular degeneration (Wahl et al, 1999). Meanwhile, elderly suffered from RP has approximately 50 percent lower light sensitivity under low illumination compared to their healthy friends. This condition will inevitably need behavioural and emotional adaptation as their condition is not as same as sighted person.

Reduced visual functioning in elderly in a way will induce symptoms of depression, decrease ambulation speed, feeling of dependency to do certain activities and social isolation (Swenor et al, 2013; Andrew et al, 2017). The limitations of mobility in older adults were contributed by multiple aspects included decline in visual acuity, contrast sensitivity and stereopsis (Swenor et al, 2015) and this will increase avoidance behaviour regarding common social activity (Andrew et al, 2017).

Older community faces difficulty in driving especially at night when their visual functions reduced. The span of usable vision at night time is limited due to scattered lighting of highway and short distance for which headlights of vehicles can illuminate the roadways (Johnson, 2013). Prolonged viewing of bright light from the headlight in a dim field will cause pupil to constrict as the off-centre rods desensitize. In normal adults, the rods will later re-sensitize to improve recognition during night driving but reduced pupillary responses in elderly will make the rods late to re-sensitize, inducing poor vision at night (NIRE, 2002). This condition will also reduce their detection and discrimination of low contrast objects in reduced illumination (Johnson, 2013) and poor depth of focus due to sluggish pupillary reflexes (NIRE, 2002). These condition will make elderly have poor dark adaptation and will increased the risks of accidents during night drive and increased fall incidence when they mobilized in low illumination.

CONCLUSION

This study indicates that visual acuity, color discrimination ability and stereopsis are inversely proportional to increase of age which may be due to physiological lenticular deterioration and changes in cortical activity which induced by changes in levels of neurotransmitters. Diminished pupil responses in old age are possibly caused by senile miosis which mediated by reduction in sympathetic input. These age-related physiological changes may cause reduction in quality of life of elderly and affect their mobility.

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