NISEB Journal Vol. 17, No. 1. March, 2017 1595-6938/2017
Printed in Nigeria (2017) Society for Experimental Biology of Nigeria
http://www.nisebjournal.org

Determination of Contrast Sensitivity and Reaction Time in Albinos Using the New Computer-Based Test

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Abstract

Albinism encompasses a group of congenital disorders characterized by absent or deficient melanin production and this often affect vision. Contrast sensitivity is gaining increased recognition as a valuable tool for measuring functional vision and from many literatures it has been shown that albinos reached a lower level of contrast sensitivity. The objective of this study was to determine contrast sensitivity and reaction time in human albinos using the new computer based test (Java program suites) and also to see if there is a relationship between age, contrast sensitivity and reaction time in albinos. 49 Albino subjects with ages ranging from 8-69 years were tested with the new computer based contrast sensitivity/reaction time test. Out of the study population of 49 albino subjects (36 males and 13 females), 7 subjects were within the age group of 20 – 29 years (20.34%), 8 subjects were within the age group of 30 – 39 years (22.03%), 6 subjects were within the age group of 40 – 49 years (15.25%), 9 subjects were within the age group of 50 – 59 years (27.12%), and 6 subjects were within the age group of 60 – 69 (15.25%). The background luminance was set at 88.5cd/m^2. Exposure time for each screen was 20 secs. The data was analyzed, using one way ANOVA statistical analysis. The mean reaction time of the sample population was 2.76 ± 2.08. It was observed that there is a relationship between reaction time and age in albinos. The research also revealed that there is no significant difference in the mean reaction time among numbers, blinking and jumping targets as measured in different age group of subjects. The mean contrast threshold was 2.3 logs CS for numbers, blinking and jumping targets in all the different age groups, but the critical contrast or the asymptote is different in all the age groups. This was shown by the increase in the slope of the graph (k) as the age group increases. Targets with high contrast gave faster reaction time than targets with low contrast. The result is similar to our unpublished data for normal humans (in press).

Keywords: Albinos, Contrast sensitivity, Reaction time, Java.

Introduction

Albinism encompasses a group of congenital disorders characterized by absent or deficient melanin production. Derived from the Latin word, *albus*, meaning white, it refers to a condition which results in hypopigmentation of the hair, skin and eyes[1,2]. Albinism is a recessive trait, a person without albinism can carry the albinism trait (carriers). Albinism is currently subdivided into two broad categories: Oculocutaneous albinism (OCA) and Ocular albinism (OA). Oculocutaneous albinism (OCA) is caused by either a complete lack or a reduction of melanin biosynthesis in the melanocytes resulting in hypopigmentation of the hair, skin and eyes. People who have ocular albinism have functional vision problems of albinism, however their skin, hair and eye color are generally in the normal range or slightly lighter than that of others in the family[3].

The different forms of albinism result in same characteristic effects on the ocular structures. Iris trans-illumination**,** Foveal hypoplasia[1]**,** macular transparency and abnormal decussation of retinal ganglion cell axons at the optic chiasma and these features lead to reduced visual acuity, high refractive errors, reduced contrast sensitivity, nystagmus, and strabismus, reduced or absent stereoacuity, amblyopia and photophobia [4,5,6].

It is important to measure contrast sensitivity in albinism. Numerous studies have shown that contrast sensitivity (CS) provides useful information about functional or real-world vision that is not provided by visual acuity, including likelihood of falling, control of balance, driving, motor vehicle crash involvement, reading, activities of the daily living and perceived visual disability[7].

Tejada & Tedó (1998)[8] conducted a study on contrast sensitivity function of albino rats. When compared with the pigmented rat, the albino reached lower sensitivity values and showed a loss of sensitivity at high spatial frequencies. Primate retinal ganglion cells (RGC) have been differentiated into small slowly conducting axons that input into the magnocellular layers (m – cells). M-cells have higher contrast sensitivity and temporal resolution and lower spatial resolution than p-cells[9].

The CSF is altered in patients with visual impairment; in general the distinctive shape of the CSF is maintained but the contrast sensitivity is reduced and the peak value occurs for lower spatial frequencies (that is, larger objects) when compared to control subjects[10].

Among the normally sighted people, both visual acuity and contrast sensitivity have a wide range of variation [10]. In visual acuity, 20/25 (6/9, 0.8) is a low normal value; the highest normal values are three times higher, 20/8

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(6/2.5, 2.5). Similarly, the range of normal variation in contrast sensitivity values is great. Therefore, a value within the range of normal may or may not mean that that particular person has normal contrast sensitivity. Repeating the measurement of contrast sensitivity would be beneficial as a part of routine health examinations to rule out changes in the visual pathways[11].

Reaction time is defined as the measure of response to a stimulus[12]. It consists of several components: the time interval during reception, the transmission, the procession of the input information and the output, and the time interval during preparation of the motor response.

Schwartz *et al.* [13] measured reaction time to sinusoidal grating as a function of spatial frequency, contrast and exposure duration and found that the perceptual latencies increase with increasing spatial frequency of the test pattern and at all contrast levels, the typical effect of RT with increasing spatial frequency is maintained.

One psychophysical method that might differentiate between the response properties of the sustained and transient channels of the visual system for supra threshold stimuli is the investigation of the simple reaction time as a function of the contrast and spatial frequency of grating stimuli[14]. This new computer based contrast sensitivity/reaction time test is an improvement on all other test because of the measurement of the reaction time. It also satisfies the design principles as set by American academy of ophthalmology for contrast sensitivity and glare test.

Albinos from literature have been known to have poor visual acuity but little have been research regarding the contrast sensitivity of these groups of people. Hence this research aimed to determine contrast sensitivity and reaction time in human albinos using the new computer based test (Java program ccsuites) and also to see if there is a relationship between age, contrast sensitivity and reaction time in albinos.

Materials and Method

This was a prospective cross-sectional study which was carried out on forty nine (49) albino subjects which included thirty-six (36) male patients and thirteen (13) female patients within age range 8 to 68 years. The albino subjects were recruited from the albino foundation Owerri, in Imo state. The test was done with the new computer based contrast sensitivity/reaction time test designed in University of California, Berkeley, by Bailey, Akinlabi and Scotfitz[22]. It is programmed in java and developed to measure reaction time as well as contrast sensitivity to search and detection time task.

The stimuli were generated by a computer program proto Genie (Pasadera) Inc using java (Sun Microsystem). The background luminance was set at 88.5cd/m^2, which corresponds to a signal value of 200 (Red=200, Green=200 and Blue=200) while the foreground color was chosen to create specific contrast for different tasks. Exposure time for each screen was 20 secs.

A detailed explanation of the research procedure was presented to each subject. In addition, the participants were assured of no discomfort or injury resulting from participating in the procedures. All the subjects signed a consent form while the parents of the children signed a consent form on the behalf of their children or wards. The visual acuity, external examination, internal examination and contrast sensitivity/reaction time test were carried out on the subjects.

This test was done in two stages:

Stage 1: subjects visual screening examination.

Stage 2: contrast sensitivity/reaction time test.

The subjects were screened to ascertain their eligibility. Albino subject with visual acuity of 6/9 (decimal 0.66) or better in each eye separately, apparent pupil size for both eyes greater than 3mm, without ocular pathology and / systemic disease or no previous history of eye disorder that might affect visual function were included in the study.

The test was first of all explained to the subject, it was explained to the subject that the test has 3 sessions. The numbers, blinking and jumping squares session. Firstly, the numbers ranging from 1, 2, 3, 4….8 scattered randomly on the screen will be seen with their sequentially reducing contrast; 1 having the highest contrast and 8 with the least contrast. It was instructed to the subject that the mouse is used to search for the numbers and should be clicked whenever the numbers (i.e. from 1 – 8) are seen. Also it was made know to the subject that the time taken for the search and click is being recorded and as such the search and the click have to be done carefully as fast as possible. The subject was also made to know that the second session has to do with the blinking squares, that the screen will be in four quadrants and a blinking square with reducing contrast will appear one at a time in any of the quadrant and it should be clicked immediately the square appears and another square will appear again in another quadrant with reduced contrast and it should be clicked on. Finally, the subject was informed that the third session of test follows the same pattern as the second session only that the squares are jumping. This test was done binocularly.

Results

A sample population of 49 albino subjects, 7 subjects were within the age group of 20 – 29 years which made up 20.34% of the sample population, 8 subjects were within the age group of 30 – 39 years which made up 22.03%

of the sample population, 6 subjects were within the age group of 40 – 49 years which made up 15.25% of the sample population, 9 subjects were within the age group of 50 – 59 years which made up 27.12% of the sample population, and 6 subjects were within the age group of 60 – 69 years which made up 15.25% of the sample population. A total of 36 male which made up 73.75% of the sample population and 13 female which made up 26.25% of the sample population were selected. The mean reaction time of the sample population was 2.76 ± 2.08.

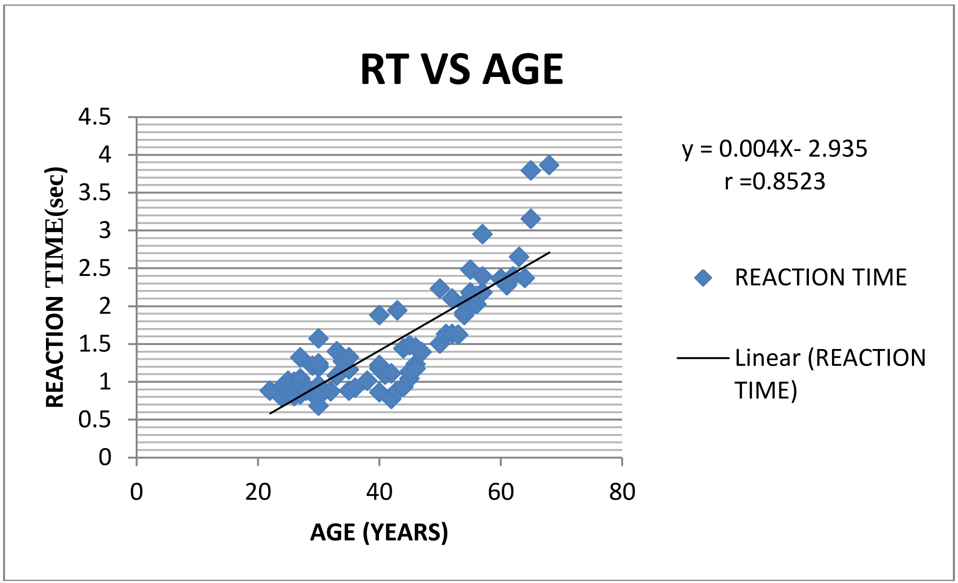


Fig 1: A graph of reaction time versus age in the sample population

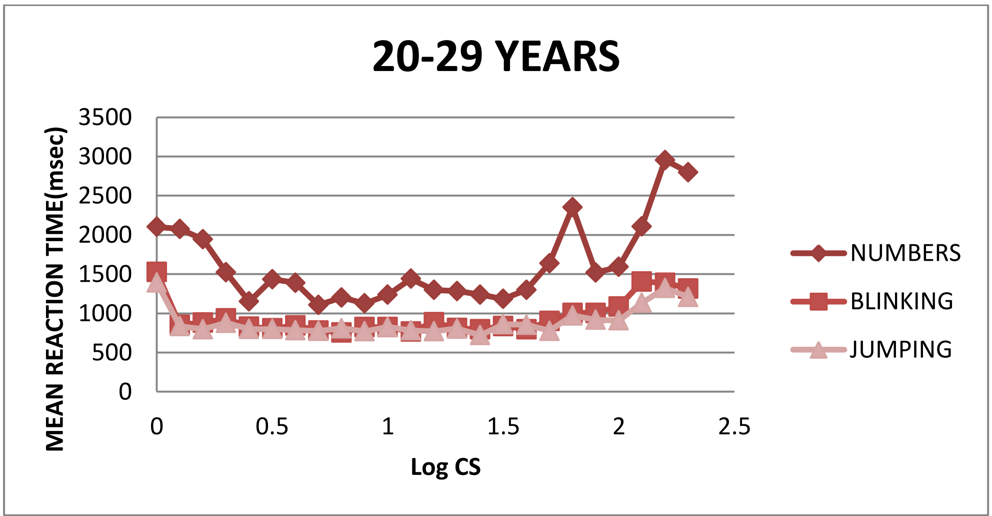
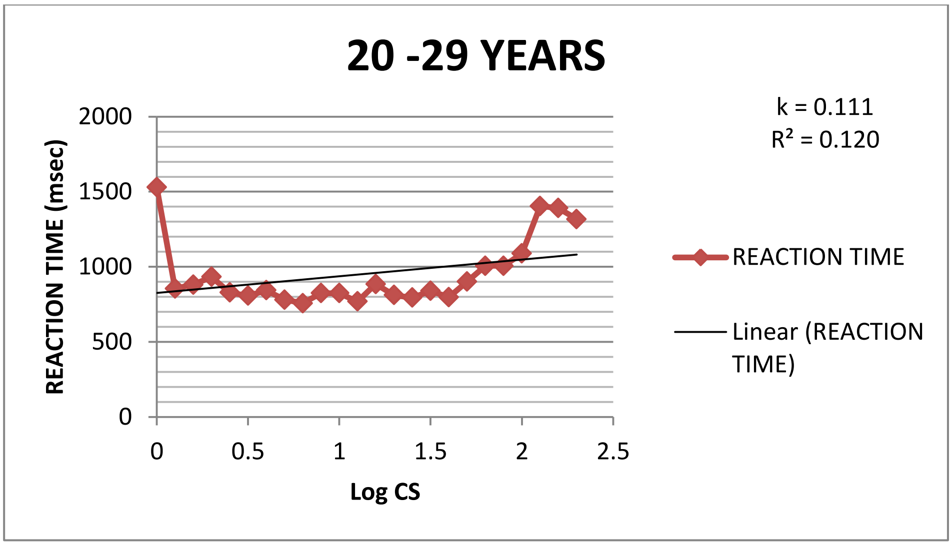


Fig 2: A graph of mean reaction time versus contrast sensitivity in 20 – 29 Years subjects.

From the research carried out, it was observed that there is a relationship between reaction time and age (fig 1). This was further confirmed statistically using the Pearson's correlation coefficient equation. Y= 0.004X - 2.935 with r=0.8523, X stands for category variable (age).

Analysis of variance (ANOVA) revealed there is no significant difference in the mean reaction time among numbers, blinking and jumping targets as measured in different age group of subjects ranging from 20-29, 30-39, 40-49, 50-59 and 60-69 years ($p<0.05$).



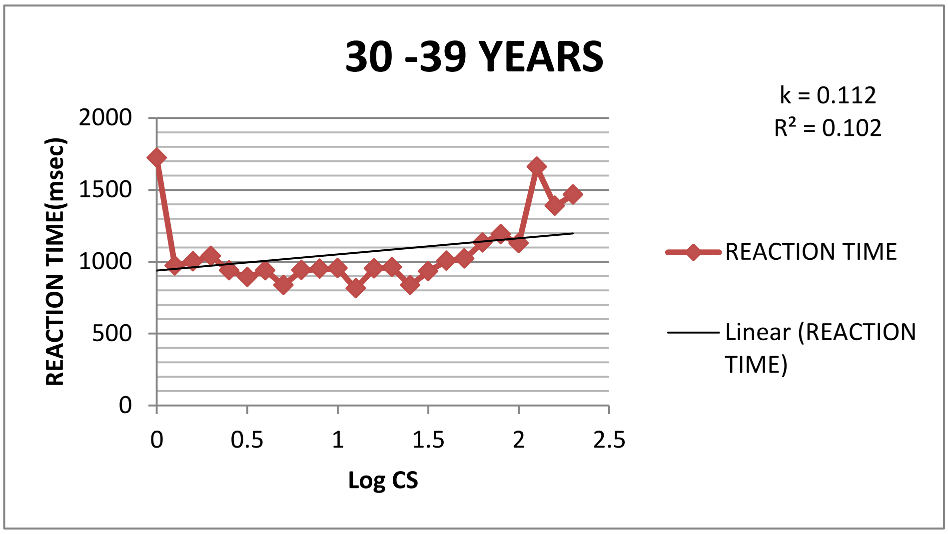


Fig 3: Plots of RT vs. contrast for 20-29 (years) and 30-39 (years) and for a specific stimulus (duration: 20 sec and luminance: 88.5cd/m^2). Each data point represents the mean of at least 15 measurements. The solid line drawn through the data is the best fit of Eq. (1).

RT decreased with increasing contrast (fig 2-6), leveling off at a specific contrast value which represents the asymptote (RT_o) of the function fitted. At 20 – 39 years, where a unit change in contrast has only a small effect on RT, the value of k was low. 40 – 59 years had moderate value of k whereas the group of 60 – 69 years was characterized by having higher value of k because of the larger effect of contrast on RT and that contrast sensitivity decreases with age which begins around 40 – 50 years of age[15].

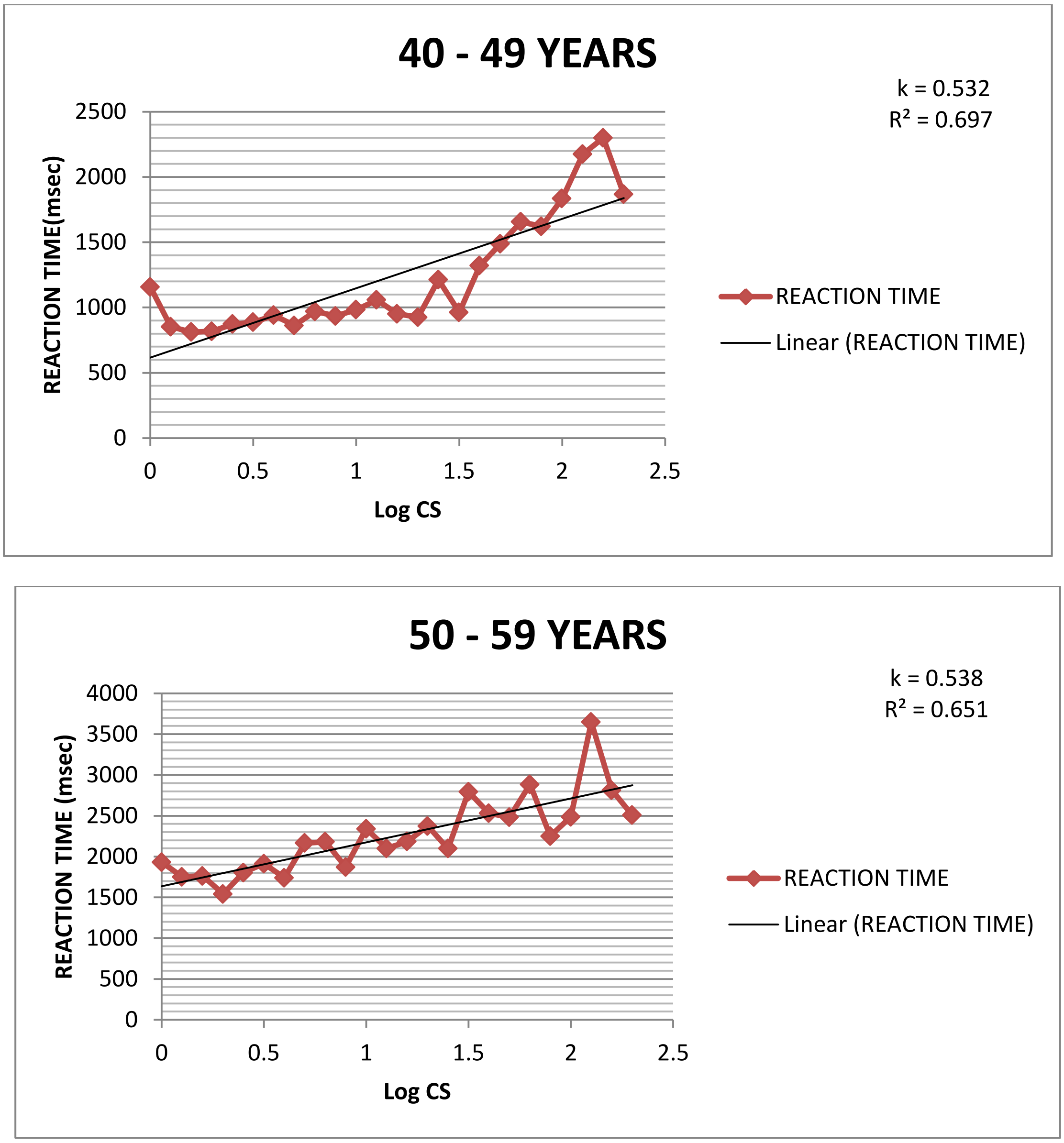


Fig 4: Plots of RT vs. contrast for 40-49 (years) and 50-59 (years) subjects and for a specific stimulus (duration: 20 sec and luminance: 88.5cd/m^2). Each data point represents the mean of at least 15 measurements. The solid line drawn through the data is the best fit of Eq. (1).

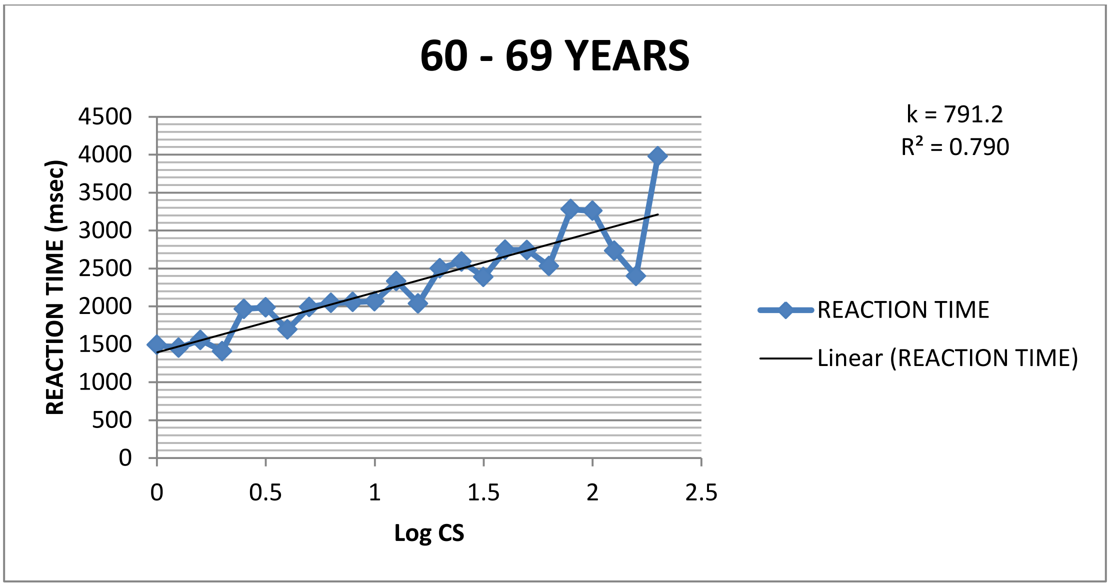


Fig 5: Plots of RT vs. contrast for 60-69 (years) subjects and for a specific stimulus (duration: 20 sec and luminance: 88.5cd/m^2). Each data point represents the mean of at least 10 measurements. The solid line drawn through the data is the best fit of Eq. (1).

Discussion

The result of the research carried out shows the contrast sensitivity and reaction time of albino individual measured using the new computer based test. Researchers from literature, shows that albinos reached a lower contrast sensitivity levels when compared with normal subjects[8].

It has been shown that this reduction in contrast sensitivity of the albino individuals may be due to the abnormal decussation of the ipsilateral nerve fibers at the optic chiasma, reduced visual acuity, nystagmus and hypo pigmentation of the retina and iris transillumination[1,4,5,16,17,18,19,20]. In people with albinism, there is a shortage or complete lack of melanin production (which directs the optic nerve on where exactly they should grow towards in the eye during embryological development), and the directions go astray. As a result, almost all of the optic nerves cross. This is called mis-routing of the optic nerve.

The results of the research carried out showed that there is a relationship between contrast sensitivity, reaction time and age in albino subjects. With increasing age, there is also an increase in the reaction time. It is in line with the research of [21] which stated that with increasing age, contrast sensitivity decreases and this decrease in contrast sensitivity with age begins around 40 – 50 years of age. Aging is a physiological process of the human system. The positive relationship between age and reaction time could be explained as a physiological process that affects the magno and parvo cellular cells of the retinal ganglion cell layer and also of the abnormal decussation of the ipsilateral nerve fibres in albinism. The efficiency of these cells depreciates with age as such a reduction in contrast sensitivity will be expected; bringing about an increase in reaction time.

There was no significant difference in the mean reaction time (at $p<0.05$) among numbers, blinking and jumping targets as measured in different age group of albino subjects . However, this is not in line with research of Bailey *et al.* (2003) [22], where on average there was marginal better (0.08log unit) contrast sensitivity and better repeatability of response times for the blinking and jumping squares than for numbers – search tests in low vision patients.

When addressing the neurophysiological basis of the variation of RT with stimulus conditions it is instructive to look in detail at the physiological experiments which have used corresponding stimuli [23]. By testing a wide range of contrasts, the distinctive contrast signatures of the M and P cells have been revealed: M and P cells are most easily distinguished by their responses to low-contrast stimuli. M cells are particularly sensitive to low contrast and (but their responses saturate at relatively high contrast around 0.2logCS), whereas P cells respond poorly below 0.2log contrast (but saturate at much low contrasts). It is clear from this study (fig 2) that RTs to low and high contrast sensitivity can be similarly distinguished by their contrast functions. At low contrast sensitivity, RTs, presumably mediated by M pathways, are high over the contrast range above 1.5logCS. At high contrast sensitivity, RTs, presumably mediated by P pathways, are short only for the range of contrasts when P cells have a strong response; that is for values above 0.2logCS.

In this research, psychophysically derived measure of contrast gain that is the RT – contrast sensitivity is used to investigate the relative contribution of neural mechanisms at supra-threshold contrast. This contrast gain which is reciprocal to slopes of RT versus C^{-1} functions has been shown to be similar to the physiological contrast gain used to represent the contrast response characteristics of neurons in the primary visual pathway[24,25,26].

As highlighted in Figs. 3, 4 and 5, that the slope of the high contrast region is steeper than for the low contrast region, that the overall slope is determined by the low contrast region, and the discontinuity of the curve as contrast sensitivity decreases as (in Fig 2). This discontinuity in the RT – contrast function between low and high contrast levels indicates a transition from M – dominated to P – dominated activity. At low contrasts, only a relatively small number of neurons, having high gain and fast responses (M cells) are activated. Increasing the contrast of the stimulus, recruits additional neurons (the more numerous P cells). Moreover, M cells tend to saturate at high contrasts [24]. It therefore follows that the faster, high contrast phase of the RT – contrast plot represents the contribution from a second population of neurons, the P cells. Moreover, at critical contrast region, it can be presumed that there is summation of the two cells.

The above explanation can be supported with the two following lines of evidence; first on the discontinuity of the RT – contrast function. It is well known that M cells are selectively activated at contrast below 0.1 and the evidence was drawn from many different types of experiments[26]; showed that low contrast (<0.08) gratings produced de-oxyglucose staining only in the M projection of macaque. Many authors[24,26,28] have used electrophysiological methods to show that P cells have much poorer sensitivity to luminance contrast than M cells for an extended range of spatial and temporal frequencies. It therefore seems unlikely that they subserve the low contrast RTs. Second, the RT – contrast functions show higher gain (shallow slopes in Figs. 3, 4 and 5) at low contrasts. Kaplan and Shapley [24] demonstrated that M cells have 10x higher gain than P cells. The result is similar to our unpublished data in normal humans.

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