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Study on simple reaction and choice times in patients with type I diabetes

Jose A. Padilla-Medina [a], Juan Prado-Olivarez [a], Norma Amador-Licona [b], Luz M. Cardona-Torres [c], Delia Galicia-Resendiz [c], Javier Diaz-Carmona [a,*]

[a] Instituto Tecnológico de Celaya, Av. Tecnológico y G. Cubas s/n, Celaya, Gto., México
[b] Instituto Mexicano del Seguro Social, Unidad Médica de Alta Especialidad No. 1, León, Gto., México
[c] Instituto Mexicano del Seguro Social, Hospital General de Zona No. 4, Celaya, Gto. México

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ABSTRACT

A study on simple reaction time (SRT) and choice reaction time in patients having diabetes is described in this paper. The study was applied to fourteen patients with type I diabetes, as well as to fourteen non-diabetic persons. The research is based on two visual signal perception experiments, both implemented on a computer based environment. The SRT experiment consisted on measuring participants' reaction times to a light change event in a simulated traffic light scenario. The choice reaction time was studied through the performance indexes (d') achieved by participants in a two alternative forced experiment, where a known visual signal is identified from two noisy images. According to the obtained results, the diabetic patients' SRTs were an average of 24% longer than the reaction time of non-diabetic persons, in the same way a significant average difference of 41% was obtained in the efficient index d' too. A positive correlation of 0.6594 between the time periods since diabetes has been diagnosed and the average SRTs of diabetic patients was obtained, also significant correlation differences between age of all experiments participants and resulting variables, SRTs and d', were observed; for instance the correlation factor between participants' ages and their average SRTs was -0.8529 for diabetic patients, meanwhile a value of -0.2905 was obtained for non-diabetic persons. The evidence suggests that the time period since diabetes has been diagnosed notably affects motor and sensorial systems maturity, and consequently conduction speed of sural and peroneal nerves.

1. Introduction

Psychophysics-based experiments have shown to be a useful tool for studying the visual mechanism in patients with diabetes [1]. Several sensitivity studies applied on diabetic patients have been reported in literature such as: spatial contrast [2], thermal, vibration [3], and color [4].

One of the first studies on average reaction time to visual stimulus in diabetic patients was reported by Dobrzanski and Rychta [5], they concluded that the average reaction times of patients having diabetes are approximately twice the average times of non-diabetic people. However, some of the study sample patients had schizophrenia too, which implies that an important parameter must be included when obtained results data are figured out. In Langan et al. [6] the average reaction times of a diabetic patients group, who had not suffered hypoglycemia, were compared with those of diabetic patients that had suffered it several times. The main experiment conclusion was that the average reaction times of diabetic patients having a hypoglycemia record were significantly longer than the ones of diabetic patients who had not suffered hypoglycemia.

A more recently study reported by Sanchez-Marin and Padilla-Medina [7] revealed that the average reaction times to visual stimulus for adult patients having diabetes mellitus type II was 33% longer than the time of non-diabetic observers.

The reaction times are strongly related with neurological complications associated with diabetes [5,8]. One of the main neurological complications affecting reaction times, more frequently presented in diabetic patients, is the diabetic neuropathy causing a decrease in the conduction speed of the peripheral nerve [8,9].

Hyperglycemia is still considered the main cause of diabetes complications. Its deleterious effect is due to, among other things, the developing of sugar-derived substances called Advanced Glycation End-Products (AGEs). For instance, AGEs are found in retinal vessels of diabetic patients, and their levels correlate with those levels in serum as well as with severity of retinopathy [10]. AGEs in blood vessels produce a permeability increase of endothelial cells and the release of vascular endothelial growth factor, which stimulates angiogenesis causing diabetic retinopathy [11,12]. According to murine models AGEs worsen diabetic

* Corresponding author. Tel.: +52 4616117575.
E-mail address: javier.diaz@itcelaya.edu.mx (J. Diaz-Carmona).

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neuropathy by reducing sensorimotor conduction [13]. Also an increase of the myelin glycation level has been observed in diabetic patients. The glycated myelin is vulnerable to phagocytosis caused by macrophages, which may be stimulated to secrete proteases contributing to diabetic neuropathy demyelination. Additionally, AGEs on the myelin may be related to plasma proteins, like IgM and IgG, stimulating immune reactions and resulting in a potential neuronal demyelination. According to experimental studies, the neuronal dysfunction is linked to the NF-κB activation and the subsequence expression of some inflammatory cytokines, just as IL-6 and TNF-α. Another hypothesis of how AGEs production is related to neuronal damage in diabetes may be deduced taking into account that AGEs interaction with its receptors triggers the NF-κB activation [12]. The resulting effect is a decrease of nerves conduction speed, for instance up to 2.8 m/s and 2.7 m/s for the sural and the peroneal nerves, respectively [9,14,15].

A study on simple reaction time (SRT) and choice reaction time in patients having diabetes is described in this paper. The research results obtained from two types of visual signal perception experiments, applied to two observers groups, are reported. The visual perception experiments consisted in measuring simple and choice reaction times for both observers groups. One group was composed by patients having type I diabetes and another by non-diabetic observers. The SRT experiment consisted on measuring participants' reaction times to a light change event in a simulated traffic light scenario. Participants' choice reaction time were studied through their achieved performance indexes (d') in a two alternative forced experiment, where the participant's task was to detect a known visual signal from two images containing Gaussian distributed noise.

The project main objective was focused to research about type I diabetes patients' behavior in visual signals perception, in particular concerning to simple reaction and choice times in simple and forced choice tasks. According to the obtained results significant differences were found, in both studied variables, with respect to non-diabetic participants. In addition, a notably correlation between simple reaction time and time period since diabetes has been diagnosed was concluded. Hence the evidence suggests that this time period has an impact on motor and sensorial systems maturity, and consequently on conduction speed of sural and peroneal nerves.

2. Methods

2.1. Sample size estimation

The minimum number of observers for each experiment group was estimated in such a way that a probability to achieve statistical significance (power) of 80% be achieved. Such number was computed by the MedCal software version 12.3.0, considering an average reaction time to visual stimulus in the diabetic group 33% longer than the corresponding to the non-diabetic group, according to previously reported results [7], a standard deviation value of 0.2078 and α value equal to 0.05 were assumed too. The obtained minimum simple size was eleven participants per group; in order to improve the statistical significance of both groups a number of fourteen participants was actually used.

2.2. Observers

The visual perception experiments were applied to two observers groups. The first group was composed by fourteen patients having type I diabetes (D group), diagnosed by endocrinologists through clinical laboratory tests, with an average age of 11.57 ± 2.71 (SD) years. None of these patients had suffered vascular complications. The second group was composed by fourteen non-diabetic (ND group) observers with an average age of 11.64 ± 2.82 (SD) years. Visual health condition of all experiments participants was tested through Snellen symbols chart. All ND participants had a visual acuity of 20/20, meanwhile three D patients resulted with a visual acuity of 20/40, 20/25 and 20/25; however, these visual acuities had no effect in their experiment performances. The rest of D observers (eleven) resulted in a visual acuity of 20/20. Ishihara test with six plates was applied to participants, assuring in this way that all participants had a healthy color vision, required in the simple reaction time experiment. Moreover, it was ensured that participants had no ocular problems by examining their eye fundus, through an indirect ophthalmoscope, after applying three drops of T–P (tropicamide and phenylephrine), each one every five minutes. In order to reduce observers fatigue effects on experimental results, the participants were instructed to take a break in the middle of the test section if fatigue sensation was felt. However, no one decided to take such rest. The Kolmogorov–Smirnov test was applied to participants of both groups with a significance level of 0.05, and with statistics values of $z_\alpha = -1.96$ and $z_{test} = -0.23$, in this way no significant difference in averages ages of both observers groups was proved.

2.3. Simple reaction time (SRT) experiment

A traffic flow scenario is a common experience for adults and children under different conditions [16,17], this is the main reason why the designed SRT experiment is based on simulating a car driver's perception in front of a traffic light. A light color change from green to red, using traffic light images, was shown on a computer screen to each participant. The observer's task was to push a foot pedal as reaction once the green to red change had happened. Such pedal was implemented like a mouse to computer connection, through a Universal Serial Bus port (USB). The experiment participants' answers were obtained like a computer mouse clicking. The use of the implemented system allowed measuring the total reaction time since the sensorial perception stage until the execution stage for each observer's reaction.

2.3.1. USB communication

The use of Universal Serial Bus (USB) port to obtain foot pedal reaction data was chosen due to its reliability and data transfer speed, which may be up to 53 megabytes per second in high speed mode [18]. The implicit time delay in measuring the reaction time is small and only the time delay due to the polling rate is taken into account, considered as 8 ms for a mouse with operating frequency of 125 kHz [18,19]. The obtained results are reported in this paper without considering such mouse-generated delay for both participants groups, which is a valid assumption for comparison.

2.3.2. Experiment conditions

A personal computer with an Intel Core^{TM} 2 Duo microprocessor working at 1.66 GHz and an Intel 950 GMA graphics card were used in the experiment. The images were shown to experiment participants on a 19 in. flat screen Sony HMD-A240, with a 1024×768 pixels of resolution.

In each reaction time test section two consecutive 640×480 pixels images were shown to the observer. The first one corresponding to a traffic light with only the green light on, shown a randomly time long in the range from 0.5 to 5 s, and the second one with only the red light on. Two test image samples are shown in Fig. 1. Each observer was instructed to push the foot pedal once the red light image had appeared on screen. A software program,