Visual field attention is reduced by concomitant hands-free conversation on a cellular telephone

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Abstract

The effect of hands-free cellular conversation on visual attention and driving capability has not been thoroughly investigated. In this experiment healthy participants performed automated visual field testing using the Esterman algorithm before and during a controlled cellular phone conversation. We found that hands-free conversation caused some subjects to miss significantly more points, react slower to each stimulus, and perform the exam with reduced precision. These results suggest that legislative restrictions on concomitant cellular-phone conversation and driving may need to be based on individual performance rather than a general ban on cellular phone usage.

Introduction

Defining the effect of cellular telephone use on visual attention during driving has far-reaching medical, legislative, economic, and life-style implications. To investigate these effects, epidemiological data has been used (Redelmeier and Tibshirani, 1997; Violanti & Marshal, 1996; Violanti, 1998). While such studies can establish a correlation between cellular-phone use and motor-vehicle accidents, they can not ascertain or quantify a direct cause-effect relationship. Controlled experiments can provide more specific observations, by utilizing various multi-task studies, in which participants are required to perform a certain visual or manual task before and during conversing on a cellular phone. It has been demonstrated and is generally accepted that the manual and visual manipulation of a telephone has a negative impact on driving. (Briem & Hedman, 1995; Brookhuis et al, 1991; Reed & Green, 1999). However, the precise effects of hands-free conversation, i.e. the phone conversation itself, on cognitive processes and driving performance are less well understood. Only a few studies have studied this matter, and each has employed a different experimental set-up, making it difficult to compile the data (Strayer & Johnston, 2001; Consiglio et al, 2003; Lamble et al, 1999). In these studies various driving simulators were used. While providing quantification of hands-free conversation on the manual task, such experimental set-up does not clarify the relative disruptive effect of the conversation on central visual processing versus peripheral motor performance. In addition, most of these studies examined the participant's reaction to a central visual stimulus, e.g. on a computer display, failing to simulate the peripheral field which is so important in real-life driving environment (Ball et al, 1993; Owsley et al, 1998).

In this study we aim to quantify the attention-diverting effect of hands-free cellular-phone conversation on central visual processing utilizing the Humphrey Systems Visual Field Analyzer. This experimental set-up has several advantages. Since this instrument is ubiquitous, it can be used to compare and compile results obtained by different experimenters. As the manual task in this set-up is negligible (pressing a button), the effects of the phone conversation on task performance can be almost entirely attributed to central attentional processes. Finally, this model allows assessment of effects on the peripheral visual field.

Methods

Twenty male and twenty-one female healthy individuals aged 25-45 years were included in the study. The Institutional Ethics Committee approved the study, all individuals agreed to participate in the study after giving informed consent, and all aspects of this research adhered to the tenets of the Declaration of Helsinki. No participant had ever undergone automated perimetry or was a professional driver accustomed to driving and using a cellular phone. To control for any effect on attention and awareness, participants had to be healthy, not under the influence of any medication, after a regular night‘s sleep, and having refrained from drinking a caffeinated beverage for two hours prior to the exam.

All participants underwent a complete ophthalmological examination, including visual acuity measurement, slit-lamp biomicroscopy, applanation tonometry, and dilated funduscopic evaluation. Uncorrected visual acuity had to be 20/40 or better in each eye and the eye exam normal.

Each subject underwent visual field examinations using the monocular Esterman program of the Humphrey Systems Field Analyzer II (model 750, software version A-

10; Humphrey-Zeiss, Dublin, CA) (figure 1). This test is internationally accepted and used to assess functional disability in drivers and other professionals. It incorporates a 10 dB stimulus in 100 points from 75 degrees temporal to 60 degrees nasal. Both eyes of each individual were tested sequentially beginning with the right eye. Two examinations were performed with an intervening rest interval of 20-40 minutes, the first serving as a “learning” exam and its result having to have no suggestion of any disease which can affect the visual field. The results of the second exam served as baseline for comparison with the test examination. Following a rest period of between 45-75 minutes, each participant underwent the third, test visual field examination. During this exam, the participant engaged in a hands-free conversation using the same cellular phone (Motorola i85s) with the speaker set at a loud volume. The conversation was maintained by a technician who sat in another room and used a regular phone which dialed to the cellular one. The same technician conducted all the conversations in the study, using a questionnaire. This technician aimed to conduct all conversations at the same pace. The questionnaire was constructed in such a way as to simulate ordinary conversation, with a few items demanding greater concentration, such as memorizing the details of a reserved flight. The experiment was designed so that during the test exam of the right eye the participant was required mainly to *listen*, whereas during the test exam of the left eye he was mainly required to *talk*. During the right eye exam, participants were instructed to answer technician’s questions without opening their mouth, using sounds such as “m-hm” for a positive answer and “m-m” for a negative answer. During the left eye exam, participants were to answer normally, trying to minimize mouth movement so as to avoid head movement.

All visual field exams were performed between the hours 13-16 and administered by the same technician. A thorough technical explanation was given to each participant by the same technician before each exam.

The following variables were recorded and compared for each eye: number of points missed in the visual field (out of 100 points), exam duration, and rate of fixation loss, false-positive and false-negative errors.

Analysis of variance with repeated measures was used to compare each variable between the three visual field examinations. Version 11.0 of SPSS for Windows was used.

Results

Mean age of the 41 participants was 32.2 years (range 25-44).

Table 1 presents the outcomes of the three exams performed by all participants.

Figures 2 and 3 present the primary outcome measure, namely the number of points missed in the visual field. Figure2 summarizes in box plots the mean, quartile (25^{th} and 75^{th} percentiles) and the 5^{th} and 95^{th} percentiles for the number of points missed during the basline and test exams of the right and left eyes. The individual results for this parameter for each participant are shown in figures 3 (right eye) and 4 (left eye).

A large variability in performance between participants can be seen, as reflected graphically in the figures, and numerically by the large standard deviations in table 1.

Table 2 presents the difference in outcome between the first and second “learning” exams. On the first two exams, participants generally performed very well, with very few missed points and good reliability. A learning effect was observed with missed points, fixation loss rate and exam duration all decreasing from the right - first eye to the left – second eye of the first exam, and then remaining fairly constant in both eyes during exam II. False-positive and false-negative rates were mostly very low. Again, table 1 shows that for all these parameters, performance was not homogeneous, with a relatively wide range of results and consequent large standard deviations.

Table 3 presents the difference in outcome between the second – baseline - exam, and the third – test – exam. There was a highly statistically significant difference in all parameters of visual field performance. Participants missed more points when conversing on the cellular phone. There was a marked increase in fixation-loss rate. False-positive and false-negative rates increased significantly. Exam duration increased by a mean of 15.8% and 17.1% for the right and left eyes, respectively. When exam duration was corrected to reflect the total number of stimuli presented, a mean increase of 0.26 second (14.1%) and 0.29 second (15.7%) per stimulus for the right and left eyes were observed.

The disruptive effects of phone conversation as reflected by the number of points missed, rate of fixation loss and duration per stimulus were greater when participants were talking (left eye exam) than when they were listening (right eye exam).

We analyzed the location of points missed by participants. During exam III of the right eye, a total of 108 points were missed. Of these, 20 points were also missed in exam II so they were not considered to be missed due to the cellular conversation. Of the remaining 88 points, 20 were one of 9 outermost nasal points, which could have been missed due to slight variation in face position and consequent artifactual "nose effect", and 8 were one of four points in the blind-spot region, also prone to be missed with slight variation in face position. Of the remaining 60 "definite" missed points, 33 (55%) were inside the central 30 degrees. A similar analysis of the left eye exam showed a total of 122 missed points in exam III, 18 of which were also missed during exam II. Forty points were in the outermost nasal periphery and 3 in the blind spot region. Of the remaining 61 missed points, 37 (60.7%) were within the central 30 degrees.

When visual field performance was compared between males and females, there was no statistically significant difference in any of the parameters.

Discussion

In this study we propose a new experimental model for investigating the effects of cellular phone conversation on visual attention and the visual field. Research on this subject has many scientific and practical implications. Since the Humphrey machine and examination protocols are world standard, different experiments using this model can be directly compared and their results compiled for greater understanding of this issue.

The use of the Humphrey machine has several additional advantages. Previous models have used visual stimuli that involved mainly central or paracentral vision, such as light bulbs or computer terminals. Only more recently, highly specialized and advanced driving simulators have been used which provide a 180^0 field of view (Strayer et al, 2003). The Humphrey machine allows convenient assessment of all or any part of the visual field.

All previous models recorded a “yes” or “no” response by the participant to different visual stimuli. The Esterman algorithm of the Humphrey machine, in addition to quantification of seen and missed stimuli, allows accurate *localization* of these stimuli in the visual field.

Most experiments involving cellular conversations use models which employ a distinct manual activity such as driving a car or shifting the foot from a gas to a brake pedal. Whereas these models may simulate real-life driving conditions more closely, their results do not demonstrate the relative disruptive effect of conversation on cognitive processing versus manual performance. In our study, the manual activity of pressing a button in response to the visual stimulus is so minimal as to allow a “cleaner” study of the effect of conversation on cognitive visual processes.

We chose to use the Esterman testing algorithm, which uses a constant high-intensity stimulus, since it is used for issuing driving license in many countries. Another important consideration was that any algorithm which measures numerically threshold sensitivity rather than a “seen” vs. “not seen” response, such as Full-threshold, Fastpac or SITA, requires significantly longer examination durations which necessarily allow testing of fewer locations in the visual field. Future studies using these algorithms may yield more precise quantification of the effect of phone conversation on specific points of interest in the visual field. Such information may be beneficial as real-life stimuli are of variable intensity.

It is interesting to note the large variability in performance on the test exam, with a few individuals who performed distinctly poorly. This was observed despite the effort to homogenize the participants in terms of age, visual function, drug use, sleep patterns, and cell phone use while driving. Whether performance could be improved with practice is a subject of future study. However, it is conceivable that even with practice, there may be subjects who cannot handle concomitant cellular conversation and driving (or other activity) as well as others. This may be especially true in older individuals (Ball et al, 1993; Owsley et al, 1998). Further research may result in an acceptable objective method to test this, and consequently legislative restrictions on concomitant cellular conversation and driving may become personal rather than general. Such driving restrictions based on scientifically-proven objective testing of the useful visual field has been proposed (Ball et al, 1993; Owsley et al, 1998).

Regarding the experimental set-up, we observed a small but definite learning effect during the first two exams, most of which occurred between the right and left eyes in the initial exam. There were fewer points missed, smaller fixation-loss rate, and shorter exam duration. Except for exam duration of the right eye, none of the measured parameters differed significantly between the first two exams. Therefore, we presume the learning effect from the second to the third "test" exam was very small. Since we cannot completely rule out such an effect, the true negative effect of phone conversation on the third exam may be slightly greater than what we observed. When engaged in cellular phone conversation, participants missed more than twice as many points compared to the baseline examination. Strayer and Johnston observed an effect of similar magnitude in a model that tested the number of missed traffic signals with a driving simulator (Strayer & Johnston, 2001). These authors proposed a form of inattention blindness caused by the concomitant phone conversation which diverted central attention from the road. Although generally few points were missed, the implications for missing sudden on-road events may be very important and deserve further research.

Fixation-loss rate increased markedly during the third exam. This can have several explanations. First, it is possible that the mental load of the conversation directly caused a reduced ability to fixate. Second, it is reasonable that during the test exam participants intentionally assumed a state of higher awareness, or even anxiety, in order to prove to both the examiner and themselves that cellular conversation did not cause more missed points. This would result in wandering gaze with the participant actively searching for the stimulus. A "happy triggerer" effect as reflected in the moderately increased false-positive rate, may have accounted for only a small part of the observed increase in fixation-loss. Finally, there may be a technical component.

The patient was engaged in conversation, and so it is possible that mouth movements brought about head movements which displaced the eye around the blind spot. The observed higher fixation loss rate during exam of the left eye, when the participant was engaged in active speaking, relative to the right eye, when the patient was only required to "hum" answers, is consistent with this explanation.

The increase in false-positive and false-negative rates during the test exam were also significant but smaller in magnitude compared to fixation-loss. Decrease in cognitive attention allotted for the exam may be partly responsible for these increases. A deliberate attempt not to miss stimuli may explain some of the increase in false-positive rate.

Fatigue is usually the cause of increased false negative rate. However, we do not believe that this factor was significant in this study. The exams were fairly short, taken by young, healthy people. Searle et al found that in normal subjects there was no consistent change in fixation loss, false positive or false negative rates as a function of testing duration despite decrease in sensitivity (Searle et al, 1991). Similar results were reported by Johnson et al (1988). The resting periods between exams in our study were similar or longer than those employed by other investigators (Johnson et al, 1997); Budenz et al, 2002; Budenz et al, 2002).

We found a mean increase in reaction time to each stimulus of 15%, or nearly 0.3 second. Studies which examined reaction time employing models in which the participant was required to initiate braking in response to a visual stimulus in simulated or actual driving found slowing of 0.5-0.6 second (Brookhuis et al, 1991; Lamble et al, 1999; Alm & Nilsson, 1995). What we observed may be a minimal "obligatory" slowing in reaction secondary to the cognitive diversion of attention by the cellular conversation task, with greater slowing observed when more complex manual tasks are studied. These time intervals may be very significant in conditions of high-speed driving.

We observed a greater disruptive effect of speaking than listening on visual field performance. This is consistent with the findings of Strayer and Johnston (2001) in their driving simulator study.

Regarding the location of missed points in the visual field, we found that roughly half of the missed points were inside the central 30 degrees, and half more peripheral.

In conclusion, we describe a novel experimental set-up for the quantification and localization of the attention-diverting effect of cellular-phone conversation on the visual field. In the current study, cellular hands-free conversation caused some of the subjects to miss significantly more points, react slower to each stimulus, and perform with reduced precision. Further multi-tasking studies may lead to legislative restrictions on concomitant cellular-phone conversation and driving that are based on individual performance, instead of a general ban of cellular phone usage.

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Table 1. Mean ± SD (and range) values for outcome parameters in the 3 visual field exams

	Exam 1		Exam 2		Exam 3	
	Right eye	Left eye	Right eye	Left eye	Right eye	Left eye
points not seen	1.4±1.9 (0-7)	1.2±1.7 (0-7)	1.0±1.5 (0-6)	1.1±1.53 (0-5)	2.6±3.4 (0-17)	3.0±3.4 (0-13)
Fixation loss rate (%)	12.2±14.9 (0-54.6)	7.7±11.4 (0-45.5)	7.8±11.0 (0-36.4)	7.2±9.5 (0-36.4)	27.4±24.4 (0-90.9)	34.8±3.03 (0-91.7)
False-positive rate (%)	3.0±6.0 (0-22.2)	2.2±5.1 (0-22.2)	2.4±6.8 (0-33.3)	3.0±6.1 (0-22.2)	9.9±12.1 (0-55.6)	9.5±11.2 (0-55.6)
False-negative rate (%	0.5±2.4 (0-11.1)	1.1±3.5 (0-12.5)	0.00 (0-0)	0.3±1.7 (0-11.1)	7.1±8.1 (0-30.0)	6.2±9.1 (0-33.3)
duration (sec)	250.6±26.19 (216-346)	239.6±12.4 (223-272)	235.7±11.1 (219-258)	236.9±15.0 (218-297)	272.5±32.6 (224-367)	277.1±31.1 (232-352)

Table 2. Mean change in outcome parameters between exam 2 and exam 1

	Right eye	Left eye
points not seen	-0.41 (p=0.107)	-0.15 (p=0.61)
Fixation loss rate (%)	-4.5 (p=0.088)	-0.5 (p=0.832)
False-positive rate (%)	-0.6 (p=0.736)	0.8 (p=0.471)
False-negative rate (%)	-0.5 (p=0.16)	-0.8 (p=0.073)
duration (sec)	-14.9 (5.9%) (p=0.001)	-2.7 (1.1%) (p=0.313)

Table 3. Mean change in outcome parameters between exam 3 and exam 2

	Right eye	Left eye
points not seen	1.68 (p=0.003)	1.93 (p=0.001)
Fixation loss rate (%)	19.6 (p<0.0001)	27.6 (p<0.0001)
False-positive rate (%)	7.4 (p=0.001)	6.5 (p=0.002)
False-negative rate (%)	7.1 (p<0.0001)	5.9 (p<0.0001)
duration (sec)	36.8 (15.8%) (p<0.0001)	40.2 (17.1%) (p<0.0001)
Duration per stimulus (sec)	0.26 (14.1%) (p<0.0001)	0.29 (15.7%) (p<0.0001)

Figure 1

EYE: RIGHT

NAME: [redacted] ID: DOB: 01-01-1969

ESTERMAN MONOCULAR

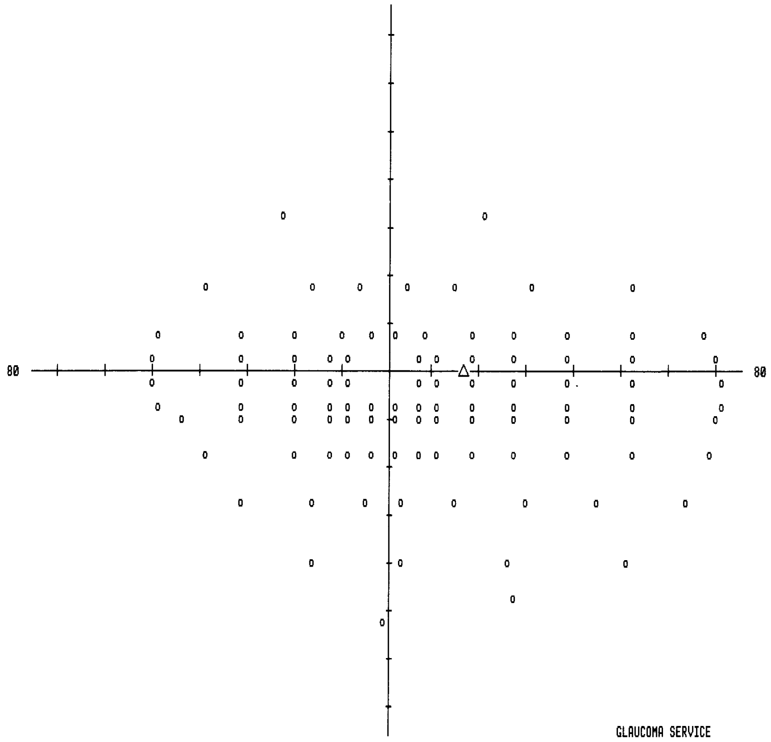
FIXATION MONITOR: GAZE/BLINDSPOT
FIXATION TARGET: CENTRAL
FIXATION LOSSES: 0/10
FALSE POS ERRORS: 0/8
FALSE NEG ERRORS: 0/9
TEST DURATION: 04:13

STIMULUS: III, WHITE
BACKGROUND: 31.5 ASB
STRATEGY: TWO ZONE
TEST MODE: SINGLE INTENSITY

PUPIL DIAMETER: 4.7 MM
VISUAL ACUITY:
RX: DS DC X

DATE: 02-12-2003
TIME: 11:00
AGE: 34

STIMULUS INTENSITY: 10 DB



GLAUCOMA SERVICE
OPHTHALMOLOGY DEPARTMENT
ASSAF HAROFE HOSPITAL

o SEEN 100/100
■ NOT SEEN 0/100
△ BLINDSPOT
ESTERMAN EFFICIENCY SCORE: 100

An example of a printout of the results of a monocular Esterman automated perimetry examination of the right eye.

Figure 2

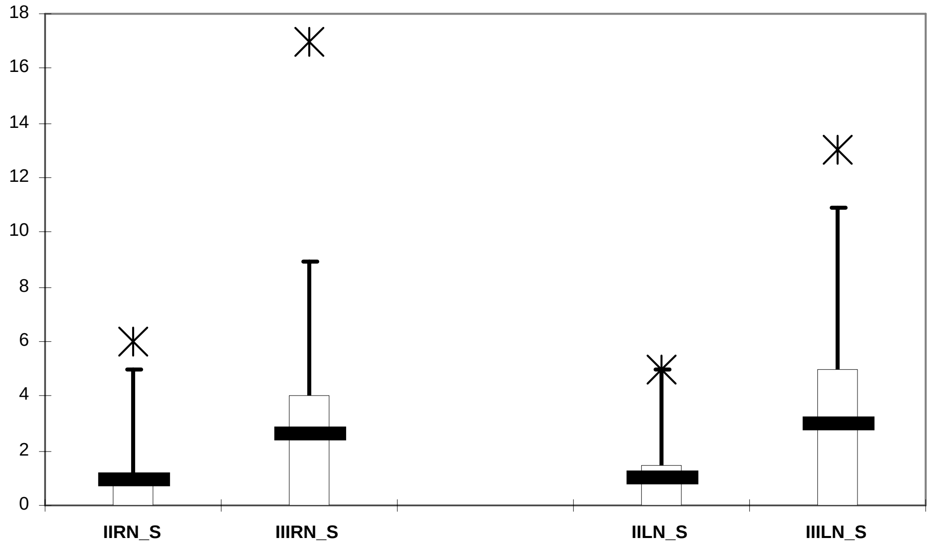
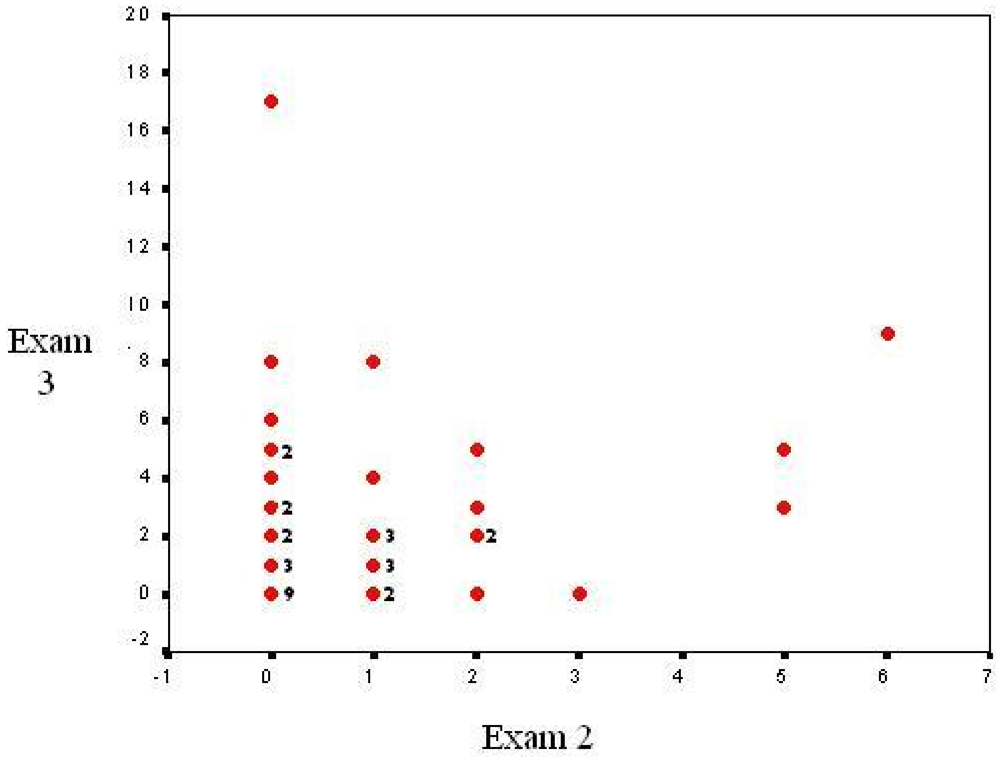


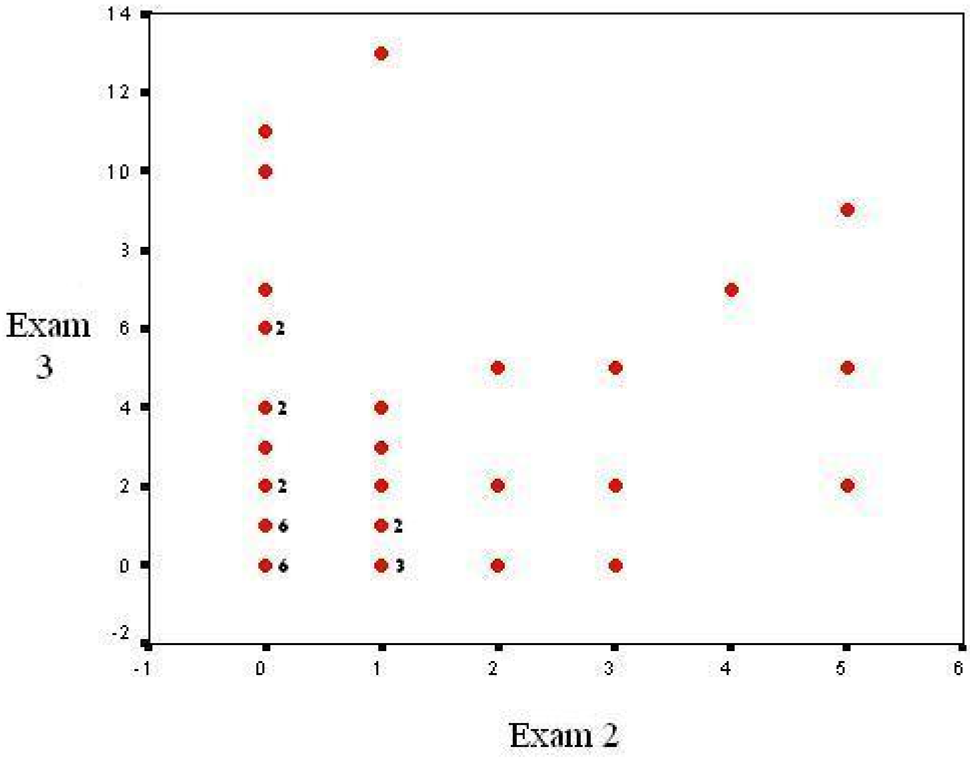
Figure 1. Box plot for the distribution of missed points by the 40 participants during visual field examination of the right eye before (IIRN_S) and during (IIIRN_S) conversation using a cellular phone and similarly for the left eye (IILN_S and IIILN_S). The thick horizontal line indicates the mean value, the upper and lower sides of the box indicate the 25th and 75th quartile values, the I bar represents the 95th percentile, and the asterisks depict individual cases outside the 95$^{\%}$ limit.

Figure 3



Scattergram showing the number of points missed during examination of the right eye before (x axis - exam 2) and during (y axis – exam 3) hands-free cellular phone conversation. A numeral indicates the number of participants with the same results.

Figure 4



Scattergram showing the number of points missed during examination of the left eye before (x axis - exam 2) and during (y axis – exam 3) hands-free cellular phone conversation. A numeral indicates the number of participants with the same results.