TIME FACTORS IN VDT-INDUCED MYOPIA AND VISUAL FATIGUE: AN EXPERIMENTAL STUDY

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In an experimental design with two matched groups (n = 13 and n = 17) working 2 and 4 hr respectively, followed by a 15-min restitution time, the study examined the effect of continuous VDT work on 1) visual acuity, refraction and oculomotor functions (ZCSV: zone of clear, single vision) and 2) the effect of 15-min restitution time on the oculomotor functions (ZCSV). In both groups there were a significant reduction in visual acuity, refraction changes in myopic direction and reduced ciliar and vergence muscle capacity. The ZCSV changes were temporary and a 15-min restitution period restored approximately half of the ZCSV changes. There were no significant differences between 2 or 4 hr of VDT work on any of the variables examined.

The last decade's research done on the influence of VDT work on the human eye has supported claims that visual functions are affected by long-term work in front of computer displays (GRANDJEAN, 1984; OSTBERG, 1980; KREUGER, 1980; CAMPELL and DURDEN, 1983; OWENS and WOLF, 1983; JASCHINSKI-KRUZA, 1988; GOBBA et al., 1988; YEOW and TAYLOR, 1989). Special attention has been given to temporary myopia, and there is a growing concern that VDT work and other types of nearwork may lead to development of more permanent myopia, especially in children and young adolescents (YOUNG et al., 1970; KINNEY et al., 1974; KELLY, 1980; YOUNG et al., 1985). This concern about a possible sustained nearwork-myopia relationship is also supported by a review of earlier myopia research, which showed a positive correlation between time spent in reading and development of myopia (YOUNG, 1975), differentiating the more traditional ophthalmological view based on twin-study evidence that myopia is predominantly genetically determined (WIXSON, 1958; FRANCOIS, 1961).

The impact of environmental factors on the development of myopia and other visual functions is also shown in clinical studies on groups such as Eskimos (YOUNG
et al., 1970) heavy readers (Morgan, 1960), American submariners (Kinney et al., 1974) and naval cadets (Hayden, 1941). Additional evidence is given by experiments on subhuman primates: Young (1963) reared monkeys comparable to a human age of 18–23 years in a restricted environment with visual distance varying between 14 and 20 inches. On average the monkeys developed a myopia of 0.75 diopters (D) during a period of 1 year. Likewise Wiesel and Raviola (1977) raised monkeys with the lids of the eyes sutured shut from birth in photopic light conditions and the monkeys developed an extreme myopia of 14 D in the eye sutured, but not in the nonsutured eye. However, when the same experiment was replicated in darkness, no myopia developed, suggesting that light and the accommodation response were essential for a myopic development. Similar experiments conducted with the tree shrew (Tupaia glis; Sherman et al., 1977) and chickens (Wallman and Turkel, 1978) have confirmed these results.

Studies on temporary myopia and visual fatigue related to VDT work show ambiguous results: Using laser optometry on radar operators Østberg (1980) showed a temporary myopia for far and a hyperopia for near stimuli after 2 hr of work, but his results were not replicated by Kintz and Bowker (1982) in a group of microfiche and hard-copy readers. Jaschinski-Kruza (1984) found a myopic induced contrast sensitivity reduction in 5 of 7 subjects after 3 hr of VDT work, and thus supported the earlier work of Schmidt and Camisa (1984). Haider et al. (1975, 1980) demonstrated temporary myopic changes and a reduced visual acuity. They also showed a color-contingent after-effect and a changed Mueller-Lyer illusion. Takahashi (1983), however, found accommodation changes in both directions for his subjects, while Nyman et al. (1985), in an epidemiological study, found no significant differences in refraction, accommodation, convergence and binocular vision between VDT and non-VDT users. Other negative results have been reported by Howarth and Istance (1982) and Gould and Grischkowsky (1984).

In a recent controlled study, Lie and Watten (1992) showed significant differences in visual acuity, accommodation and vergence changes between a 3-hr VDT group and a control group doing the same type of VDT work, without looking at the display. The study showed the amount of visual work to be the main factor behind the observed optometric changes. The present study is a follow-up study from the above-mentioned study but we are now focusing on the temporal relationships between VDT work and a set of visual functions and especially the restitution time of oculomotor changes.

SUBJECTS AND METHOD

Thirty students from an introductory class in computer science were screened for manifest strabismus, use of contact lenses and systemic diseases. Subjects with glasses were allowed to wear their habitual corrections. Since earlier studies have
shown age to be an important factor in explaining VDT-induced changes in visual functions (Hedman and Briem, 1984; Yeow and Taylor, 1989) we selected a sample at the age of optimal vision (20–22 years). Group A (n = 13, 11 men and 2 women, mean age 21.7 years) worked 2 hr and group B (n = 17, 15 men and 2 women, mean age 22.1 years) worked 4 hr. The self-paced task consisted of simple programming (in the language Simula) which was part of their computer class. The task consisted of several easy exercises and the subjects should solve as many as possible. They were instructed to keep their gaze at the display all the time while doing the programming and that they would be inspected at irregular intervals through a one-way screen. As an extra motivation, both groups were paid for their participation (NKr 100 and NKr 200; i.e. approximately 8 and 16 U.S.$). Group A was served a cup of coffee/tea after 1 hr and group B after 1 and 3 hr.

Since we wanted to study time course of the dependent variables we chose a repeated measurement factorial design with two levels on the group factor (A/B) and two/three levels on the treatment factors (pre/post/post) restitution. The independent variable was the VDT work and the dependent variables were visual acuity, refraction and oculomotor fatigue. Besides a statistical test of interaction between the factors, the major advantage of this design compared to a neutral control group design is that it allows a control for the individual differences among the subjects. It is well known that the subject's responses even to the same experimental treatment are quite variable and this source of variance will increase the experimental error. Minimizing this error variance from the experiment by letting the subjects be their own control will markedly increase the sensitivity of the design (Neale and Liebert, 1973; Cook and Campbell, 1979). To test the main effect of the VDT work on the dependent variables we used a 2 X 2 and 2 X 3 ANOVA with two and three repeated measurements. Paired t-tests were added to test the within-subject pre/post changes.

APPARATUS, MEASUREMENTS AND PROCEDURE

The computer terminal was a monochrome TDV 2230 S (Tandberg Data A/S, Oslo, Norway) with a green display (Phosphore: P31 medium short) in negative contrast; i.e. light characters on dark background. This terminal had a refresh rate of 70 Hz and a 195 X 260 mm height X width text area. Character height was 4.45 mm and character width was 2.1 mm. The average screen luminance was 13 cd/m².

Visual acuity (VA) was measured binocularly with the optotypes of the Pola Test (Zeiss). The range of the acuity scale was from 0.1 (social blind) to 1.5 (excellent) in increment steps of 0.10 (0.1, 0.2, 0.3, 0.4 etc.). Pre/post Rx-status (refraction) was objectively measured with an infrared Topcon RM-100 Refractometer (Tokyo Kogaku Kikai K.K., Japan). The refraction measurements followed this order: left eye, right eye.

Oculomotor status was assessed with the OEP's (optometric extension pro-
gram; Hofstetter, 1945) measurement of the zone of clear and single vision (ZCSV), consisting of PRA (positive relative accommodation), NRA (negative relative accommodation), PRC (positive relative convergence) and NRC (negative relative convergence). ZCSV was assessed in this way with a Rodenstock Phoropter (G. Rodenstock, Munich, FRG): While viewing a target of small letters at 40 cm, minus (−) lenses were slowly added binocularly in 0.25 diopter (D) increments until the subject first noticed a total blurring or doubling of the test letters (the break criteria). The lens’ value at this point was recorded as the positive relative accommodation (PRA) value. Negative relative accommodation (NRA) and positive and negative relative convergence (PRC, NRC) were recorded in the same manner by using plus (+) lenses, base out and base in prisms respectively (Lie and Watten, 1990). Tests of muscular balance were not included.

The procedural order of the measurements of the dependent variables was the following: visual acuity, refraction and ZCSV. VA, Rx-status and ZCSV were measured pre and post VDT work and ZVSC again 15 min after termination of the VDT work (post restitution). Due to interaction between the ZCSV measurements and oculomotor functions (the phoropter is “stressing” the ciliar and extraocular muscles) a valid and reliable RX-status was only obtained pre/post the VDT work. VA was also measured twice since the 15-min interval between termination of the work and the end of the restitution time was too short to avoid the transfer-of-learning error (remembering the test letters of the Pola test). The VA measurements lasted approximately 20 sec, the RX-status 30 sec and the ZCSV measurements approximately 1 min. The groups were comfortably seated on a multi-adjustable chair and were given individual instructions according to guidelines of CAKIR et al. (1979) matching posture with the visual task to avoid postural discomfort. Reading distance varied between 50 and 70 cm. Ambient luminance, temperature and humidity in the room were kept constant and at the same level for both groups.

RESULTS

The ANOVA results showed consistent VDT-induced changes in VA, refraction and ZCSV, but since there were no significant differences between the 2 and 4 hr group on any of the dependent variables, we collapsed the two groups into one group of 30 subjects. In the following presentation of the data we therefore refer to the results of the total sample.

Table 1 shows visual acuity and refraction for the total sample. There is a significant main effect of time on VA (F=20.40, df=1, 28, p <0.000). On average the reduction in VA is 9.2%.

There were substantial individual differences in Rx-status ranging from mild hyperopia to myopia. Some subjects showed negligible pre/post changes, others more marked, but for the total sample there is a significant main effect of VDT work for both eyes (left eye: F=12.79, df=1, 28, p <0.001; right eye: F=21.48, df
Table 1. Visual acuity and refraction pre/post VDT work.

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<thead>
<tr>
<th></th>
<th>Pre VDT work</th>
<th>Post VDT work</th>
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<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
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<tr>
<td>VA</td>
<td>1.30</td>
<td>0.31</td>
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<tr>
<td>Rx R.E.</td>
<td>-0.29</td>
<td>0.61</td>
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<tr>
<td>Rx L.E.</td>
<td>-0.20</td>
<td>0.50</td>
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VA = visual acuity, Rx = refraction, R.E. = right eye, L.E. = left eye, Rx = diopters. n = 30.

Figures 1 and 2 show the ZCSV data for the sample. The ANOVA shows a significant effect of time on PRA ($F=17.50$, $df=1$, 28, $p<0.000$). There is a 23.9% reduction in PRA during the work period ($T=4.8$, $df=29$, $p<0.000$) and a 10% increase (from post work level) in the 15-min restitution period ($T=3.2$, $df=29$, $p<0.01$). For NRA there are no significant pre/post changes (2.7%), but a significant 7.1% increase during the restitution period ($T=4.1$, $df=29$, $p<0.01$). The vergence muscles follow the same tendency as the ciliar muscles. There is a significant intra-subject effect of time on PRC ($F=20.40$, $df=1$, 28, $p<0.000$). The pre/post reduction for PRC was 21.9% ($T=6.1$, $df=29$, $p<0.000$) and the post/post restitution period increase was 17.3% ($T=3.4$, $df=29$, $p<0.000$). The NRC data shows also a general main effect of time ($F=8.21$, $df=1$, 28, $p<0.001$). The pre/post reduction was 10.4% ($T=3.5$, $df=29$, $p<0.01$) and NRC increase during the 15-min restitution period was 8.2% ($T=2.8$, $df=29$, $p<0.01$).
Our results demonstrate myopization and vergence fatigue under conditions of continuous visual work; showing significant changes in visual acuity, refraction in myopic direction and reduced accommodation and vergence capacities.

Unexpectedly, working 2 or working 4 hr on the same task did not make any difference for the variables examined in this study. It may demonstrate that the visual and oculomotor effects of continuous VDT work do not accumulate in a linear way. Another explanation could be that a 2-hr interval between VDT work periods simply is too short to differentiate between two levels of visual work load and especially when individual differences may be masking systematic effects (notably the Rx-status).

The eye muscles are restituting fairly quickly; roughly half of the reduction in accommodation and vergence capacity is regained after 15 min of rest. The ciliar muscles seem to restitute somewhat faster than the vergence muscles, another indication of separate neural control of tonic accommodation and vergence (Hung and Semmlow, 1980). Our restitution data correspond well with the results of Ebenholtz (1983) and Wolf-Kelly et al. (1986).

Temporal myopization and eye muscle fatigue should be interpreted in a visual ecological perspective (Gibson, 1979). Being mainly distance receptors, our eyes are primarily developed for scanning/fixation operations (the striated extraocular vergence muscles) and focusing activity (ciliar muscles). Prolonged near-vision activity (such as VDT work) represents a "visual-ecological arrest," overloading the oculomotor system by keeping the focusing system and the scanning/search
system “arrested” (LIE and WATTEN, 1987). Even if the eye muscles seem to restitute partially during a short period of rest, it is reasonable to ask if a day-by-day accumulation of myopia, vergence fatigue and visual acuity reduction may lead to more permanent negative effects.

REFERENCES


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