

Short Research Article

Eye Movements In Congenital Neurosensorial Deaf subjects As Assessed By 2D video-Oculography™

ABSTRACT

Aims: There is evidence that the deprivation of a sensory system at early developmental stage may lead to a functional change of the remaining one(s). Even if this process has been widely studied, results are still controversial. In particular, the auditory system might affect the oculomotor control, since saccades (FEMs) and slow eye movements (SEMs) are modulated by the cochlea-vestibular input. It follows that hearing impairment would affect the SEM and saccadic pattern. Therefore, in this study FEM and SEM patterns have been evaluated in congenital deaf subjects in order to state whether early auditory deprivation has influence on the oculomotor function.

Study design: Case-control study.

Place and Duration of Study: Sample: Department of Ophthalmology (Orthoptics Center), University of Turin, duration of the study: 6 months.

Methodology: 20 congenital deaf subjects (12 males, 8 females: age range 7-15 years) and 21 age-matched normal hearing subjects (11 males, 10 females: age range 10-16 years) were recruited. Both groups, who had normal visual acuity, underwent SEM and FEM examination by means of 2 D video-oculography. SEM left/right cycle gain and velocity and upward/downward FEM latency, velocity and precision were analysed. Results were then compared in the two samples.

Results: no differences in SEM and FEM efficiency was found between deaf and normal hearing subjects.

Conclusion: Auditory deprivation, does not seem to lead neither to a compensatory enhancement nor to a worsening of the oculomotor function, in contrast to the found improvement of peripheral spatial visual attention. We suggest fine ocular movements program, even though strictly influenced by cocleo-vestibular modulation, does not look to be linked to the auditory processing.

Keywords: deafness; videoculography; ocular movements; FEM; SEM; multisensory integration.

1. INTRODUCTION

Two opposite theories have been formulated about the origin and nature of the change in the visual functions observed after auditory deprivation. The deficiency theory starts from the supposition that integrative processes are essential for a normal sensorial development, so that multisensory integration looks to be critical for the maturation of each single sensory modality. Based on this hypothesis the deprivation of one sensorial modality would result in the deficiency in the others [1,2].

In turn, according to the compensatory theory the deprivation of one sense would lead to a compensatory enhancement of the remaining ones [3-5].

Indeed, for visual functions like brightness discrimination [6], contrast sensitivity [7], temporal discrimination [8] and temporal resolution [9,10], the visual threshold in deaf subjects is shown not to be lower as compared to normal hearing subjects; on the contrary for more complex visual tasks, especially if tested in the peripheral visual field, there is some evidence that deaf individuals' visual performance is enhanced [11]. The improvement of the peripheral visual function in the deaf refers in particular to motion perception [12, 13] and attentive functions [14, 15,16 17]. It is possible a reorganization of the attentional gradient across the visual field takes place in these subjects: indeed, attentive resources, which tend to be focused on the central field and to decrease quite steeply from the center to the periphery in normal hearing people, are equally distributed across the visual field in deaf subjects [5]. A similar pattern has been found in congenitally blind individuals for the spatial distribution of auditory attention [18].

In spite of the large number of studies concerning visual sensorial function, oculomotor efficiency is still largely unknown in this class of subjects.

There is some evidence that the oculomotor system is abnormal in deafness. For example saccadic movements seem to be less precise in deaf individuals than in normal subjects when undergoing attentive tasks [19].

In order to better evaluate the oculomotor pattern in presence of hearing deprivation, congenital deaf subjects underwent videoculography and results were compared to those obtained in a normal-hearing control sample.

2. METHODOLOGY

20 subjects affected by congenital neurosensory hearing impairment, (12 males and 8 females) and, as controls, 21 normal subjects (11 males and 10 females) were recruited. Mean age was, respectively, 11 ± 4 and 13 ± 3 . Exclusion criteria for both groups were ophthalmological or general diseases, genetic diseases (such as Usher syndrome), myopia/hyperopia $> \pm 2$ diopters and/or astigmatism $> \pm 2$ diopters, visual acuity $< 60/60$. After a thorough ophthalmological examination, both groups underwent 2-D videoculography (2D VOG, Sensomotronic Instruments, Berlin, Germany). 2D VOG is a non-invasive infrared-based technique which exploits current technology in CCD sensors and digital image processing and that provides quantitative measurement of eye movements (Fast Eye Movements, FEMs and Slow Eye Movements, SEMs). Video images of the eye are acquired on a miniaturized CCD video sensor mounted in a mask, and the resulting video signal is processed online, yielding a measure of horizontal and vertical components. Eye movements are represented by sampling eye position at discrete time intervals (50 samples per seconds) and eye tracking is shown in real time on a PC screen, while subjects follow a moving target on a 17" video (Samsung). The reference point for eyes position registration is the dark pupil centroid. This is performed by thresholding the incoming video image so that all pixels with intensity below a given value are identified as belonging to the pupil. For a full and detailed description see Clarke, Teiwes and Scherer H (1991) and Scherer, Teiwes and Clarke (1991)[20,21].

The fixation target was a circular white spot displayed on a grey background.

For the SEM estimate the target moved smoothly across 40 degrees from the left to the right of the screen and vice versa at a mean velocity of 5deg/sec and with a sinusoidal acceleration profile.

For the horizontal/vertical FEM registration, the same target jumped along the horizontal (left to right and vice versa) or vertical (up to down and vice versa) axis, respectively.

The subjects sat in front of the screen with the mask worn, at a viewing distance of 50 cm and horizontal SEM as well as horizontal and vertical FEM were registered in random order.

The SEM parameters considered were:

-right and left Short Phase Velocity (SPV, expressed as deg/sec), that in normal conditions are expected to be equal to the fixation target velocity.

- right and left Gain (G) expressed as per cent and computed according to the equation:

$$G = (SEM \text{ amplitude} / SEM \text{ amplitude} + FEM \text{ amplitude}) * 100$$

The gain quantifies the efficiency of the slow eye movement. If the ocular movement following the target results to be totally made of SEM, the Gain value will be 100%, while if saccades occur during the displacement target period, SEM gain decreases proportionally to their amplitude.

The FEM parameters considered were:

-latency (L), that is the interval between target movement and saccade triggering,

-velocity (V) (deg/sec)

-precision (P), computed according to the equation:

$$P = (X_{FEM} - X_0 / X_T - X_0) * 100$$

where: X_0 is the starting point of both target and eye movement, X_T is the final point of the target and X_{FEM} is the landing site of the saccade.

If P is around 100%, then FEM amplitude is adequate to the target position, if it is under or over 100%, it means that FEM amplitude is respectively too short or too long as compared to the target position.

Results obtained in the two samples were therefore compared and appropriate statistical analysis has been performed. Significance level was set at $p \leq .05$.

We certify that the research followed the tenets of the Declaration of Helsinki, that informed consent was obtained from the subjects after explanation of the nature and possible consequences of the study and that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed.

3. RESULTS AND DISCUSSION

The obtained results are depicted in the following tables. No statistical differences were found in SEM and FEM pattern between the two groups except for left horizontal saccades precision, which resulted higher in cases as compared to controls. Right horizontal saccades precision turned out to be close to significant level ($p=.06$)(table 1-5).

Table 1. SEM results in cases and controls.

	Gain Left (%)	Gain Right (%)	SPV Left (deg/sec)	SPV Right (deg/sec)
Cases	94 (25-123)	97 (3-184)	3 (0-13)	3 (0-11)
Controls	97 (46-111)	99 (46-114)	3 (1-9)	3 (1-8)
P	.15	.14	.11	.36

(Gain left: Matt-Withney U= 916.5, Gain right: Matt-Withney U= 912, SPV left: Matt-Withney U= 895.5, SPV right: Matt-Withney U= 984). In brackets are median (min-max) values.

Table 2. Horizontal leftward FEM results in cases and controls.

	Latency (msec)	Velocity (deg/sec)	Precision (%)
Cases	190 (86-400)	197,88(±85.01)	103 (30-165)
Controls	185.5 (111-236)	169,90(±68.75)	92 (31-209)
P	.31	.08	< .005

(Latency: Matt-Withney U= 882.5, velocity: unpaired t-test $t= 1.72$, precision: Matt-Withney U= 580). In brackets are median (min-max) or mean (±SD) values.

Table 3. Horizontal rightward FEM results in cases and controls.

	Latency (msec)	Velocity (deg/sec)	Precision (%)
Cases	181(101-301)	166,45(±78.38)	100 (3-118)
Controls	181 (140-270)	169,51(±57.07)	96 (50-206)
P	.84	.84	.06

Latency: Matt-Withney U= 757, velocity: unpaired t-test $t= 0.19$, precision: Matt-Withney U= 583.5. In brackets are median (min-max) or mean (±SD) values.

Table 4. Vertical upward FEM results in cases and controls

	Latency (msec)	Velocity (deg/sec)	Precision (%)
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Cases	180.5 (21-295)	144.5 (73-438)	100 (7-152)
Controls	202.5 (40-400)	129.5 (17-268)	97 (22-166)
P	.07	.2	.53

Latency: *Matt-Withney U= 823.5*, velocity: *Matt-Withney U= 896.5*, precision: *Matt-Withney U= 979*. In brackets are median (min-max) values.

Table 5. Vertical downward FEM results in cases and controls.

	Latency (msec)	Velocity (deg/sec)	Precision (%)
Cases	195.5 (40-301)	155 (76-552)	97.5 (26-153)
Controls	205 (105-259)	166 (75-339)	100 (62-154)
P	.92	.92	.79

Latency: *Matt-Withney U= 1022.5*, velocity: *Matt-Withney U= 1022.5*, precision: *Matt-Withney U= 1002*. In brackets are median (min-max) values.

In conclusion, according to our results the oculomotor pattern of the congenitally neurosensorial deaf sample seems to be neither better nor worse compared to the normal individuals, with the only exception of the leftward FEM movements, which turned out to be more precise in the former. However, this last finding could be a bias and therefore needs further confirmation. As reported in literature, the effect of deafness on the visual peripheral localization has its counter part in the same effect blindness has on auditory localization: for example auditory spatial attention is found to be improved in blind humans [18, 22-25]. This finding has been interpreted as a consequence of a reorganization of the neural substrates for early auditory selection. In other words, visual areas might be recruited for non-visual processing when visual input is not available [18]. So, if on the one hand the compensatory theory looks to hold in the perceptive domain both for visual and auditory systems, on the other hand according to our results it seems to fail in the oculomotor domain, since auditory deprivation does not lead to appreciable SEM/FEM improvement. This conclusions, indeed, is not unexpected, considering the relevance sounds have on the direction of gaze in everyday life.

As a matter of fact, it should be considered that if the similarity in the anatomofunctional architecture between temporal (auditory) and occipital (visual) areas is similar, the first are basically organised in a different way compared to the frontal oculomotor regions.

4. CONCLUSION

In summary, our findings suggest that an auditory deprivation does not lead to a substantial compensatory enhancement or worsening of the oculomotor function.

As a future investigation it may be interesting to study correlations between SEM and FEM parameters and different patterns of auditory frequencies deprivation as well as to take into consideration differences in audiometric profiles between the left and right ear.

CONSENT

The authors declare that written informed consent was obtained from the parents of the examined subjects for publication.

ETHICAL APPROVAL

The authors hereby declare that the experiment has been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTEREST

The authors have declared that no competing interests exist.

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