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Use dependent limb dominence and somatosensory evoked potentials (SEPs) in the congenitally blind

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Abstract: *Background and purpose:* Vision has been considered as the dominant modality in the human multi-sensory perception of the surroundings. The congenitally blind individuals use cortical areas that are normally reserved for vision during Braille reading. Use-dependent reorganization and neural plasticity changes occur as a consequence of many events, including the normal development and maturation of the organism, the acquisition of new skills. The research was designed to study the effect of blindness on SEPs in the dominant hand (Braille reading hand) compared to the non dominant (non Braille reading hand) in the congenitally blind. *Material and methods:* SEPs were recorded in 15 Braille reading congenitally blind females and compared with 15 age matched normal sighted females following right and left index finger stimulation. Latency and amplitudes of SEP waveforms (N9, N13, and N20) were measured. *Results:* The SEP-N20 amplitude was significantly increased in the congenitally blind ($p < 0.0001$ for right index finger and $p < 0.005$ for left index finger). There is a very large effect of blindness (3.11) on right index finger. *Conclusions:* The congenitally blind individuals have larger N20 amplitude, which is suggestive of greater somatosensory cortical activity. Effect of blindness and Braille reading skills is greater on SEPs recorded from the dominant and preferred hand. A varied contribution from Basic mechanisms in plasticity like neurogenesis, activity-dependent synaptic and neuronal plasticity may be involved.

Keywords: Braille reading, congenitally blind, index finger, N20, SEP.

Introduction

Vision has been considered as the dominant modality in the human multi-sensory perception of the surroundings. The congenitally blind individuals use cortical areas that are normally reserved for vision during Braille reading and other nonvisual tasks involving tactile discrimination [1-2]. They require compensating for the lack of visual information by other sensory inputs, in particular, the somatosensory and auditory inputs. Thus, nonvisual sensory inputs are of greater behavioral relevance in the blind individuals to enable effective interaction with the world around.

Specific electrophysiological recordings in the totally blind individuals have reported plasticity–brain reorganization changes in the involved neural tracts and the higher central nervous system following visual deprivation and dependence on non-visual sensory modalities [3-7]. Focused attention on behaviorally relevant stimulation over extended periods has been found to produce a substantial enlargement in the representational zones of the involved body portions in the somatosensory cortex in animals and humans [8-9]. The adaptive advantage of neural plasticity probably links to fine tuning development of Braille reading in the congenitally blind. Neural plasticity is beneficial and the neural tissue in the brain continually responds to the changes in stimuli by reorganizing itself [10]. Use-dependent reorganization and neural plasticity changes occur as a consequence of many events, including the normal development and maturation of the organism, the acquisition of new skills (learning) [11] - Example following Braille reading. Also, the blind individuals have preferences / predominance in hand and finger use during Braille reading. Earlier data have shown augmentation of auditory evoked potential changes and somatosensory potentials in congenitally blind [4-6]. But, what would be more interesting is the result of preferential use of the dominant hand in Braille reading. There is not enough clarity in data available about the somatosensory evoked potential (SEPs) changes between the preferred / dominant hand and the non dependent hand. The present work is based on the hypothesis of use dependent cortical reorganization caused due to usage of a preferred/dominant hand in Braille reading. The research was designed to study SEPs and the probable plasticity of the somatosensory system in response to Braille reading in the dominant hand compared to the non dominant (non Braille reading hand) in the congenitally blind.

Material and Methods

The study consisted of 30 subjects in the age group 18- 40 years-15 congenitally blind females and 15 age matched sighted females. Subjects with congenital blindness [12] were recruited from blind schools and from those attending outpatient departments at M.S. Ramaiah Medical and Teaching Hospital, Bangalore. The ophthalmologist certified them for blindness through ophthalmologic and fundoscopy examinations. The blind individuals used Braille for their education (average years of Braille use was more than five years). The blind individuals included in the study used their right hand predominantly during Braille reading. 15 age matched normal sighted, right handed females from the general population were studied as controls. Subjects were screened for general physical health to rule out any clinical disorder, touch threshold and two point discrimination to rule out any peripheral sensory disorders likely to interfere with the study findings. Tactile sensations were tested for by clinical examination. Individuals' details like menstrual history, last date of previous menstrual cycle and handedness was procured through history from all subjects. Subjects with history of decreased/loss of sensory perception, other neurological disorders, using any drugs–narcotics, stimulants and neurotrophic drugs were excluded from the study. Informed written consent was obtained from all subjects. The study was approved by the institute's ethics committee.

Procedures: SEPs (Somatosensory Evoked Potentials) were recorded with the subjects awake, comfortably lying down in the bed in a semi-darkened room and were requested to remain calm keeping their eyes closed. SEPs were recorded using NIHON KOHDEN-Neuropack (MEB 2200 Version 03.02) instrument. Electrode placing, nomenclature and methodology of SEP recordings were according to Chiappa [13]. The electrodes were arranged over the Erb's point, C5 spine on the back of neck, contra lateral parietal-occipital scalp over the sensorimotor cortical areas (C3' or C4') and referenced to F_Z. The 3 channel montage [7] used consisted of:

Channel I : Erb's point response, referred contralaterally to record N9

Channel II : Neck (C5S) referred to Fz to record N13

Channel III : Scalp (C3' or C4') referred to Fz to record N20

Recordings were obtained with silver cup electrodes filled with contact gel. The skin surface was prepared with abrasive gel, electrodes fixed and secured with adhesive plasters. At all recording sites, electrode impedance was kept below 5Ω. All subjects were delivered with a short duration electrical stimulus (200-300μs) using a bipolar electrode to stimulate the wrist. The repetition rate of the stimulus was 2Hz. A total of 500 evoked responses were recorded and averaged for two trials each (to assess reproducibility) from the right (dominant Braille reading hand) and left (non dominant Braille reading hand) index fingers. Broadband pass filters at 10 to 2500Hz, restrictive filtering of 150 and 300 to 3000Hz and amplification at 3,00,000. All channels were recorded and averaged simultaneously with a dwell period of 50μs. Samples contaminated with artifacts were auto discarded. Absolute latency and peak amplitude of SEP waveforms, (N9, N13, N20) and interpeak latencies of SEP waveforms (N9 – N20, N13 – N20) were measured.

Statistical Analysis [14-15]: Paired Student t test has been used to find the significance of latency and amplitude of various parameters within the congenitally blind group between the right (dominant Braille reading hand) and left (non dominant Braille reading hand) index fingers. Two tailed independent student t test has been used to find the significance of basic characteristics between the congenitally blind and the normally sighted and also the significance of Latency and Amplitude of all parameters between the 2 groups. Effect size (d) has been calculated to know the effect of blindness on the study parameters.

$$d = \frac{mean1 - Mean2}{PooledSD}$$

No effect	d<0.20
Mild effect	0.20 <d<0.50
Moderate effect	0.50 <d<0.80
Large effect	0.80<d<1.20
Very large effect	d>1.20

Statistical software: The Statistical software namely SPSS 11.0 and Systat 8.0 were used for the analysis of the data and Microsoft word and Excel have been used to generate tables.

Rationale for sample size estimation was based on the existing literature [16] which reveals that the mean latency (N9 – N20) amongst the blind to be 9.37±0.71. Sample size (n) was estimated based on 5% significance level with an error of 0.4 and calculated using the formula

$$n = \frac{Z\alpha^2 \quad \sigma^2}{E^2} = 13 \text{ (approximated to 15)}$$

Where, Zα is standard normal variate = 2 for 5% significance level, σ is standard deviation = 0.71 and E is error = 0.4.

The age group 18 - 40 years was selected for this study based on the experience in existing literature [13] which opines that SEPs in this age group are not affected by age and thus are comparable. The subjects recruited for the present study belonged to a much smaller age subset of the above mentioned age group. The age matched congenitally blind and normal sighted were of 27.50±3.28 and 24.95±1.67 years respectively.

Results

The study design was a comparative study design consisting 15 congenitally blind (Group A) and 15 normal sighted individuals (Group B). SEP parameters of the two groups were compared. The basic characteristics did not show significant difference between the two groups (p > 0.05) (Table-1).

Table-1: Basic characteristics of the study

Basic characteris-tics (Mean ± SD)	Group A (n=15)	Group B (n=15)	P value
Age in years	27.50±3.28	24.95±1.67	0.654
Height in cm	151.71±8.78	154.47±3.62	0.273
Weight in kg	48.71±10.01	52.13±2.64	0.212
Head Circumference In cm	52.79±1.05	53.40±1.06	0.128
Arm Length in cm	65.07±2.73	66.27±1.53	0.154

The mean pattern of amplitude (peak-peak) of SEP - N20 after index finger stimulation showed significant difference between the two groups (p < 0.0001 for right index finger and p < 0.005 for left index finger). There is a very large effect of blindness (3.11) on right index finger and large effect of blindness (1.12) on the left index finger. N9, N13 amplitudes (peak-peak) did not show significant difference (p > 0.05) (Table-2).

Table-2: Comparison of Mean Pattern of Amplitude of Index Finger SEPs between two groups

Amplitude (Mean ± SD)	Index	Group A	Group B	P value	Effect size
N9	Right	2.83 ± 0.85^a	3.11 ± 0.98^a	0.416	0.30(S)
	Left	3.21 ± 0.85^a	2.77 ± 0.82^a	0.163	0.51(M)
N13	Right	2.45 ± 0.89^a	2.97 ± 1.26^a	0.210	0.46(M)
	Left	3.04 ± 0.56^b	2.75 ± 0.72^a	0.232	0.44(M)
N20	Right	4.86 ± 0.95^a	2.47 ± 0.64^a	<0.001**	3.11(VL)
	Left	4.42 ± 1.41^b	2.82 ± 1.38^a	0.005**	1.12(L)

* Significance at 5% ** Significance at 1%, N: No effect; S: Small Effect; M: Moderate effect; L: Large effect; VL: very large effect, Superscripts - Comparison with in each group - Right vs Left, Non-Identical Superscripts (a vs b) are Significant at 5% level of significance, Identical Superscripts (a vs a) are non-significant

Table-3: Comparison of Mean Pattern of Latency of Index Finger SEPs between two groups					
Latency (Mean ± SD)	**Index**	**Group A**	**Group B**	**P value**	**Effect size**
N9	Right	11.14±1.04[a]	11.51±0.85[a]	0.310	0.38(S)
	Left	11.52±0.94[a]	11.32±0.91[a]	0.570	0.21(S)
N13	Right	14.49±0.91[a]	14.86±0.76[a]	0.262	0.43(S)
	Left	14.77±1.21[a]	14.64±0.61[a]	0.711	0.13(N)
N20	Right	20.19±1.05[a]	20.22±0.83[a]	0.923	0.03(N)
	Left	20.19±1.23[a]	20.26±0.76[a]	0.874	0.07(N)
N9-N20	Right	9.04±1.66[a]	8.71±0.84[a]	0.502	0.24(S)
	Left	8.68±0.84[a]	8.94±0.63[a]	0.356	0.34(S)
N13-N20	Right	5.69±1.26[a]	5.36±0.97[a]	0.422	0.29(S)
	Left	5.43±0.54[a]	5.62±0.64[a]	0.393	0.31(S)

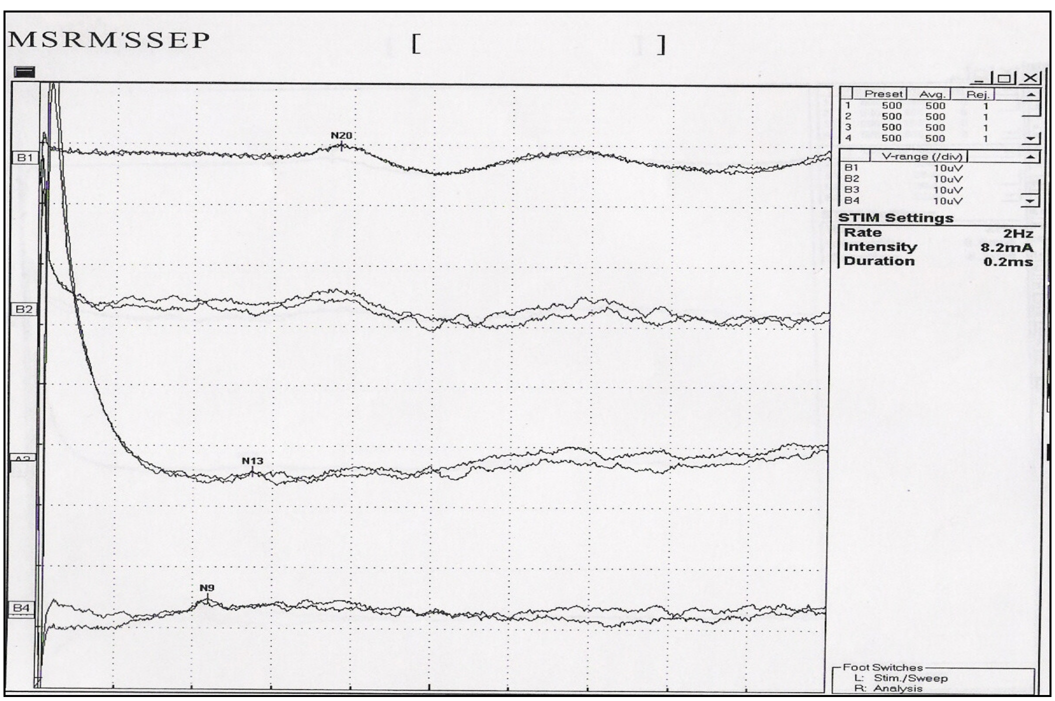
N: No effect; S: Small Effect; M: Moderate effect; L: Large effect; VL: very large effect
Superscripts - Comparison with in each group - Right vs Left
Non-Identical Superscripts (a vs b) are Significant at 5% level of significance
Identical Superscripts (a vs a) are non-significant

The mean pattern of absolute latencies of SEPs (N9, N13 and N20), inter-peak latencies (N9-N20, N13-N20) after index finger stimulation did not show significant difference between the two groups ($p > 0.05$) (Table-3). The absolute latencies, inter-peak latencies of SEPs after index finger stimulation did not show significant difference between right and left side within the same group ($p > 0.05$) (Table-3).

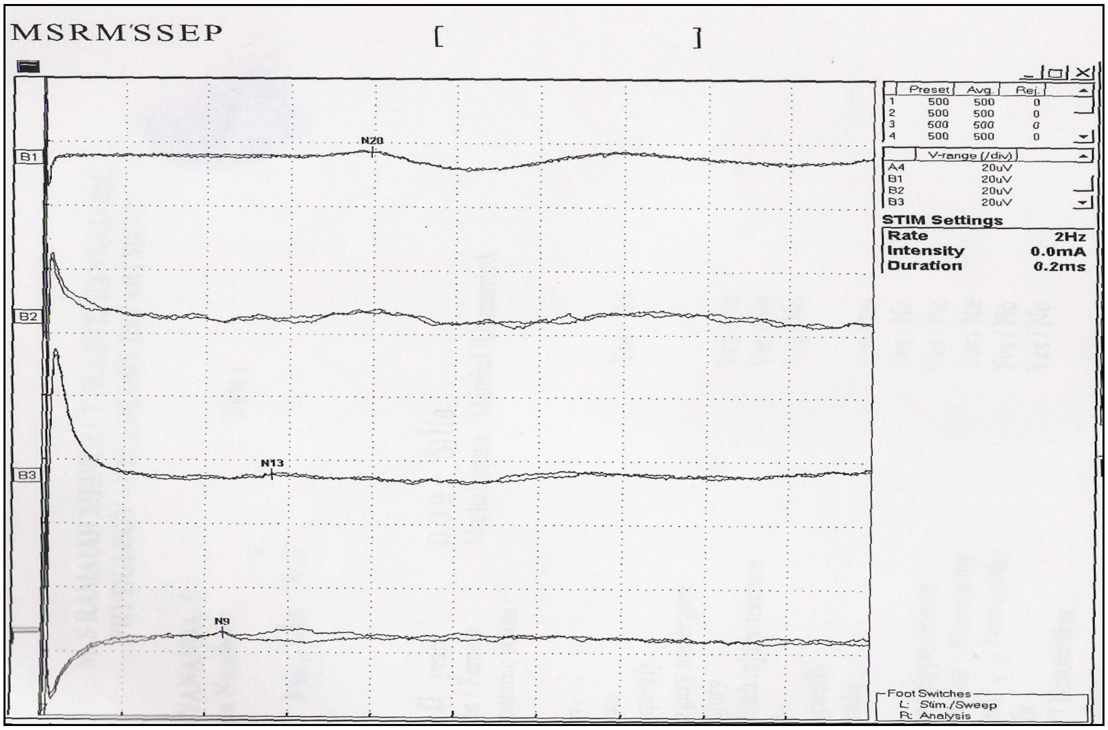
Discussion

The researchers studied median nerve SEPs elicited by index finger stimulation in the congenitally blind individuals (Graph 1 and Graph 2). The difference in SEPs between the Right index finger (dominant / preferred Braille reading hand) and the left index finger (non dominant hand) were observed.

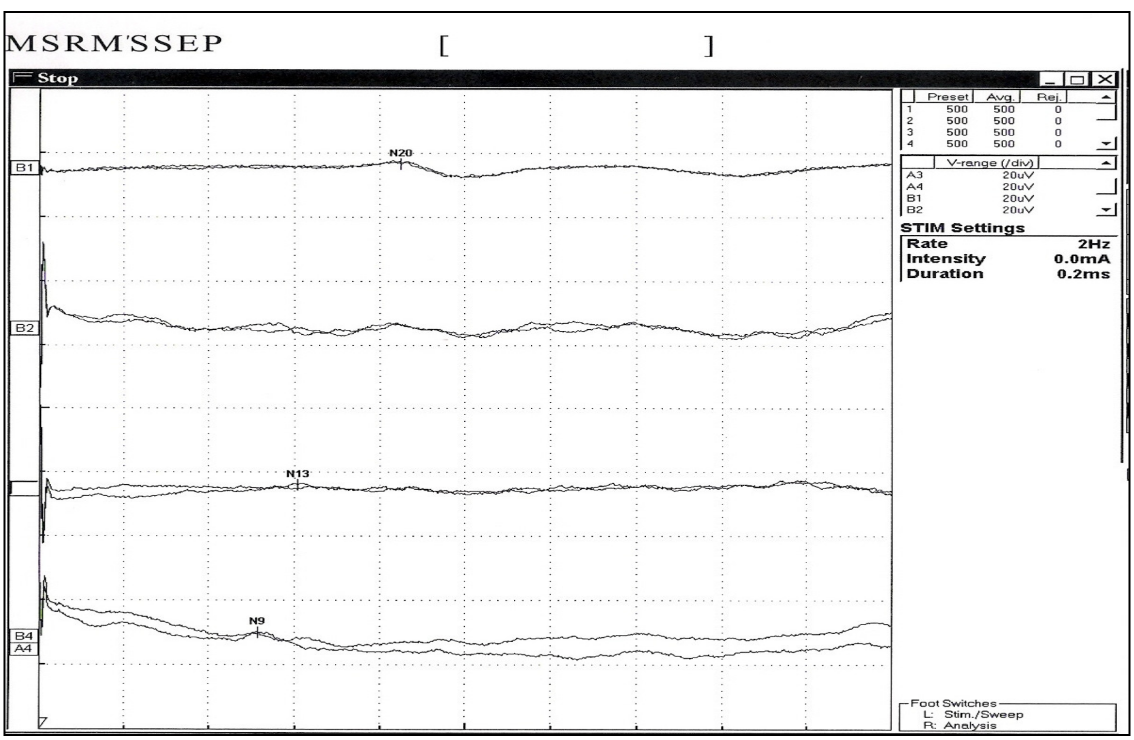
Graph-1: Somatosensory Evoked Potentials after Median nerve stimulation at Right Index Finger. In Totally Blind Individuals



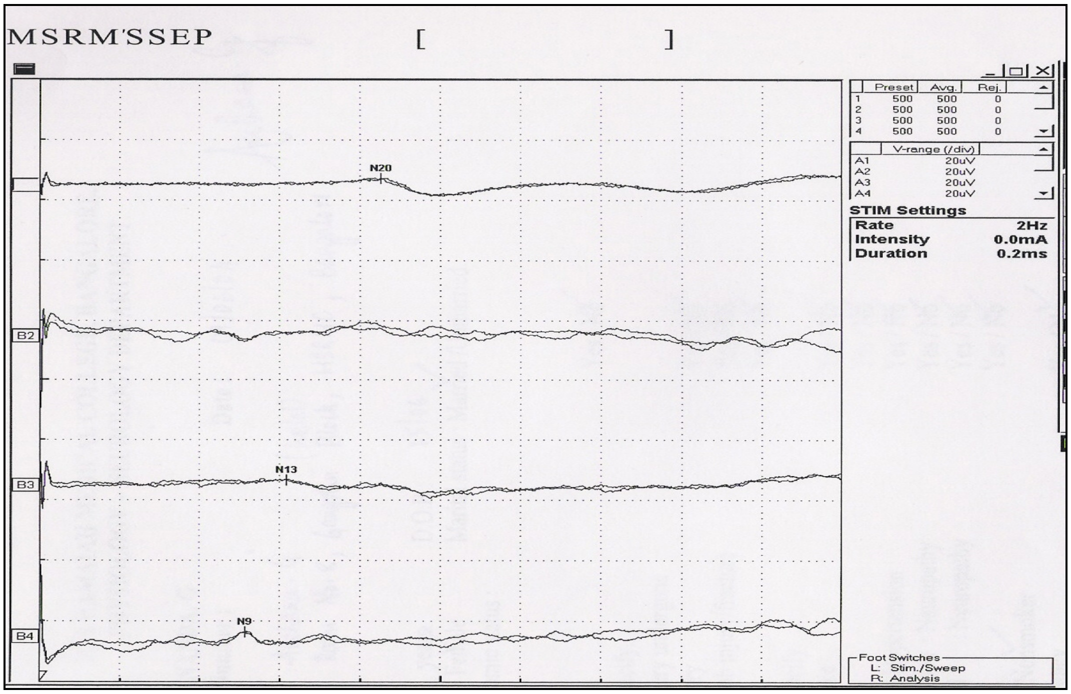
Graph-2: Somatosensory Evoked Potentials after Median nerve stimulation at Left Index Finger. In Totally Blind Individuals



Graph-3: Somatosensory Evoked Potentials after Median nerve stimulation at Right Index Finger. In Normal Sighted Individuals



Graph-4: Somatosensory Evoked Potentials after Median nerve stimulation at Left Index Finger. In Normal Sighted Individuals



The peak to peak amplitude of all SEPs – N9, N13 and N20 were measured. The amplitudes of N9 and N13 were comparable in both the right and left index fingers in the congenitally blind. Also no significant difference was observed as against the sighted individuals (Graph 3 and Graph 4). The N20 amplitudes, in the congenitally blind individuals were significantly larger as compared to normal sighted individuals. The increased amplitude of N20 in congenitally blind shows its large scalp distribution and can be interpreted as a true enlargement of the somatosensory cortical representation of the Braille reading finger. These findings are in agreement with those of Alvaro Pascaul-Leone et al [16].

Among the congenitally blind individuals, N20 amplitudes were significantly increased on right index finger stimulation (dominant hand) than the left. This was determined by the effect size which indicated that blindness had a very large effect on the Braille reading right index finger (dominant hand) than the left index finger. The SEP amplitudes after index finger stimulation (cutaneous nerve) appeared smaller than those after mixed nerve stimulation [17]. This difference is expected considering the proportion of sensory component excited.

All SEPs – N9, N13 and N20, in Right / left index finger and between the two groups did not differ in their latencies and Inter-peak latencies. This suggests that there is no change in the conduction (peripheral and central conduction) time of the stimulus. These findings are in agreement with those of Alvaro Pascaul-Leone et al [16]. Contradictory findings have been reported with decreased SEP latencies in the totally blind individuals by recording event related potentials [18]. These findings may be explained by the increased attentiveness contributing to a quicker information processing during the discrimination tasks of an event related potential [19].

These observations of the study suggest the brain reorganization in response to blindness, possibly as a result of greater attention to and reliance on nonvisual sensory avenues to maintain interaction with the world around. The findings are equivocal with earlier similar findings and indicate that the results drawn are not related to the differences in the peripheral sensory system. Similar adaptive neuronal plasticity and reorganization of cortical maps of the fingers is observed in response to practice playing a stringed musical instrument [20].

The use dependent Neuronal plasticity allows the central nervous system to learn skills and remember information, to reorganize neuronal networks in response to environmental stimulation [21]. Acquisition of Braille reading skill involves a heavy differential sensory input. Dominant use of a body part, limb / finger in the congenitally blind result in neuronal plasticity is enhanced in the developing brain [21]. Basic mechanisms that are involved in plasticity include neurogenesis, programmed cell death, and activity-dependent synaptic plasticity [22].

Repetitive stimulation of synapses can cause long-term potentiation or long-term depression of neurotransmission [21, 23]. These changes are associated with physical changes in dendritic spines and neuronal circuits. An overproduction of synapses during postnatal development in the congenitally blind children probably contributes to enhanced plasticity by providing an excess of synapses that are pruned during early adolescence [21].

There is also a fair possibility that this larger representation of the Braille reading finger could be a consequence of plasticity of motor cortex along with the sensory cortex secondary to the speed of the Braille reading finger. These findings of use dependent cortical reorganization in the congenitally blind [16-17] appear to be an excellent composite example of the principle formulated by Merzenich et al [18] of the continual competition for cortical space.

Conclusions

The congenitally blind individuals have larger N20 amplitude, which is suggestive of greater somatosensory cortical activity. Effect of blindness and Braille reading skills is greater on SEPs recorded from the dominant and preferred hand. A varied contribution from Basic mechanisms in plasticity like neurogenesis, activity-dependent synaptic and neuronal plasticity may be involved.

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