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Website: www.jehp.net
DOI: 10.4103/jehp.jehp_654_19

Neurophysiological parameters of sensory perception and cognition among different modalities of learners

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Abstract:

INTRODUCTION: Different types of learners based on sensory modalities are observed. Cognition or physiological alterations in the sensory pathways might play its role in different modalities of visual, auditory, read and write, and kinesthetic learners which are based on different sensory modalities of perception

OBJECTIVE: The objective of this study is to ascertain an objective parameter (neurophysiological parameters) for the classification of learners based on their preferred sensory modality

MATERIALS AND METHODS: An experimental cross-sectional study was conducted among 100 medical students. Learners were classified into visual, auditory, read-write, and kinesthetic learners based on the interpretation drawn on the basis of the VARK questionnaire. Sensory-evoked potentials (SEPs), including pattern shift visual (PSVEPs), brain stem auditory (BAEPs), short-latency somatosensory (SSEP), and event-related potentials (P300) were measured. SEPs measured in microvolts were recorded from the scalp with the help of active and reference electrodes. Multiple responses to sensory stimuli (using NIHON KOHDEN Corporation Neuropack X1, Tokyo, Japan) were recorded and averaged using the computerized signal averaging technique.

RESULTS: No statistically significant difference was observed in conduction velocities (in terms of latency and amplitude) of SEP among different type of learners, except latency N145 wave form in VEP ($P < 0.05$). A characteristic pattern of minimal comparative latency was observed among the majority of visual learners. Similarly, P300 has shown a characteristic pattern of decreased comparative latency among majority of read and write learners.

CONCLUSION: Study findings suggested that among existing teaching and learning modalities, visual modalities were observed faster but to retain it in memory and for abstract thinking, students should utilize read and writing skills which are lacking in the era of digitalization and overuse of electronic devices.

Keywords:

Event-related potentials, Evoked potentials, VARK learners

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Received: 28-10-2019
Accepted: 21-05-2020
Published: 30-06-2020

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Introduction

Learning is an acquired appropriate response to a stimulus, which tends to change the environment of the organisms. This property is seen even in unicellular organisms which exhibits adaptive behavior in signal processing to environmental stimuli.^[1,2]

With the rise in the evolutionary scale of the process of the organism of learning becomes infinitely more complex and yet the basis of adaptation lies within constituent cells of the pathway mainly neurons.^[3]

The neuropsychologists subdivide the learning process as perception, cognition, and conation. Perception depends on transmission from relevant receptors to intermediary neurons on the way to

How to cite this article: Parashar R, Shukla M, Ganguly A, Hulke SM. Neurophysiological parameters of sensory perception and cognition among different modalities of learners. J Edu Health Promot 2020;9:162.

specific sensory cortex. Cognition, however, is more complex and involves the integration of information from various modalities of sensory pathways and its comparison with prestored memory and also alteration of this memory based on the new stimulus.^[4] All these pathways and neuronal cells can be gazed by certain physiological properties of conducting fibers and synaptic junctions such as nerve conduction velocity and latencies at specific synaptic junctions to specified modality of sensory stimulation which could be visual, auditory, or somatosensory. The late responses of the cortex to specified sensory stimulus represent cognitive processing among which P300 is a late endogenous positive event-related potential (ERP) occurring approximately 300 ms after the onset of novel stimulus.^[5] Detection of P300 is based on a visual or auditory odd-ball paradigm. The principle of this paradigm is to differentiate the P3b component of the P300, i.e., detection of rare events in general (target and distracter), from the P3a component, and these potentials are kind of persistent pattern of generators that emerged in the parietal and the cingulate cortex and novelty-related activations, mainly in the inferior parietal and prefrontal regions. For the visual stimulus modality, effectors come from the inferior temporal and superior parietal cortex and from the superior temporal cortex for the auditory-evoked potentials.^[6,7]

VARK model of learning that depends on the sensory channels and pathways has classified learning into four types of learning modalities, namely auditory, visual, read and write, and kinaesthetic, by Fleming and Teaching.^[8,9] Different sensory modalities are used by different type of learners for assimilating knowledge, and multimodality is preferred as compared to unimodality in the medical field.^[10] Simple, noninvasive neurophysiological parameters, i.e., measuring evoked potentials (EPs) such as pattern shift visual (PSVEPs), brain stem auditory-evoked potentials (BAEPs), short latency somatosensory-evoked potentials, and P300 (ERPs) that measures conduction velocity in terms of latency and amplitude of sensory pathways using the computerized averaging techniques and have been widely used for neurodiagnostic purpose.^[11-15]

According to the basic principles of electroencephalography, VEPs gets elicited by flash type or checkboard pattern type visual stimuli, whereas auditory or BAEPs gets elicited by the auditory stimulus and are mediated by visual pathway and auditory pathways, respectively.^[16] On the other hand, P300 or ERPs are not spontaneous and provide useful information about the response to cognitive tasks processing that reflects attention memory and other higher functions as well as it can provide additional information regarding the discriminative ability of the brain and neurocognitive

processing with the shift of attention. Research studies have not investigated on the quantitative aspect of different type of learners. Hence, this kind of initial study had assessed the physiological alterations in sensory pathways and level of cognition in different type of learners, and it was worth investigating and to note in view of the foregoing, whether physiological alterations in different sensory pathways are different in learners who prefer specific mode of sensory information acquisition to ascertain an objective parameter.

Objectives

The objective of this study is to ascertain an objective parameter (neurophysiological parameters) in the classification of learners based on their preferred sensory modality.

Materials and Methods

A cross-sectional comparative study was conducted in 100 young participants (17–20 years) in the Department of Physiology, All India Institute of Medical Sciences, Bhopal, Madhya Pradesh, India.

Study participants

Assuming moderate effect size around 200 participants were recruited in the study. However, around 15 participants were excluded because of technical error and 35 participants refused to participate in the study and 50 students did not turn up on the date of examination. Hence, the study was conducted in 100 participants, and participants were freshly selected medical students of All India Institute of Medical Sciences, Bhopal, who came from different regions as their selection or admission is based on a merit in the competitive examination.

Inclusion criteria

- Age group of 17–20 years including both sexes
- Apparently healthy
- Free from diseases such as anemia, disabilities, mental, and psychotic disorders.

Exclusion criteria

- Participants suffering from any chronic ailments such as diabetes, chronic pain, injury, or infectious diseases such as tuberculosis were excluded from the study.

Procedure

This study was approved by the Institutional Human Ethics Committee. The VARK questionnaire was distributed to the 1st-year medical students just few months after their admission to classify them in different categories. The purpose of the study was explained to them in details. Participation was voluntary for students, and written informed consent was obtained from the willing students. Students were not required to write

their names on the questionnaire and relieved from any kind of pressure. Using VARK questionnaire (which depends on sensory perception), study participants or learners were classified into either unimodal or multimodal, and unimodal learners were subclassified further into visual, auditory, read and write, or kinaesthetic depending on their preferred modality. They were allowed to quit the study at any time. Willing students were called in afternoon to measure their related neurophysiological parameters. Sensory-evoked potentials (SEPs) were measured in microvolts were recorded from the scalp, with the help of electrodes after giving appropriate sensory organ stimuli. The ERPs were recorded from the scalp using electrodes (silver electrodes, 8 mm in diameter, placed on the scalp with the help of conductive paste). The specific ERP under the study is the P300 which was recorded as responses to an auditory oddball paradigm with 20% oddballs incorporated randomly. Thirty such responses were averaged to obtain the response which was then marked manually as per the standard convention. These NP parameters were measured for 100 participants in the neurophysiology laboratory by using Neuro pack X1 NIHON KOHDEN (ERP measuring system-JAPAN).

Sensory-evoked potentials

Three types of SEP were measured: (i) pattern shift visual (PSVEPs), (ii) BAEPs, and (iii) short-latency somato SEP. In each of these tests, related peripheral sense organ is electrically stimulated, and their conduction velocities were recorded in terms of latency and amplitude by using the computerized signal averaging technique. The participants were briefed about the test procedure and were made to sit comfortably in a chair. The SEP were obtained from scalp electrodes (Ag/AgCl disc electrodes) anchored on the vertex with collodion. Both right and left sides were tested.^[16] The active electrode and reference electrodes were placed according to the 10–20 system as given below

Brain stem auditory-evoked potentials

Active electrode was on the ipsilateral ear lobe or mastoid process, and reference was kept at vertex (CZ). The stimulus consisted of 0.1 ms square waves, intensity around 90 dB with masking of 40 dB for contralateral ear and averaging of around two thousand stimuli was done. Bandpass was between 100 Hz and 3 kHz.

Pattern shift VEP

Active electrode was on occipital (oz), reference was at the vertex (CZ), a stimulus of 1 Hz, Bandpass 1HZ–100HZ and stimulation patterns were recorded as follows for both eyes:

- Black and white checkerboard
- Size of the checks: 14 × 16 mins (size and distance from the monitor should produce a visual angle of 10–20)

- Contrast: 50%–80%
- Mean luminance: central field – 50 cd/m² and background – 20–40 cd/m².

Somatosensory-evoked potentials

Active electrodes for the upper extremity SSEP sites were as follows: • Erb's point – EP1/EP2, • cervical spine – C2 or C5, • contralateral scalp overlying the area of the primary sensory cortex – C3 or C4, reference electrodes were placed at forehead Fz, and ground electrode was at proximal to stimulation site or FPz. The stimulus was given on median nerve as electrical square-wave pulse of duration: 100–200 ms at a rate of 3–7/sec with intensity equal for producing observable muscle twitch or 2.5–3 times the threshold for SNS unilateral stimulation for localization described in text book of neurology by Michael J Aminoff.

P300-Cognition was measured with the help of assessment of late-onset waveform P300 in auditory ERPs based on oddball paradigm.^[17] The following was during the procedure:

- Active electrode was placed on the vertex (Cz), frontal (Fz), and parietal (Pz)
- Reference at both earlobes (A1+A2/A+)
- Auditory oddball paradigm: 20% odd stimuli presented randomly.
- Oddball stimulus of 2 kHz, 40 dB at 0.5 Hz interspersed with assigned stimuli of 1 kHz, 40 dB at 0.5 Hz
- Bandpass: 0.1 Hz–50 Hz.

The P300 of participants was also recorded in terms of latency and amplitude. All the potentials were measured as per the guidelines of the International Federation of Clinical Neurophysiologists.^[18,19]

Statistical analysis

Data were compiled and analyzed using the statistical software Statistical package for the social sciences (SPSS version 21.0, IBM Corp, Armonk, NY, USA), and numerical variables are presented as mean, standard deviation, median, and interquartile range. Difference between mean scores was tested using the analysis of variance with *post hoc* analysis. $P \leq 0.05$ was considered statistically significant.

Results

A pattern of learning styles in half of the study population in the present study has shown auditory learning modality (49.1%), followed by kinaesthetic (27.7%), multimodal (16.8%), read/write (3.9%), and visual (2.9%), respectively. About two-thirds of the students in auditory and read/write learning modality group were males. All the three participants in the visual category were male. However, in the multimodal learning group,

the distribution was almost equal, both among males as well as females [Table 1].

Conduction velocities of SEP were measured in terms of latency and amplitude. No significant difference was observed in conduction velocities of SEPs among different types of learners, except latency N145 waveform in VEP. A characteristic pattern of minimal comparative latency was observed among the majority of visual learners. p300 has shown a characteristic pattern of decreased comparative latency among the majority of read and write learners. Their detailed response pattern is as follows:

Somatosensory-evoked potentials were measured as following waveforms, i.e., N20, P23, P33, and P45 in terms of latency and amplitude [Figure 1]. The latency of N20 was minimum for read/write, and then, visual modality learners on the left side, whereas on the right side, the same was minimum for multimodal learners (18.55 ± 2.51 ms) and then visual learners. Latency was the highest on the right side (25.00 ± 11.75) μV for the read/write modalities of learners. The amplitude of N20-p23 was the highest among read/write modality (2.7 ± 1.29) μV learners (2.3 ± 0.85 μV) on the left side, whereas on the right side, the multimodal learners had the highest amplitude (3.45 ± 4.36 μV). However, no significant difference was observed in the mean value of N20 latency and amplitude on both sides between different modalities of learners ($P > 0.05$). The latency of P23 was minimum for the visual modal learners (19.63 ± 4.02 ms) on the left side, whereas on the right side, the same was minimum for auditory learners (23.50 ± 4.33 ms) with a very slight difference visual was the second least latency. The amplitude of P23-N33 was the highest among multimodal learners (2.18 ± 4.95 μV) on the left side, whereas on the right side, the auditory learners had the

highest amplitude (1.3145 ± 2.51061 μV). However, no significant difference was observed in the mean value of P23 latency and amplitude on both sides between among the different modalities of learners ($P > 0.05$). The latency of N33 was minimum for both on the left (25.1 ± 5.57) and right sides (30.4 ± 2.06) for the visual modal learners, and it was the highest for the read and write modality learners both on the left (27.77 ± 4.90) and right sides (38.10 ± 17.23). The amplitude of N33-P45 was the highest among multimodal learners both (2.49 ± 1.20) on left and right sides (2.07 ± 1.28). However, no significant difference was observed in the mean value of N33 latency and amplitude on both sides among the different modalities of learners ($P > 0.05$). The latency of P45 was minimum for visual modality both on left (32.63 ± 9.04) and right sides (41.83 ± 6.15) and the highest for READ and write modality on right side (47.57 ± 13.97) and multimodality for left side (36.64 ± 7.82) [Table 2].

Auditory-evoked potentials

Among different waveforms I, II, III, IV, and V are shown in Figure 2. the latency was minimum in visual modality learners, as shown in Table 3, except waveform I where latency was minimum among read and write learners on both left (1.35 ± 0.17 ms) and right sides (1.31 ± 0.33 ms), and in waveform II (2.49 ± 0.11 ms) and III (3.50 ± 0.10 ms), where it was minimum among multimodal learners on the left side. Among the intervals of auditory-evoked potentials, latency measured was minimum for visual modality Table 3 except interval I-III left side (2.06 ± 0.12 ms) minimum for multimodal learners and interval III to V on left-side latency was minimum for read and write learner modality. Moreover,

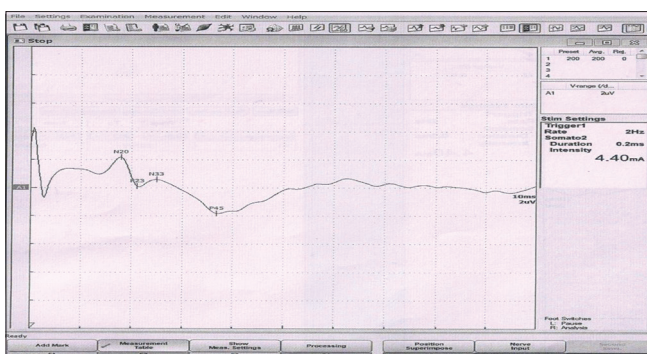


Figure 1: Waveforms pattern in somatosensory-evoked potentials

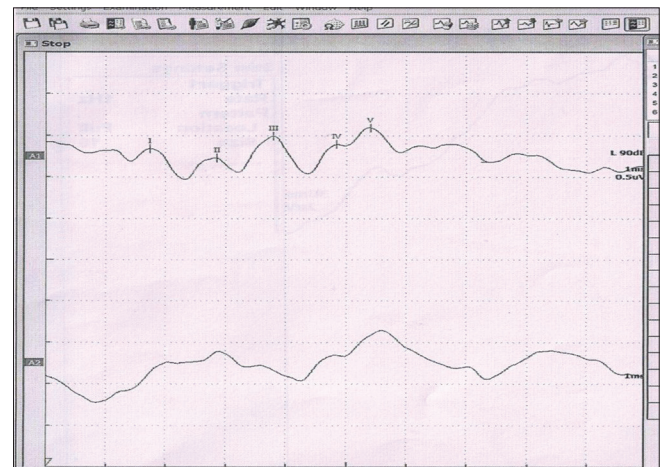


Figure 2: Waveform pattern in auditory brain stem responses

Table 1: Gender-wise distribution of the study population

Gender	Learning modality				Total (n=101)	
	Auditory (n=49)	Kinesthetic (n=28)	Multi-modals (n=17)	Read and write (n=4)		Visual (n=3)
Female	14 (28.6)	10 (35.7)	8 (47.1)	1 (25.0)	0 (0.0)	33 (33.1)
Male	35 (71.4)	18 (64.3)	9 (52.9)	3 (75.0)	3 (100.0)	68 (66.8)

Table 2: Latency and amplitude of waveforms in somatosensory-evoked potentials

Parameter	Side	Mean±SD (range) (maximum-minimum)				P
		Visual	Auditory	Read/write	Kinesthetic	
N20 latency (ms)	Left	16.36±4.39 (11.3-19.2)	16.84±4.25 (4.3-32.8)	15.88±4.149 (9.9-19.5)	17.22±2.55 (10.6-20.6)	0.963
	Right	19.2±0.52 (18.6-19.6)	18.86±2.34 (16.1-29.7)	25.00±1.75 (17.1-42.5)	19.854±5.94 (9.1-40.9)	0.078
P23 latency (ms)	Left	19.63±4.027 (15-22.3)	20.58±4.314 (10.3-38.8)	23.13±0.97 (22.2-24.3)	19.79±4.420 (1.8-23.9)	0.646
	Right	23.56±1.36 (22.5-25.1)	23.5±4.33 (20.1-40.2)	31.37±13.19 (23.4-51.1)	24.054±6.68 (14.6-46.6)	0.132
N33 latency (ms)	Left	25.1±5.54 (18.7-28.5)	26.68±5.13 (17.6-47.7)	27.77±4.90 (20.9-32.5)	27.31±3.64 (18.3-34.9)	0.635
	Right	30.4±2.06 (28.1-32.1)	31.34±6.03 (23.3-56.4)	38.1±17.23 (19.7-61.3)	32.11±11.1 (12.2-62.2)	0.683
P45 latency (ms)	Left	32.633±9.04 (22.2-38.3)	36.46±8.53 (20-56.7)	35.5±3.99 (32.9-41.4)	35.72±6.73 (14-45.7)	0.93
	Right	41.833±6.5 (37.6-48.9)	42.14±8.06 (32-74.5)	47.575±13.95 (34.3-65.8)	43.95±13.9 (22.4-78.5)	0.8
N20-P23 amplitude (µV)	Left	2.3±0.85 (1.4-3.1)	2.58±1.29 (0.1-11.3)	2.7±1.290 (1.2-4.2)	2.46±1.66 (0.5-7.6)	0.987
P23-N33 amplitude (µV)	Right	1.9±0.529 (1.5-2.5)	2.953±4.023 (0.33-29.2)	1.455±1.607 (0.4-3.8)	2.34±1.521 (0.2-7)	0.743
	Left	1.1±0.655 (0.4-1.7)	1.66±1.804 (0.1-9.5)	0.65±0.597 (0.1-1.5)	0.96±0.725 (0.1-2.6)	0.481
N33-P4 amplitude (µV)	Right	0.63±0.503 (0.1-1.1)	1.314±2.51 (0.08-17.2)	1.017±1.11 (0.1-2.6)	1.28±1.23 (0.1-4.8)	0.898
	Left	1.9±0.781 (1-2.4)	2.24±1.357 (0.2-6.8)	1.42±1.056 (0.5-2.8)	1.84±1.021 (0.5-4.7)	0.305
	Right	1.566±0.577 (0.9-1.9)	2.014±1.713 (0.1-10.8)	0.48±0.295 (0.25-0.9)	1.81±1.17 (0.2-5.3)	0.346

SD=Standard deviation

regarding amplitude for waveform I and V, it was the highest among read and write learners modality ($0.65 \pm 0.18 \mu\text{V}$). However, no significant difference was observed in the mean value of latency and amplitude on both sides between the different modalities of learners ($P > 0.05$) [Table 3].

Visual-evoked potentials (VEPs) that got elicited from visual stimulus, as shown in Figures 3 and 4, three different waveforms were recorded named as N75, P100, and N145, and their latency and amplitude were measured, and latency was found to have minimum for visual modal learners in all the waveforms on both left and right sides. The significant difference was observed in the mean with minimum latency of N145 waveform on the right side between different modalities of learners ($129.2 \pm 9.676 \text{ ms}$) ($P < 0.05$). Amplitude was the highest among read and write learners; however, no significant difference was observed for different modalities of learners [Table 4].

Regarding p300 also known as long-latency-evoked potentials that represent cognition latency in ms and amplitude in μV was measured at different levels, i.e., frontal, central, and parietal level and found that latency was minimum among read and write learners modality at all levels, i.e., frontal (309 ± 22.13),

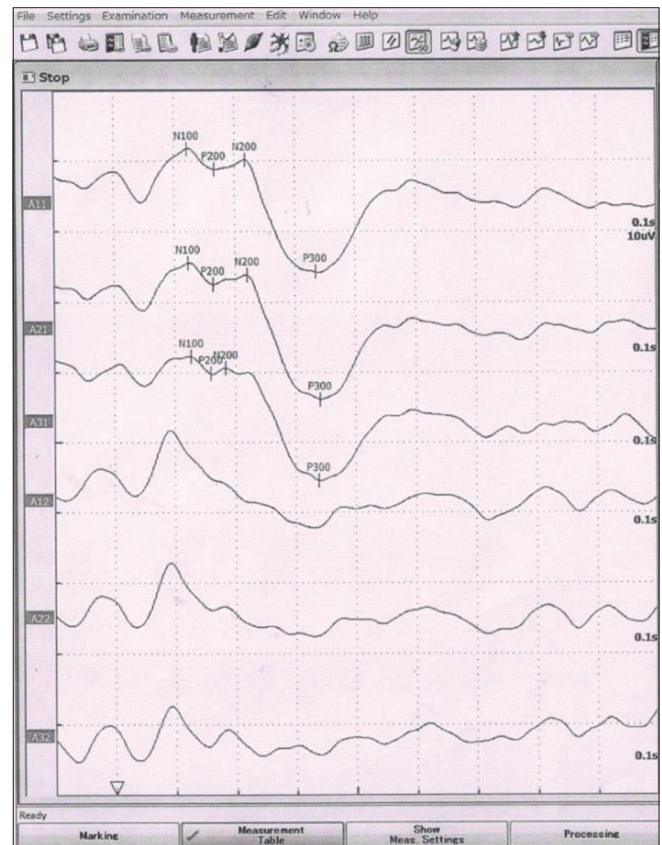


Figure 3: P300 waveforms at frontal (A11) central (A21) and parietal level (A31)

Table 3: Latency, amplitude, and intervals of waveforms for auditory brainstem response

Parameter	Side	Mean±SD (range) (maximum-minimum)				P
		Visual	Auditory	Read/write	Kinesthetic	
I latency (ms)	Left	1.45±0.045 (1.4-1.49)	1.47±0.18 (1.23-2.49)	1.35±0.176 (1.1-1.5)	1.44±0.122 (1.31-1.81)	1.4418±0.14205 (1.18-1.8)
	Right	1.56±0.132 (1.42-1.68)	1.51±0.32 (0.95-2.72)	1.31±0.332 (0.83-1.58)	1.48±0.26 (1.18-2.66)	1.4325±0.13324 (1.26-2.69)
II latency (ms)	Left	2.52±0.112 (2.4-2.62)	2.61±0.261 (2.23-3.72)	2.49±0.097 (2.36-2.58)	2.55±0.21 (2.17-3.33)	2.49±0.11 (2.3-2.71)
	Right	2.48±0.127 (2.37-2.62)	2.56±0.030 (1.47-3.46)	2.58±0.439 (2.16-3.17)	2.55±0.21 (2.21-3.41)	2.5469±0.254 (1.82-3.01)
III latency (ms)	Left	3.54±0.036 (3.5-3.57)	3.66±0.353 (2.81-4.78)	3.74±0.55 (3.4-4.57)	3.60±0.268 (3.29-4.55)	3.50±0.10 (3.31-3.71)
	Right	3.51±0.121 (3.43-3.65)	3.65±0.28 (3.29-4.77)	3.53±0.37 (3.16-4.05)	3.66±0.368 (3.28-4.83)	3.57±0.19 (3.32-4.17)
IV latency (ms)	Left	4.66±0.24 (4.41-4.9)	4.80±0.30 (4.02-5.32)	4.92±0.439 (4.64-5.57)	4.79±0.21 (4.42-5.44)	4.75±0.24 (4.41-5.21)
	Right	4.49±0.27 (4.18-4.7)	4.84±0.394 (4.21-6.74)	4.73±0.566 (4.26-5.54)	4.78±0.27 (4.47-5.62)	4.77±0.25 (4.28-5.11)
V latency (ms)	Left	5.34±0.16 (5.21-5.53)	5.60±0.513 (4.81-7.03)	5.35±0.35 (5.17-5.89)	5.75±0.74 (5.02-8.61)	5.6118±0.59 (5.01-6.89)
	Right	5.29±0.17 (5.11-5.46)	5.60±0.536 (4.89-7.28)	5.35±0.603 (4.84-6.22)	5.5625±0.54 (4.96-7.39)	5.5219±0.58 (4.74-6.68)
Interval I-III (ms)	Left	2.09±0.072 (2.01-2.15)	2.183±0.35 (1.41-3.36)	2.39±0.72 (1.9-3.47)	2.15±0.0281 (1.8-3.15)	2.06±0.123 (1.76-2.26)
	Right	1.94±0.24 (1.77-2.23)	2.1308±0.23 (1.47-2.92)	2.22±0.67 (1.8-3.22)	2.18±0.299 (1.82-3.14)	2.13±0.219 (1.83-2.79)
Interval IIV-V (ms)	Left	1.80±0.150 (1.66-1.96)	1.9424±0.44 (1.14-3.34)	1.61±0.20 (1.32-1.78)	2.04±0.419 (1.61-3.21)	2.11±0.687 (1.45-3.58)
	Right	1.78±0.10 (1.66-1.87)	1.96±0.40 (1.54-3.41)	2.19±0.74 (1.66-3.25)	1.90±0.345 (1.07-3.01)	1.952±0.62 (1.12-3.08)
Interval I-V (ms)	Left	3.89±0.15 (3.81-4.07)	4.12±0.50 (3.37-5.6)	4.005±0.526 (3.68-4.79)	4.19±0.51 (3.66-5.43)	4.1729±0.67 (3.49-5.71)
	Right	3.72±0.30 (3.43-4.04)	4.09±0.514 (3.4-6.33)	4.41±1.052 (3.48-5.39)	3.97±0.71 (1.08-5.4)	4.082±0.658 (3.17-5.35)
Amplitude V-A (µV)	Left	0.45±0.185 (0-1)	0.66±0.605 (0-4)	0.76±0.131 (1-1)	0.54±0.234 (0-1)	0.66±0.373 (0-1)
	Right	0.51±0.0907 (0.41-0.58)	0.607±0.231 (0.2-1.43)	0.81±0.30 (0.37-1.04)	0.63±0.24 (0.12-1.03)	0.675±0.33 (0.12-1.36)
Amplitude I-A (µV)	Left	0.33±0.055 (0.27-0.37)	0.52±0.24 (0.03-1.06)	0.635±0.190 (0.47-0.87)	0.52±0.26 (0.03-1.09)	3.44±11.61 (0.03-47)
	Right	0.36±0.141 (0.23-0.51)	0.55±0.302 (0.02-1.34)	0.65±0.18 (0.44-0.89)	0.52689±0.25 (0.053-0.93)	0.563±0.23 (0.26-1.01)

SD=Standard deviation

Table 4: Latency and amplitude of waveforms for visual-evoked potentials

Parameter	Side	Mean±SD (range) (maximum-minimum)				P
		Visual	Auditory	Read/write	Multimodal	
Latency (ms)	Left	76.5±6.78 (70.8-84)	78.68±10.75 (19-91.2)	76.65±8.83 (63.9-84.3)	77.69±4.78 (66.5-87.6)	0.783
	Right	72.4±6.24 (65.4-77.4)	77.22±11.75 (7.53-87.9)	75.3±5.33 (67.5-78.9)	76.189±5.36 (67.2-89.7)	0.919
Latency (ms)	Left	105.2±2.12 (103-107)	111.67±19.55 (2-171)	112.28±5.98 (105-119)	110.97±5.009 (101-125)	0.356
	Right	103.4±6.41 (96-107.4)	111.56±7.00 (95.4-124.8)	111.6±5.91 (104.1-117.3)	110.93±6.47 (98.1-125.1)	0.434
Latency (ms)	Left	151.4±11.77 (138.3-161.1)	165.95±32.10 (20.13-248.7)	170.55±17.16 (151.2-192.9)	165.81±20.34 (128.1-200.7)	0.327
	Right	129.2±9.67 (120-140)	163.54±28.47 (117-265)	167.1±24.37 (141-199)	164.28±22.35 (128-214)	0.017
Amplitude (µV)	Left	7.46±3.153 (4.4-10.7)	11.47±11.37 (1-81.1)	13.29±6.10 (5.59-19.6)	8.96±3.64 (2.6-16.4)	0.594
	Right	6.93±2.55 (4.9-9.8)	9.80±5.043 (1.9-24.4)	10.56±3.69 (5.56-13.6)	8.92±3.59 (2.72-16.7)	0.751
Amplitude (µV)	Left	8.3±3.29 (4.5-10.3)	9.32±4.027 (2-22)	14.94±5.82 (7.39-21.6)	9.39±4.65 (4.1-22.76)	0.165
	Right	6.26±2.159 (4.00-8.3)	8.66±4.77 (1.2-20.4)	13.12±4.25 (7.28-17.2)	8.84±4.84 (0.1-18.57)	0.214

SD=Standard deviation

Table 5: Latency and amplitude waveforms for P 300

Parameter	Side	Mean±SD (range) (maximum-minimum)				P
		Visual	Auditory	Read/write	Multimodal	
Latency (ms)	A11 frontal	364.33±95.69 (276-466)	325.429±46.92 (240-559)	309±22.13 (276-323)	337.321±61.76 (249-494)	0.534
	A21 central	371.33±91.59 (289-470)	322.49±51.70 (241-556)	300.75±20.61 (270-313)	336.57±62.53 (252-505)	0.44
	A31 parietal	372±92.98 (285-470)	317.918±46.69 (240-513)	296.5±10.84 (284-309)	324.53±47.53 (272-490)	0.334
Amplitude (µV)	A11 frontal	21.633±8.540 (11.8-27.2)	18.43±10.20 (3-58.4)	11.125±5.51 (2.9-14.7)	16.911±12.258 (1-60.4)	0.677
	A21 central	18.76±1.51 (17.7-20.5)	16.38±7.57 (0.5-35.2)	10.85±1.30 (9-11.9)	13.95±7.44 (3.9-30.9)	0.322
	A31 parietal	16.1±4.419 (11-18.8)	14.59878±6.66 (1.3-29.5)	9.62±2.0003 (7.706-11.5)	13.190±4.80 (5.7-23.4)	0.517

SD=Standard deviation

central (300.75 ± 20.61), and parietal (296.5 ± 10.8) and p300 amplitude was maximum among visual learners. However, no significant difference was observed in the mean value of latency and amplitude for P300 [Table 5]. Regarding p300 also known as long-latency evoked potentials that represent cognition, latency was measured at different levels, i.e., frontal, central, and parietal level, as shown in Figure 3.

Discussion

Five types of learners were classified based on sensory channels and pathway based on VARK modality, visual, auditory, readwrite, kinesthetic, and multimodal learners. A visual student prefers visual mode for learning, i.e., by seeing graphs tables; aural student prefers listening techniques. Read and write learners prefer reading and writing for assimilating and accommodating the information. A kinaesthetic student experiences by doing. Results of previous studies on learning styles are contradictory as studies suggested the preferred modality are auditory and kinaesthetic, while on the other hand, studies suggested by Panambur *et al.* and Lujan and DiCarlo found differences in sensory modality preferences.^[18,19] Different sensory modalities are used by different types of learners for assimilating knowledge and multimodality is preferred said by Zoghi *et al.* as compared to unimodality in the medical field that strengthen the results of our present study [Table 1]. So far, there was not any experimental proof or quantification of studies done on preferred modality by different learners. Hence, this study was conducted with the intention to know whether physiological alterations in different sensory pathways are different in learners who prefer specific mode of sensory information, To serve this purpose, some noninvasive neurophysiological parameters were measured which included SEP such as short-latency somatosensory-evoked potentials, pattern shift visual (PSVEPs), BAEPs, and P300 (ERPs) with the help of above techniques, conduction velocity in terms of latency and amplitude was measured using computerized averaging techniques that had already been widely used for neuro-diagnostic purpose.^[20]

Evoked potentials were measured after giving different types of sensory stimuli such as visual stimulus for VEP that signifies the visual pathway and auditory stimulus for BAEP that signifies the auditory pathway. This might ascertain an objective parameter for visual and auditory learners, and in short-latency somatosensory-evoked potentials, that signify the pathway for read and write and kinaesthetic modality where brief electric stimulus was given on the median nerve.

Somatosensory-evoked potential (SEP), latency (conduction), and amplitude depend on spinal cord

reflexes, or we can say its conduction (latency) depends on time taken for volleys' transmission at various level till brain through large fiber Ia or II of sensory system, that traverse through the posterior columns and medial menisci), that was recorded in pattern of waveforms named N20, P23, P33, and P45, named according to the time taken in milliseconds for action potentials to travel along the large fiber [Table 2 and Figure 1]. These waveforms may signify the pathway that is involved mainly for read and write and kinesthetic learners, the pattern of mean latency was found to be minimum among read and write modality in just one waveform, i.e., N20 on the left side. Visual modal learners among waveforms P23 left side, N33, P45 (both on left and right side), but the results of mean latency was insignificant, and the pattern of amplitude was showing variably insignificant results.

VEP evaluates the function of the visual pathway from the retina to the occipital cortex. It measures the conduction in terms of latency and amplitude of the visual pathways in waveform N75, P100, and N145 [Table 4 and Figure 4] from the optic nerve, optic chiasma, and optic radiations to the occipital cortex. The generator site for VEPs is believed to be peristriate and striate occipital cortex. The mean of latency or conduction was minimum for visual modality learners and amplitude was maximum for read and write learners in all waveforms and only significant findings were present for mean latency of N145 waveform, and none of the waveforms were showing right and left asymmetry.

BAEP or brainstem auditory-evoked response (BAER) measures the functioning of the auditory nerve and auditory pathways in the brainstem [Table 3]. Wave forms I-V were recorded [Figure 2], and generators of these different waveforms are as follows. Wave I-Action potential of cranial nerve (CN) VII, wave II-Cochlear

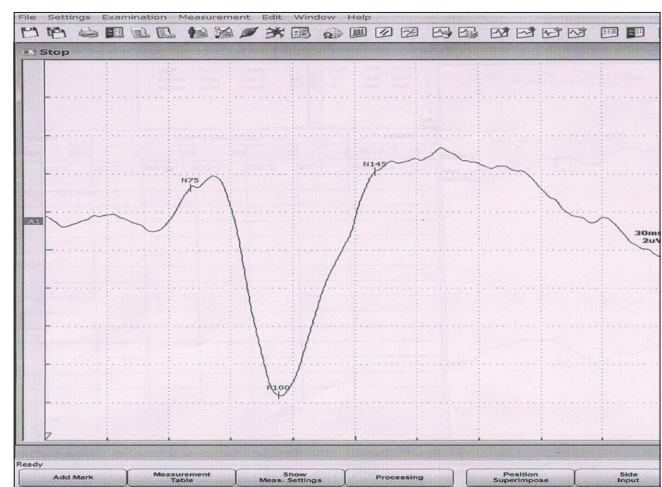


Figure 4: Waveform patterns of visual-evoked potentials

nucleus (and CN VIII, Wave III-Ipsilateral Superior Olivary nucleus, Wave IV-Nucleus or axons of Lateral Lemniscus, and Wave V-Inferior colliculus).

Latency or conduction measured after auditory stimulus between the intensity of 60–90 dB showed the minimum mean latency pattern again among visual modality learners as shown in Table 3 a except waveform I where latency was minimum among read and write learners on both left (1.35 ± 0.17) and right sides (1.31 ± 0.33), and in waveform II (2.49 ± 0.11) and III (3.50 ± 0.10), where it was minimum among multimodal learners on the left side.

However, amplitude for waveform I and V was the highest among read and write learners modality.

Hence, it suggest that pattern of having minimum mean latency among visual learners in auditory-evoked potentials, VEPs, and somatosensory-evoked potentials. However, the results were insignificant for all type of leaners but getting continuous characteristic pattern among means of latency in different types of evoked potentials favored the better conduction among visual type of learners. Reason for insignificant results may be proven by the studies of Banoub *et al.* which suggested that certain physiologic factors may influence the results of evoked potentials which includes temperature, blood pressure, hematocrit, acid–base balance, and oxygen and carbon dioxide tensions.^[21] In another study, results by Sharma *et al.* suggested that VEPs depend on factors like head size because of which gender differences may be found.^[22] Other reasons could be one of the following:

1. Less number of data in favor of visual modal learners
2. Other factors such as head size and pupillary diameter might have improved our study results.

Hence, the pattern of mean latency should get our attention and reason may be explained with the fact that about 40% area in the cortex is represented by visual sense that is why conducted fast

P300 wave is a positive deflection in the human ERPs. The P300 wave generators involve multiple intracerebral generator areas including the hippocampus and various association areas of the neocortex. Hence, latency and amplitude of p300 waveform at frontal parietal and occipital level may represent, a process that involves many different regions of the brain i.e., transfer of information to consciousness and will be helpful for knowing the cognition suggested by Picton and Sur and Sinha.^[23,24]

Results of P300, according to Table 5 and Figure 3, show the pattern of minimum mean latency or better conduction among read and write learners modality,

and mean amplitude was maximum among visual modal learners that suggest that learners who learn by writing and reading understand better, and it retains in memory and regarding the pattern of amplitude found in our study cannot be commented. As only very low amplitude is an indicator of the broad neurobiological vulnerability such as alcohol dependence, drug dependence, nicotine dependence, conduct disorder, and adult antisocial behavior (Patrick *et al.*, 2006), it is also suggested that amplitude and amplitude ratio values are not normally distributed in control populations, so it is inappropriate to use the mean value plus standard deviations to determine the limits of the normal control population said by Patrick *et al.* and American Clinical Neurophysiology Society.^[25]

Hence, finally, we may suggest that getting almost same pattern of decreased mean latency or better conduction of SEP among visual modal learners while the pattern of better conduction or decreased mean latency in long-latency-evoked potentials or P300 among read and write learners. It may have some scientific implications which may be strengthened by increasing the sample size and insignificant results might be because of reverse 'P' hacking as suggested by Chuard *et al.*^[26]

Hence, according to result pattern of latency of SEP, which shows the better conduction among visual modality learners and then auditory or multi-modal learners, we may suggest that one should concentrate in teaching on visual modality to explain various things like beautiful picture and diagrams and concentrate on auditory modality as well. On the other hand, results of p300 that provides useful information about cognitive tasks is showing the better conduction among read and write learners. Hence, promoting using this modality by learners will help in retaining the things and make them understand better, which are lacking during digitalization also said by report of Barshay in 2015.

Limitations

The study findings should be interpreted in light of some limitations. The small sample size is one of the major limitations of the study. However, the use of well-calibrated equipment during measurements and strict adherence to standard methods and protocols while making the interpretation of different waveforms somehow help to overcome this limitation and provide a more valid result. Second, since the study was conducted among medical students, it cannot be generalized over the whole population.

Conclusion

Study findings suggested that among existing teaching and learning modalities, visual modalities were observed

faster but to retain it in memory and for abstract thinking, students should utilize Read and writing skills which are lacking in the era of digitalization and overuse of electronic devices.

Acknowledgment

We are really thankful to all our study participants to show their patience, and we are extremely thankful to our esteemed Prof. Dr S. S. Mishra for his critical suggestions related to our study protocol and Prof. Neil Donald Flemming for his valuable questionnaire

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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