COGNITIVE EVENT RELATED POTENTIALS DURING A LEARNING TASK

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Department of Clinical Neurological Sciences
Faculty of Medicine
University of Southampton
United Kingdom

By

Mohamed Fath EL-Bab

MB B Ch, MSc

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ABSTRACT

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by MOHAMED FATH EL-BAB

Cognitive evoked potentials have been used to study a number of mental processes but little work has been on learning. This may be because the act of learning alters the nervous system and the experiments can not be repeated on the same subject.

This work examines the hypothesis that there are scalp recorded brain potentials in 99 healthy subjects learning a task.

Recording was by using cap electrodes with linked mastoids as reference. The volunteers was asked to observe a series of two hundred different images obeyed the rule for two patterns A and B, which had been generated by computer program and displayed randomly on a screen for 2sec and the screen was blank for 2sec. The images were classed according to the subject's decision by pressing one of two buttons. Clues from border effect or contrast change were eliminated. One subject group was told the nature of the task beforehand some groups had feedback for correct/Incorrect answers and a control group simply observed the screen. Artefact due to eye movement, inattention and drowsiness were taken into account. Performance was monitored by the CUSUM quality control method. Learners were clearly distinct from non-learners. There were about half the subjects in each group.

Observers showed no significant electrical activity after the initial visual evoked potential, which ended at about 200msec. Learners showed a Positivity Associated with Learning (PAL) whether they learned or not. The PAL began at 200msec and lasted up to 2000msec. It was distributed over the frontal lobes but greater on the right side. Amplitude was about 6 μv and long lasting with no clear peak.

In general, the better the performance, the greater the positivity. Positive increased towards the end of a successful learning seen. Non-learners showed a similar positivity of lower amplitude. Positivity was greater after a single successful trial than after an incorrect answer. The frontal distribution of the PAL corresponds to metabolic studies by fMRI using a similar task. Our work gives temporal information and association between the potentials and subjects performance. It is proposed that similar studies will be useful in determining the pathophysiology of learning difficulties.

Dedicated to

All members of my beloved family

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Abbreviations

μv = Micro Volt
ADC = analogue-to-digital converter
ANOVA = Analysis of Variance
ATL = left anterior temporal electrode
ATR = right anterior temporal electrode
Bit1 = trigger electrode one
Bit2 = trigger electrode two
C3 = Left central electrode
C4 = right central electrode
CA1 & CA3 = regions of Ammon's horn in the hippocampus.
CI = Confidence intervals
CS = Conditioned Stimulus
CSD = Current Source Density
Cz = central midline electrode
DF = Degree of Freedom
df = degree of freedom
DT = Decision Time
EEG = Electroencephalogram
EPSP = excitatory post-synaptic potential
ERPs = Event related potentials
F = F ratio
F3 & F7 = Left frontal electrodes
F4 & F8 = Right frontal electrodes
FCZ = fronto-central midline electrode
Fig = Figure
FMRI = Functional Magnetic
Fr = with feedback and without rule
fr = without feedback and rule
FR = with feedback and Rule
fR = without feedback and with rule
Fz = frontal midline electrode
Heog = Horizontal electro-oculogram electrode
IPSP= inhibitory post-synaptic potential
KΩ = Kilohm
L = Learner
Loc = Location
Lt = Left
LTD = long term depression
LTM = long term memory
LTP = long term potentiation
MRI = Magnetic Resonance Image
MS = mean square
msec = Millisecond
MTL = Medial Temporal lobe
MTL = medial temporal lobe
n = number of subjects
nL = Non-learner
NMDA = *N*-methyl-D-aspartate
O1 = left occipital electrode
O2 = right occipital electrode
Oz = Occipital midline electrode
P = P value
p value = probability value
P3 = left parietal electrode
P4 = right parietal electrode
PET = positron emission tomography
POZ = parito-occipital midline electrode
PZ= Parietal midline electrode
rCBF = regional cerebral blood flow
Resonance Image
Rt. = Right
SD = Standard deviation
SE = standard errors
Sec = second
SIG = significance
SS = sum of squares
STM = short term memory
T3 & T5 = left temporal electrodes
T4 & T6= right temporal electrodes
TPL = left temporoparietal electrode
TPR = right temporoparietal electrode
US = Unconditioned stimulus
Veog = Vertical electro-oculogram electrode

Chapter 1: Introduction and Literature Review:

1.1. Historical aspect:

Diamond (1990) asked the leading Berkeley astronomer and Nobel Laureate Charles Townes "Which is more complex, the 100 billion stars in our galaxy or the 100 billion nerve cells in the 3-pound mass within our head?" Townes answered without hesitation, "the brain," "For, after all," Diamond responded "it is only the brain that can interpret our galaxy." And it is only the brain that can interpret its own cognizance.

Men ought to know that from nothing else but the brain come joys, delights, laughter, sports, sorrows, griefs, despondency, and lamentations. And by this, in an especial manner, we acquire wisdom and knowledge, see and hear know what are foul and what are fair, what are bad what are good, what are sweet and what are unsavory... And by the same organ we become made and delirious, and fears and terrors assail us... All these things we endure from the brain when it is not healthy...In these ways I am of the opinion that the brain exercises the greatest power in the man - Hippocrates, on the sacred disease (Fourth Century).

In 1848 in Berlin, Du Bois-Reymond recorded the standing potentials between the surface and the cut end of a nerve. The 'action potential' as we know now he described as a sudden negative variation in response to a stimulus.

Spontaneous EEG activity was first discovered in animal studies during the late nineteenth century in Liverpool by Caton (1875) using a Thomson reflecting galvanometer and Du Bois-Reymond's coated, non-polarisable electrode. The Polish scientist Adolf Beck repeated many of Caton's experiments and presented the electrical activity of the brain in 1890. He found that a spontaneous occipital oscillation disappeared with light stimulation, but not

with noise. In 1929 Berger came up with a systematic description of the human EEG, but scientists at first had difficulty in accepting that his recordings were generated by, or even related to actual brain events. Berger speculated that the EEG was the manifestation of continuous psychological processes underlying non-localizable mental functions. It was not until Adrian and Mattews in 1934 validated his findings that the scientific community took Berger's work seriously. From 1935 onward Gibbs et al established EEG as a clinical diagnostic tool in epilepsy.

Since then the technology has advanced and clinical applications such as epilepsy diagnosis has been developed. EEG activity has been assumed to represent underlying neural processes and the brain waves are generated by the synchronous electrical activity of literally millions potentials of individual neuron. By recording an EEG with certain stimuli or tasks it is tempting to speculate a cause and effect relationship. The actual process that scalp electrical potentials represent, is very difficult to establish due to the volume of unrelated and parallel activity that is occurring.

An evoked potential (EP) is the sequence of voltage changes generated in the brain, and in the sense organs and pathways leading to the brain, following the reception of the transient physical stimulus. It is represents electrical activity in those 100 billion nerve cells and is a useful research and clinical technique. Evoked potentials (EPs) developed from the electroencephalograph (EEG) that is used to record electrical brain activity. The EEG is a medical imaging technique that measures aspects of brain function by analyzing the scalp electrical activity generated by brain structures. It is a completely non-invasive procedure that can be applied repeatedly in patients, normal adults, and children with no risks or limitations. Both EP and EEG have the advantage of high temporal resolution but poor spatial resolution.

1.2. Normal Electroencephalogram:

Four kinds of the brain waves are recognized from the scalp of normal individuals (Figure 1.1):

1. Alpha Wave: Rhythmic wave occurs at frequency of 8 to 13 cycle/sec or hertz -one hertz (Hz) is one cycle per second- it is the commonly unit used to express frequency.

2. Beta wave: Appears during periods of mental activity. Its frequency is between 14 Hz to 30 Hz.

3. Theta wave: Normally occurs in children and in adults experiencing emotional stress. It's frequency between 4 Hz to 7 Hz.

4. Delta wave: Frequency of these waves between 1 Hz to 4 Hz and occurs during deep sleep and is normal in awake infants.

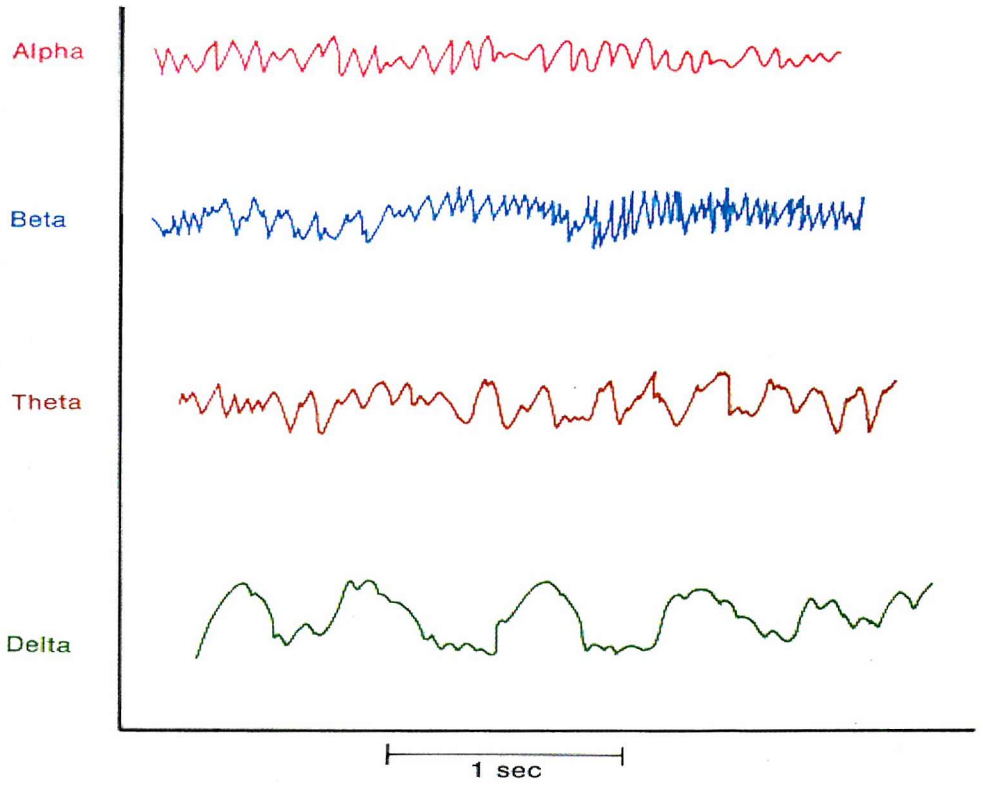


Figure 1.1 shows kinds of waves recorded in normal encephalogram (EEG)

Event related potentials (ERPs) studies are an attempt to eliminate unrelated potentials and noise. This is accomplished by time-locking the recording to the stimulus presentation and taking the average response to many stimuli. Only events that occur time and time again at the same point in the recording will actually show up in the final average. This assumes that little habituation occurs.

The evoked potentials are the electrical responses of the nervous system to motor or sensory stimulation with short latency potentials principally reflecting activity generated in the sensory receptors, a neural afferent pathway and its primary receiving area in the brain to a stimulus. These potentials are very small 0.5uv to 100uv- and they are usually recorded within the first 0.2 s of stimulus delivery. Sensitive amplifying equipment and the use of averaging technique (Dawson 1954) are required to detect these potentials, which are picked up at a considerable distance from the generator source, and have to be discriminated from other, usually much larger, potentials of physiological and environmental origin with which they are intermixed.

The term-evoked potential is defined as the average of multiple responses; the term-evoked response is defined as the electrical recording following a single stimulus. The term peak, or wave is defined as the positive (downward) or negative (upward) deflections from the baseline that make up the EP. The term component is defined as an individual contribution to the potential such as low-frequency component or late component.

1.3. The brain:

In order to understand how event related potentials illustrate brain functions, we should understand and know the brain cortical organization and structures (Figure 1.2).

In order to understand how event related potentials illustrate brain functions, we should understand and know the brain cortical organization and structures (Figure 1.2).

The Egyptian papyruses were the first systematic written medical records, and the word brain first appeared in the Edwin Smith (1822-1906) translation of an Egyptian surgical papyrus. The brain basically consists of major parts; the brainstem, the cerebellum, the cerebrum, the diencephalon. All our conscious living such as thinking, memory, movement, consciousness, language, sensory perception, and emotion depend on the largest and complex part which is the cerebrum. It is divided into two hemispheres.

Two cerebral hemispheres have the same general appearance, and are incompletely separated by longitudinal cerebral fissure, at the bottom of this fissure they are united together by the corpus callosum. They are subdivided into four lobes frontal, parietal, temporal, and occipital. Each hemisphere has three surfaces lateral surface (convex), medial surface (flat), and inferior surface (very irregular). The gray matter (cortex), the white matter (axons), and the basal ganglia are the compartments of each hemisphere (figure 1.3a & b).

The right hemisphere is responsible for the simple language comprehension, the perception of spatial relationships, conceptual non-verbal ideas, general thought processes, and concentrates on the whole. The left hemisphere is active in speech, writing, calculation, language comprehension, analytical thought processes, and basically sorts out the parts. Carola et al. 1992 concluded that the left hemisphere sees the trees but not much of the forest, while the right hemisphere sees the forest but not too many of the trees.

Most people are right handed, and almost all of them have left-hemisphere dominance which generally speaking is more analytical, logical, precise and time-sensitive. While some left-handed people have right hemisphere

dominance or mixed left and right dominance which is dreamier, more holistic and more involved with sensory perception and abstract cognition. The both sides of the brain are actively involved while anyone performing thought processes (Bryden, 1982).

1.4. Meninges of the brain (figure 1.4):

There are three connective tissue membranes covering the brain from outside to inside known by names as:

1. Dura mater it is a double layered membrane and known as the tough or the hard mother.

2. Arachnoid: it is a lose membrane covers the brain and separated from the dura mater by the subdural space.

3. Pia mater it is very delicate connective tissue rich in blood vessels and known as the gentle mother.

1.5. Cerebral Cortex:

The advanced intellectual functions of the human depend on the activity of the cerebral cortex and interaction of this structure with other portions of the nervous system.

The cerebral cortex was examined by the first microscopists, as early as 1776 and the first recorded structural detail was the stria in the occipital cortex, which was noted by Gennari, and named after him.

The cerebral cortex is involved in many aspects of memory, storage, and recall. It is very essential for musical and mathematical talents and for comprehension and execution of language. Higher cognitive function, and many complex motor activities depend on the cortex, and it is responsible for the perception

and conscious understanding of all sensations, and it is a site in which any modality of sensation can be integrated with others.

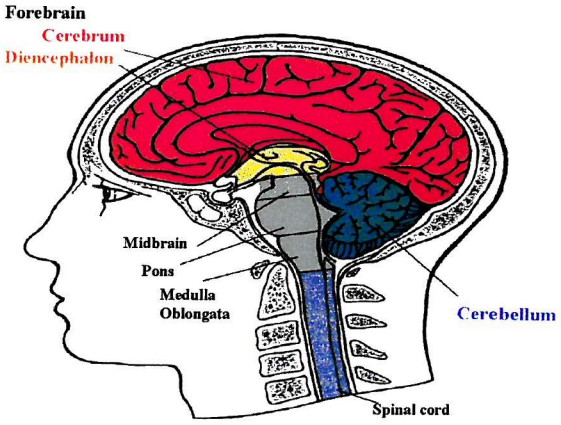
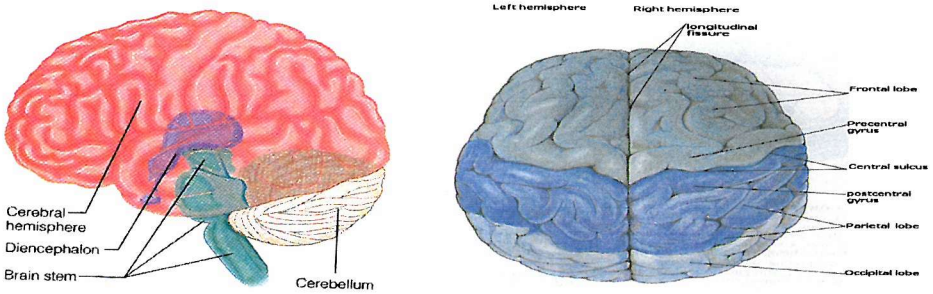


Figure (1.2) shows side view of the human brain location in relation to the skull, the spinal column and the spinal cord.



(a) (b)

Figure (1.3) shows the brain compartments and relations (a) left lateral view and (b) superior view

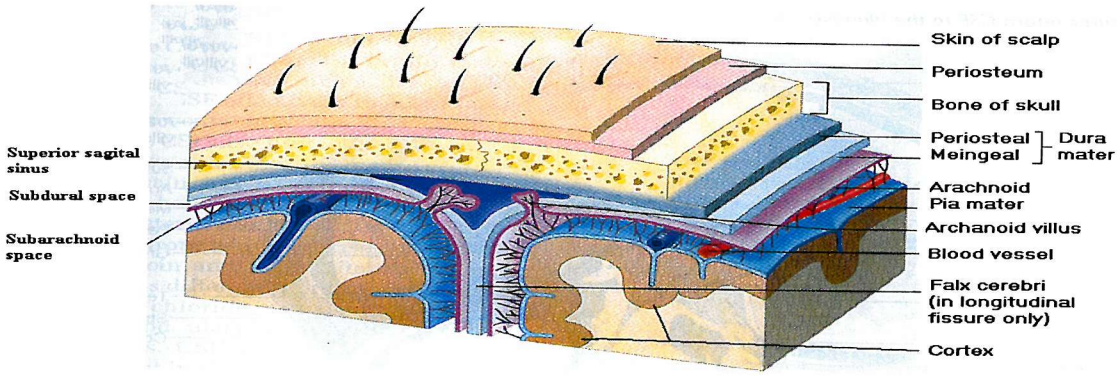


Figure (1.4) shows the brain covers starting from outside the Skin, the Skull, and the Meningese.

1.6. The Cerebral Cortex Structures (Figure 1.5):

To the unaided eye it forms a complete mantle 'pallium' covering the hemisphere and obviously variable in the thickness (1.5 to 4.5 mm). It is thicker on the exposed convexities of gyri than in the depths of sulci. The cerebral cortex containing over 100 billion neurons and 250 billion glial cells.

The cerebral cortex can be divided into five types based on its structure complexity. By the largest part is the neocortex. Whichever piece of cortex is examined, it is all constructed on the same plan. There are six recognizable areas arranged in laminated manner, superficial to deep (Brodmann 1909) as follows:-

(I) Plexiform lamina (Molecular or Zonal layer): contains the sparsely scattered horizontal cells (of Cajal), and apart from a dense net of tangentially oriented fibers, derived from pyramidal cells (apical dendrites), Stellate cells (Vertical axons), cells of Martinotti (Centrifugal axons), and afferent fibers, both projection and associational.

(II) External granular lamina: contains the somata of Stellate and small pyramidal cells.

(III) External pyramidal lamina: contains the cell bodies of medium sized pyramidal cells. Stellate cells also occur in this layer, including horizontally disposed basket cells, vertically orientated fusiform cells, their dendrites and axons extending far beyond the layer itself.

(IV) Internal Granular lamina: Usually narrow than other layers except layer I, Mainly characterised by the somata of stellate cells, and occasionally small pyramidal cells.

(V) Internal Pyramidal (ganglionic) lamina: contains largest pyramidal cell somata and smaller elements of the same type occur. Stellate cells in small numbers may also occur.

(VI) Multiform lamina: contains a considerable range of cell types, most of these cells are small and considered to be modified pyramidal elements, despite the fusiform, triangular, ovoid and other profiles of their somata. The small multipolar Martinotti cells are often prominent. It is not always well demarcated from the subjacent cortical zone of fibers approaching or departing from the cortex itself.

Careful examination of the thickness and number of cells in these layers reveal systematic differenceson the basis of these differences brodmann 1909 recognised 52 areas. Many of these areas have specific functions; areas 1, 2 & 3 are primary sensory cortex, area 17 is visual and area 4, the motor cortex.

As well as the organisation in layers, there is an organisation in radial columns. Afferent and efferent fibers run radially, neurons in a radial column tend to respond to different aspects of the name thing e.g. movement in one direction.

The afferent fibers to the cortex run radially towards the surface and synapse in Layer one through layer four. Projection fibers come from the Thalamus, association fibers from widely dispersed areas, and the third group from several specific subcortical structures outside the Thalamus. These include the locus ceruleus (origin of noradrenergic fibers), the raphe nuclei of the brain stem (origin of serotonergic projections), and the basal nucleus of Meynert in the basal telencephalon (origin of cholinergic projections). The corpus callosum and anterior commissure contain commissural fibers that link corresponding and non-corresponding regions of the two hemispheres. The efferensts projecting to the brain stem and spinal cord arise from layers V and VI.

The neurons of the pallium have been described and categorised into different classes; the great majority falling into these cell types.

Pyramidal cells named from the shape of their somata, varying from small elements measuring about 10μm across to the giant pyramidal cells (of Betz) measuring up to 70μm or more. The pyramidal cells in layer II, III, and V, serve the major efferent pathway of the cerebral cortex. Their apices are oriented towards the surface of the cortex. The small pyramidal cells in layers II and III project to other cortical regions. The projection axons of the large pyramidal cells in layer V extend centripetally out of the cortex to reach more or less distant subcortical structures, such as basal nuclei, brainstem nuclei, and the grey matter of the spinal cord. The so-called pleomorphic cells are considered as modified pyramidal cells with axon entering the white matter. Their somata are variably shaped. The pyramidal cells are perpendicular to the cortical surface with dendrites long enough to form effective dipoles. The perpendicular spatial organization leads to the summation of the associated currents, especially when these neurons are synchronously activated. Non-synchronous activity and activity from radially symmetrical stellate cells do not appear in EEG or ERPs. Most of the evidence available at present suggests that the scalp recorded potentials are due to excitatory (depolarising) or inhibitory (hyperpolarising) postsynaptic potentials developed by the cell body and dendrites of pyramidal neurons, rather than axonal action potentials (Allison et al. 1986).

♦ **Stellate nerve cells:** They appear in variable density of distribution in all cortical laminae except lamina I, and they are usually concentrated in greater abundance in lamina II and IV often called granule cells because of their small size and appearance in Nissl-stained material. They are small, of the order of 6

to 10μm in diameter, with a rounded soma drawn out at numerous angles by their richy branching dendrites and a single relatively short axon.

- **Horizontal cells (of Cajal)** are confined to the plexiform lamina I; they are small, fusiform, and their dendrites spread short distances in two opposite directions in the plexiform layer. Their axons, often derived from one of the dendrites, divided into two branches travelling to much greater distance in the same layer

- **Cells of Martinotti** occur at the most levels in the cortex. They are small and multipolar, with a localised dendritic field and a long axon which runs centrifugally to the plexiform lamina (layer I), producing a few short horizontal collaterals en route.

- **Fusiform** cells are found in layer six and project primarily to the Thalamus.

1) **Mesocortex** has three layers of the neurons in zones next to the allocortex and six layers of the neurons in zones that lie adjacent to isocortex. It is consists of five paralimbic areas which surround the medial and basal parts of the cerebral hemispheres. (1) Cingulate complex (cingulate gyrus, retrosplenial area, and subcallosal area which include the paraterminal gyrus). (2) Parahippocampal gyrus (3) Temporal pole (4) Insula and (5) Caudal orbitofrontal cortex.

2) **Allocortex** it is three-layered structure consists of the hippocampal formation (known as Archicortex because phylogenetically very old structure) and the pyriform or primary olfactory cortex (Paleocortex because it is older than Neocortex but not older than the Archicortex)

3) **Corticoid** areas include the septal region (deep to the paraterminal gyrus), Substantia innominata, and parts of the amygdaloid complex, these regions at the base of the forbrain and contain simple, poorly differentiated cortex.

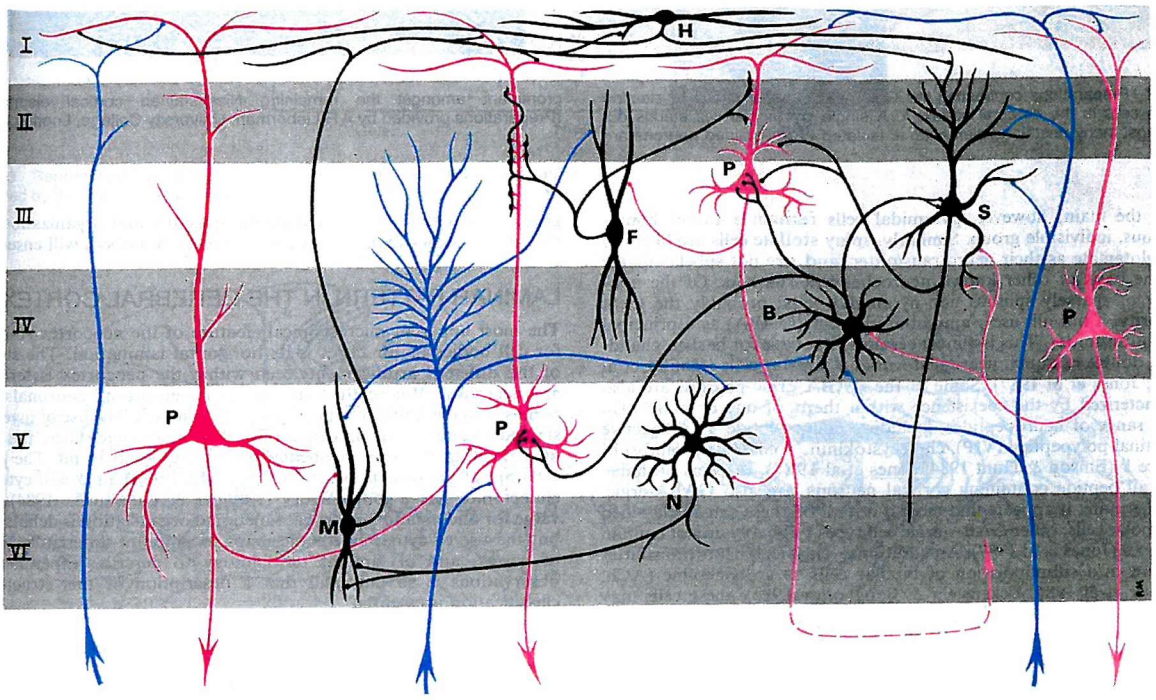


Figure 1.5. Cerebral cortex layers and the most frequent types of neo-cortical neurons, connections with each others and afferent fibers (blue). Neurons (black). Efferent (Magenta), Pyramidal (P), Fusiform (F), Horizontal (H), Neurogliaform (N), Martinotti (M), Basket (B), Stellate (S)

1.7. Physiological basis:

Neurons collect, process, and relay information by generating electrical signals that are transmitted via the cell axon to synaptic junctions with other cells. Their ability to perform this complex task is due to the unequal distribution of electrically charged particles on either side of its semi-permeable cell membrane.

A neuron forms synaptic connections with axon terminals from many different nerve cells. Several excitatory as well as inhibitory ionic disturbances can therefore occur simultaneously, or nearly so, in neighboring portions of the post-synaptic cell membrane. Both temporal and spatial summation of excitatory and inhibitory post-synaptic potentials occurs. The outcome of these interactions determines the size of the membrane potential at any point in time.

It is often said that humans consist of 2/3 water. Strictly speaking, that should be 2/3 salt water, the principal salts being the positively charged cations of

sodium (Na+); potassium (K+), calcium (Ca2+) and magnesium (Mg+) and the negatively charged anions of chloride (Cl-) and phosphate (P-) and various organic acids (A-). All of these chemicals (and more) are contained in both the extracellular fluid surrounding each neuron, and intercellular fluids (cytosol) of neurons, and both contain high concentrations of compounds, called electrolytes, that in solution, conduct an electric current and are decomposed by it into atoms called ions capable of carrying positive or negative electrical charges. Their concentrations are not the same. The fluid inside neurons contains more negative anions and/or fewer positive cations than the surrounding extracellular fluid from which it is separated by the semipermeable cell membrane. (The permeability of this membrane to specific ions is determined by the presence of specific ionic channels.) The unequal distribution of positive and negative charges between the inside and outside a neuron results in an electrical potential of -70 mV. This resting membrane potential of the cell comes about because of interplay of several forces including (1) diffusion, (2) electrostatic pressure; and (3) active sodium and calcium pumps.

1.8. Post-synaptic Potentials (EPSPs and IPSPs):

The preceding discussion describes the neuron at rest. To do its job of collecting, processing and distributing information, the cell's membrane potential must be disturbed. In humans, and other mammals, this is most commonly instigated or "stimulated" by the release of a chemical transmitter substance from an axon terminal. The neurotransmitter diffuses across the synaptic cleft and acts on chemical receptor s on the membrane of a dendrite or the cell body of the post-synaptic neuron. The action of the transmitter chemical on the special protein receptor structures of the post-synaptic membrane opens the gates of "transmitter-dependent" ion channels. This permits a particular type

of ion to pass through the cell membrane, thus changing the local membrane potential

There are two modes of transmitter action. In the simpler case, the neurotransmitter acts directly on the gates of ion channels to allow the influx or efflux of a particular ion (e.g., sodium). A more complex process involves the activation of G-proteins that may open ionic gates directly or stimulate the synthesis of a second messenger chemical (the neurotransmitter is the first) in the cytoplasm of the cell. The second messenger then starts a cascade of chemical reactions to open specific ion channels. The action of second messengers, like that of some neurotransmitters, is usually terminated by rapid enzymatic destruction of the second messenger. In many neurons, the second messenger is cyclic adenosine monophosphate (cyclic AMP) which is rapidly destroyed by the enzyme phosphodiesterase.

These transmitter/receptor interactions may increase or decrease the potential difference between the inside and the outside of a cell, depending on the type of ion channel that is affected. An increase in the influx of positively charged cations, such as sodium or calcium, reduces the membrane potential and thus depolarizes a portion of the post-synaptic membrane. This results in an excitatory post-synaptic potential (EPSP). An influx of negatively charged anions, such as chloride or an efflux of positively charged cations, such as potassium, increases the local membrane potential and thus hyperpolarizes the postsynaptic membrane. This produces an inhibitory post-synaptic potential (IPSP).

Both EPSPs and IPSPs are low-amplitude electrotonic potentials (tonic = tension) that are propagated passively and hence decrementally (their size decreases) along the neuronal cell membrane. They are "graded" potentials - i.e., their amplitude reflects the intensity and duration of the interaction

between the neurotransmitter and its receptor complex. Neighboring EPSPs and IPSPs interact (i.e., sum and subtract).

Both EPSPs and IPSPs are very transient phenomena, their duration being determined by the length of the transmitter/receptor interaction or the life span of the second messenger. Neurotransmitters are quickly removed from the synaptic cleft, most commonly by re-uptake into the axon terminal that secreted them, although enzymatic destruction of the transmitter molecule terminates the action of some neurotransmitters. The most common second messenger, cyclic AMP, is also very rapidly destroyed enzymatically. Some second messengers have more persistent effects, thus prolonging the effective action of some neurotransmitters.

1.9. Electro-physiological basis:

The potentials of the brain recorded in an EEG appear in waves ranging from 1 to 40 or more cycles per second (hertz or Hz), with amplitude ranging from -100 to +100 microvolts. The amplitude of the EEG signal strongly depends on how synchronous the activity of the underlying neurons is.

Each activity is the result of electrical and physiochemical changes in the brain tissue. The external world is transmitted to the cortex via sense organs and the characteristics of these organs and the transmission pathways are reasonably well understood. However, what happens once the sensory activity reaches the cortex is still poorly understood. The transmission of information to the brain involves the flow of ions across the neuronal membrane producing a voltage field around each active neuron. The potential difference between the postsynaptic membrane portion and the other parts of the neuronal membrane causes an electrical current to flow along the cell body and dendrites with a return current in the extracellular space. These electrical potentials summate in the cortex and extend through the coverings of the brain to the scalp. These

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1.10. Event related potentials:

1.10.1. Event related potentials (ERPs)

Event related potentials (ERPs) recorded from scalp electrodes have been used widely to study human cognitive processes and their neural substrate.

Event-related potentials (ERPs) are small voltage fluctuations resulting from evoked neural activity. These electrical changes are extracted from scalp recordings by computer averaging epochs (recording periods) of EEG time-locked to repeated occurrences of sensory, cognitive, or motor events. The spontaneous background EEG fluctuations, which are random relative to the stimuli, are averaged out, leaving the event-related brain potentials. These electrical signals reflect only that activity which is consistently associated with the stimulus processing in a time-locked way.

We assume that the EP (signal) has known time relationship to the stimulus whereas background brain activity (noise) does not. Averaging is the presentation of a stimulus many times and signals for the duration of interest immediately following are summed before being divided by the number of presentations to give the average EP. The aim is to improve the signal to noise ratio (S/N ratio) so that the EP is more discernible. S/N ratio improves by factor of the square root of the number of presentations (Table 1.1); (Regan 1989)

Number of presentation	Signal (μv)	Noise (μv)	S/N ratio
1	1	1	1:1
4	1	½	2:1
9	1	1/3	3:1
16	1	¼	4:1
81	1	1/9	9:1

Table (1.1) shows the signal to noise ratio (S/N ratio) improvements.

We only need 9 presentations to treble the S/N ratio but a further 72 (i.e. 81 total) presentations are needed to triple the ratio again.

The nomenclature of EP entails labeling by their polarity and latency. "N" and 'P' refer to negative and positive polarity respectively. A number denoting the latency in milliseconds follows this.

Clinically, the most useful response is obtained following, stimulation of the sensory modalities for vision audition (Auditory Evoked Potentials. AEP) (Figure 1.7), (Visual Evoked Potentials. VEP) (Figure 1.8), and bodily sensation (Somatosensory Evoked Potentials. SEP) (Figure 1.9). These early, short latency potentials principally reflect activity generated in the afferent pathway and its primary receiving area in the brain. These potentials vary as the physical characteristics of the stimulus vary. There are also potentials, occurring at longer latency, which appear to influenced by mental processes such as attention to the stimulus or expectation that particular stimulus will occur. These are the potentials, which I am interested in and these are termed "endogenous or event related potentials" (ERPs) to distinguish them from the evoked potentials elicited by external physical events (Halliday 1992).

It is possible also record a longer latency ERP to a non-event, such as the omission of an expected stimulus from regular train. Such ERPs have been termed 'emitted potentials', since there is no outer event to the trigger them (Picton, 1988).

Other ERPs may be recorded in association with awaiting an expected stimulus ('expectancy wave' or 'contingent negative variation', CNV) or when preparing to make a motor response ('readiness potential'); these are recorded as gradually rising negativities located over the central cortex for 1 or 2s before the relevant event.

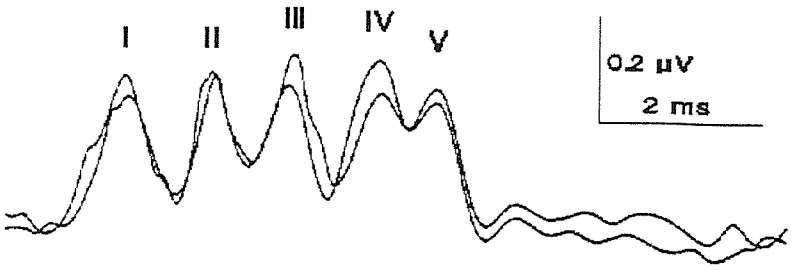


Figure (1.7) Normal Brainstem Auditory Evoked Potential to stimulation of the right ear, recorded between vertex (CZ), and right ear (A2) top tracing. Bottom tracing between vertex and left ear (A1).

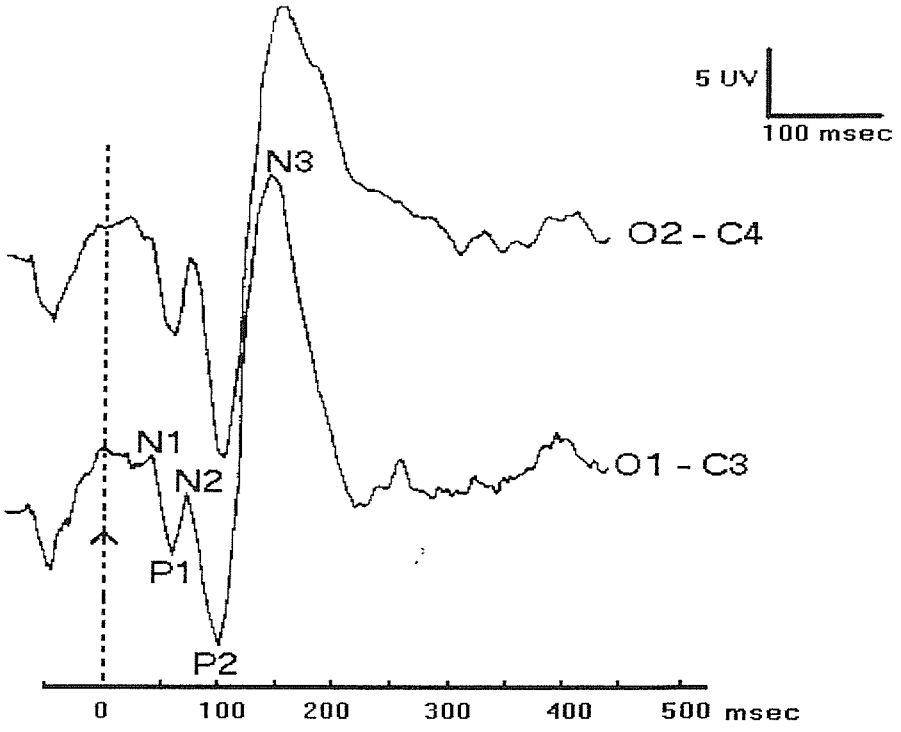


Figure (1.8) shows the normal Visual Evoked Potential (VEP), to diffuse light flash. The VEP divided into a primary response and secondary response. Negativity at the occipital plotted upward.

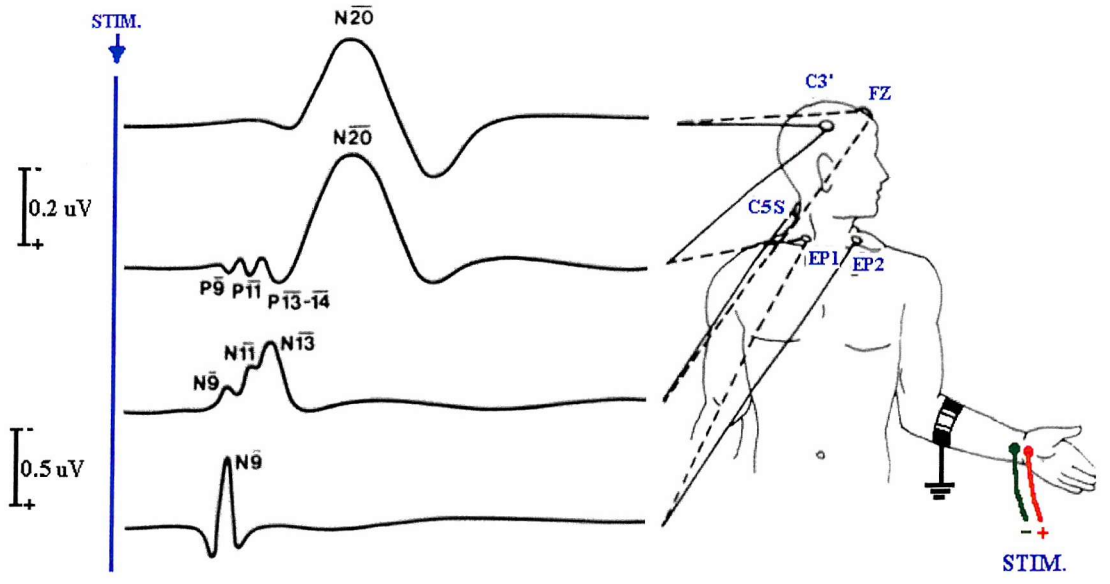


Figure (1.9) shows the normal Somatosensory Evoked Potential (SEP) to arm stimulation, from top to bottom, Far field recorded between scalp and cephalic reference electrodes, and between scalp and non-cephalic reference electrode. (N20), Erb's point potential N9, and Cervical SEP N13.

1.10.2. Early event related potentials:

The first waveforms in the visual are the N100 and P100, which represent the physiological action of the visual system. The P100 is thought to represent visual cortical activity.

The earliest components of the EP are far field potentials and they reflect activity in the receptors and peripheral relay stations. (Calloway et al 1975). Following these are the early cortical evoked responses, which appear to be generated in the primary receiving areas of the brain. Example include N100 and P100 (both occurring 100msec after presentation of a visual stimulus) which reflect activity of the visual pathways and cortex. Far field and early cortical evoked potentials only reflect the physical properties of the stimulus and are insensitive to the succeeding cognitive processes.

First of three components in visual discrimination tasks is a posterior N200 wave and has been named 'selection negativity' (Czigler, 1995). It has been shown to increase in amplitude to task deviant stimuli. Secondly an anterior positivity to task related stimuli occurs around 200 msec its behavior is to increase to correctly recognized stimuli. Both the selection negativity and the P200 are dependent on the on-line processes that identify relevant visual features. The third component is the N400, which thought to be correlate of stimulus categorization or orientation and is increased by task relevant deviant stimuli. (Czigler, 1995).

The evoked potentials that are determined by physical aspects of the stimulus have been labeled, 'exogenous', appearing in the first 80 msec of recording. Up to 200 msec after a stimulus sensory-encoding is occurring. After 200 msec the cognitive components of the ERP are observed. Labeling the components is by latency and polarity. A positive component at 100 msec is called 'P100' and a negative deflection at 200 msec is a 'N200'. Many of the cognitive waves are named after their latency when first seen, these names have stuck, e.g. a 'P300' can occur at any point between 300-800 msec and consequently the 'N400' may occur prior to it. (Figure 1.10) of course the electrodes from which a potential is recorded must also be known.

In contrast, Event related potentials (ERP) which occur after 200msec are of considerable scientific interest in this study because of their relationship to cognitive functioning. The ERP waveform is normally viewed as a series of components, each of which is a manifestation of the synchronized activity of a population of neurons (Ducan-Johnson and Dochin 1982). In general, scientists believe that learning involves an alteration in the functional properties of neurons and synapses (Ciesielski and French 1992). ERP could supply a long

sought after physiological correlate of learning but as of yet there has been very little research.

1.10.3. Late event related potentials:

It is the study of the ERP components that are related to higher cortical functions, and thus have captured the interest of researchers interested in perceptual, cognitive, and motor behavior.

1965 Sutton et al first described P300 and related potentials associated with cognitive function.

The known parameters governing the form of P300 are

- Positive deflection in the latency range 280-800 ms
- Posterior scalp distribution with maximum at Pz, monotonous inverse relationship between amplitude and stimulus probability.
- Amplitude is directly related with task relevance.
- Amplitude is sensitive to feedback and to informational value of the stimulus.
- Amplitude related to recall.
- Latency related to categorization time.

The P300 wave is a positive peak with latency of approximately 250-800 msec of the human event related potential (ERP) has been typically characterized in terms of latency, amplitude and scalp amplitude distribution. P3 latency has been shown to covary with speed of information processing as indexed by reaction times, the faster speed of processing, the earlier P3 latency (Ritter et al.

1972; Picton et al. 1974; Ford et al. 1976; Courchesne et al; 1977 & Kutase and Donchin, 1978).

The latency of P300 increases with the time the subject needs to distinguish the rare stimulus. The amplitude increases with rarity of the stimulus and to some extent with stimulus intensity. This is a late wave positivity that occurs with a variety of stimuli in many experimental conditions. It has been linked with many processes and has been classically evoked with the oddball paradigm. This is where two stimuli are presented one of which is an infrequent attended target. When the target is attentionally discriminated from the other stimuli, by being counted for example, the P300 is of greater amplitude (Yamaguchi and Knight, 1995; Polich, 1989 & 1990; Duncan- Johnson and Donchin, 1977). In normal young adults a positive wave over the Centro-parietal scalp is seen. A P300 can be provoked in multi-stimuli paradigms.

As well as the attention dependent P300 a passive or 'novelty' P300 occurs to infrequent non-target stimuli (Courchesne et al, 1984; Knight, 1984). The characteristics of the wave are different in that it is of shorter latency (250msec), of frontal-central recording sites and habituates rapidly (Polish, 1994). This waveform has been titled the P300a to distinguish it from P300 (now P300b). Most data exists in the form of auditory trials. In different modalities it as been reported as Centro-parietal (Pfefferbaum et al, 1980 & 1984), and also a later parietal potential (Courchesne, 1978).

The amplitude of the P300 has been shown to be inversely proportional to stimulus presentation probability and directly to task complexity (Johnson, 1988). Visually patients with temporoparietal lesions show a decreased novelty P300 with no target decrement (Yamaguchi and Knight, 1995). Different generators of cortical circuits are engaged in target or novelty P300 generation.

P3 amplitude has been shown to be inversely related to a prior probability, the lower probability, and the higher the P3 amplitude. (Tueting et al. 1971; Squire et al. 1973,1975a; Ford et al. 1976b; Picton et al. 1976; Duncan-Johnson and Donchin, 1977), and to be influenced by the sequence of immediately preceding events, i.e., sequential event structure (Squire et al. 1976; Duncan- Johnson and Donchin, 1977).

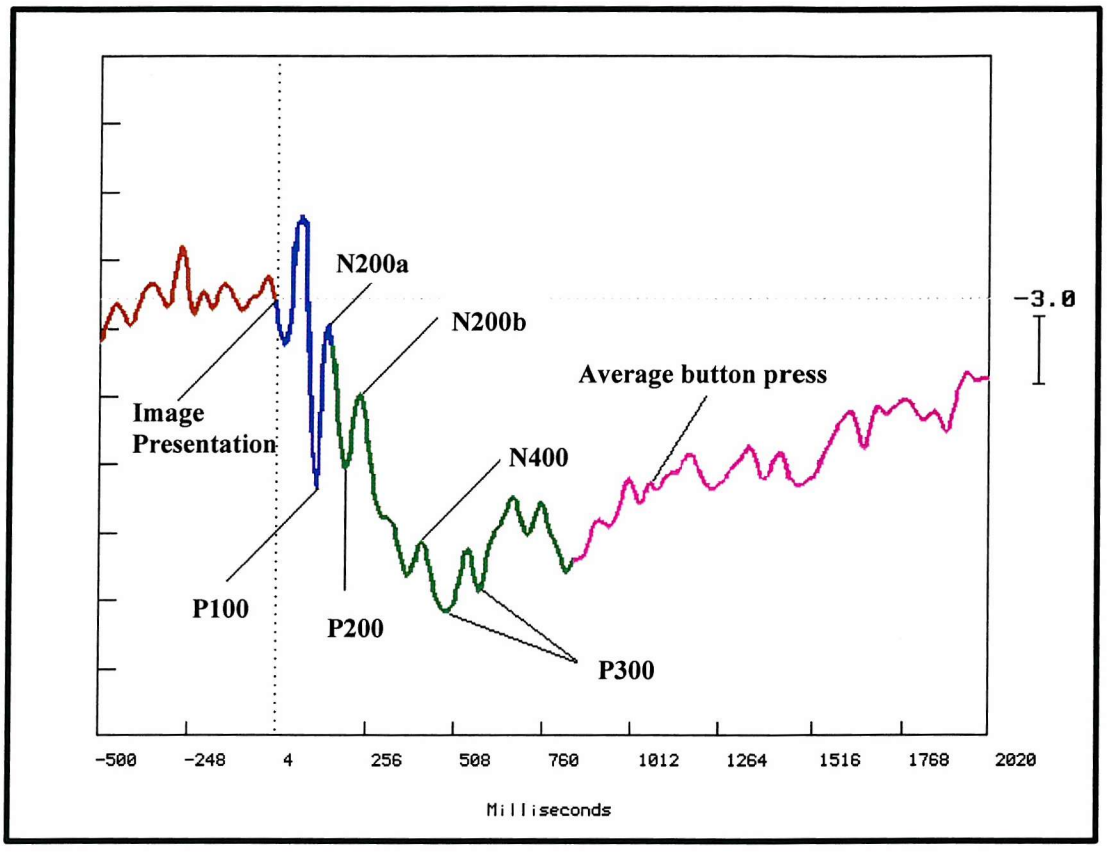


Figure (1.10) shows an example of the Event Related Potential ERP recorded from mid-frontal site at FZ electrode during a learning task. Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Downward deflection represents the positivity. Upward deflection represents the negativity.

The P300 has a wide distribution with maximum in parietotemporal areas, unrelated to the specific sensory areas but probably related to the parietotemporal association cortex and subcortical structures such as

hippocampus and thalamus. The P300 to novel stimulus may be located more frontally.

Differences in P3 scalp amplitude distribution have been related to differences in the cognitive processes underlying the generation of these waves (Courchesne et al. 1975; squire et al. 1975b; Stuss and Picton 1978).

Across time P3 scalp distributions do not change so long as the task and eliciting event category do not change, and the effect of the prior probability and sequential event structure on P3 amplitude are relatively constant across time. That is the subject has been considered to be passive and a consistent responder to the event categories, the event probabilities and the task specified by the experimenter. These views of P3 waves and their underlying cognitive processes do not take into account the dynamic nature of human information processing, a given event may later generate notions about past as well as future events. When such alterations occur, the cognitive processes is brought to bear on succeeding events which might differ from those brought to bear on past (earlier) events.

If different P3 scalp amplitude distributions do reflect different cognitive processes, then it is conceivable that changes in P3 amplitude and distribution might be found when subjective notions about an event category are altered. Some researchers (Courchesne et al. 1975, 1977 &1978. Courchesne 1977) have suggested that very novel events elicit frontal P3 waves while less novel events elicit parietal waves. The subjects expressed surprise and interest over initial presentations of both very novel and less novel events, but indicated that they soon began to expect them and, finally to ignore them. These findings suggest that (1) successive presentation of novel events should elicit successively less frontally and more parietally maximal P3 waves, and (2) both novel and less novel events should elicit successively smaller P3 waves as

subjects come to ignore them. These two possibilities are inconsistent with the two views current in literature, which were mentioned above.

Mecklinger and Ullsperger (1995) hypothesized that the relationship between P300 amplitude and categorization tasks might be modulated by ease of assignment to category. e.g. after learning the task the P300 increased. When categories are distinct enough to easily classify stimuli the P300 amplitude reflects the chance of target category. In other words before an internal category representation is formed the P300 reflects the ease of stimulus category designation. Whereas after learning the target probability is the deciding factor. These attributes of P300 will be of importance in our experiments.

The P300 name is somewhat misleading since it may occur anywhere between 300msec and 1000msec (Rosler et al 1986). It is a composite potential which appears to have numerous component entities e.g. P3a, P3b, and slow wave. Learning may be linked to changes in ERP and it has been reported that learning evokes specific changes within the domain of the P300 (Rosler et al 1981).

Amplitude and latency of ERP components can be used as indices of the nature and timing of a subject's cognitive response to stimulus. The two parameters of P300- latency and amplitude are believed to provide indices of information processing (Johnson et al 1985). P300 amplitude is a measure of the amount of information processing. It reflects the amount of information carried by the stimulus (Looren et al 1988 and Woestenburg et al 1992). P300 supplies information about the chronometry of information processing (Kramer and Strayer 1988). P300 latency is proportional to the time it takes the subject to evaluate and categorize the stimulus (Horst et al 1980 and Ducan-Johnson 1981).

P300 latency is age dependent, being longer in children, progressively decreasing until 18 before increasing by 1.25msec per year (Barajas 1991 and Diniz and Fukuda 1997).

In adult, aging increases the latency, decrease the amplitude and cause forward shift in the distribution of P300 (Misulis 1994)

A large number of clinical studies of the P3 component have demonstrated reduction in P3 amplitude in individuals expressing a wide range of behavioral dysfunction, one of which is memory impairment (Rugg, et al. 1990).

The ERP thus reflects, with high temporal resolution, the patterns of neuronal activity evoked by a stimulus. Due to their high temporal resolution, ERPs provide unique and important timing information about brain processing. Mental operations, such as those involved in perception, selective attention, language processing, and memory, proceed over time ranges in the order of tens or hundreds of milliseconds. Most other functional imaging techniques require the integrating evoked brain activity over many seconds and are thus unable to capture the time sequence of these operations. ERP recordings, however, provide a millisecond-by-millisecond reflection of evoked brain activity.

For this reason, ERPs are an ideal methodology for studying the timing aspects of both normal and abnormal cognitive processes.

On the other hand, ERP data provide less accurate spatial information than positron emission tomography (PET) or functional magnetic resonance imaging (fMRI), which lack fine temporal resolution. As a result, ERPs represent the natural complement of PET and fMRI to study human cognition. Whereas PET and fMRI can localize regions of activation during a given mental task, event related potentials ERPs can help in defining the time course of these activations.

PET studies provide a consistent set of data for the localization of areas active during learning, although they cannot provide the extraordinary time resolution.

Mapping human cognitive function is a major emphasis of ERP studies at our department. Research will help explore the organization of cognitive processes such as selective attention, memory, language, and learning both in normal In a clinical setting, the temporal resolution of ERPs is useful in identifying at which level along the sensory pathways a lesion is localized. Visual ERPs help the early diagnosis of multiple sclerosis before any structural abnormality is detected. ERPs are also used to monitor comatose patients to evaluate the functionality of vital centers in the brainstem.

1.10.4. Learning & Memory and the P300

Learning probably involves many different parts of the brain and no one has been able to say with any degree of certainty where it occurs (Hilgard et al 1966). Learning establishes long-term memory during learning (Sqiure and Zol-morgan 1991), and the process involves many brain structures including the frontal lobe.

In a study of ERPs evoked by the Von Restorff effect on memory recall, Karis et al. (1984) established striking differences between subject's strategies they used to perform the memory task. The Von Restorff effect can be described briefly as an increased recall probability for an item which different from others in an obvious way (e.g. in size, color, class or nature) in a list of items to be remembered (this different items called an isolate). Fabiani et al. (1990) confirmed the observation of Karis et al. (1984). These differences make a novel task relevant target. Earlier data suggested that the P300 reflected processes invoked when there is a need for context updating i.e. evaluation of current representation in working memory (Donchin, 1981; Nageishi and

Shimokochi, 1980). This is not far from the orienting response (Polish, 1988; Donchin, 1986).

The effect is larger with decreased probabilities and tempered by time. The interval between stimuli suggests P300 is sensitive to the strength of a decaying memory representation. At short inter stimuli intervals only rare targets need updating upon representation as frequent event are likely to occur while their previous image is still held in working memory. The amplitude is related to the overall degree of updating that is required and may be a global closure of encoding (Fiztgerald and Picton, 1981). Donchin (1981) stipulated that P300 is a manifestation of processes that maintain an accurate environmental model, or schema, by continually revising this modal according to most recent useful sensory input.

P300 amplitude is proportional to the amount of attentional resource allocated when the stimuli are processed (Polish et al, 1994; Siddle, 1991). The latency is associated with the speed of stimuli to class during memory update (Duncan-Johnson, 1981; Magliero, 1984).

In agreement with Von Restorff effect, memory for events that elicit a large P300 is better than otherwise (Karis et al, 1984 and Fabiani et al, 1986). Consequently larger amplitude is measured in a memory test to repeat items and to correctly identify old items. Older studies also show this increase with the degree of confidence with which the decision is made (Squire et al, 1975a and 1975b; Paul and Sutton, 1972).

Generation of the P300 is dependent on an inter-hemispheric interaction in the temporal parietal junction (Yamaguchi and Knight, 1995). This leads to the conclusion that the P300 response is dependent on association cortex with the limbic system, sustaining and updating a model of external envelopment (Donchin, 1979). Could the novelty P300 be a momentary shift of attention

towards an unexpected event in the working memory trace (Ford et al, 1976c; Näätänen and Gaillard, 1983)? The generation has been suggested to be a summation of similarly active neural generators each faithful to a specific cognitive processes.

1.10.5. The medial temporal lobe and the P300:

The medial temporal lobe (MTL) consists of the hippocampus, amygdala and parahippocampal gyrus and has been linked to recent event memory. Bilateral damage to this area causes permanent anterograde global amnesia (Scoville and Milner, 1957; Squire, 1986). Brief disruption of the MTL during the first 650msec following stimulus presentation for encoding leads to decreased performance in recall tasks (Halgren et al, 1985). This shows the time course for the MTL encoding, integration and storage contribution to memory.

The P300, which actually appears around 600msec increases with stimulus repetition and thought to reflect closure of the completed encoding/integration, process (Altafullah et al, 1986). In these terms the closure of encoding or contextual integration is active (Heit et al, 1990).

A MTL P300a occurs to infrequent unattended stimuli but is too early to be mistaken for the P300b. Performance in an oddball paradigm is not altered by unilateral anterior temporal lobectomy (Stapleton et al, 1987). MTL activity tasks require recent contextual memory, no lexical decision nor sensory discrimination effect can be seen.

1.10.6. N400:

Numerous studies that have employed a task in which items were presented sequentially and subjects were asked to respond if the stimulus was unmatched (incongruent) or matched (congruent) with the preceding items (Barrett, and Rugg, 1989, 1990). A late negative component, peaking around 400 msec, in

frontal area is observed and is larger in non-matched items than matched items. It has been proposed that it is represent the associated activation of neural networks basic to stimulus integration (Halgren and Smith, 1987). The N400 is larger to non-repeated words or faces and semantically incongruent words at the end of a sentence (Kutas and Hillyard, 1980, Iragui et al, 1996). The P300 on the other hand is maximal to repeated words and attended infrequent tones (Smith and Stapleton, 1986; Halgren and Smith, 1987).

It is interesting to know that N400 component, as recorded from the scalp is severely attenuated following unilateral anterior temporal lobectomy (Smith and Halgren, 1988) suggesting that the temporal lobes may have an important role in eliciting N400.

The N400 has been hypothesized to represent a construction of a cognitive gestalt that encodes the stimulus and its prior contextual occurrences through associative activation of a neocortical MTL network (Halgren and Smith, 1987). Some evidence for this is seen in the decreased amplitude and duration to repeated stimuli (Smith et al, 1986). This repetition sensitivity is lost after left anterior temporal lobectomy (Smith and Halgren, 1989).

1.10.7. Abnormal P300

It is well known that bilateral lesions of the human medial temporal lobes produce severe amnesia for recent events (Scoville and Milner, 1957; Squire, 1982). Causes of amnesia syndromes include thiamin deficiency, resulting from alcohol abuse or severe malnutrition or malabsorption, head injury post-herpes encephalitis all of that can cause severe damage to the medial aspect of the temporal lobes as well as other damage. Severe hypoxia, deep midline tumors and posterior cerebral artery occlusion, Alzheimer's disease, etc. can all cause amnesia.

It has been reported P300 latency to be prolonged in adult patients with mental retardation, in patients with dementia of various causes, in patients with parkinson's disease, in chronic schizophrenic patients.

Patient with temporal lobe epilepsy may have delayed P300 which is independent of seizure manifestation or antiepleptic drugs (Fukai 1990).

Abnormalities in P300 latency may develop in early Alzheimer's disease and progress proportionately to intellectual decline (Ball et al 1989, and Polich et al 1990)

Delayed P300 has been reported in patients with AIDS and AIDS-related complex even before psychometric tests could detect cognitive deficits (Ollo et al 1991). P300 amplitude changes have been described in various conditions, including frontal lobe lesion, hyperactive children treated with methylphenidate, increase blood lead levels in children, infantile autism, and schizophrenia.

1.11. Learning

1.11.1. Definitions:

The world of science, like that art or religion, is a world created by the human imagination, but within very strict constraints imposed both by nature and the human brain (Jacob. 1988).

What exactly is the definition of learning and memory? Learning and memory are different sides of the same coin. Memories are what left behind as a result of learning, and we infer the existence of learning from the presence of memories. What exactly do we mean by the term of learning and memory? The

definition of these apparently innocuous terms has been a topic of passionate debate by psychologists.

The definitions are numerous and few satisfactory for this multifactorial process but perhaps the most comprehensive I have encountered is:

Learning is the storage of the information as a function of experience and resulting in a relatively permanent change in personality (including cognitive, affective, attitudinal, behavioral, experiential, and the like) and reflect a changes in performance usually brought about by practice although it may arise from insight or other factors including memory. Which we mean any process whereby a person or a machine increases its knowledge or improves its skill.

This is a good reflection of the multitude of components involved in learning and is not within the scope of this treatise to comment on all of them. Rather, a synopsis of what are believed to be the fundamental features will be presented.

Memory is learning's faithful partner. It refers to stored information produced by learning, and is an abstract term that describes mental states which carry information, while learning describes a transition from our mental state to a second, in which the information is in some way different.

When we say that the dog in a laboratory Pavlovian conditioning experiment has learned and remembers something about the relation between food and bell, what we mean is just that a new behavior has been conditioned: the dog salivates to the bell, whereas previously it did not. On such a view, we should only consider the term of 'leaning' and 'memory' if there is some observable change in behavior, in which case the new behavior is the learning and memory

However, there are two obvious problems with that definition. The first is that learning may occur without any concomitant change in behavior; if a CS and US such as a shock are presented to subject administered with drugs that block

muscular activity, conditioned responses may perfectly well occur to the conditioned stimulus when the paralytic drug has worn off (Solomon and Turner, 1962).

Learning clearly occurs when the animals are paralyzed, even though no behavioral changes take place at that time. The second problem is that many in cases it can be established that organisms do much more than simply acquire new types of behavior. For instant, in a famous experiment, MacFarlane (1930) trained laboratory rats to run through a maze to obtain food, and found that when the maze was filled with water, the animals continued to take the right path to the food even though they now had to swim to reach it. Clearly, learning in this case does not merely involve equitation of a set of particular muscle activities conditioned to a set of stimuli, but instead involves acquiring knowledge of spatial lay out of the maze and this knowledge is capable of revealing itself in a variety of different ways.

1.11.2. Learning varieties:

There is one major distinction between types of learning concerning the complexity of the information to be learned. The following list is a hierarchical order of the types, beginning with the simplest. Although this study concentrates on human learning, organisms possessing fairly well developed neural systems have proved capable of learning.

First one is **"Relational"** learning, the learning of a relation between two stimuli or between a stimulus and behavior required. Concerning this one there are many subtypes the simplest one is **the classical conditioning** which involves learning specific relations between environmental stimuli, and there are more complex types of relational learning. **Nonassociative learning** is obtained by repeated exposure to a single stimulus type; **associative learning** comes from comparison of one stimulus to another (**classical conditioning**), or

comparison of a stimulus to the organism behavior (**operant conditioning**). Knowledge can also be acquired by repeated practice (**reflexive learning**).

Second is "**Nonrelational**" learning, only a single stimulus (an environmental event) is involved, and the simplest form of nonrelational learning is **"Habituation",** we have all experienced this type of learning when frequently occurring nonnoxious stimuli such as household noise decrease to attract our attention. And the second form of nonrelational learning is "**Sensitization**" in which an organism learns to increase the vigor of a response after exposure to a noxious or threatening stimulus. We can say it is reverse habituation but it is not exactly dishabituation.

Motor learning this is the learning of skilled motor tasks e.g. tying shoelaces. It arises through a combination of sensory ability, physical dexterity and cognition. A sequence of two more stimulus-response associations is 'chained' together resulting in the motor skill.

Language and verbal learning is concerned with the acquisition of human language, similar to sensorimotor learning in the sense that it too uses 'chaining', albeit on a verbal level. It is best seen when learning a foreign language e.g. end (English) →finish→fin (French)

Only a small part of information entering the consciousness is stored, concepts and ideas can be stored as words (verbal memory) or non-verbal codes.

Categorical learning: This is learning to categorize objects and events. Categorical learning process of experiencing various stimuli, recognizing that some of them share important common traits and then grouping them together so that we react to them in similar way. Our ability to identify an object is dependent on this skill. **Abstraction** is the process of recognizing that certain stimuli, which share similar attributes, belong in a particular category.

Generalization allows us to recognize new instances of a category when encountered. The difference between two objects may the incredibly subtle yet an adult can classify more than 100.000 items.

For example, every instance of a fish encountered is stored as a featural description (**exemplar**) in memory a new object is analyzed by the sensory system to create a list of features that allows comparison with stored exemplars. The new object is categorized as a fish if it is more similar to the stored exemplars of fish than exemplars of others categories.

Three types of categories are used in categorization. **Conjunctive** categories have members identified by the presence of two or more memberships. In **disjunctive** categories membership is based on either the presence of one attribute OR the presence of another attribute. **Relational** categories do not simply use the presence or absence of attribute but rather a relationship between attributes.

Rule learning: this is the highest form of learning and as such recruits the most advanced perceptual skill.

Perceptual learning refers to such things as recognizing or distinguishing between objects or stimuli in the past from their visual appearance, how they feel, how they smell, or their sounds, each of our sensory systems capable to perceptual learning. We can also recognize surrounding peoples from their faces, movements, voices, and we can recognize their emotional status by recognizing the word they are saying. Learning visual stimuli recognition involves changes in visual association cortex, by receiving information from lateral geniculate nucleus of the thalamus to the primary visual cortex (Striate cortex). Within it individual's modules of neural analyze information, V3 is devoted to analysis of orientation, area V4 to analysis of colors, and V5 to analysis of movements. Then these sub-regions of prestriate cortex send the

results to the Inferotemporal Cortex, which combines the informations and produces neural activity that corresponds to the perception of particular three-dimensional stimuli. Auditory stimuli associated with changes in auditory cortex and so on. Perceptual learning seems to be accomplished by changes in the sensory associated cortex.

Reber, 1965, 1967, & 1969 introduced the term of implicit learning, which was about characterization of how one develops intuitive knowledge about the underlying structure of a complex stimulus environment. He argued that the characterization of the implicit learning is basically by these two critical features. First is that the implicit learning is an unconscious process, and the second is that it yields abstract knowledge, stimulus environment display and abstract representation of a structure induction lead to implicit knowledge.

Since then a lot of evidence to support the claim that sequence learning may occur without concurrent awareness of sequential structures has been based on dissociation between performance increments in the serial reaction time task and performance in measures of conscious knowledge. The first, reliable performance increments in serial reaction time tasks have reported subgroups of participants who were not able to verbalize the sequence structure after training or who had not even noticed that there was a structure (Cohen, et al. 1990; Curran & Keel, 1993; Reed & Johnson, 1994). Second, participants showed learning of serial reaction time tasks even if their performance in a subsequent prediction task in which they had to predict on each trial at which location the next stimulus would appear, was not superior to that of control participants who had been presented with a random sequence (Cohen, 1990; stadler, 1989; Willingham et al 1989). Third, sequence learning appears to be spared in amnesic patients suffering from Korsakoff's and Alzheimer disease who show

severe impairments of conscious episodic memory (Nissen & Bullemer, 1987; Nissen et al 1989).

There is some controversy about whether sequence learning is really unconscious. Perruchet et al, 1990; Perruchet, 1994; Shanks, & St. John, 1994. noted that the serial reaction time task was not well interpreted. Perruchet and Amorim 1992 conclude that the better way to assess by recognition and free-recall tasks for conscious knowledge about sequential structures.

1.11.3. Mechanism of learning:

Learning comprises three identifiably different dimensions: accumulation of knowledge, sequence of learning and varieties of learning.

The engram may exist as information in a reverberating circuit. (Dynamic engram), or as a modifications of synaptic connections (Structural engram).

Engram is the physical representation or location of a memory and known as memory trace. Hebb pointed out that memories can result from subtle alterations in synapses and these alterations can be widely distributed in the brain. Hebb postulated that learning and memory may rise from use-dependent alteration in the strength with which synapses transmit activity (Hebb, 1949). Synapses become strengthened as a result of persistent or repeated correlation between pre-synaptic and post-synaptic neuron activity.

Lomo 1966 first reported Use-dependent alteration in synaptic strengthen the rabbit hippocampus, eight years later, the term long term potentiation was used to characterize stimulus frequency dependent changes in population EPSPs and the amplitude latency of population spikes in the rabbit dentate, with and without anesthesia (Bliss and Lomo 1973). There may be changes in the proportions of nucleotides in RNA during learning, but attempts to extract and

transfer these changes (as memory traces) between one organism and another have given inconsistent results and are now disregarded.

Accumulation of knowledge: Learning begins at birth when infant learns to associate feeding with the presence of parents. Children learn about their language. Adults attempt to use their accrued knowledge to comprehend the world and themselves.

1.11.4. Sequences of learning (3 stages):

Many researchers, especially the psychologists believe that learning sequences consists of three stages at least. The first one is Short Term Memory (STM), which roughly means storing a limited amount of information temporarily. The second stage is Long Term Memory (LTM), Which means storage of an information permanently, e.g. you could repeat seven dictated numbers, but you could not, in the same situation, repeat fifteen numbers. You could memorize fifteen numbers if you studied and rehearsed them for enough time, thus the simple way explaining how the entry of sensory information to the short term memory, then the conversion from short term memory to long term memory has been known as consolidation.

1. Stimulus input: The relevant stimulus is selectively attended to and other distracting events are ignored. Comprehension is the amount of information that can be captured from environment at any one time. Registered (recently received) information enters short-term memory (STM) which is very vulnerable to interference. STM acts as a buffer which retains new information just long enough for to be transferred, if necessary, to long term memory (LTM). The limited capacity of STM (seven items ± 2) means protection from acquiring too much irrelevant data, which would impede learning. Rejected information is not entirely excluded; our information processing system briefly

retains and analyses a lot of information we are unaware of which is only passed on to consciousness if it is deemed important.

2. **Storage of information:** Registered information is encoded into a form that permits practice of the information. This entails sorting out of complex stimuli and recognition of their meaningful attribute e.g. letters speech sounds, words, etc. Storage in the STM occurs in a verbal manner irrespective of the sensory modality of the input. Stimuli are named and practiced using these names.

3. **Retrieval of information:** The final event in learning is the recall and utilization of previously learned material. Failure to retrieve information may be due to a cause that may have occurred during any of the preceding stages of learning e.g. registration, encoding, and storage.

These stages are not necessarily independent of each other. In fact interaction between them may be essential. Past experience (stored in LTM) tells us what to expect and what to look for. Stimulus recognition is reliant upon information in LTM.

Practising simple visual tasks leads to a dramatic improvement in performing them. This learning is specific to the stimuli used for training. Ahissar, and Hochstein 1997, said that the degree of specificity depends on the difficulty of the training conditions. They found that the pattern of specificities maps onto the pattern of receptive field selectivities along the visual pathway. With easy conditions, learning generalizes across orientation and retinal position, matching the spatial generalization of higher visual areas. As task difficulty increases, learning becomes more specific. The dynamics of learning show a corresponding feature. Improvement begins with easy cases and only subsequently proceeds to harder cases. This learning cascade implies that easy conditions guide the learning of hard ones. The specificity and dynamics suggest those learning proceeds as a countercurrent along the cortical hierarchy.

Improvement begins at higher generalizing levels, which, in turn, direct harder-condition learning to the subdomain of their lower-level inputs. They conclude that the learning can be effective using only difficult trials, but on condition that learning onset has previously been enabled. A single prolonged presentation suffices to initiate learning. We call this single-encounter enabling effect 'eureka'.

1.11.5. Where are learning does and memories themselves stored?

The answer seems to be that they are laid down in the cortex.

Karl Lashley 1920s conduct experiments to study the effects of brain lesions on the learning in rats. The studied question was how performance on this task was affected by making a lesion in same part of the rat's cortex. Another experiment about the effect of the brain lesion location and size, He found in the first experiment that the rats given brain lesions before learning took more trials before they could perform the task. The second experiment concluded is that all cortical areas contribute equally in learning and memory.

Subsequent research has proven Lashley's conclusion to be incorrect. All cortical areas do not contribute equally to memory. Lashley was correct that memories are distributed, and had an important and lasting impact on the study of learning and memory because he led other scientists to consider ways in which memories might be distributed among the many neurons of cerebral cortex.

Kluver and Bucy (1938) observed in animals that the complete removal of both temporal lobes resulted in a well-delineated syndrome known as the Kluver-Bucy Syndrome, which included a failure to recognize visual stimuli.

In 1954 Scoville described a grave loss of recent memory in human which he had observed as a sequel to bilateral medial temporal-lobe resection in one

psychotic patient and one patient with intractable seizures. The removal extended posteriorly along the mesial surface of the temporal lobes for distance of approximately 8 cm. from tips of the temporal lobe and probably destroyed the anterior two third of the hippocampus and the hippocampal gyrus bilaterally. A human form of Kluver-Bussy syndrome is seen sometimes after herpes encephalitis, which damages the temporal lobe selectively.

The postoperative findings in 10 patients point to the importance of the hippocampal region for normal memory function (Scoville, 1957).

Lesions of the infero-temporal area are sufficient to produce visual memory deficit (Iwai and Mishkin 1968; Cowey and Gross, 1970)

Some evidence for this comes from pioneering experiments by Wilder Penfield (Penfield and Perot, 1963). But Penfield's data have been criticized, for instance by Loftus (1980).

1.Penfield was able to electrically stimulate areas of the cortex of patients who were awake while undergoing surgery for focal epilepsy.

2.He found that the stimulation of temporal lobes led most of these patients to experience very vivid and realistic images.

3.These often involved hearing music, somebody's voice, such as when one person said, " I hear someone talking... I think it was about restaurant or something"

4.Penfield assumed that subjects were in fact recalling past events that had happened to them, and proposed that memories are stored at very precise cortical locations (as in computer's memory), and can be stimulating with a small electrode in contact with that location.

5.Loftus criticized Penfield's data, on the ground that many of the reported experiences were fantasies and could not possibly be real memories.

6.In fact, Penfield was unable to provide clear evidence that any of the reported experiences were true memories. Rather than being stored in precise locations, what is more likely is memories are stored in a distributed fashion across the cortex, with many different parts of the cortex contributing to a given memory.

7.What Penfield detected were probably not memories themselves, but rather combinations of the basic experiences that make up true memories.

Modern brain researches have established that memories are encoded in the brain via the plasticity of synaptic connections between neurons, with individual memories being stored in parallel across huge numbers of neurons organized into "macrocolumn" in the cerebral cortex (Squire 1987). Each approximately 10 –11 neurons in the brain receive inputs from very many other neurons, and these inputs consists of neurotransmitter molecules that attach themselves on receptor sites on the dendrites of the neuron. When the input activation reaches a sufficient level, channels are opened which allow ions to be admitted into the neurons. These ions cause an electrical impulse to be generated, which then travels down the output pathway (the "axon") of the neuron, and which leads to neurotransmitter molecules being released, which can then act on other neurons.

When two connected neurons are excited at the same time, the synaptic connection between them may grow stronger, leading to facilitation between them. This is thought to be the basic way in which memory is stored. The process of synaptic plasticity has been extensively studied in the hippocampus, where so-called Long-term potentiation (LTP) has been observed. As a result of sending a train of impulses down a microelectrode attached to a part of hippocampus, increase in the strengths of connections are observed, such that a

signal from one neuron elicits a much stronger response from another neuron than would normally be the case. These changes can last for a weeks or months. Although controversial, it is widely though the LTP is the basic process whereby the brain stores information.

Recognition memory may well depend on interactions involving the hippocampus, inferior temporal neocortex and the amaygdala, and retrieval perhaps more dependent on frontal-thalamic medial thalamic nuclei interaction (Joseph, R. 1996).

Frontal lobe: consists of (A) Primary motor cortex: Provides the main cortical output for the voluntary movement.

(B) Premotor cortex: Important for integration and programming of sequential movements.

(C) Prefrontal cortex: Covers a large area anterior to primary motor cortex and premotor cortex, divided into (1) Orbital frontal region (anterior tip of the frontal lobe), and (2) dorsolateral region. There are intricate connection between regions of prefrontal cortex and posterior cortex; the prefrontal cortex also has primary subcortical projections to and from the mediodorsal nucleus of the thalamus. (Goldman-Rakic, 1987; Fuster, 1989)

If there is prefrontal cortex dysfunction a variety of behavioral mental disturbances are seen in humans e.g. personality disorders, motor control & planning, language, problem solving, and memory impairment secondary to cognitive disorders such as deficits in attention, inferential reasoning, and cognitive mediation (Milner, et al 1985; Benton, 1991; Shimamura, 1991).

Three Occipito-temporal areas in the ventral object vision pathway had mostly transient responses to stimuli, indicating their predominant role in perceptual processing, whereas prefrontal areas demonstrated by sustained activity over

memory. The posterior and inferior frontal gyri, the second inferior frontal gyrus and the anterior middle frontal gyrus (Courtney, et al.1997).

In a visual learning task, functional fields of activity appeared in the following anatomical structures:

1. The primary visual area in and around the calcarine sulcus.
2. Visual association areas: regional cerebral blood flow 'rCBF' increased over the rest of cuneus, the posterior part of the precuneus, the lingual gyrus, the fusiform gyrus, the occipital gyri, the angular gyrus, and the posterior part of the superior parietal lobule.
3. Prefrontal cortical regions, especially the cortex lining the superior frontal sulcus and the frontal eye field.
4. Limbic and paralimbic structures: the anterior hippocampal formation (but not the posterior), the anterior cingulate cortex, temporal pole, and anterior sector of insula.
5. The anterior midpart of the neostriatum, 'rCBF' (Roland, et al. 1994).

The anterior cingulate cortex is assumed to play an important role in various aspects of human behavior, including affect, verbal expression, response selection, and initial action (Devinsky et al 1995).

The function of the cerebellum was traditionally described as motor, in the history of learning and memory, Thompson and colleagues brought attention to the role of cerebellum in classical conditioning and in the storage of memory engrams (McCormick & Thompson, 1984; Thompson & Donegan, 1986). More recently, neuropsychological, neuroimaging, and anatomical evidence has converged on the idea that the cerebellum also makes important contribution to

cognition (Leiner, et al 1991. 1995). Cerebellar damage has been found to produce deficits in a variety in a cognitive measures, including intelligence (Botez et al., 1989), cognitive skill learning (Fiez & Petersen, 1993), in perception (Kolher et al., 1995), and working memory (Paulesu, et al 1993; Petrides et al., 1993).

There is a good evidence-in particular, from work on implicit learning in animals where Packard, and McGaugh (1996) concluded that:

- the hippocampus and caudate nucleus selectively mediate expression of place and response learning, respectively

- In a visually cued extramaze environment, hippocampal-dependent place learning is acquired faster than caudate-dependent response learning.

- When animals shift to caudate-dependent response learning with extended training, the hippocampal-based place representation remains intact.

McClelland & Goddard (1996) were discuss a framework for the organization of learning systems in the mammalian brain, in which the hippocampus and related areas form a memory system complementary to learning mechanisms in neocortex and other areas. The hippocampal system stores new episodes and "replays" them to the neocortical system interleaved with ongoing experience, allowing generalization as cortical memories form. The data accounted for include first neurophysiological findings concerning representations in hippocampal areas. Second, behavioral evidence demonstrating a spatial role for hippocampus. Third, effects of surgical and pharmacological manipulations on neuronal firing in hippocampal regions in behaving animals.

A memory separation, storage, and retrieval subsystem, supported by pathways between EC, dentate gyrus and area CA3, including the CA3 recurrent

collaterals, which facilitates encoding and storage in CA3 of individual EC patterns, and retrieval of those CA3 encodes, in a manner that minimizes interference. A memory decoding subsystem, supported by the Shaffer collaterals from area CA1 to area CA3 and the bi-directional pathways between EC and CA3, which provides the means by which a retrieved CA3 coding of an EC pattern can reinstate that pattern on EC.

1.11.6. The principal brain areas involved in learning and memory (Fig 1.11):

The hippocampus that receives inputs from sensory cortex, and it is a part of circuit in which signals are transmitted from the subiculum (the "output" part of the hippocampus) to the mammillary bodies via a pathway called the fornix. From the mammillary bodies, signals are sent via the cingulate cortex back to the hippocampus. Although HM's surgery removed structures in addition to the hippocampus, evidence suggests that highly localized lesions to the hippocampus, fornix, or mammillary bodies can create profound amnesia (Squire, 1992).

We can conclude the brain structure involved in memory when sensory inputs stimulate a cortical sensory area, cortex flow through parallel circuit to amygdala and hippocampus, both circuit encompass parts of diencephalon, prefrontal cortex; and dorsal forbrain, finally feedback to the sensory cortex closing the memory loop. The corpus striatum mediates the automatic connection between a stimulus and motor response.

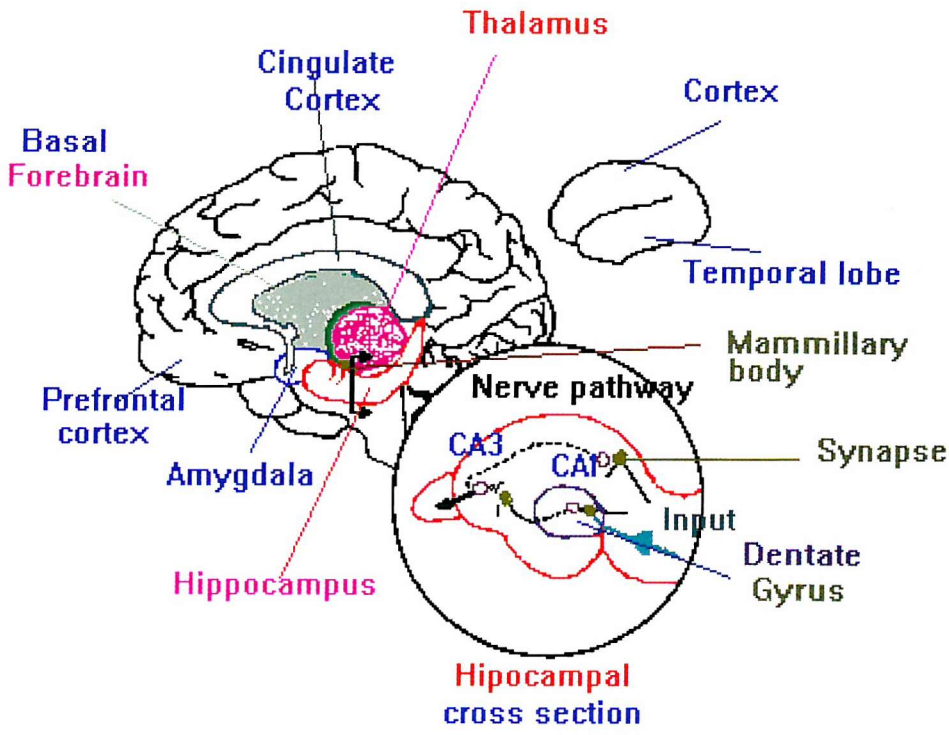


Figure 1.11 shows the principal brain areas involved in learning and memory.

1.12. MEMORY:

1.12.1. Types of MEMORY:

Working memory involves the short term maintenance of an active representation of information, and is responsible for the short-term storage and on-line manipulation of information necessary for higher cognitive functions, such as language, planning and problem-solving, and described as a buffer where a sensory inputs kept functional so that it can be used for further processing.

Implicit memory: is revealed when previous experiences facilitate performance on a task that does not require conscious or intentional activation of those experiences.

Explicit memory: is revealed when the performance on a task requires conscious recollection of previous experiences.

Sensory memory: Sensory information (Visual received by retinal receptors) stored automatically for a few 100msec are evaluated and forgetting by. Placement of other information immediately processed verbal or non-verbal or distinguished.

Primary memory: Short-term memory verbally coded information is temporarily stored in the order received, repetition ensures the transfer of the contents of the primary memory to the secondary memory. New information may arrive before transfer to secondary memory, hence the original information is forgotten

Secondary memory: Long term memory stored in order of significance as engram previous experience or information acquired subsequently proactive or retroactive informations may interfere with the learning processes. So partial or complete forgetting may occur proactive inhibition is important bin causing memory loss.

Tertiary memory: Important information is stored indefinitely, is rarely forgotten, rapidly retrieved (e.g. an individual name).

Two types of working memory are thought to exist. A brief mental after image lasting hundreds of milliseconds and a longer less literal vivid recollection of sensory features for up to thirty seconds. Evidence for this can be seen in Sperling's (1960) ingenious experiment. Just after a complex image was displayed, auditory clues were given to indicate which part of the image to remember. If this clue was given within 250 msec of the image it aided memory, suggesting that aspects of working memory be converted to categorical within this time. Further evidence is shown by the fusion of TV

pictures. Successive visual stimuli within 200 msec fuse perceptually (Haber and Standing, 1969 & 1970). Briefly presented stimuli are masked by a subsequent pattern presentation within 200 msec (Turvey, 1973). It has been hypothesized that trace develops with attention. After the construction of an automated tool of stimulus processing, that is automatic in the absence of attention (Näätänen and Alho, 1995).

Traditionally, working memory processes have been divided into two types, the first one is an executive control (governing the encoding manipulation and retrieval of information in working memory) and the second one is an active maintenance (keeping information available on line). It has also been proposed that these two types of processes may be subserved by distinct cortical structures, with the prefrontal cortex housing the executive control processes, and more posterior regions housing the content-specific buffers (for example verbal versus visuo-spatial) responsible for active maintenance. However studies in non-human primates suggest that dorso-lateral regions of the prefrontal cortex may also be involved in active maintenance. Working memory involves the short-term maintenance of an active representation of information so that it is available for further processing.

Visual working memory tasks, in which subject retain the memory of a stimulus over brief delays, require both the perceptual encoding of the stimulus and subsequent maintenance of its presentation after the stimulus is removed from view.

Visual memory tasks require both the perceptual encoding of the stimulus and a prolonged maintenance of its representation after removal from view. These two mechanisms are, an executive control responsible for encoding and retrieval of information in working memory, and an active representation consists of a visual sketchpad and phonological loop (Cohen et al, 1997).

The visuospatial sketchpad is assumed to be the comprised of separable visual and spatial components, serving different functions, and these functions is also consistent with recently proposed models of two mental imaginary, one that preserves the appearance of objects including color and form information, and second spatial component that preserves representation of layout (location & size) of objects in space.

Mismatch negativity (MMN) has been seen as a response to change in an ongoing series of tones and thus linked to working memory. MMN absence using inter-tone delays of more than two seconds, suggests that the representation was transient (Mantysalo and Naatanen, 1987). In recent study evidence for activation up to ten seconds has been found (Czigler et al, 1992). The similarity between these timing and behavioral discrimination tasks suggests that the internal representation is sensory.

During stimulus encoding certain stimuli can produce memory representation or codes of multiple types, e.g. printed word can yield separate lexical, orthographic and phonological codes. This 'sensory' or working memory cannot be equated with particular type of stimuli but rather the type of codes produced in the brain.

Such tasks activate multiple areas in visual and prefrontal cortices. To delineate the roles these areas play in perception and working memory maintenance, we used event related potentials ERPs to obtain potentials measures of neural activity related to different components of event working memory categorical task, non selective response to visual stimuli, selective transient response to images and sustained response over memory delay.

The systemic progression in relative strength of perception and memory related activity from the posterior extra-striate through to prefrontal areas would suggest that the neural system for working memory be hierarchically organized.

The prefrontal regions also are activated during long-term memory recall. Active presentation of recalled material might mimic working memory images. The temporal cortex shows a similar sustained activation but is disrupted by further stimulus, unlike the frontal cortex (Miller et al, 1996). This implies that the temporal cortex is predominantly perceptual but helps in working memory unless recruited for perceptual tasks.

Experiments by Cowan (1984 & 1988) show working memory include a transient nature for comparison of two consecutive stimuli. Discrimination declines as inter-stimulus time increases up to 30 seconds. Although some long-term components are present e.g. the end performance is greater than the chance (Cowan, 1995).

The object property pathway runs from occipital lobe to inferior temporal lobe and spatial properties pathway runs from occipital lobe to parietal lobe and both of them called what system and where system respectively. There are some physiological evidences about increase the regional blood flow (**rBF**) to superior parietal cortex with spatial task (dot location matching), and with face matching task, the rBF was towards the posterior temporal cortex and lateral occipital area was involved in the tasks (Haxby et al. 1991).

Functional MRI Imaging studies have shown that both visual and prefrontal cortices are active during visual memory task. Work using these techniques with face discrimination task, has shown that the ventral Occipito-temporal extra-striate visual areas are active during stimulus representation. A region in the posterior lingual and fusiform gyri showed a non-selective response to stimuli. The anterior fusiform gyrus activity was face stimuli dependent, and suggested that it was concerned with perceptual processing of faces and could hold the active representation. Three prefrontal areas have been connected with working memory, The posterior middle and inferior frontal gyri, The second

inferior frontal gyrus and the anterior middle frontal gyrus, showing sustained activity during memory delay (Courtney et al, 1997).

1.12.2. Memory disorders

1. **Antegrade amnesia** (Korsakoff syndrome) & (Amnesiac syndrome)**:** Inability to learn new long-term information, failure to transfer from primary to secondary memory.

2. **Retrograde amnesia:** Inability to retrieve information from primary or secondary memory due to disruption of access to secondary memory, memory loss is proportional to degree of damage.

3. **Hysterical amnesia:** New information can be easily remembered.

4. Dementias: Loss of recent memory, impaired learning, intellectual decline and others aspect of mental decline, e.g. Alzheimer's diseases.

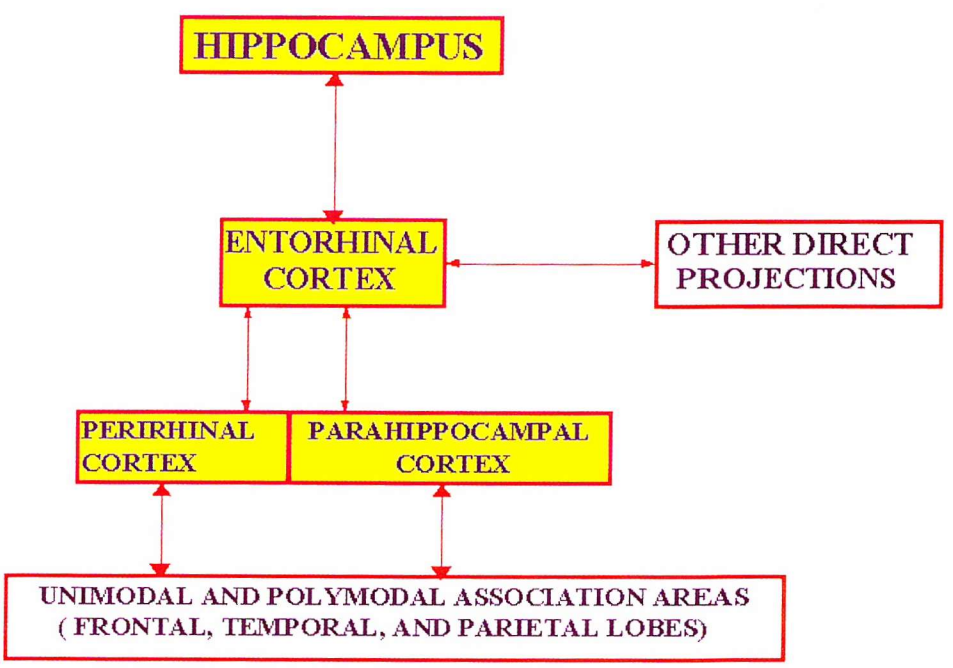


Figure 1.12 shows a schematic view of the brain structures, and the important connections for the declarative memory. Yellow areas indicate the structure within the medial temporal lobe

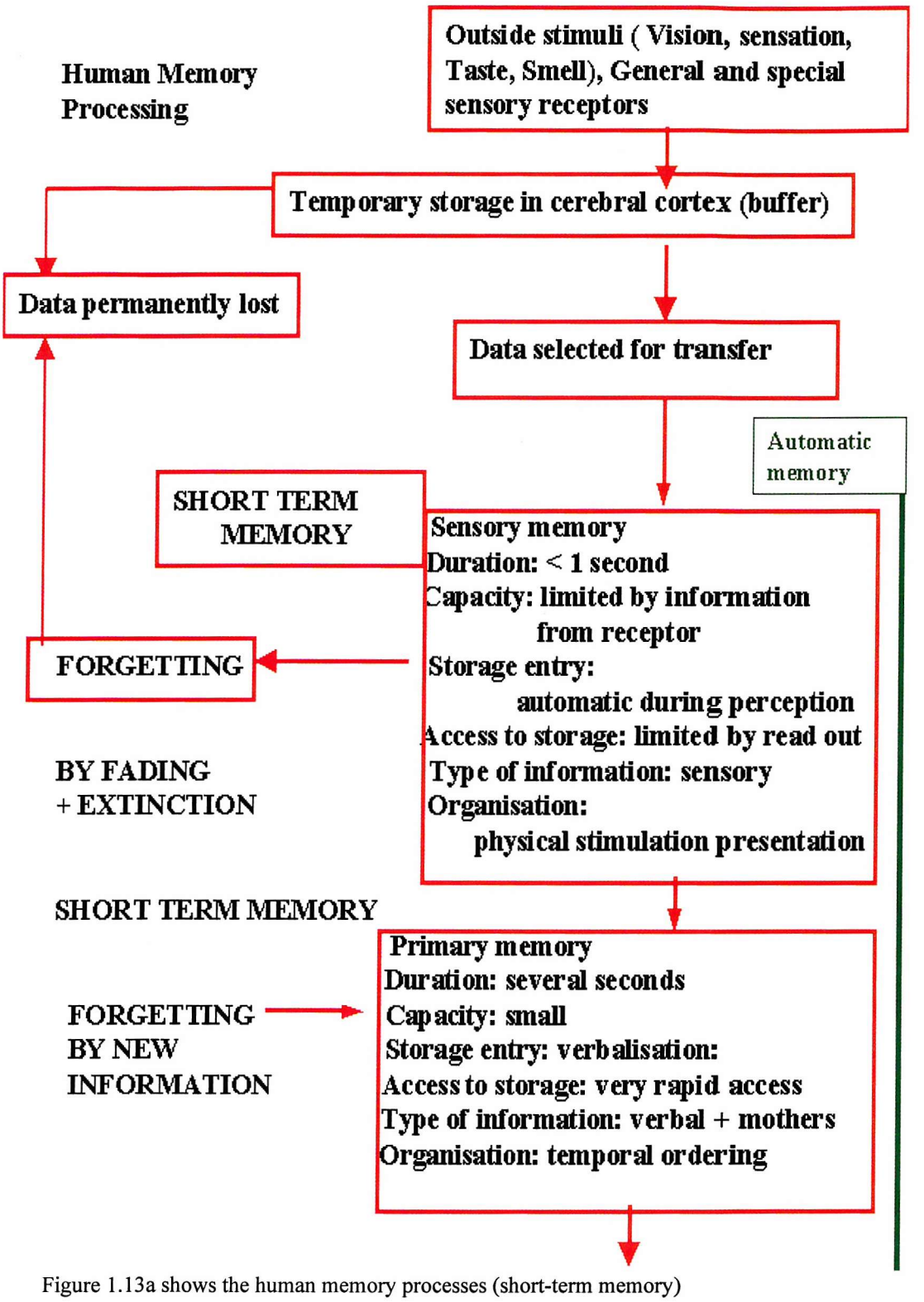


Figure 1.13a shows the human memory processes (short-term memory)

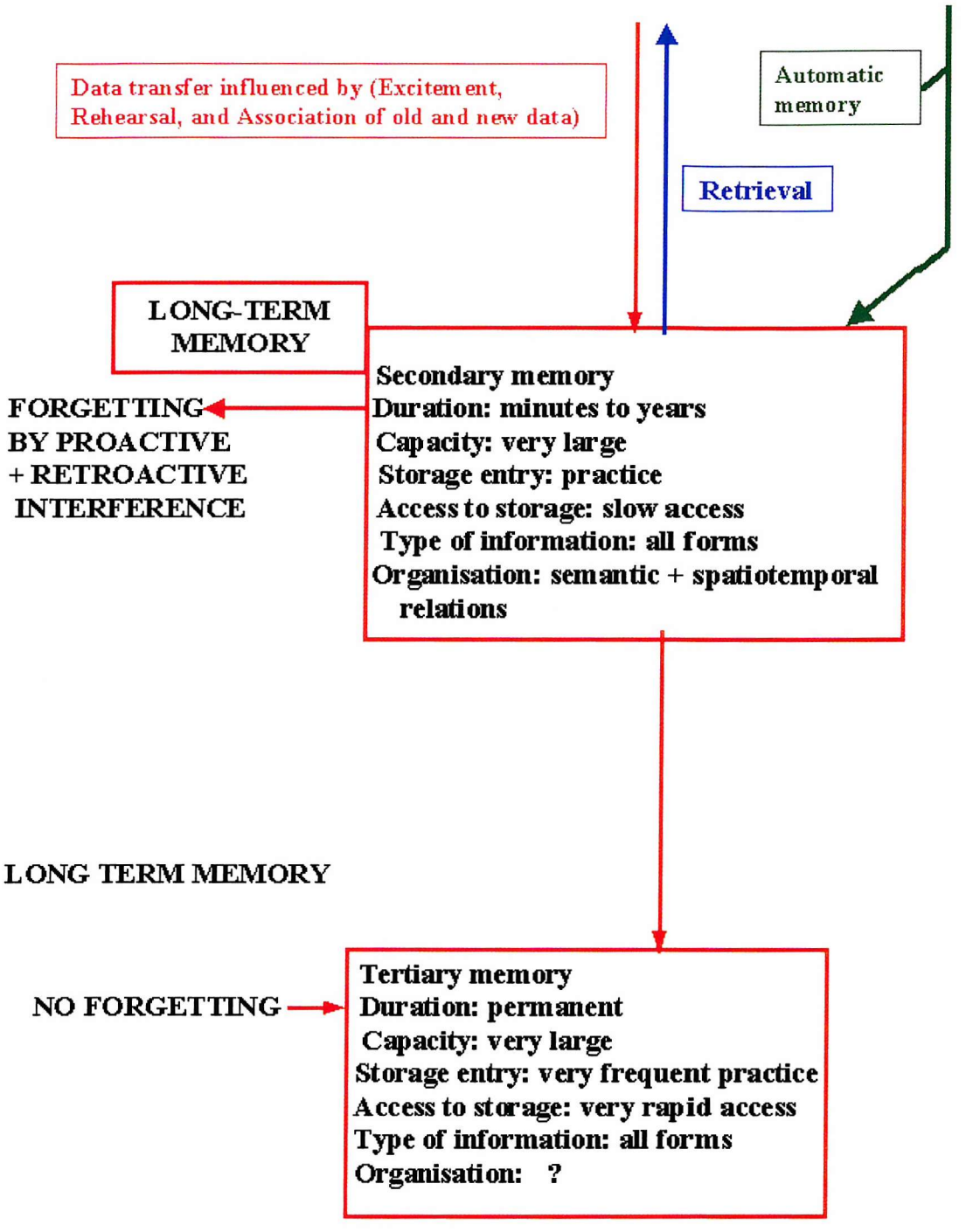


Figure (1.13b) shows the human memory processes (long term memory)

1.13. Categorical Perception:

1.13.1. Categorical perception:

Since the beginning of the experimental study of categorisation in psychology (Hull 1920), there has been a tendency to assume that all acts of categorisation are accomplished by the same means.

Who can imagine a world without categories? Categorization helps to reduce the complexity of the environment, identify objects, reduce the need for learning, relate objects to a hierarchy of knowledge, and help make decisions.

Categorical perception occurs when the continuous, variable, and confusable stimulation that reaches the sense organs is sorted out by the mind into discrete, distinct categories who members somehow come to resemble one another more than they resemble member of other categories.

In general various investigators have defined the categorical perception in terms of identification performance, discrimination performance, or both. Simply there is no uniform definition of categorical perception (Medin, D.L. and Barsalou, L.W. 1987).

Categorical perception (CP) is a process that allows the brain to place continuous variables that are transuded by the sense organs into discrete, distinct, categories. Categories are members somehow come to resemble another one, more than they resemble members of another different categories, or by another words members within groups resemble each other more than across boundaries. The perceptual difference inter-category can be more than suggested by the actual physical attributes. Consequently the perceptual similarities within a group are increased. A well used example of categorical perception is that the color continuum.

Physically the spectrum of light that is perceived as color varies in a linear way. Although the light wavelength varies in an analogue fashion, we classify the colors as distinct groups with boundaries. This means that a red and orange can be physically closer in wavelength than two oranges but are perceived as different categories. Unlike categorical perception of color, which is not present at birth, and unill six weeks after birth due to late demylination of the system. Infants learn to tell the difference between cats and dogs using the same grouping technique. A child of three may see a lot of similarities between the two classes and struggle to qualify individual examples (Harnad, 1987)

Chicken sexing has been quoted as a working example. A difficult task that has to be learnt so that two groups can be reliably distinguished, categorical perception is thought to be a basis for cognition and thus learning.

The phenomenon of categorical perception was first suggested within each perception research (Liberman et al, 1957; Liberman et al, 1967), unto which it was originally thought unique. Although now CP. has been proved to exist in other contexts. CP can be seen as an analogue to digital conversion. Where qualitative differences and perceptual boundaries have arisen between groups.

CP and continuous perception were initially thought of as two distinct processes, even isolated to left or right hemisphere (Liberman et al, 1967). Psychological models have been proposed that expand on this distinction. Braid (1969) defined a model with two parameters, trace and context. Trace referring to the comparison of the stimulus to a previous sensory working memory image. The context to certain anchor features. From this model you can see that short term, long term and working memory are involved.

Harnad (1987) has asked two questions considered as the most basic questions about the human or the animal perception and cognition. The first one is "how do we sort objects, people, and ideas in the world into their proper categories?

The second is "What transforms the "booming, buzzing confusion' that enters our eyes and ears at birth into that orderly world we ultimately experience and interact with?

Perception refers to the means by which information acquired from the environment via the sense organs is transformed into experiences of objects, events, sounds, tastes, etc.

Perception is a very complex process, depends on physiological systems associated with each sense modality, plus central brain processes, which integrate and interpret the output from the physiological systems (Frisby. 1979).

1.13.2. Theories of Category classifications:

1. Feature Comparison Theories.
2. Prototype Theories.
3. Exemplar Theories
4. Boundary theory

Feature Comparison theory of category classification: A category (or concept) is defined by matching the features of an object to a logical arrangement of features in a category (stored in our memories). All features are considered equally good and necessary. All category members are equally representative.

Types of feature rules used in categorizing:

1. Simple Rules: presence or an absence of a single feature.
2. Conjunctive Rules: necessary presence of more than 1 feature.

3. Disjunctive Rules: necessary presence of one of several features.

4. Conditional Rules: necessary presence of feature 2 only if feature 1 is present. (All without features 1 are also members of the category).

Prototype theory of category classification: Theory Basics: It is suggested that categorization is based on similarity of features in perception and memory, but that none of the features are necessary for defining. Generally speaking, the prototype of a category contains characteristics attributes of its category exemplars, namely, attribute that highly probable across category members, but that neither necessary or sufficient for category membership.

Exemplar theory of category classification: People classify entities on the basis of their similarity to memories of previously experienced category members. They compare it with memories of specific category exemplars, each memory representing an encounter with an exemplar at specific place and time. Stimuli are assigned to the category having the most similar exemplar or exemplars.

Boundary theory of category classification: A final classification strategy is that people determine category membership on the basis of category boundaries rather than characteristics or ideal attribute.

1.13.3. Where is Categorical Perception executed?

There is no one area where we can look for CP. activity. We are concerned with a system that allows two way interactions between the current stimulus and ongoing evaluation of perception. The new stimulus has to be incorporated into the perceptual model, but also has to be perceived in the cortex of this model. That is affective and effective process occurring within the same mechanism.

In primate there are cells within the occipital striate cortex that respond faithfully to analysis of physical dimensions such as length, width and orientation (Hubel and Wiesel, 1968). Areas of a visual stimulus within the prestriate cortex contain multiple representations of the visual fields for further analysis (Zeki, 1978). Visually responsive areas exist in the inferior portions of the temporal lobe (Gross et al, 1972).

To add another dimension to the processing that possible, associative cortical areas receive a secondary neural input from the thalamus as well as the visual sensory area (Diamond, 1979). This enables a two way system as suggested involving parallel projections from clusters of thalamic nuclei that serve different perceptual functions (Benevento and Rezak, 1976). For example the multiple connections of lateral and inferior portions of the pulvinar nucleus of thalamus are afferent and efferent to the visual cortex. Thus allowing reverberating sustained circuits.

Categorization plays a critical role in perception, thinking, and language and is probably a significant factor in motor performance.

1.13.4. Effect of brain damage on Categorical Perception:

In animal studies monkey inferotemporal lesions lead to loss in categorization. Complementary to the striate lesions which cause a loss in acuity not CP (Wilson and DeBauche, 1981).

In human examples, CP of visuospatial and tactuospatial continua were more affected by damage in the right hemisphere (Bertelson, 1982). There are many examples of the right side of the brain playing an important and independent part in categorical perception.

1.14. Cognition

The word cognitive comes from the Latin word *cognoscere,* meaning *to know* and this indicates what cognitive psychophysiology is all about.

Cognitive psychophysiology tries to explain how the human mind comes to know things about the world around it people, and about itself, and how it uses this knowledge to perform an impressive range of tasks such as remembering, speaking, performing skilled action, solving problems and reasoning.

Cognitive science is the study of the human mind as an information processing system. As such it seeks to utilize any method in its power to quantitatively model the mind. It seems that a huge aspect of what it is to be human is ignored by this definition, as humans are both spiritual and emotional beings. From my point of view cognitive science deals only with one of several aspects of what it is to be human. To take its concepts and beliefs, they are an absolute model of how people are, seems to me to be very dangerous, as this would lead to a very mechanistic view of people which manifestly we are not.

1.15. Attention:

There is one thing for sure about attention. It is not something concrete inside our body, it is not directly observable, and it is a cognitive process. Attention is a hypothetical construct, which accounts for the selective capacity of humans and animals to respond to certain stimuli and ignore others that appear equally potent on the physical and the time dimension.

Attention is the taking possession by the mind, in clear and vivid form of one out of several simultaneously possible objects or trains of thought. Perceiving, and remembering need attention and attention is initiated by appraisal that this is good to know, good to do, and want to do-good to want result in wanting and

approaching it. One of the most common daily activities is to select something to focus on. That is the operation of attention! The basic assumption is that we are limited in only being able to focus on a few things or carry out a few skills at the same time. Attention is switchable from one focus to another. Two types of attention models, namely the filter (or bottleneck) models and the capacity model.

The fact that we recognize structures in our environment without any effort, although these structures are always embedded variety of visual contexts, actually we use two different attentional systems voluntary or active (endogenous), which involves the attention-paying process that results from intention, instructions, etc. Involuntary or passive (exogenous) which involves the attention getting process that results from the intrinsic properties of a stimulus and usually defined in terms of orientation responses.

1.16. The Mind

The word *mind* is frequently use as noun in English. If the mind is a noun we tend think that it must refer to a thing, but it is a strange one if it is a thing. It has no weight, color, extension, and it is non-physical. How can such a thing exists and how can it affects and be affected by the brain? It is an abstract noun.

But if we consider that thing as a set of processes and activities it will be easier. Such a word as "respiration" refers not to single thing but to physiological biochemical processes and activities starting with inspiration...expiration. These steps or processes and activities can take place because there exist physiological organs, such as mouth... trachea...etc., which support them and make for interaction of biochemical processes.

In similar way we can think of there being a set of mental processes carried out by mental organs, the brain, which are needed to carry out activities such as memory, language, and thinking.

Mind is better described as a set of processes, which rely on the brain, rather than as a separate, mysterious thing. These processes relate to what a person says or do, and are linked to observable behavior, which allows us to test theories about inner mental processes by observing their effect on outward measurable behavior

To have a mind is to have feelings. Not just feelings like pain or anger etc., feelings like what it feels like to be hungry, to see a red chair, to want to eat, to imagine a pink elephant and what it feels like to believe that the earth is round, a sentence understanding, a word meaning, etc.

In short, to have a mind is to be capable of having experience (because there's something that it feels, like to experience each of the many things we are able to experience). Things like rocks and computers have no minds: they do not have any experiences.

There is no exact definition of the mind - it is a very personal concept. Some people may believe that the mind is conscious awareness, or even a soul. It is a consolidation of all the different mental process that is occurring at one time - e.g. vision, hearing, speaking. Another definition of 'the mind' may be having a theory of mind - being able to understand other's thoughts and feelings.

Who can prove that we have mind. Only that we ourselves have a mind, but we can never know that someone else has a mind, surely all of what we are studying can said to be brain related!

This lead to the well-known Descartes famous conclusion:

"Cogito ergo sum"..."I think therefore I am"

1.17. Aims and Objectives :

The human nature is to be curious about many mysterious things like, how we see, hear, move, learn, remember, and forget

- The objective is to record the electrophysiological changes in the brain associated with learning
- The aims of this research is to develop a categorical learning task in which people learnt and some people did not
- This would provide a control group and a learning group
- Event Related Potentials were to be recorded before and after learning and these averages compared inter-group and intra-group. The cognitive area and especially late positive waves were the area of interest
- During a presentation of a learning task there are differences in the event related potential at the beginning of the task before while the subject trying to learn compared with the end of the task
- We wish to extend our initial findings and confirm that these changes are related to learning as opposed to boredom, frustration or disappointment with incorrect answers
- We wish to separate out the event related potentials due to:-

a) Decision-making

b) Feedback according to whether the decision is correct or incorrect

METHOD OVERVIEW

2.1 Introduction

Most ERP experiments demand some sort of task from the subject but the task is the same on each trial. The resultant potential is assured to be one which occurs with each trial but require averaging to improve the signal to noise ratio. In these experiments we expect the brain to change during repeated performance of the task so that the potential at the start of the experiment is expected to be different from that at the end. Once the experiment has been done it can not be repeated in the same subject as he or she is no longer naive to the task.

A further complication was that learning was accomplished by forming and testing internal hypotheses. Developing the subjects revealed a wide variety of learning hypotheses which were all wrong (except in one instance) but many hypotheses allowed that subjects to perform adequately and be classed as learners.

Unlike most ERP studies we had to monitor the performance of subjects throughout to assess their learning ability at the task.

Fortunately about half the subjects learned and half did not.

2.2 Subjects

Ninety-nine young adult volunteers participated in different experiments during the study. They were free from any significant diseases, such as brain damage, and all the diseases of the nervous system and all had normal or corrected to normal vision. They were given a full verbal explanation of the recording procedure, taken from the research information sheet (appendix 5.1.), and they were given a brief tour in the laboratory. A general questionnaire (Appendix 5.2.), fulfilled from each participant about his/her personal details, and state of health. Written consent was obtained from the subjects who were interested to continue.

Ethical approval was obtained from the Local Ethical Committee for the ERP experiments (041/99)

2.3. Subject's handedness:

The subjects were questioned about:

1) Fine manual skill: repeated writing hand, drawing, holding needle.
2) Hand and wrist skill: Holding things, combing hair, using razor, etc.
3) Hand, wrist, and arm skill: Holding a racquet in sport, throwing a ball, using a hammer, etc.
4) Strength: which arm is stronger.
5) Family trait.

All subjects are right handed as indicated in a chart of Edinburgh Handedness inventory (Oldfield. 1971) Appendix 5.3.

2.4. Task

Subjects viewed **200** images of two types and had to recognise them as type A or type B indicating their decision by pressing one of two buttons within two seconds. These two hundred categorisation trials were broken into quartiles (four groups of 50 trials) for purposes of statistical analysis. All the images are individually different but belonged to type **A** or **B**. each image (stimulus) was presented for Duration of **2000msec,** and was followed by a **500msec** interval during which the screen was blank.

2.5. Images

The images were computer generated in black and white, with equal numbers of black and white pixels, so there were no brightness changes. Their properties were as follows.

(1) The pattern on the screen 10 x 10 pixels matrix contains 40 wide x 32 high elements (total 1280). All the subjects confirmed that they could see the individual elements.

(2) The actual elements being made up of blocks **2 x 2** pixels in size.

(3) Four different elements are employed, each element is U shaped but displayed as a U, upside-down, or on its side with the bottom on the left or on the right.

(4) The individual elements are designed so that they each have the same number of black and white pixels, so the overall luminance of the display is the same during each stimulus presentation.

(5) The order of the elements in each field is randomly distributed, but randomness follows certain rules.

(6) The outer 3 rows and columns were always the same so that there were no clue from edge effect. This represents the image frame.

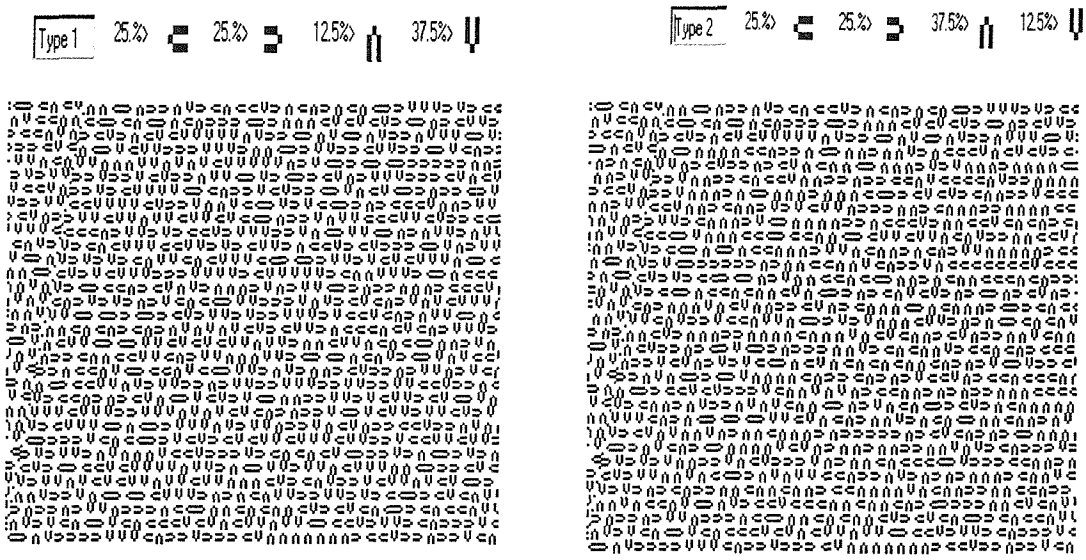
(7) Within the frame the position of the elements was randomly arranged but with the proportions fixed as for type A or B pattern (25 % of each of the individual elements).

(8) Within the frame, the remaining in 884 elements of four different types was displayed in unequal proportion from each pattern Table (2). Element III and IV were the U shape and the upside down U shapes. Element II and I were horizontal U's. (Figures 2.1a & 2.1b).

Elements	Pattern A (Fig. 8).	Pattern B (Fig. 7)
Element I	50 %	50 %
Element II	50 %	50 %
Element III	37.5 %	12.5 %
Element IV	12.5 %	37.5 %

Table (2.1.) the distribution of the four elements in bot patterns A and B.

(9) Type of pattern presented (A & B) and the subjects response (correct or incorrect) were recorded in the evoked potential file.



(a) (b)

Figure (2.1.) shows the two-task images (a) type 1 or type A, and (b) type 2 or type B

2.6. Recording montage

When pair of electrodes are attached to the surface of the human scalp and connected to a differential amplifier, the output of the amplifier reveals a pattern of variation in voltage over time. This voltage variation is known as the 'electroencephalogram' (EEG). Channel is a given name for each pair of electrodes connected to an amplifier and Montage is an established pattern of connections involving several electrodes. The recording electrodes location on the scalp should be dictated primarily by the expected scalp distribution of the brain evoked potentials of interest. Although you made every single electrode

placement carefully, the individual variation of brain shape makes the detection of what exactly the underlying brain structure nearly impossible.

The locations for these electrodes include all the standard international **10-20** system location **(Jasper, 1958).** In this system, the recording site of each electrode is specified in terms of its proximity to particular region of the brain and the subscript Z for midline: frontal (Fz), central (Cz), parietal (Pz) and occipital (0z). Odd number for the left side and even numbers for the right side of the location in the lateral plane over frontal (F3, F4) and (F7, F8), temporal (T3, T4), parietal (P3, P4) and occipital (01, 02) sites. Picton et al. (1978) have suggested an elaboration of the 10-20 system to include the specification of sites which lie between the standard locations (mostly halfway), and which are more suitable for evoked potential recording.

Additional scalp derived sites along with some electrodes fixed to the cap in appropriate positions, these sites were employed in a pattern previously used in ERPs language studies (Holcomb, and McPherson 1994; Holcomb, 1993; Holcomb & Neville, 1991). These include the following:

Left and right temproparietal **TPL & TPR** which were over the Wernicke's area and its right hemisphere homologue (WL - WR 30 % of intra-aural distance. Lateral to point 13% of the nasion-inion distance posterior to **CZ.**

Left and right anterior temporal **ATL &.ATR** 50% of the distance between **T3/T4** and **F7/F8**

Three midline sites. **FCZ** 50% of the distance between FZ and CZ, **OZ** 10% of the inion-nasion distance and POZ 50% of the distance between PZ and OZ, These electrodes were concentrated over the areas of interest, the frontal, the parietal, and the temporal (Figure 2.2.)

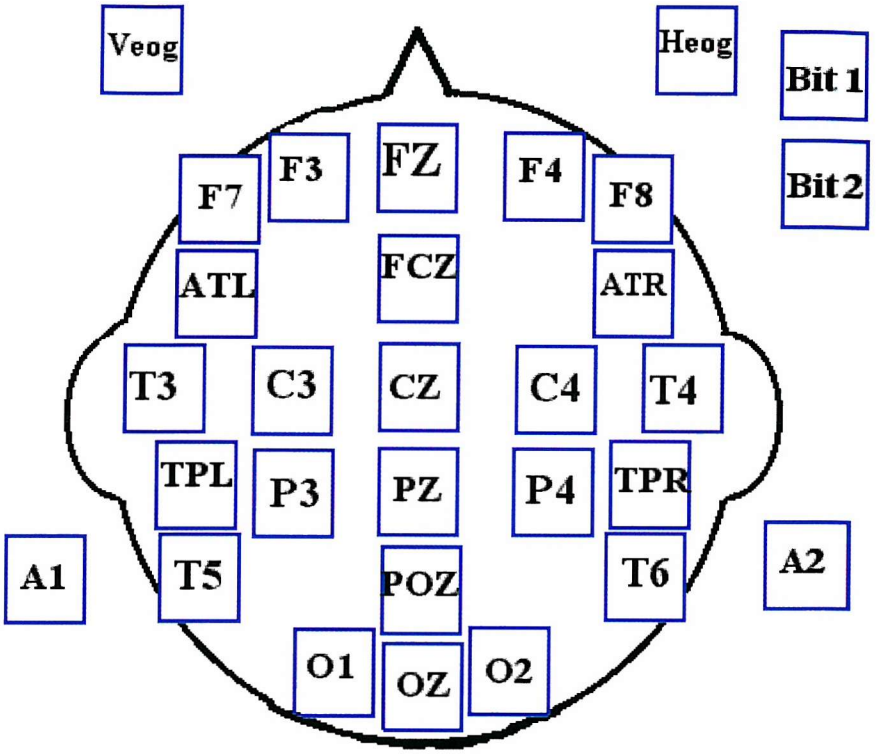


Figure (2.2.) shows my study electrodes and cap electrodes scalp montage position for placement of ERP recording. The abbreviation stand for A= Auricle, C= Central, F= Frontal, Fp = Frontal-pole, O= Occipital, P= Parietal, and T= Temporal. The odd numbers represent the left hand side electrodes, the evens numbers represent the right hand side electrodes, and letter Z represent the central line.

2.7. Electrodes

A few general rules made the studies easy to perform and greatly reduced the number of examiner errors. The electrode site on the patient's skin is cleaned and free of oil, grease, and soil. The site of the electrode should be cleaned and abraded, as necessary, to reduce impedance at the electrode/skin interface.

All the recording points are measured in correct way and markedly clearly with visible ink. All electrodes are electrically tested for broken wires or defective contact points, if defecte repair or replace the electrode.

The electrode must be washed after each application; sometimes possible to draw blood during the scarifying process, and the risks of cross-infection must always be considered.

The event related potentials (ERPs) recorded by electroencephalography (EEG) electrodes of the tin disc or "stick on" type which consists of cupped disc, about one centimetre in diameter, a conducting medium (electrolyte), commonly isotonic (gel solution), is needed to act as a transmission bridge between skin and electrode. The skin/Electrolyte/Electrode interface, forms the first and in many ways the most vital link for faithful recording of scalp potentials. Neglect in the care of the electrodes, and poor application, leads to the most common recording problems. The capacitative and resistance depend on such factors as the kind of electrode metal, the nature, concentration, and temperature of electrolyte, and the frequency and density of the current passed.

The electrode was attached before to the scalp by the collodion adhesive applied round the rim of the electrode, the adhesive being dried by a steam of air from an air gun, or alternatively, bentonito electrode past is available used to hold the electrodes to the scalp and also offer a minor degree of adheasiveness, others prefer to place a small square gauze over the electrode disc and cove this with collodion, having beforehand vigorously rubbed the area underlying the electrode with a swab impregnate with saline, gel or wiped the skin with alcohol swab or a specially formulated compound.

A more recent development is the used blenderm or transport tape, approximately 2.5 centimetre. being taped over the electrode and hair holding the electrode firmly in place of normal length of a ERPs recording.

The electrode has a hole in the cupped part through which a needle can be inserted, inserting electrode gel into the cup; the electrode may be removed after use by pulling off the blenderm tape or by dissolving the collodion with acetone. This is an inflammable aliphatic solvent and care must be taken, so it must be administered sparingly to minimise the amount of fumes, which can irritate the eyes and the throat of both the subject and the recordist. It is strongly advisable to use vinyl shoulder cape on the patient to protect clothing. The eyes must be protected with eye pads when removing the frontal area electrodes.

Electrodes have a finite life (between 60 to 100 recording) usually failing due to breakdown at the joint between the electrode and lead.

2.8. Sterilisation

To avoid the possibilities of cross infection through the use of unsterilized electrodes by the most transmittable diseases have been particularly highlighted: AIDS, hepatitis B, and Creutzfeldt-jacob disease. All have been shown experimentally to be transmitted by cross -contact of blood host and recipient.

Guidelines have now been published for the laboratory and recording staff on how to handle the subjects and on routine and special procedure for sterilising electrodes and other equipment. For during and after use, the recording head stick-on electrodes are treated by ten minutes immersion in 0.1 % hypochlorite. Stick-on electrodes with autoclaved leads can now be readily purchased. Electrodes used for

patient known to have, Creutzfeldt-jacob disease, should not be used again, and should be destroyed by incineration.

If secretion from infected patient (coughing, sneezing, & salivation) come in contact with the equipment, etc., these should be wiped with a 2 % solution of formaldehyde or weak hypochlorite solution (0.1 %). It is not advisable to use the strong hypochlorite solution as it is corrosive and may react with metal and plastic surfaces.

2.9. Artefacts of the eye-movement

The amplifiers used to record ERPs usually include optional filter settings that allow the researchers to filter the waves and attenuate activity above and below selected frequencies.

The eye movements and eye blink are the two major source of artefact. These movements occur at the same frequencies as important features of the ERP waveforms. The electrical potentials produced by blinks and eye movements present serious problems for electroencephalograhic (EEG) and interfere with correct event related potentials analysis and interpretation (Jung et al 2000). The eyeball has positive and negative charge with the cornea positive. Movement of the eyeball produces the electro-oculogram (EOG). This corneo-retinal potential, generated by the cup-shaped retinal sheet of separated charge, can be approximated by a single equivalent dipole located near the centre of the eye (Picton et al. 2000). Because of this standing potential of several millivolts at each side of the eyeball (positively charged anterior pole of the eyeball with respect to the other side), eye rotation can cause a transient potential recorded over the scalp, and this potential can be large.

The simple upward movement of the eyeball mainly produces blink potentials as the eyelid descends. A voluntary downward rotation the eyeball of 10 degrees produces a negative shift of about 50 microvolts at the vertex (Lins et al. 1993). This field of eye movement (EOG) artefact in association with blinking or other movements of eyes are picked up by scalp electrodes and contaminate and distort the recording of the brain activities. Consequently, Scalp-recorded activity associated with eye-blinks, for example, looks remarkably like the ERPs components from the oddball task, whereas horizontal or oblique variations in gaze can appear as slow potential shifts on the scalp. For elimination of the effect of these artefacts, investigators use one of several approaches (Burnia et al. 1989 and Gratton et al. 1983)

Many investigator discard all EEG epochs for which eye movements or blinks are detected and the associated EOG activity exceeds a percent amplitude level for a minimum duration (e.g. 50 μV or 100 μV for at least 15 ms). This method works well although it does not cope with the small number of subjects who make eye-movements with associated EOG which are of lower amplitude than the exclusion level but time-locked to the stimulus. There may be insufficient numbers of artefact-free trials for the tasks that need eye movement to get good performance, or according to the age group (the young and the aged subjects). Investigator some times instruct the subjects to maintain their gaze at a fixation point and to avoid blinking except at the designated times when the task events are not present. The problem is that this task may interfere with the ERP waveforms because attentional resources were diverted to from the target task (Verleger 1991, Kok 1997, and Christian et al. 2000). However, whichever method is chosen it is

obviously essential to include electrodes for monitoring EOG activity when recording ERPs.

The electrodes were placed above the right eye and beneath the left eye to check for the vertical movements. For the horizontal movement the electrodes placed on the outer canthus of the right and the left eye.

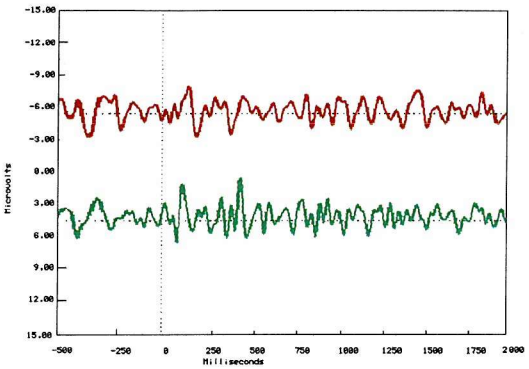


Figure 2.3a shows before rejection horizontal and vertical eye movement traces

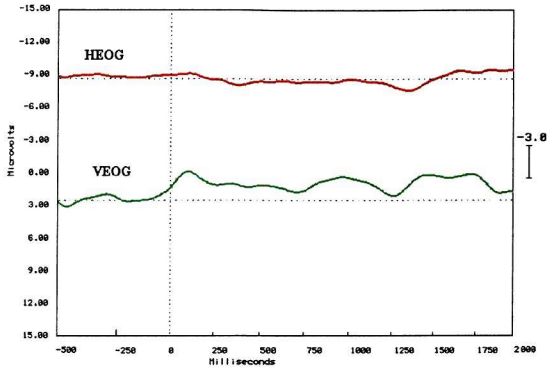


Figure 2.3b shows after rejection horizontal and vertical eye movement traces

2.10. Reference electrode

Where should the electrode be placed? We need to record the voltage difference between two electrode sites to obtain ERPs. The form in any evoked potential component is partly dependent on the choice of the reference electrode. Knowledge of the reference is of fundamental importance when interpreting waveforms, and the difficulty of finding a true reference is an important issue.

The most glaring errors in interpreting ERPs appear to originate from a misunderstanding of the reference electrode in scalp recording. Distribution or topography across the scalp recording array has always been one of the criteria for component identification. Because each 'active' scalp site is referred to a common

reference, scalp distribution will depend on the location of the reference. An ideal reference site is one that is immune to brain activity (inactive).

The most common reference procedure uses a non-cephalic electrode (e.g., Erb's point) as an 'inactive' site. While the other inputs, are from electrodes over or near an 'active' area. It is important that the reference site is not influenced by the spatial field of the evoked potential or at least only minimally. So, it is clear that none of the more commonly used cephalic reference sites, such as the mastoid (bony process right behind the ear), the inion, the earlobe, the chin or the nose is completely insulated from brain activity. However, there is no electrically silent reference and no true reference electrode. It is also important to note that extra-cephalic reference can avoid brain potential contamination but it introduces heart and muscle electrical activities.

Recently much effort has done into the development of procedures for obtaining reference free estimates of the ERP and several have been created. One solution is to connect all active electrodes through resistors of equal value, to a single point, which is then used as an average reference. In this case, the reference for any given site is the average activity across all the other recorded sites. The advantage of this method is that it does not favour any particular electrode site (Bertrand et al. 1985).

There is another reference-free procedure, which provides, instead of the standard voltage measure, an estimate of the instantaneous electrical current flowing into and out of the scalp at each recording site.

Current source density (CSD) analysis is another method (Nunez, 1981, 1990). CSD is often used in combination with a spherical spline function to interpolate data recorded from irregularly spaced electrodes and to infer current sources that are not

directly beneath a recording site. However CSD, like the average reference procedure, requires good spatial sampling of the scalp surface (often 64 sites or more) with precisely defined loci.

ERPs recording researches have the linked ears or linked mastoids reference as a very popular reference procedure for that it deserves a very special consideration due to this popularity. The pre-existing potentials of the two ears are not average by connecting the ears or the mastoids, but rather modifies the current flow and thus potential distribution over the whole scalp. The linked mastoid was used by most of the researchers (Coles et al. 1997). Therefore I selected the same reference electrode of linked mastoid to facilitate comparison with results in the literature.
Three experimental approaches at least were described by using the term-linked mastoids:

- The electrical resistance between the mastoids for current flow along the electrode wire is equal the sum of the contact resistance at the left-hand side and the right hand side mastoid (physically linked).

- The placement of two equal resistors in series with the contact resistance at the left-hand side and the right hand side mastoids. The reference electrode is then located between the resistor.

- The approach of recording data with separate references electrode at the mastoids and average the resulting potentials by analogue of digital method (Mathematically linked).

Fortunately digital recording allows re-calculation of signal with any choice of reference after recording.

2.11. Recording Procedure: (Figure 2.4.)

Subjects had an electrodes cap on their head hold 32 tin electrodes sites to the scalp (Figure 2.5.), Electro-cap international were designed by **NASA** in United States of America and made of elastic fabric which fits the geometry of the head, available in different sizes, large 58-62 cm head circumference, medium 54-58 cm head circumference, and small 46-50 cm head circumference. This cap contain 22 tin electrodes, built into small plastic buttons (0.5 cm) in an enhanced international 10/20 electrode placement system (Jasper, 1958). They did not use the more common silver electrodes, because it would be impractical for silver to be imbedded in a cap, as it needs to be regularly chlorided to prevent oxidation and polarisation. Gold, silver, and platinum can be polarised, which occurs when a current passes between a pair of electrodes and causes electrolysis and produce a standing voltage between electrodes. Variation in this voltage is a source of noise and can affect the electrode's frequency response. A non-polarisable electrode is one whose properties do not change if a current passes through, and any ion transfer that does occur can be completely reversed. Pure tin possesses the qualities necessary in an electrode material of minimal standing potential between electrodes and is non-polarising. This ensures low and constant resistant to the flow of the current.

To insure the correct size of the cap, we had measured the subject's head circumference with tape measure. Rubbing a cotton swab dipped in a suitable conductive abrasive preparation compound called SkinPure (Figure 2.6) cleaned skin electrode sites. Two tin electrodes were fixed on the subjects' right and left mastoid, and then used as a linked reference. Electrodes were affixed with surgical adhesive tape, and **Elector-gel (eci)** was injected to fill the gap between the skin and the electrodes. Mastoid references are preferred for examining the distribution of cortical activity. Then the cap pulls over the head adjusted to give correct electrode

placement, and fixed and secured by elastic straps from each sides of the Electro-cap to around a chest belt, to be fit secure, and avoid the discomfort feeling from fixing and securing it under the chin. The gap between the electrodes and the skin was filled and bridged with a high conductivity, non-saline electrode gel to prevent corrosion of the electrode and skin irritation, and which is formulated for use with Electro-cap system (Electro-gel. Figure 2.6.), after the skin was slightly scratched and scarified (abraded) through the hole on the top of the electrode using a blunt needle to remove the sebum or the scale and lower the impedance. Scarifying and adding the Electro-gel was continued till equal electrode impedance below 5 KΩ was achieved.

Electrodes are applied for long-term recording (1-1.5 hours), thus electrode gel should not contain irritants such as calcium chloride because this substance has occasionally caused skin burn and granulomatous reactions (Schoenfeld et al. 1965; and Giffin & Susskind, 1967) The locations for these electrodes include all the

standard international **10-20** system location **(Jasper, 1958) Figure 2.7.** Four electrodes were affixed with surgical tape and were filled with Elector-gel for monitoring the eye movement artefact, the skin electrode site prepared by rubbing the skin with Skin Pure gel. The first couple **(VEOG)** above the right eye and beneath the left eye to check for eyes blinks and vertical movements. The second couple **(HEOG)** was placed on the outer canthus of the right and the left eye to check the lateral and horizontal movement. The impedance between each recording site and reference was reduced to below **5Kohms.**

Subjects were seated in front of a computer monitor (IBM 14 inch) on a comfortable reclining chair, the chair back was high enough to allow all subjects to relax. Any

tension of their head and neck muscles could interfere with our recording. The recording room was quiet, temperature controlled and dimmed (Figure 2.8.).

I asked the subject to avoid blinking except when the screen was blank. We did all our best to put the subjects at their ease.

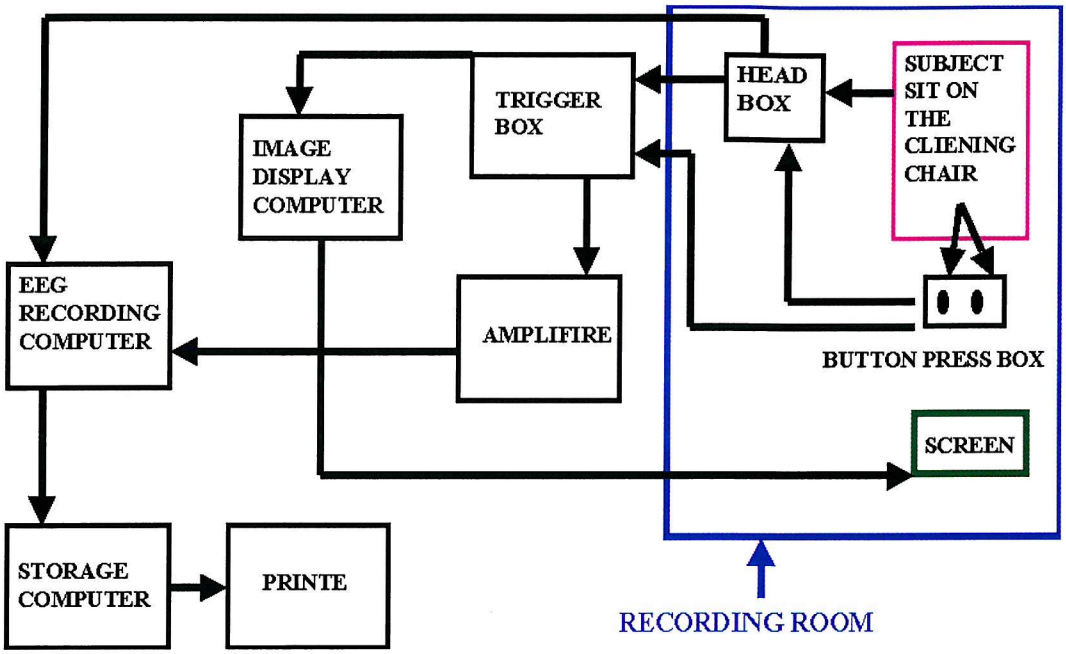


Figure (2.4.) shows the recording procedures diagram.

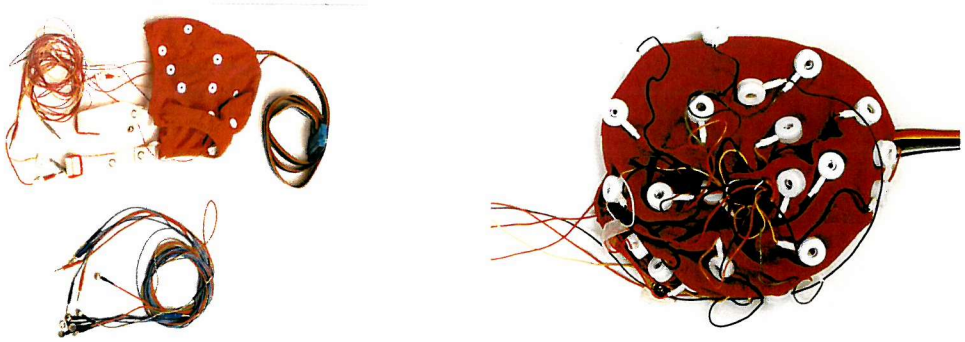


Figure (2.5.) shows my study ERPs recording cap electrode with the extra electrodes and the connecting cable to the headbox. Group of the tin electrodes

Figure (2.6.) shows my study ERPs recording materials, flexible tape measure, swabs, blunt ended needle (scarifier), syringe, electrode gel (eci), a mild skin abrasive (skin pure).

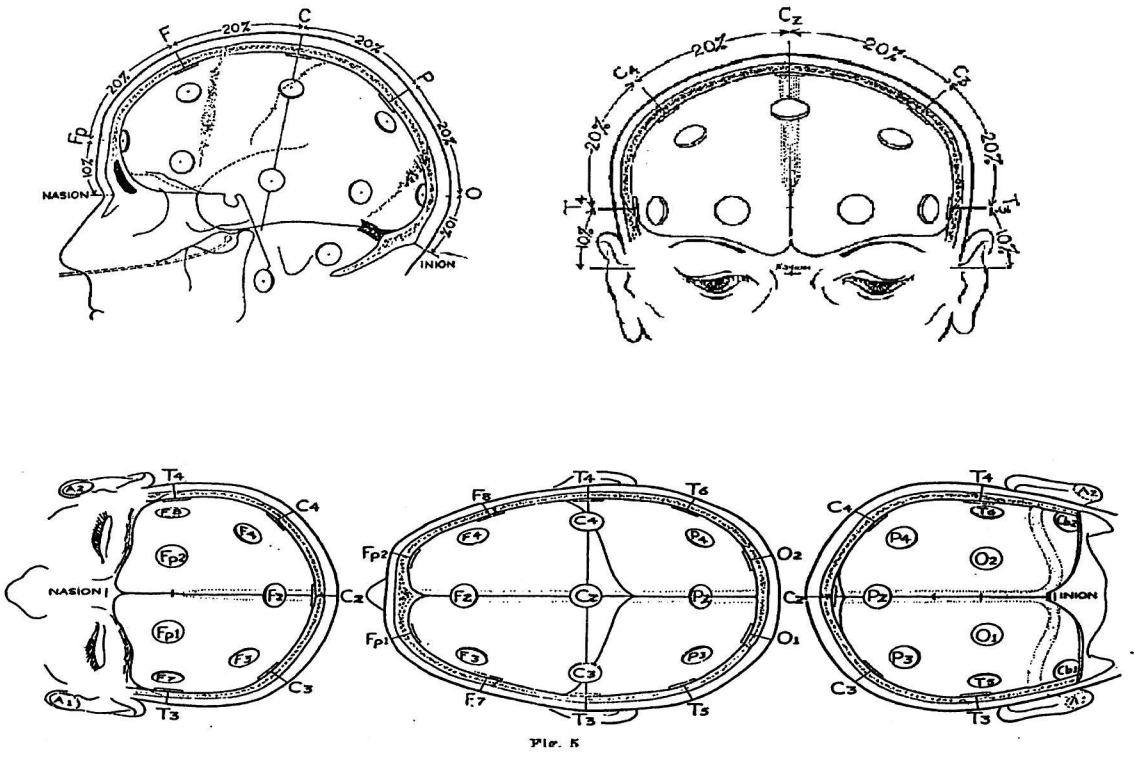


Figure (2.7.) Shows the Standard Position for placement of EEG electrodes in the 10-20 system. The abbreviation stand for A = Auricle, C = Central, F = Frontal, Fp = Frontal-pole, O = Occipital, P = Parietal, and T = Temporal. Letter Z represents the midline electrodes.

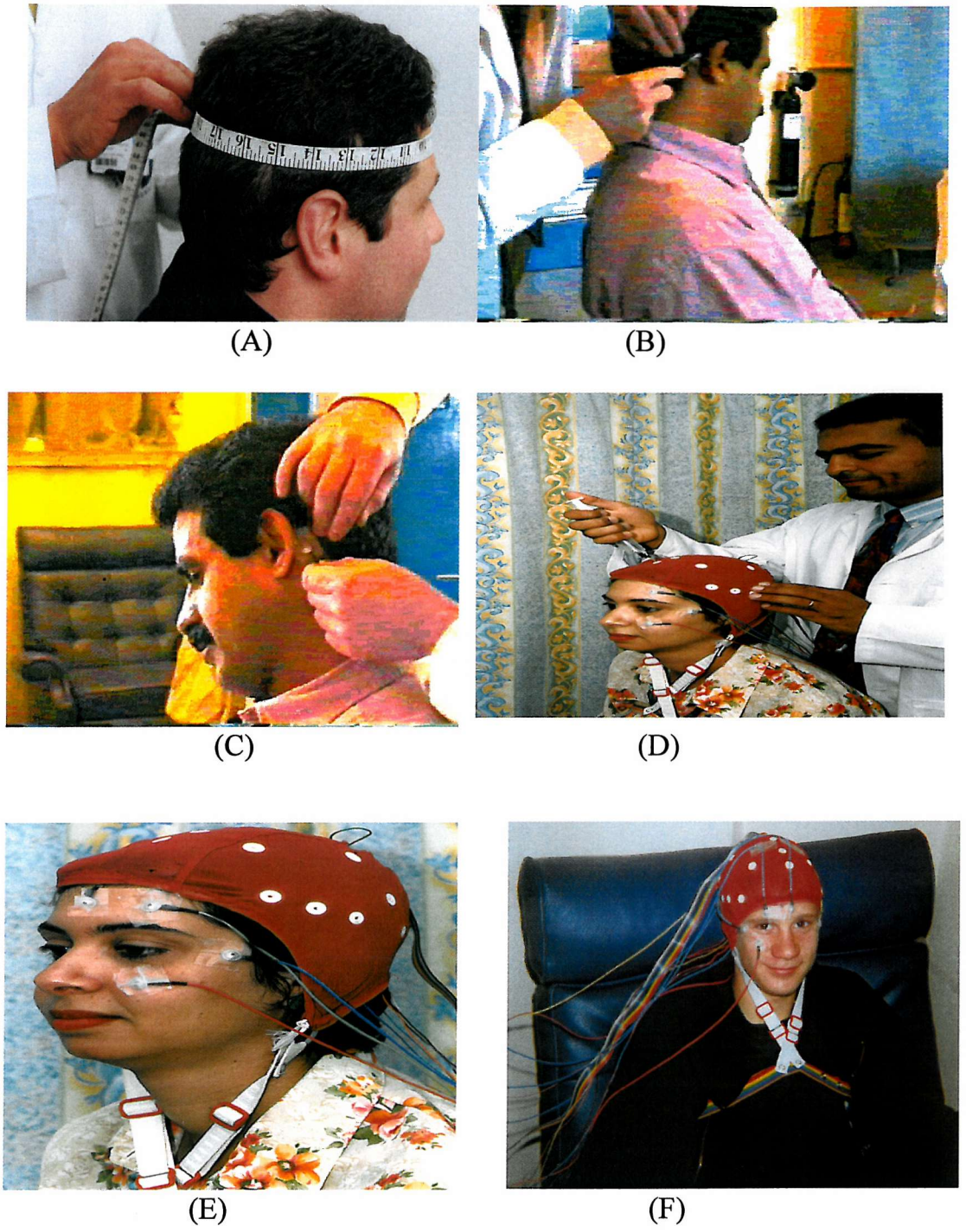


Figure (2.8.) shows recording procedures (A) Head measurement, (B) skin preparation, (C) placement reference electrode (D) injecting the electro-gel (E) electrodes and cap electrodes placement, and (F) Subject sitting in the recording room

The electrodes and the cap could be removed without difficulty and the gel wiped off easily. We cleaned the cap thoroughly to be ready for the next recording.

All subjects completed the questionnaire after finishing the task to give us their comments about the task. (Appendix. II)

2.12. Equipment and recording systems (Figure 2.9.):

The cap electrodes discs are made of pure tin with low resistance to the current flow and good polarisation characteristics fitted to the cap by plastic rings and connected to the head box by one-meter length cable. It is a thirty-two channels head box. There are two channels for the ground, two channels for the subject response buttons and two channels for the references. It contains the first stage of amplification to reduce the effect of noise encountered during conduction into the main amplifier. **The input impedance was high (15)** The signals pass by shielded cable to be amplified by the SynAmps amplifiers in AC mode, containing analogue components needed to amplify the low level signals. An analogue-to-digital converter (ADC) coverted the analogue signals to digital for further processing, and was controlled by NeuroScan 3.0 (386 version 1992) software model 5083, amplifier filter bandwidth was 0.01-30.0 HZ. Further digital filtering could be applied.

Personal computer GATEWAY2000 displayed the stimuli and was linked to a specially designed box (trigger box), which was also linked to a channel of the amplifier. The trigger box required the timing, and categorisation of the stimuli and the subject responses to a second computer, which ran the NeuroScan acquisition software. This recording EEG computer was linked to extra computer used as a

storage unit for the raw EEG and averaged ERPs. Coloured printer (HP Desk Jet 550) was connected to both computers to produce a hard copy of the results.

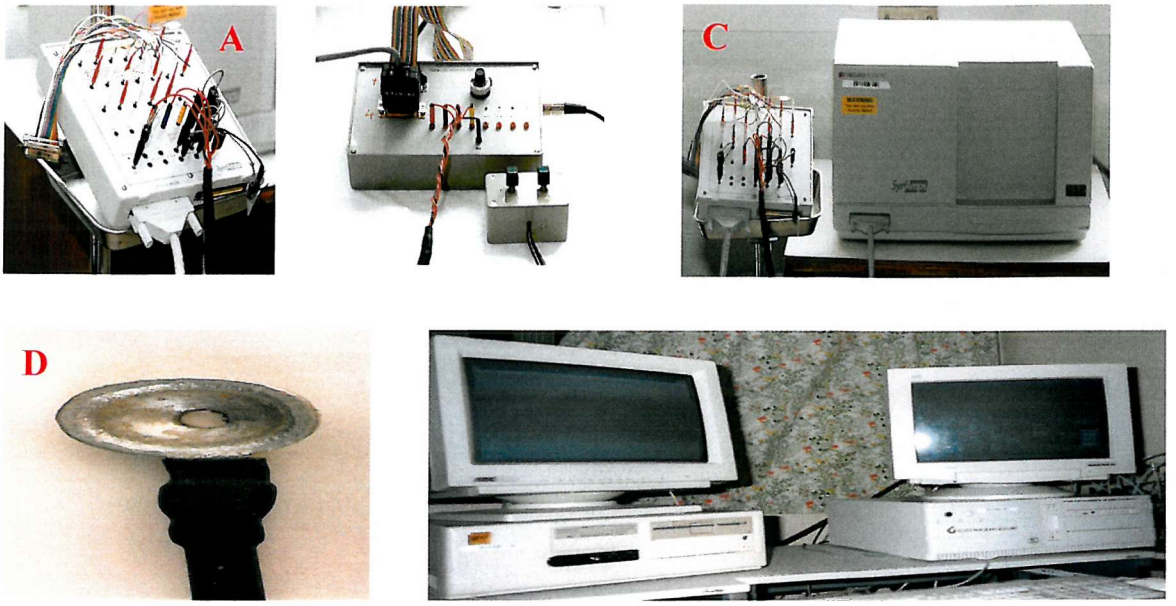


Figure 2.9. Shows recording equipment's (A) the head box (B) the trigger box (C) the head box connected to the amplifier, (D) zoom to one tin electrode cup, and (E) EEG and Pattern Computers

2.13. The acquisition value: (Figure 2.10.)

The EEG was digitised at **4 ms per point** for **630** points and time-locked to stimulus presentation. This gave individual epoch recording from **-500 msec**. to **2020 msec**. Thus a **2520 msec** recording. With **500 msec** pre-stimulus baseline.

Sweeps in which the EEG exceeded ± **70**μv were manually rejected **(2%);** post recording baseline correction between **-200 ms**. and **0 ms**. was applied to individual average files.

The signal filtering capabilities required depend on the frequency component of the signal. Approximate values of 1, 5, 10, 25, 100, and 300 Hz should be available as

low cut-off (high pass) and 100, 250, 500, 1000, and 3000 Hz should be available as high cut-off (low pass) filters. To record the endogenous event-related potentials 0.3 to 1-Hz high pass and 30.0 to 100.0 Hz low pass filters are commonly used. We used 0.3 Hz high pass and 30.0 Hz low pass.

Another problem that can arise concerns sampling. The input waveform is sampled at constant intervals along the time scale. The number of points used for sampling or the sampling rate (points per sec) is an important parameter in digitisation. If it is incorrect aliasing can occur. This effect can be illustrated in western movies. The film camera samples the visual scene at some fixed rate, each sample occupying one frame of the film. If a wagon wheel is rotating slowly enough, the motion is reproduced faithfully, but at higher rates of motion the wheel may appear to rotate more slowly than its actual rate and may even appear to rotate backward. The false rotation speeds are generated because the movie camera's sampling rate is too low to accurately record high rate of rotation.

Similar considerations apply to the sampled EEG waveform. Errors will result unless the sampling rate is more than twice the highest frequency present in the EEG. This minimum sampling rate requirement is known as "the Nyqvist criterion". Inadequate sampling introduces an "alias' error if the frequency content of the input signal is too high in relation to the sampling rate; the Nyqvist theorem requires that the rate of sampling must be at least twice the highest frequency in the analogue signal. In practice it is better to have an even higher sampling rate than the theoretical one.

A third potential problem concerns high frequency cut-off amplifiers. Unlike the short latency responses to auditory or somatosensory stimuli, the late components themselves have comparatively low frequency (e.g. P300) or even slow potential

waves lasting for second rather than milliseconds (e.g. CNV). The consequences of having a time constant that is too short are a reduction in the amplitude of the component and a shortening of its latency, thereby distorting its true value. The choice of high frequency cut-off amplifiers is also different from that for sensory evoked potentials. Many investigators record with a cut off less than 50 or 60 Hz, thus avoiding possible problems with main interference while adequately characterising the ERPs.

AMPILIFIERE	
Gain	50
Low cutoff	30 Hz
High cutoff	0.15 Hz

Analogue to digital rate	250
Acquisition type	Epoch
Negativity	Upward

Epochs	
Sweeps	200
Points	625
Start (msec)	- 500
End (msec)	2000
External hold value	0
Multiple window display	☒

Baseline correction	
Start (msec)	- 200
End (msec)	0

Epochs Display	
Y min (uV)	**- 100**
Y min (uV)	**100**

Channels (n = 30)			O1	O2	F3	F4	C3
C4	P3	P4	FCZ	POZ	F7	F8	T3
T4	T5	T6	FPZ	FZ	CZ	PZ	OZ
ATL	ATR	TPL	TPR	TRG1	TRG2	HEOG	VEOG

Figure 2.10. Shows the recording acquisition value.

2.14. Noise and interference

Methods of recording and measuring very small signals such as ERPs are basically procedures for eliminating noise (defined as undesired signals). Event-related recording requires separation of the nervous system's responses from accompanying noises. In ERP recording the three major sources of noises are:

1) The electrical environment (nearby AC voltage sources, such as main-powered lights and main cables), and magnetic or radiated interference.

2) Internal instrumental noise e.g. amplifier noises.

3) Biological noises: examples of such artefacts are those resulting from main pulses, eye movements, eye blinks, the activity of facial muscles, tongue movement or movement of the subject (myogenic electrical activity). These artefacts fall into two classes:

a) Those that are not time-locked to the stimulus.

h) Those that are time-locked to the stimulus.

Commercial averagers are often provided with an artefact reject mode of operation. This mode cuts out any trials with unusually large voltage. The ability of modern equipment to extract a hidden signal from noise is indeed impressive, but it is a dangerous mistake to overestimate the equipment's ability to reject non-signals.

Prevention is by far the best approach when dealing with noise and artefacts: clean inputs are preferable to noisy inputs. Rather than relying entirely on the computer, it can be enormously to one's advantage to decrease both the number of artefact-contaminated trials and the degree of contamination by carefully instructing

the subject to relax and to blink as little as possible during the recording, and ensuring that the subject is truly comfortable. For example, if a chair is used, the correct height is crucial.

2.15. Average

The electrical response of the brain to the stimulus always occurs at the same interval after the stimulus, whereas the background electrical activity is not coupled to the stimulus. Averages will extract the desired ERP waveform from the random background noise (Chiappa, 1982). This technique makes a significant improvement of the signal-to-noise ratio and permits the recording of very small ERPs.

The principal of averaging method is similar to the superimposition technique, which was used more than a century ago by Galton. One of his aims was to identify common features in the faces of murderers and violent criminals.

It was the practical problem of recording reliable somatosensory ERPs in myoclonic epilepsy that led Dawson to use the superimposition technique of signal-to noise enhancement in ERP recording. Using the statistical theory of averaging he created a powerful practical tool, known as an automatic signal averager, which he demonstrated to the Physiological Society in May 1951 (Dawson, 1951). Dawson's automatic signal averager can be seen in the Science Museum in London.

With the advent of computer averaging, it became possible to obtain an estimate of activity, which is time-locked to an arbitrary point, such as the onset of a stimulus. At the scalp an event related potentials (1-20 microvolts) is substantially smaller in amplitude than the background EEG (50-100 microvolts) and must, therefore, be extracted by an averaging procedure using software such as NeuroScan. This involves recording ERPs for repeated presentation of 'similar' stimuli. Each stimulus

is recorded as a discrete 'sweep' lasting a few seconds each. Once enough of the same type has been recorded they can be averaged together. To record late event-related potentials, fewer than 25-30 trials on average do not usually provide a good signal-to-noise ratio (Kutas & Van Petten, 1990). However, as the number of sweeps is increased the ERP waveform becomes easier to distinguish from the background activity. Fifty or more sweeps have been averaged usually in my work.

The mainstay-evoked potential signal processing is averaging. The stimulus is presented many times and the EEG signals for the duration of interest immediately following are summed and then divided by the number of presentations to obtain the average evoked potentials as shown here and in the equation, the 'n' is the number of sweeps.

$$S/N \propto \sqrt{n}$$

This technique makes a significant improvement of the signal-to-noise ratio and perm to the recording of very small-evoked potentials.

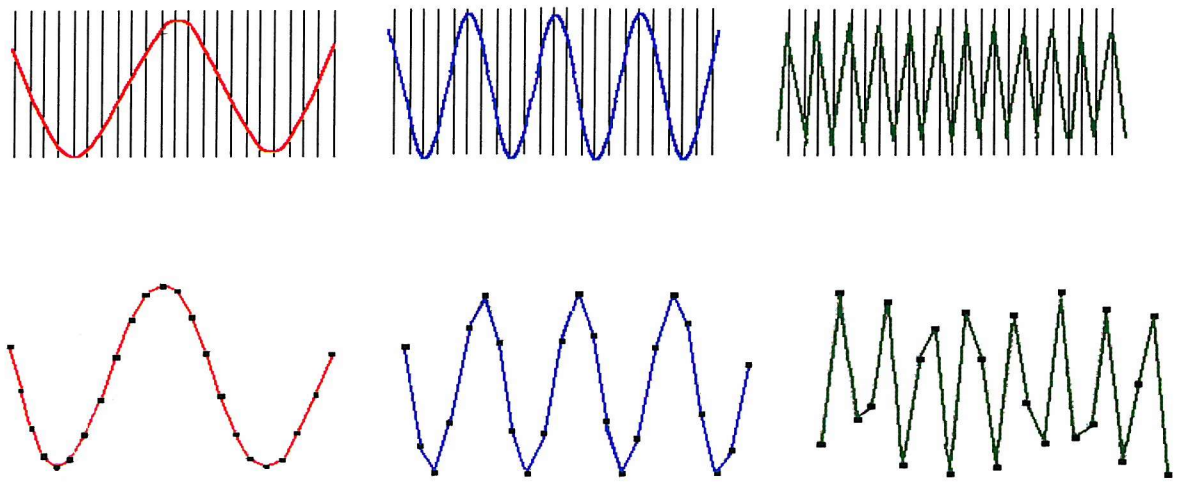


Figure 2.11. Shows the relation between the sampling rate and the signal frequency. The sampling rate must be at least double the fastest signal of interest frequency.

2.16. BRAIN MAPPING

The goal of the brain mapping is to isolate local neural activity associated with sensory, motor, and cognitive functions. The current flow either into or out of a cell through charged neuronal membranes generate the ongoing EEG. The EEG recorded at the scalp is largely attributable to graded postsynaptic potentials (PSPs) of the cell body and large dendrites of vertically oriented pyramidal cells in cortical layers three to five (Lopes da Silva, 1991). These synaptic potentials are of much lower voltage than action potentials, but they also last much longer and involve a larger amount of surface area on cellular membranes and, as a result, the extracellular current flow produced by their generation has a relatively wide distribution. Several factors determine the degree to which a cortical potential will be recordable at the scalp, including the amplitude of the signal at the cortex, the size of a region over which PSPs are occurring in a synchronous fashion, the proportion of cells in that region which are in synchrony, the location and orientation of the cells in relation to the scalp surface, and the amount of signal attenuation and spatial smearing produced by conduction through the intervening tissue layers of the dura, skull, scalp. PSPs are thought to be synchronised by rhythmic discharge from thalamic nuclei (Lopes Da Silva, 1991), with the degree of synchronisation of the underlying cortical activity reflected in the amplitude of the EEG recorded at the scalp.

2.16. NeuroScan

NeuroScan software (version 386 and version 4.0.30) was used to record and display of the data. This program is divided into six sub-modules as shown in (Figure 2.12. & 2.13.). Each module performs a different function on the data: Acquisition and on-line processing is performed by **Acquire program;**

Topographic mapping by **Window program;** Statistical analysis by **Stats program;** map template construction by **Mapgen program,** retrieve raw data, viewing and edit by **Edit program** and image editing by **Draw program.**

The NeuroScan Acquire program records averaged, epoch, and continuous EEG data from up to 64 channels with the scan system. The collection of data mainly done by the general steps, first step is to select a set-up file to configure the system (set individual parameters related to data acquisition), then number two enter subject information and finally acquire (and save) the data.

The NeuroScan Edit program performs a variety of off-line modifications to EEG data attained by the acquire program. Mainly used for averaging after observing all the sweeps one by one by eye, then rejection done for contaminated trials by eye-movement, muscle, or amplifier saturation artefacts. Baseline correction was set for -200 msec to 0 msec.

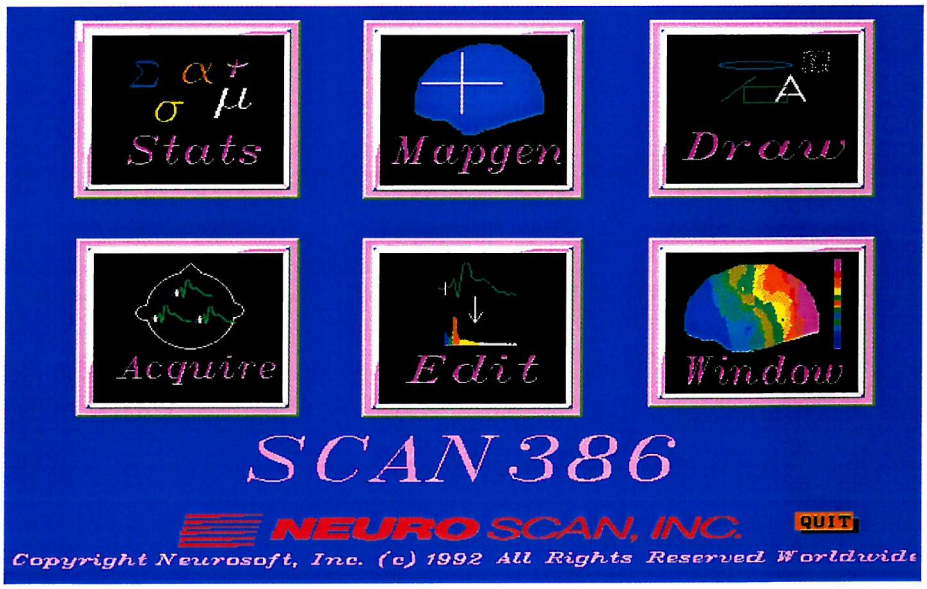


Figure 2.12. Shows Neuroscan version 3.0

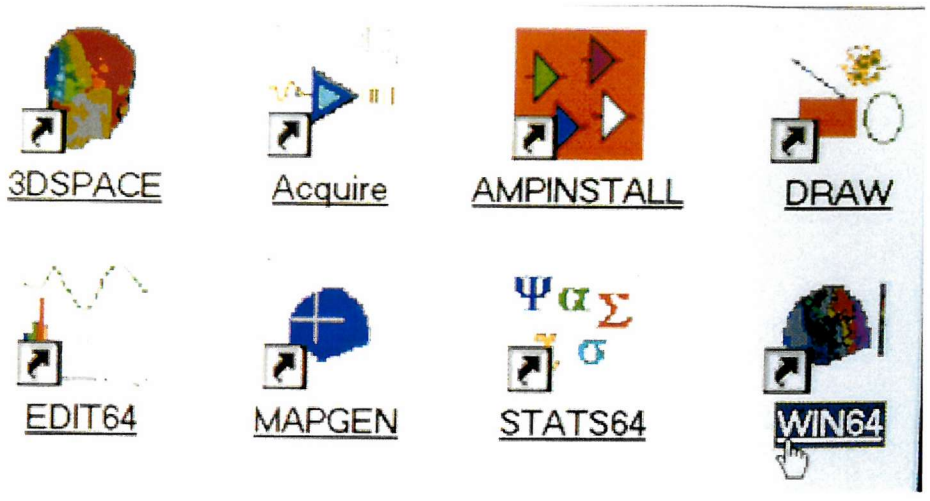


Figure 2.13. Shows NeuroScan version 4.0

The ERPs were averaged for each subject in each needed condition (all the trials, First and last fifty trials, Correct and incorrect trials, and for the pattern A & B trials). Over an epoch beginning 500 msec before stimulus onset and extending 2000 msec post-onset. The stimuli were exposed for 2000 msec on a computer monitor, and the interval time between them was 2000 msec and saved.

The NeuroScan WINDOW program topographic mapping package in colour or black and white, can map the averaged sweeps or single sweep of the recording data. This technique of the topographic mapping for displaying the waveform data from large multi-electrode arrays. The results are a multicolour surface that represents the scalp distribution of voltage. The general idea is to take an array of electrodes, e.g., the 10-20 system, and place this array on a computer-generated surface. The WINDOW program (part of Neuro-scan) applies a colour gradient to a range of voltage (or other computed statistic) amplitudes represented at all electrodes. With mapping, the voltage values are displayed on a surface in the form of colour

intensity gradients. Since there are typically fewer electrodes than points on the surface, missing values between the individual electrodes are 'filled in' with an interpolation algorithm. Then, the greater the number of electrodes used to cover the scalp, the smaller the inter-electrode spacing, and the greater the spatial resolution. The result is a multi-coloured surface that represents the scalp distribution of voltage. Basically there are four methods can be displayed by which the map in NeuroScan. Animated maps can be made into movies, which are played back on the computer screen. Cartoon maps of each msec. for a given time window can sequentially be displayed and run in several pages and can also be scrolled through, the cartoon series of small maps each corresponding to a short segment of large time window from the averaged waveform and show evolution of potentials. A large map can also be made for specific time range. These maps can be shown with or without the electrodes superimposed, by placing the cursor anywhere we can map at any latency. To study the potentials we were using the top view, right view, and left view. The scale is always shown to the right-hand side of the cartoons or large map figures, in the form of colour intensity gradient. Brain activities can be highlighted in different scale because these maps depend on the potentials scale factor. Maps show spatial and temporal changes, but the comparison is qualitative rather than quantitative, and it is useful method for combining the information from multi-channel recording.

Large maps and cartoon maps were used (Figures 2.14a and 2.14b). A large map is a full-sized map of a waveform over an interval of time. The cartoon is a series of small maps, each corresponding to a short segment of a larger time interval for a waveform average file and shows the evolution of potentials. The colour scale represents the maximum and minimum amplitudes and all other intervening amplitudes.

The rationale for topographic mapping is that the traditional EEG or ERP tracings contain information, which under normal circumstances is not observable by the naked eye. This is because there is simply too much data in a form unsuited for visual analysis. In this instance, the solution is to apply mathematical processing for interpolation of data to derive spatial bitmaps. To discern the interrelationships between different scalp locations, one can merely arrange such a plot in a manner so as to mimic a head diagram. This results in a two-dimensional spatial bitmap. In the MAPGEN program, the window can display data on mapping templates created by the user.

The NeuroScan MAPGEN program general purposes map template generation and editing. The program uses a shape created with the draw screen editor as a surface for mapping template, this mapping template contains information about the location of the electrodes in addition to the surface, and it is used by window program to construct topographic maps of waveforms and spectral data. I draw my own electrodes configurations for the top, right hand side electrodes, left hand side view to give me the opportunity to use WINDOW program to process my volunteers brainmaps.

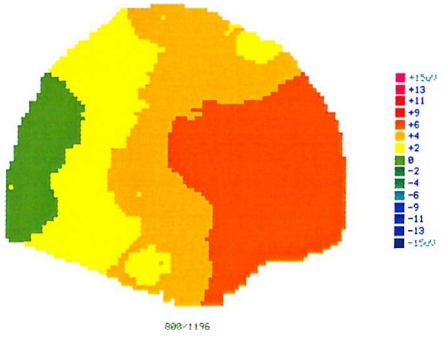


Figure 2.14a. Shows right-hand side view large brainmap. The maximum and minimum amplitudes and all other intervening amplitudes represented by the colour scale.

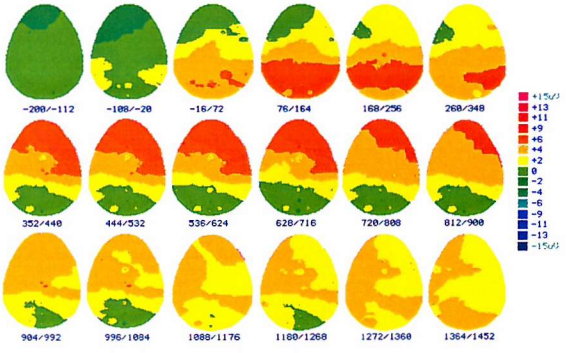


Figure 2.14b. Shows top view cartoon brainmaps. The maximum and minimum amplitudes and all other intervening amplitudes represented by the colour scale.

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The NeuroScan STAT program is designed as an exploratory data analysis tool for first look at statistical comparison creating group average waveforms. Comparing two group-averaged waveforms, comparing individual average waveforms with group averaged waveform, comparing two individual average waveforms. Import of ASCII data files obtained from another acquisition system for further analysis. Export scans averaged files to ASCII files format. Subtraction of two groups averaged waveforms and left hand side and right hand side averaged waveforms.

2.18. Statistical Analysis:

There were many quantitative measures and statistical procedures available. The files can be exported to other programs for required analysis. Before embarking on analysis I had to access the subjects' performance.

2.18.1 The subjects' performance learning was accessed by CUSUM statistical method:

Industrial processes were monitored by the developed control chart during the 1930's, the important processes control parameters (mean or standard deviation) of sequences of random variables were plotted in simple graphs versus time, or the number of items produced (De Bruyn, 1968; Royston, 1992).

The CUSUM (Cumulative Sum) technique is among simplest statistical manoeuvre available that makes possible rapid analysis, identification, and powerful assessment of trends in a series of data (De Saintaoge et al, 1974; Kinsey et al, 1989). The cusum assessment is retrospective, not prospective (Robinson et al 1974).

More recently, CUSUM was used by several researchers to do rapid, and accurate evaluation for variables such as, surgical trainee performances (Van Rij et al, 1995),

sigmoidoscopy results of novices performances in comparison with experienced personnel (Williams et al, 1992). There is no universally accepted method of quantifying circadian blood pressure patterns, but the cusum is a valuable methods for circadian blood pressure assessment (Staton et al, 1992), also measuring the competence of anaesthetic trainees at practical procedures (Kestin, 1995). Retrospective analysis by cusum plots conventional temperature charts of neutropenic patients (Kinsey et al 1989), pregnancy, death, recurrence of diseases, and so on, occur commonly in medicine.

The CUSUM starts at zero, increasing in the cusum trend indicate success (figure 2.15), and a declining in the cusum trend indicate failure (Figure 2.16). We have derived learning curves from the results of the random visual stimulus experiment, by assigning the value 1.0 to each success, and the value 0.0 to each failure. As the performance of the subject is seldom perfect, it is usual to allow a certain tolerance e.g. a 10% (0.1) failure rate. A subject performance with 90% success will generate an upward line and the line will move downward for a worse performance. Individual increments for the cusum would then be 1.0 - 0.1 = 0.9 for each success, and 0 - 0.1 = -0.1 for each failure.

This may be express mathematically as: - CUSUM (i) = $\sum$ (Result (i) - Tolerance)

The results were analysed, and curves plotted, using the MathCad computer aided design software package (MathSoft).

We set our tolerance at 30%. Subjects learning within this tolerance produce ascending line, subjects not learning produce a descending line (Figures 2.15 & 2.16.)

Connectionally, at the beginning of measurement, the CUSUM start at zero. With a successful process the CUSUM increases to positive value, with failure it declines to more negative value.

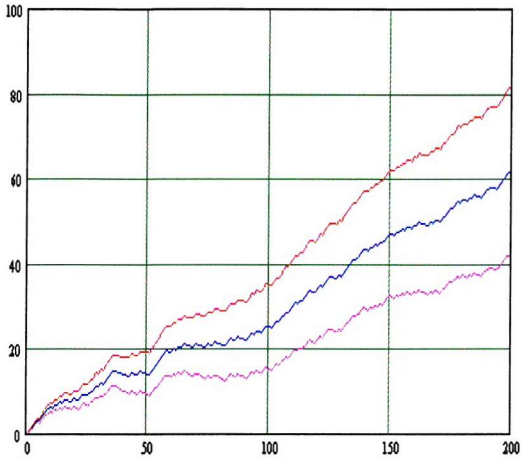


Figure 2.15. Shows learner's performance. Tolerance 10% (0.1) failure rate in red line, tolerance 20 % blue line, and tolerance 30% pink line. Y-axis: represents the performance. X-axis: represents the 200 trials.

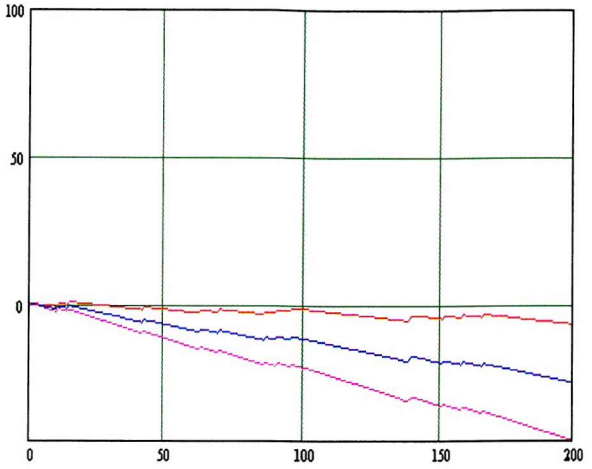


Figure 2.16. Shows non-learner's performance. Tolerance 10% (0.1) failure rate in red line, tolerance 20 % blue line, and tolerance 30% pink line. Y-axis: represents the performance. X-axis: represents the 200 trials.

2.18.2. Decision time statistical analysis:

Each subjects decision time and performance for each experimental condition in both groups (learners group and non-learners group), logging (text) files were transferred to the Statistical Package for the Social Sciences **(SPSS).** Then Mean maximum value, minimum value, and standard deviation (SD), have been quantified and compared for each one of these conditions all the task subjects decision time. Beginning of the task (first fifty), end of the task (last 50). Correct, incorrect trials subject's decision times and patterns A, and pattern B as well

2.18.3. Event related potentials statistical analysis:

I have grand averaged for learners group and non-learners group, the correct & incorrect answer trials sweeps, and first fifty & last fifty sweeps; the ERPs were measured, quantified & compared. There are some common methods to measure the amplitude and the most commonly used are these two which called "absolute amplitude". First is "baseline to Peak" but sometimes it is difficult to define the base line, which make this more subjective method than the second one. Second one is "Peak to peak" by measuring the peak of one polarity to the immediately following peak of the opposite polarity. Because of the activity producing the first polarity may have nothing to do with the immediately following peak of the opposite polarity so it looks like mixing apple with orange. Area measurement is another method, which is theoretically the most sensible technique and effectively can be done by using the computers. To be more accurate I chose the most commonly used method in this same research area. The mean amplitudes were calculated, by using the mean value of many points within a time window. The windows which extend from the beginning to the end of the target or desired component. The first time window was (250 msec to 500 msec) after the stimulus and the second time window was (500 msec to 800 msec) after the stimulus and both of them is 75 sampled points.

Then the data was transferred in an ASCII format to the statistical package for the social sciences (SPSS) for statistical analysis, by using the file export Programme facility which is part of Neuro-Scan software. The latency and amplitude were analysed for each experimental condition and each single subject separately by using summarise, and descriptive procedures, and the data expressed in mean, minimum, maximum, and standard deviation (SD). The amplitude and latency

means were compared by Independent samples & paired T-test for within group, electrode locations and within the two hemispheres in the same group for the same experiment condition. Repeated measures of Variance ANOVA-models with different independent variables and different groups. A repeated measure design is when the same variable is measured on several occasions for each subject. The simplest repeated measures design is one in which two measurements such as pre-test and post-test scores are obtained for each subject. These types of data are usually analysed with a paired t test. The advantages of repeated measures are, besides requiring fewer experimental units (in this study, human subjects) they provide a control over differences among units. That is to say variability, due to differences between subjects, can be eliminated. In repeated measures ANOVA, several hypotheses are automatically tested.

The first hypothesis is that the overall mean of the data is (0). For example, I recorded ERPs from 24 locations (electrodes), 6 electrodes for the midline locations, and 18 of them placed laterally (9 on each side of the head). I presented two different Images (type A & type B), and recorded from 99 subjects. I analysed statistically if there is any difference between the amplitude of ERPs obtained from 25 different locations of scalp, whether the amplitude of ERPs is affected by the pattern type and whether there is any interaction between locations and types (Location X experiment recording condition = two ways repeated measures). If there is any interaction between locations, left and right hemisphere and the type of stimuli and the type of the subjects group (Location X experiment recording condition X left to right side = three ways repeated measures), which tends to be overly conservative, especially for small sample sizes. The Greenhouse-Geisser correction procedure was used to adjust the degree of freedom for violation and sphericity assumption intrinsic to repeated measure in ANOVA design when

appropriate. These corrected results are approximate and are based on the adjustment of the degrees of freedom (DF) of the F ratio.

Table (2.2a & 2.2b) shows an example of the results of repeated measures, the mean square (MS) shown in the fourth column which is obtained by dividing each of sum of squares (SS) by the degree of freedom. Hypothesis tests are based on the ratios of each source of variation mean squares to the residual mean square. The larger the F value, the smaller the observed significant level (≤ 0.05) and indicate that the hypothesis that the constant is zero is rejected.

Source of Variation	SS	DF	MS	F	Significance of F
Location	264.185	(8,112)	33.023	2.18	0.034
(greenhouse-Geisser)	264.185	1.896	139.354	2.18	0.01

Table (2.2.2.) shows the significance of F value before and after using the greenhouse-Geisser for location within subjects effect. p * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001.

The following table (2.2.3.) are an example of testing interaction. The F value associated with the group and electrodes locations is 20.60 and the significant level by considering Greenhouse-Giesser correction is 0.135, therefore, it appears that there is not an interaction between group and locations.

Source of Variation	SS	DF	MS	F	Sig. Of f
Group X Locations	489.560	24	20.398	20.60	0.324
(greenhouse-Geisser)	489.560	2.412	202.943	2.060	0.135

Table (2.2.3.) shows the significance of F value before and after using the greenhouse-Geisser by using two ways ANOVAS (group X location within subjects). p * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001.

Latency and amplitude increase and decrease were studied and assessed by inspection through the event related potentials waves morphology (positive and negative deflections), comparison was made between the averaged all sweeps,

correct & incorrect responses sweeps, first & last 50 sweeps, and right and left side sweeps too.

Most of the statistical results obtained from my experiments are presented as tables and Error Bar charts that plot the mean value of data, the confidence intervals, standard error, or standard deviations of individual variables. I have chosen Error Bar charts for many reasons. Firstly, they can show summaries for groups of cases or summaries of separate variables and can be simple or clustered. Secondly, they can present three different types of statistics: confidence intervals, standard errors, or standard deviations. 1 have chose the 95% confidence interval, which reaches approximately two standard deviations on either side of the mean.

2.19. Experiments:

2.19.1. Experiments 1: with feedback and without rule (Fr)

2.19.1.1. Subjects:

The subjects were **34** young adult volunteers **(15 females & 19 males)** participate in the same task, aged **21:34** years.

2.19.1.2. Task:

Subjects were asked to make a single response as promptly and accurately as possible to each image within the image display time (2-sec.). As soon they pressed one of two buttons **A** or **B** according to his/her decision and we gave them screen message feedback 'Right' (Figure 2.17a) or 'Wrong' (Figure 2.17b) directly

without delay. Feedback may be defined as any signal to a learner, which indicates the correctness or incorrectness of his previous response (Bourne, et al. 1971).

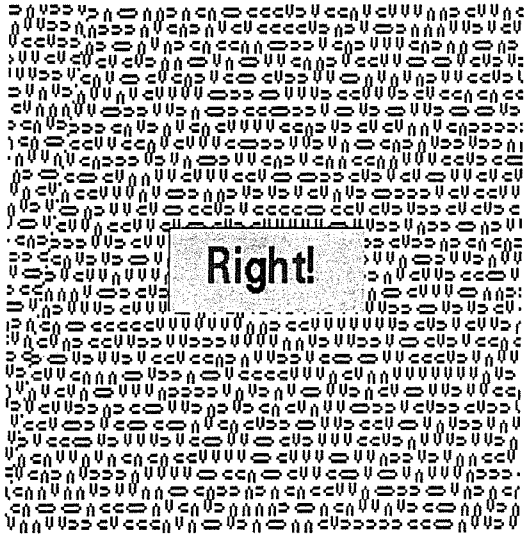


Figure 2.17a. Shows image type A when displayed and feedback is correct as shown according to the subject response.

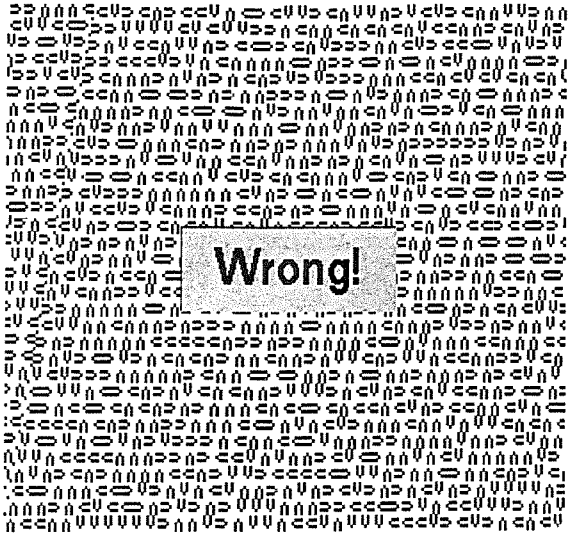
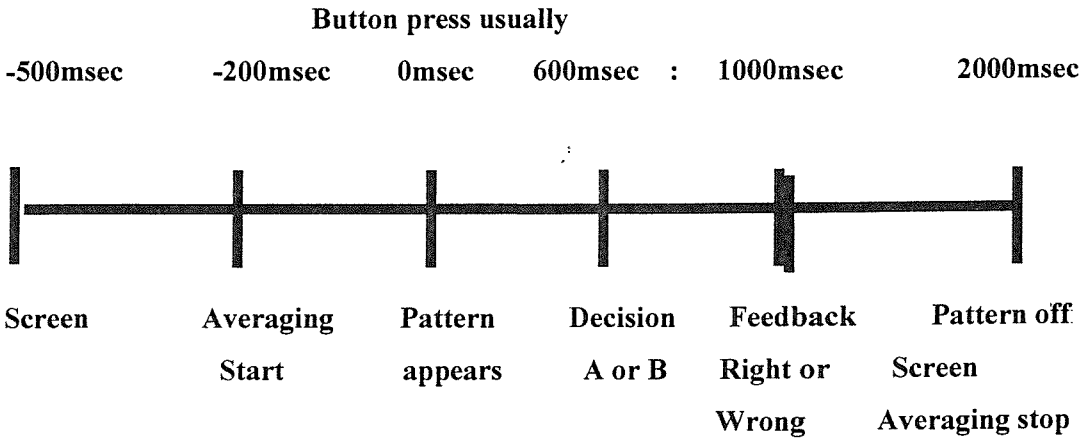


Figure 2.17b. Shows image type B when displayed and feedback is incorrect shown according to the subject response.

2.19.1.3. TRIAL



2.19.2. Experiment 2: with feedback and with rule (FR)

2.19.2.1. Subjects:

The subjects were 15 young adult volunteers (7 females & 8 males), participated, aged 18: 24 years (mean 21.13 ± 2.23).

2.19.2.2. Task:

All information's (explicit information) were given for these subjects about all the details of the pattern contents, and the differences between both patterns, simply telling them what is going on. 200 images of pattern A & B were displayed randomly for these subjects. Subjects were asked to watch the screen and find out the differences between the both patterns and making decision by pressing one of two buttons. We gave them feedback (right) or (wrong) according to them decision.

2.19.3. EXPERIMENT 3: without feedback and without rule (fr)

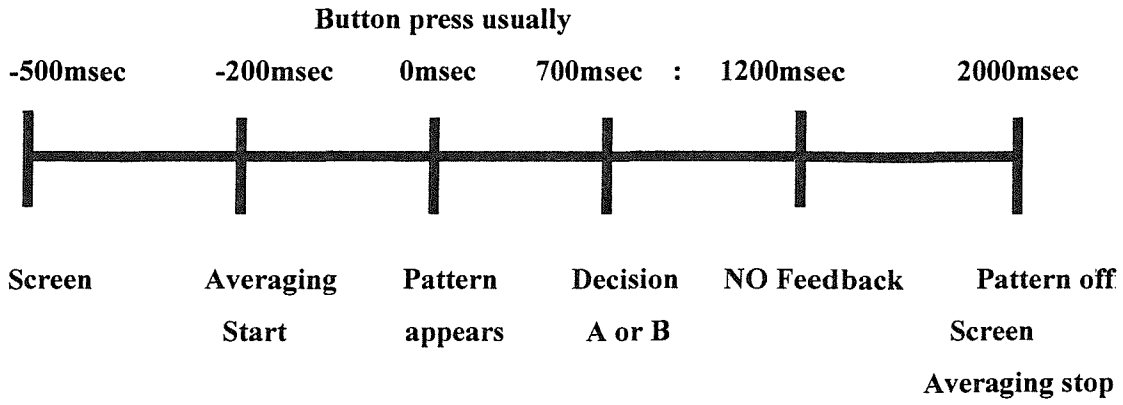
2.19.3.1. Subjects:

The subjects were **24** young adult volunteers **(10 females & 14 males)** participate in the same task, aged **19: 28** years.

2.19.3.2. Task:

Subject made a single response to each image as soon as possible within the image display time (2 sec.) by pressing the mouse button **A** or **B** according to his/her decision and we did not give them screen message feedback (guessing group).

2.19.3.3. TRIAL



2.19.4. Experiment 4: without feedback and with rule (fR)

2.19.4.1. Subjects:

The subjects were 15 young adult volunteers **(7 females & 8 males),** participated, aged **18: 24** years.

2.19.4.2. Task

All information's (explicit information) given for these subjects about all the details of the images contents, and the differences between both patterns. 200 images of pattern A & B were displayed randomly for these subjects. Subjects were asked to watch the screen and find out the differences between the both patterns and making decision by pressing one of two buttons, but feedback was not given to them.

2.19.5. Experiment 5: Observers

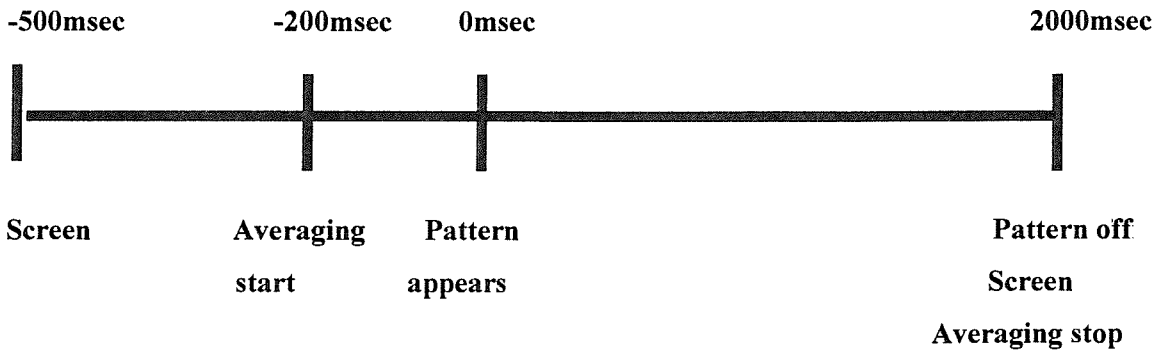
2.19.5.1. Subjects

The subjects were 11 young adult volunteers **(5 females & 6 males)** participate in the same task, aged **18: 30** years.

2.19.5.2. Task

The same patterns (A & B), and all the same image numbers (200) were displayed for these subjects. Subjects were just asked to watch the screen without either decision making or pressing buttons (Passive Group).

2.19.5.3. TRIAL:



Chapter3: RESULTS

3.1. General results:

Event related potentials were recorded from 24 scalp electrodes on ninety-nine normal healthy adult volunteers. They were aged from 18 years to 34 years (Mean 23.15 ± 3.21). There were 44 females (23.25 ± 2.83) and 55 males (23.07 ± 3.52). All subjects had normal visual acuity or corrected to normal.

Table 3.1.1. Summarizes the numbers of the female and male volunteers distributed in each group according to their age range. The first group (Fr n= 34) the females were 15 and they were aged 19-29 years, and the 19 males aged 18-34 years. The second group (FR n=15) 7 females aged 19-24 years and the males were 8 aged 18-24 years. The third group (fr n=24) there were 10 females aged 20-28 years and 14 males aged 19-27 years. The fourth group (fR n=15) 7 females aged 19-24 years and 8 males aged 18-24 years. The fifth group (observers n=11) 5 females aged 18-29 and there were 6 males aged 18-30 years. With feedback (F), without feedback (f). With rule (R), and without rule (r).

SEX	FEMALES		MALES		**Total**
	Number	Age	Number	Age	----------
F r	15	21 - 29	19	21 - 34	**34**
F R	7	19 - 24	8	18 - 24	**15**
f r	10	20 - 28	14	19 - 27	**24**
f R	7	19 - 24	8	18 - 24	**15**
Observers	5	19 - 29	6	18 - 30	**11**
Total	**44**	----------	**55**	----------	**99**

Table (3.1.1.) shows the numbers of the participant distribution and age range for the females and males in all groups. With feedback (F) without feedback (f) with rule (R), and without rule (r).

Table 3.1.2. Summarizes the age means ± standard deviations comparison between the learners (L) and non-learners (nL) in each of the experiments groups. There was no statistical significant difference between the ages of learners and non-learners in any of these groups. With feedback (F) without feedback (f) with rule (R), and without rule (r)

GROUPS	LEARNERS (L)	NON-LEARNERS (nL)
Group 1 (Fr)	**25.70 ± 3.08**	**24.10 ± 2.90**
Group II (FR)	**21.13 ± 2.23**	**----------**
Group III (fr)	**23.70 ± 3.24**	**23.00 ± 2.00**
Group IV (fR)	**20.17 ± 2.40**	**21.00 ± 2.24**

Table (3.1.2.) shows the mean and standard deviation of age for the learners and non-learners in all groups. With feedback (F) without feedback (f) with rule (R), and without rule (r)
P value ≤ 0.05, ≤ 0.01, ≤ 0.001.

Figure 3.1.1. Shows an error bar chart representing the mean, confidence intervals (95%) and standard errors for the learners and non-learners age in each experimental group. There were no statistical significant differences.

Figure 3.1.2, and figure 3.1.3. Show the error bar charts representing the mean, and standard deviations of age for the females and males according to them classification as learners or non-learners in each experimental group. There were no statistically significant differences.

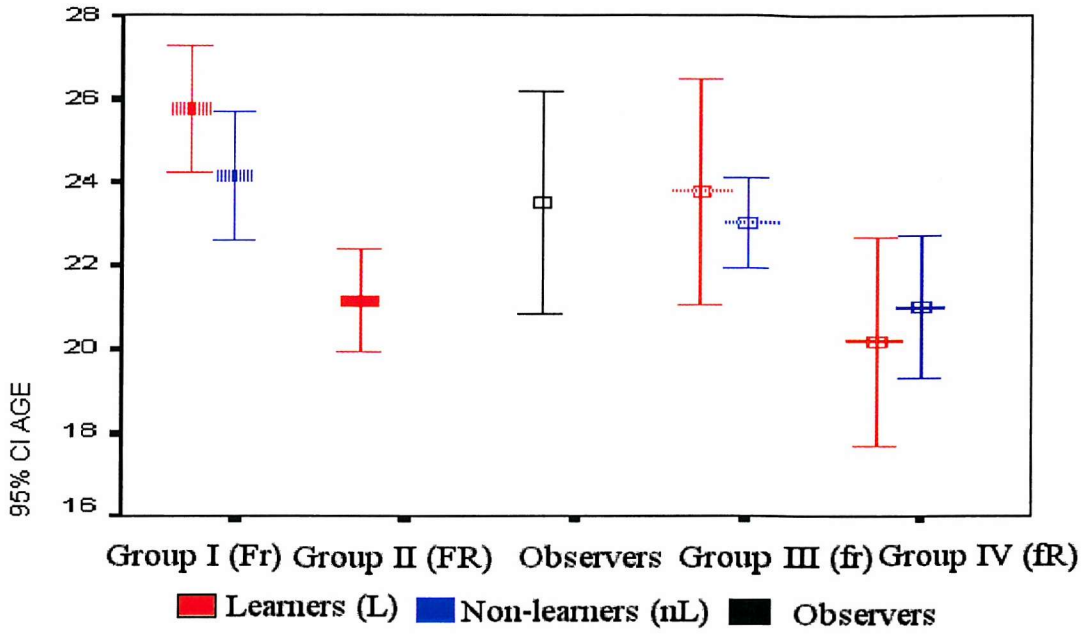


Figure 3.1.1. Shows the error bar chart of the mean age for the learners in red and non-learners in blue and the observers in black. Y-axis represents the mean and confidence interval (CI). X-axis represents the different experiments group. Thick line with feedback (F) thin line without feedback (f). Solid line with rule (R), and interrupted line without rule (r)

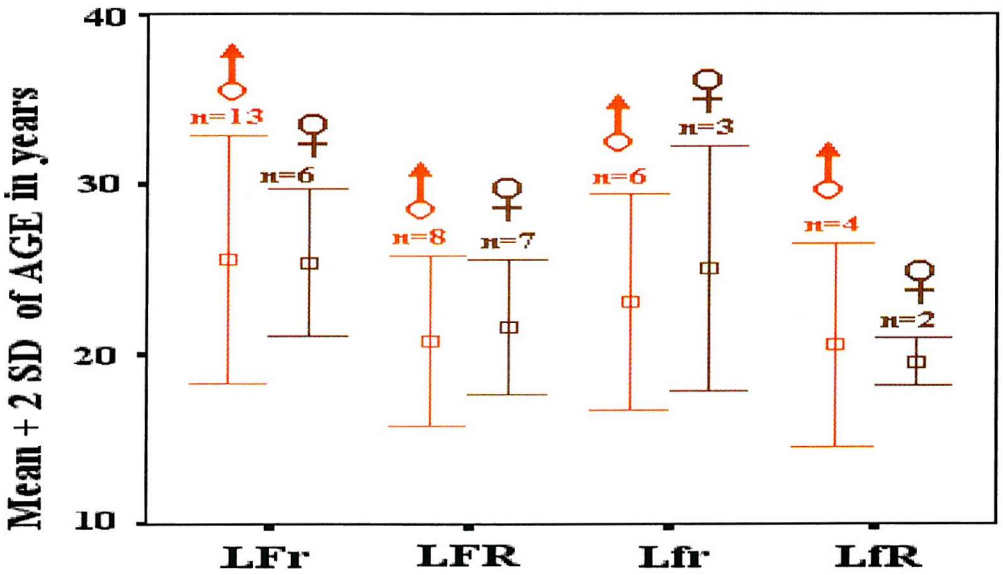


Figure 3.1.2. Show the error bar chart of the mean of age for the learner's females in brown and the learner's males in light brown. Y-axis represents the mean and two standard deviations. X-axis represents the different experiments group. Thick line with feedback (F) thin line without feedback (f). Solid line with rule (R), and interrupted line without rule (r)

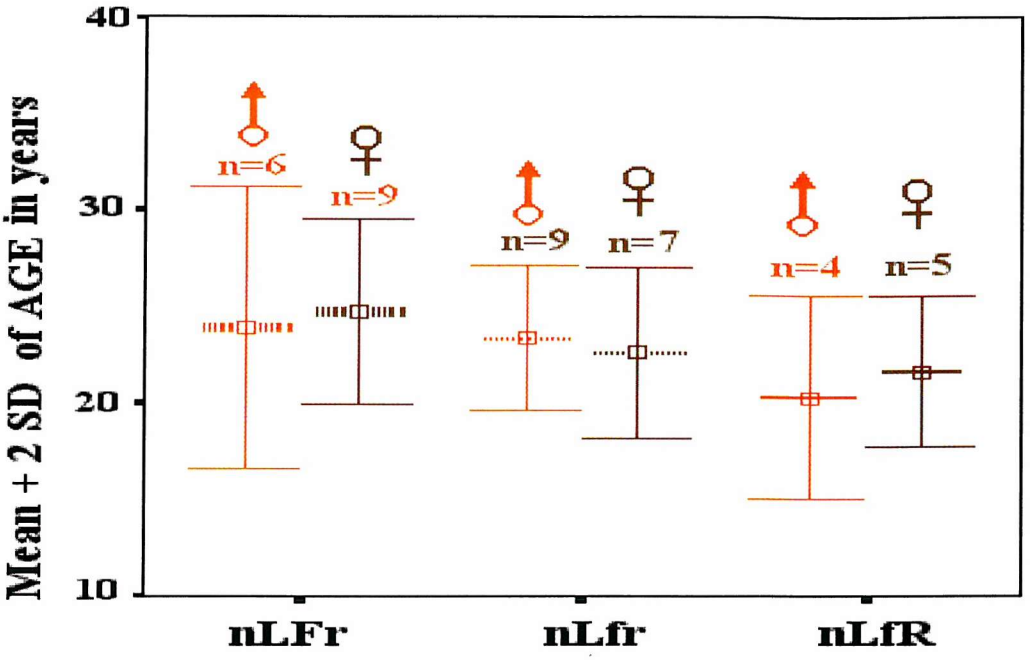


Figure 3.1.3. Show the error bar chart of the mean of age for the non-learner's females in brown and the non-learner's males in light brown. Y-axis represents the mean and two standard deviations. X-axis represents the different experiments group. Thick line with feedback (F) thin line without feedback (f). Solid line with rule (R), and interrupted line without rule (r)

3.2. Performance Results:

3.2.1. Learning performance:

My five experiments divided the 99 participants into five groups and three of these groups subdivided into two subgroups of learners and non-learners. Table (3.2.1.) summarizes all participants' performance.

According to the questionnaire II, the learners in-group I (LFr) concluded, that the task was for 5% very difficult, for 40% difficult, for 35% moderate and for 25% easy. Group II (LFR) who got the details before performing the task concluded that it was easy. Group III (Lfr) concluded, that the task was for 80% very difficult, for 15% difficult, and for 5% moderate. Group IV (LfR) concluded that it is very difficult by 55%, and difficult by 20%, 15% moderate, and 10% easy. The most interesting observation that all of the non-learners reported that the task was very difficult.

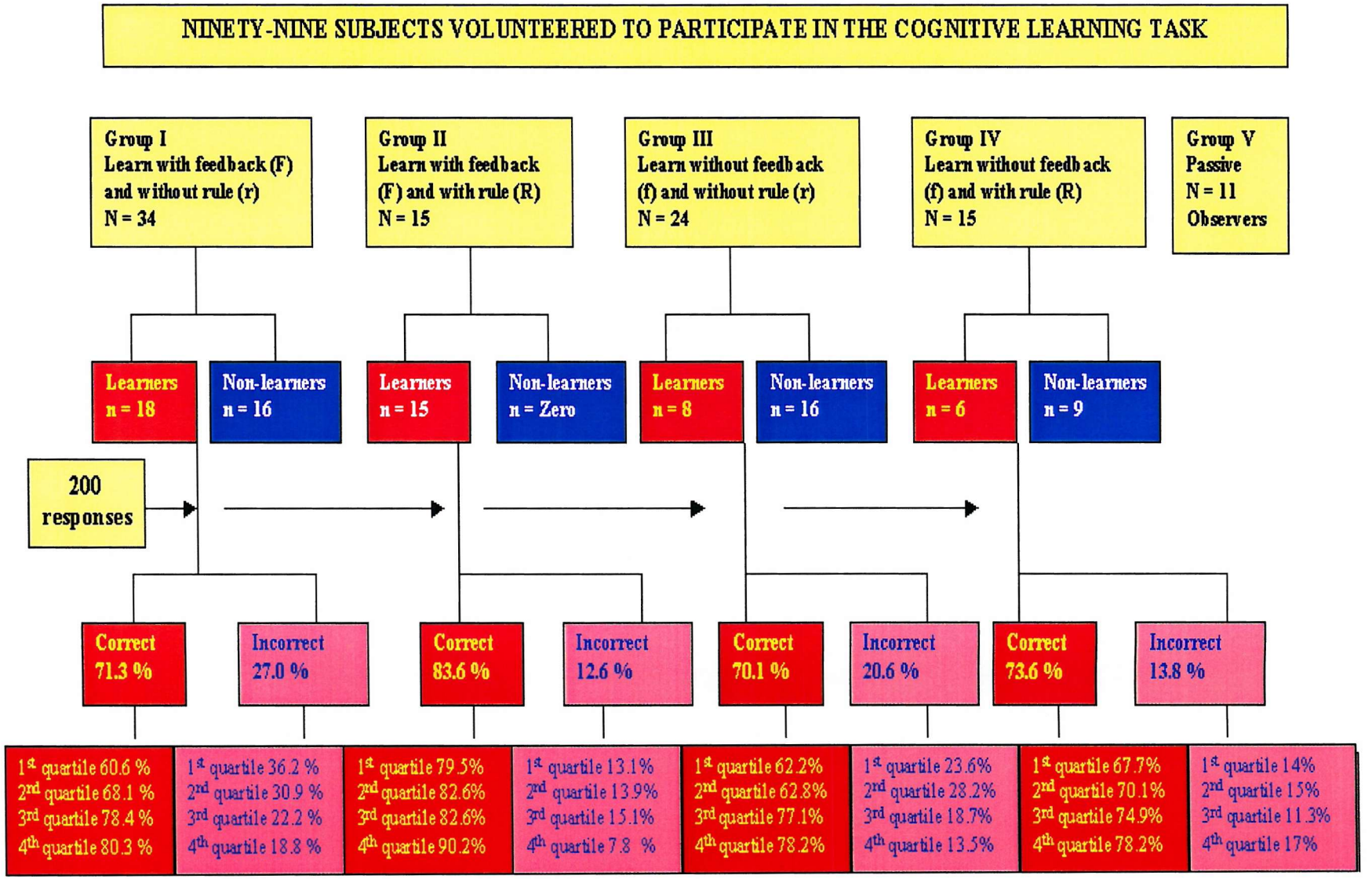


Table 3.2.1. Summarizes the all participants' performance

The cut off point for learning was set at 70% correct answers of the last fifty trials. The learning profile was divided into two categories, the learners (L) and the non-learners (nL). Figure (3.2.1.) shows the numbers of subjects (females and males) meeting the 70% criterion.

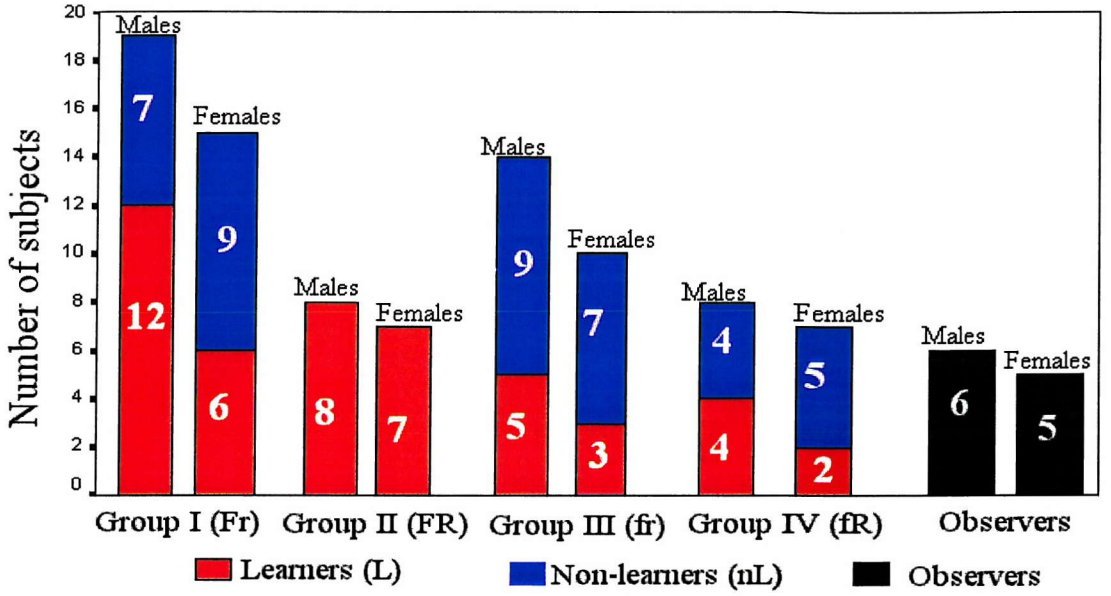


Figure 3.2.1. Summarizes the females and males distribution according to their performance in each group. Learners (L) in red, Non-learners (nL) in blue, and Observers in black. Y-axis represents the number of subjects. X-axis represents the females and males in different experiments group.

The subjects performed three responses, correct (when they made the right decision), incorrect (when they made the wrong decision), and no response (when they did not press any button within the image display time). Criteria of 70% correct answers during the last fifty trials answers were set for learning.

A clear divide was seen between the learners (LFr) and the non-learners (nLFr) in the first group where seven out of the eighteen learners performance only was 70%, three out of sixteen non-learners correct answers were ranged from 50% to 59% during the last fifty trials (Figure 3.2.2.). Three out of sixteen non-learners (nLfr) in the third group correct answers were ranged from 50% to 59% and five out of eight them correct answers percentage ranged between 70% and 79% during the last fifty trials (Figure 3.2.3.). None of the non-learners in these two groups have got more than 60% correct answers. One out

of nine non-learners in the fourth group (nLfR) got over 60% correct answers (Figure 3.2.4.).

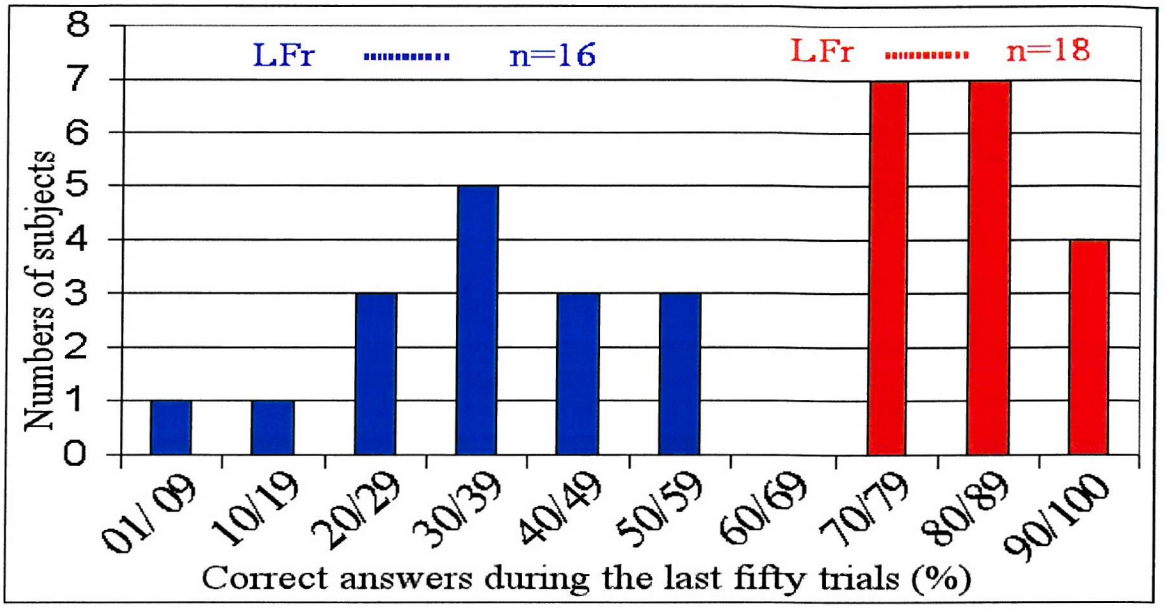


Figure 3.2.2. shows the first group learners (LFr n=18) in red and the non-learners (nLFr n=16) in blue correct answers performance percentage during the last fifty trials of the learning task. Y-axis represents number of subjects. X-axis represents correct answers percentage during the last fifty trials. With feedback (F) and without rule (r).

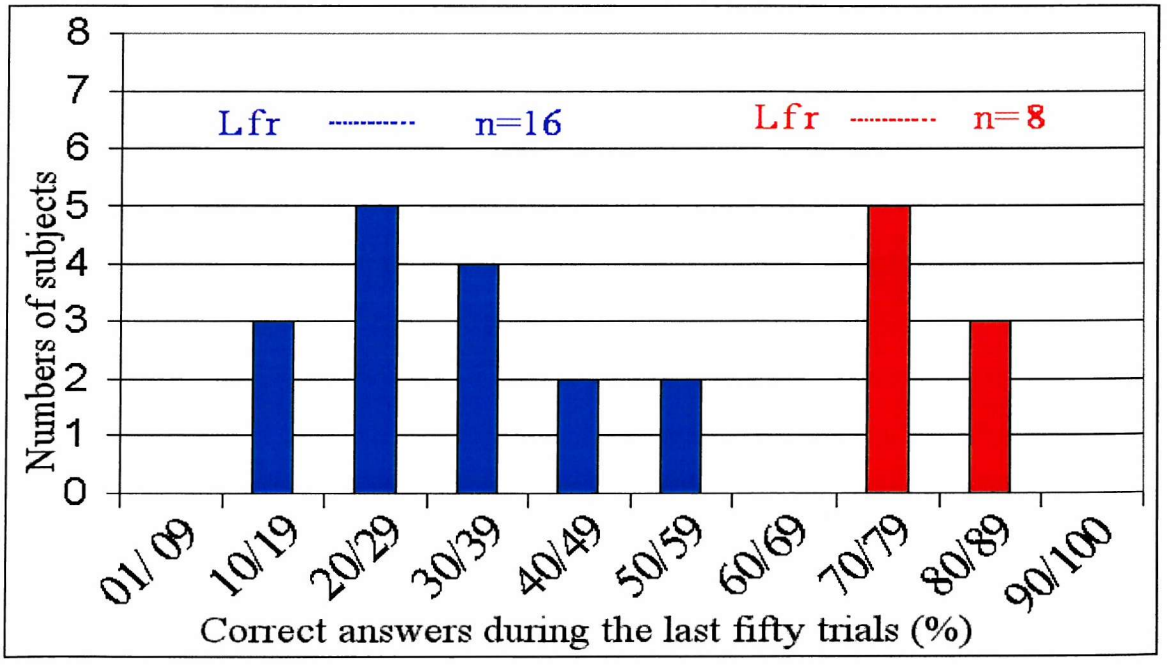


Figure 3.2.3. shows the third group learners (Lfr n=8) in red and the non-learners (nLfr n=16) in blue correct answers performance percentage during the last fifty trials of the learning task. Y-axis represents number of subjects. X-axis represents correct answers percentage during the last fifty trials. Without feedback (f) and without rule (r).

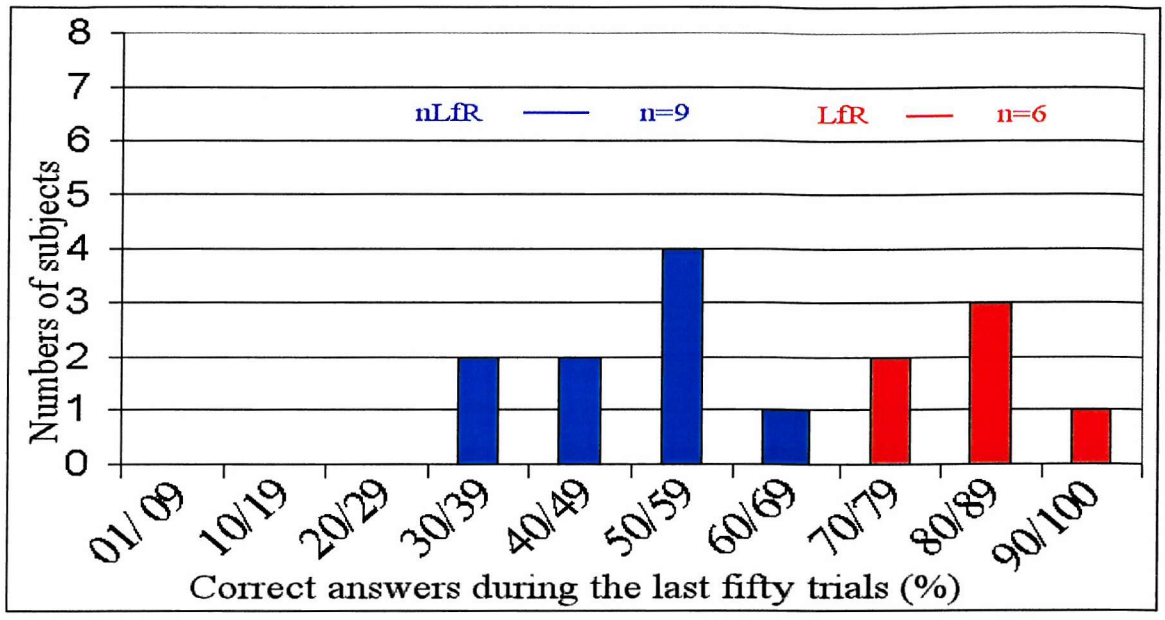


Figure 3.2.4. shows the fourth group learners (LfR n=6) in red and the non-learners (nLfR n=9) in blue correct answers performance percentage during the last fifty trials of the learning task. Y-axis represents number of subjects. X-axis represents correct answers percentage during the last fifty trials. Without feedback (f) and with rule (R).

3.2.2.Cusum charts:

The Cusum statistical method was used to assess the subject's performance. Cusum charts for some of learners and non-learners subject can be seen in appendix No 3.

The Cusum charts by visual inspection showed that all subjects have relatively poor performance at the beginning of the trials. (Figures 3.2.5. & 3.2.6.).

The cusum charts for the learners and non-learners show that each subjects starts with a score of zero. Each trial earns a score of 1-tolerance level, for a correct answers, and 0-tolerance level for an incorrect answer. The score for each trial is added to the one before giving the CUmulative Sum. The CUSUM graphs have three lines for tolerance level of 30% in pink color, 20% in blue color, 10% in red color.

For the learners they were effective after the first fifty trials. Figure 3.2.8. Shows a learner who performs badly during the first 150 trials (1st, 2nd, and 3rd quartiles) but then the graph turns to give a consistently positive gradient indicating that the learning criterion has been achieved, where the subject had got the clue.

There were some subjects in non-learning group who seemed to have learned early and perform well over the first and second quartiles, and with some hesitation in the middle, but the curve becomes horizontal or descends during the last fifty trials and the subject has not learned (Figure 3.2.6.).

A typical cusum chart is shown from non-learner who struggles to achieve the required success, good starts during the first fifty and then the subject is clearly failing throughout the trials with very bad performance to the end of the task (Figure 3.2.7.), whereas figure (3.2.8.) appeared to learn early with a very good performance for one of the learner who scored consistently well from about the eighty trials onward to the end.

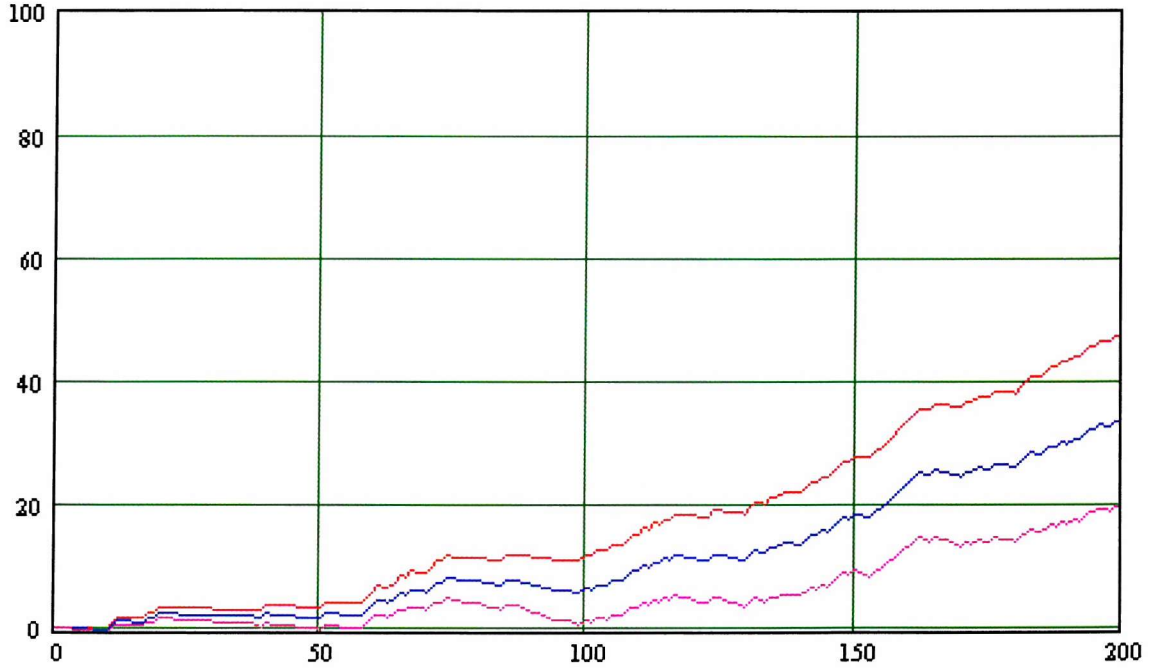


Figure 3.2.5. Cusum chart for learner, the three lines for tolerance level of 30% in red color, 20% in blue color, and 10% in pink color. X-axis represents the task trials, Y-axis represents the subject performance.

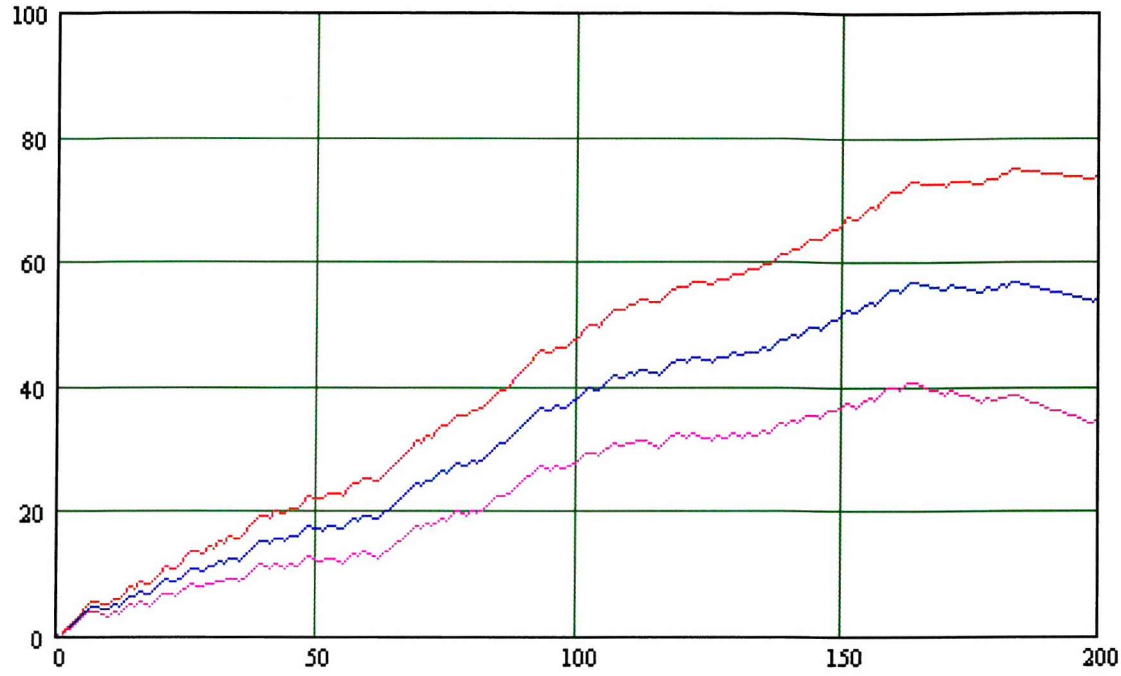


Figure 3.2.6. Cusum chart for non-learner, the three lines for tolerance level of 30% in red color, 20% in blue color, and 10% in pink color. X-axis represents the task trials; Y-axis represents the subject performance.

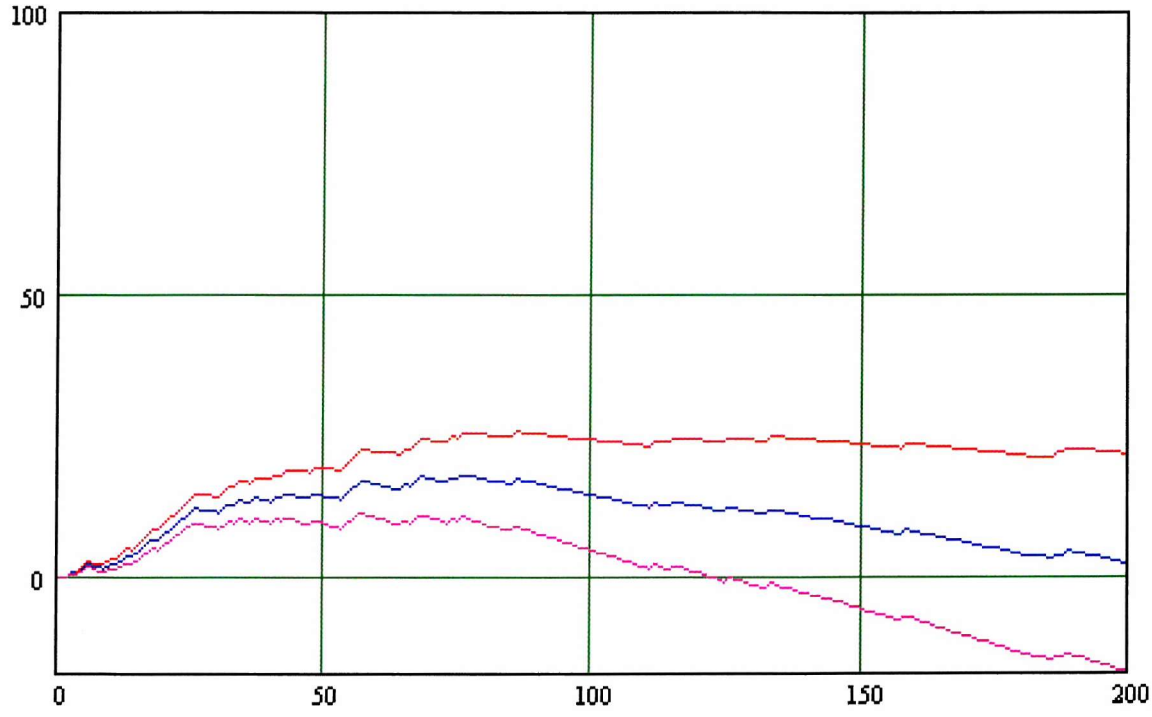


Figure 3.2.7. Cusum chart for non-learner, the three lines for tolerance level of 30% in red color, 20% in blue color, and 10% in pink color. X-axis represents the task trials, Y-axis represents the subject performance.

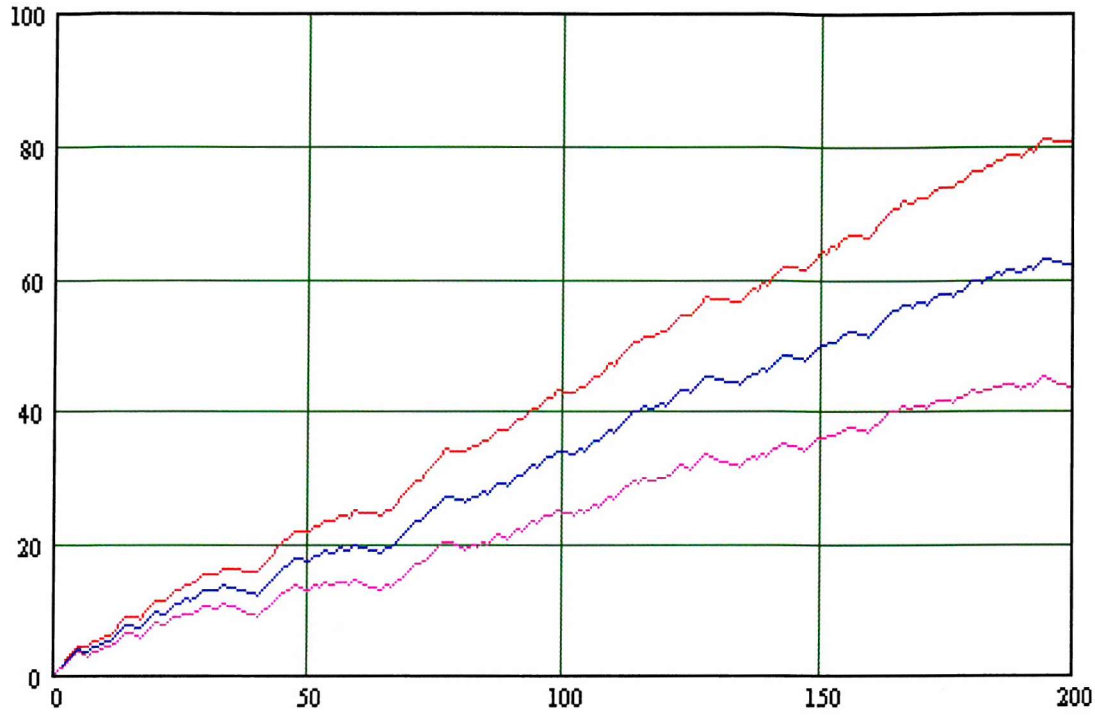


Figure 3.2.8. Cusum chart for learner, the three lines for tolerance level of 30% in red color, 20% in blue color, and 10% in pink color. X-axis represents the task trials; Y-axis represents the subject performance.

3.2.3. The Correct answers:

The learners performance shows steady increase, and as expected the non-learners exhibited no start to finish difference (see learning curves, Figure 3.2.9.), that summarizes the learning curves for the learners in red color lines and the non-learners in blue color lines during the learning trials for each group.

Figure (3.2.10.) shows that the learners in first group (LFr n=18) represented by thick interrupted line where their performance started just below 60% correct answers. Beyond the middle trials answers they never fell under 70% correct answers to the end of the task and they finished at the top of all other groups except the second (LFR).

Figure (3.2.11.) shows the learners in the second group represented by the solid thick line (LFR n=15) and their steady increase in average performance. They

had the highest start score and from the beginning and they never fell fewer than 70% correct answers. Twice during the trial they achieved scores of over 90% in the first half of the task and the end score was 89.5% correct answers

Figure (3.2.12.) shows that the third group (Lfr n=8), that performed the task with neither information nor feedback. They started with 55.2% correct answers and after few trials the curve morphology looks like a zigzag in shape to the end of the second quarter (second fifty), and they reached 80% correct answers during the first two quarters but this level was not sustained. They started the third quarter at 65 % and ended the last one or the task at 78.1% correct answers.

Figure (3.2.13.) shows that the fourth group learners (LfR n=6) knew the rule but had no feedback. Thin solid line represents their performance and shows a very close start 59.2% correct answers to the learners in the first and fourth group and even the non-learners of the same group. The end correct answers trials percentage of 80.1% was very close as well to the fourth group (Lfr). Their curve morphology looks like the second group curve morphology but it was very different in the correct answers percentage which is lower in the case of the fourth group condition (LfR).

The learning curve for the all non-learners is represented in blue line color and shows their performance while they were trying to learn the difference between pattern A and B throughout the all trials. Group I non-learners (nLFr n=16) represented by the interrupted thick blue line, there is no difference from the start to finish trials figure (3.2.11.). The non-learners in group III (nLfr n=16) that perform without no idea about the task and feedback not given as well, they are represented by a interrupted thin line figure (3.2.12.). The thin solid line represents the non-learners in fourth group (nLfR n=9) that had only one of the all clues to make achievement. Although they did show very good start (59.2 % correct answers), they could not able to keep going in the same direction and they made much wrong decision in the middle of the trial. They

tried to catch up near the end but they could not able to do more than 70%. Figure (3.2.13.). For the all learners and non-learners in each group see also figure 3.2.9.

The subjects in group one (Fr). There was a steady increase in learner's average performance. As expected, the non-learners exhibited no start to finish difference. A middle period of above chance level was shown reaching the 70% criteria set for the learners. The percentage for non-learners incorrect answers were 46.3 % and were lesser for learners 27.0%, but for the correct answers percentage were 71.3 for learners and were less for non-learners 49.1 % for whole experiment see appendix 5 Table (5.5.1.).

Table (3.2.2.) shows that the learners and non-learners correct answers for type A (36.5% & 26.9%) were more than for type B (34.8% & 22.2%) respectively. Incorrect answers for both groups were learners and non-learners (12.2% & 20.7%) respectively for type A and were more for type B (14.8% & 25.6%).

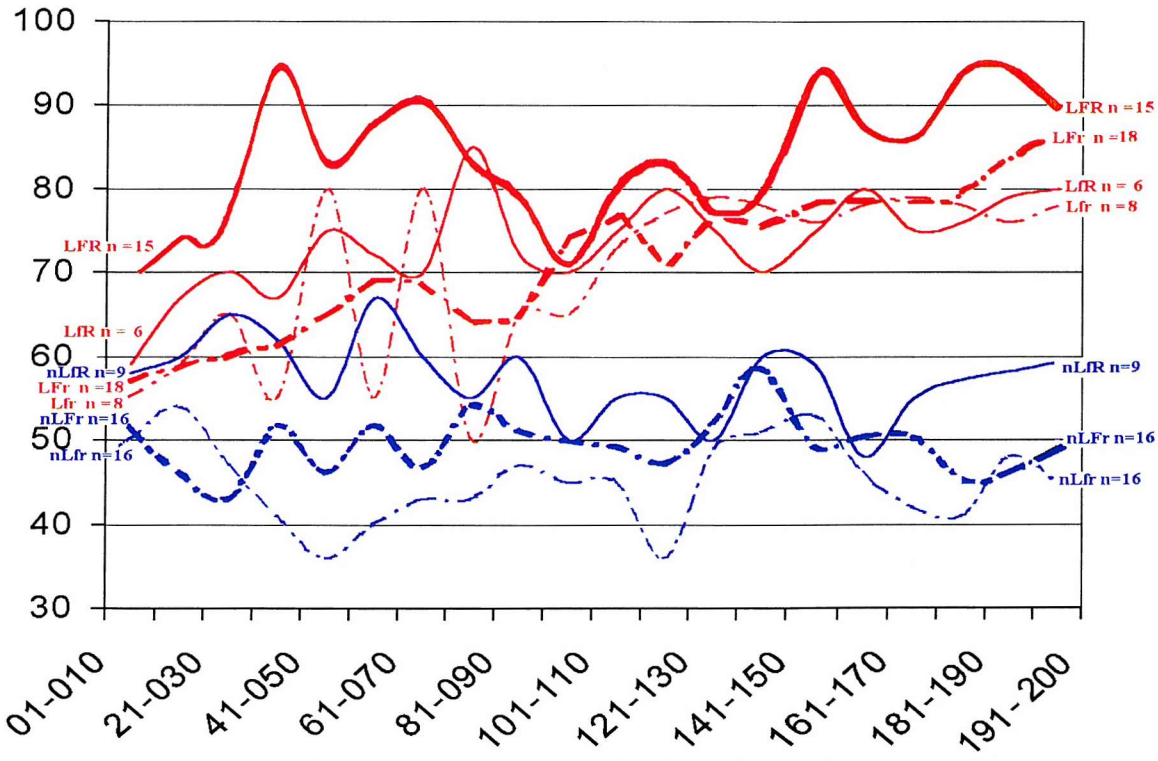


Figure (3.2.9.) shows the subjects performance during a learning task. Y-axis represents the correct answers responses percentage. X axis represents task trials number. Learners in red color (L). Non-learners in blue color (nL). Thick line with feedback (F), thin line without feedback (f). Solid line with rule (R), interrupted line without rule (r).

The second group (FR) which has all learners as subjects, the percentage of the correct answers was 70% at the first ten trials and never been under 70% through the all trials. The average percentage of the correct answers was 83.6% and was 12.6 in the case of the incorrect answers, see appendix 5 Table (5.5.2.).

Table (3.2.3.) shows that the learners correct and incorrect answers percentage for type A were (42.1% & 6.4%) where were for type B (41.5% & 6.2%).

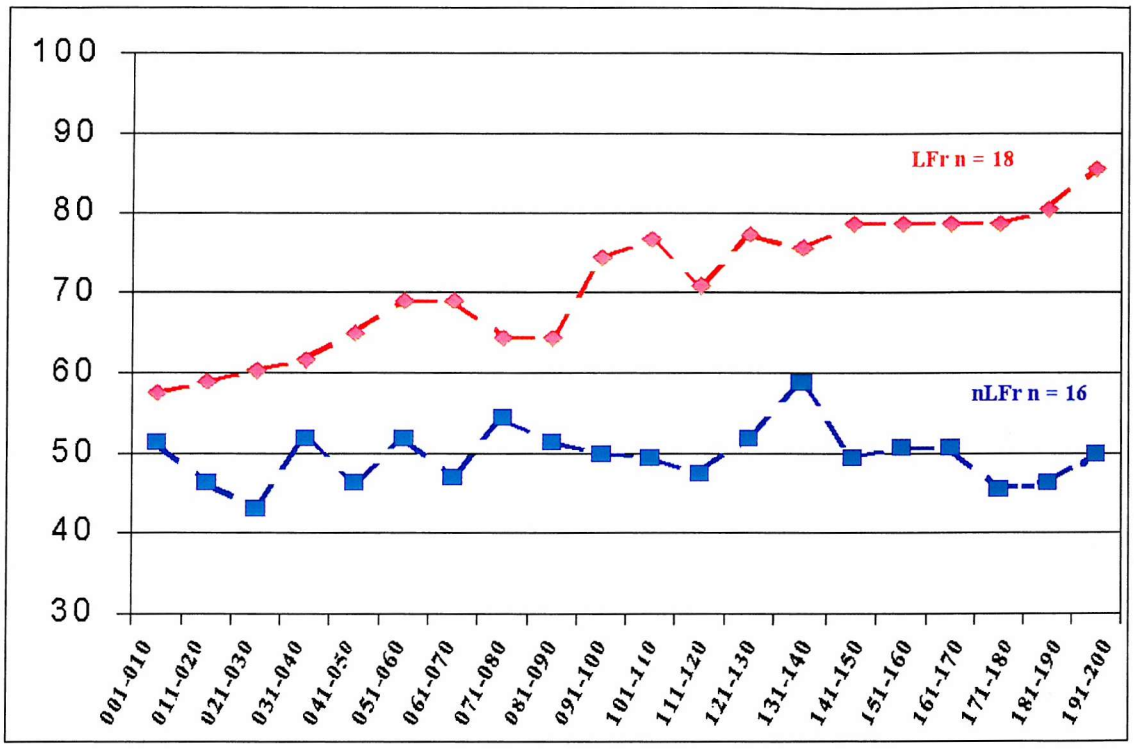


Figure 3.2.10. Shows the subjects performance during a learning task. Y-axis represents the correct answers responses percentage. X axis represents task trials number. Learners in red (L). Non-learners in blue (nL). Thick line with feedback (F), and interrupted line without rule (r) representing group I (Fr).

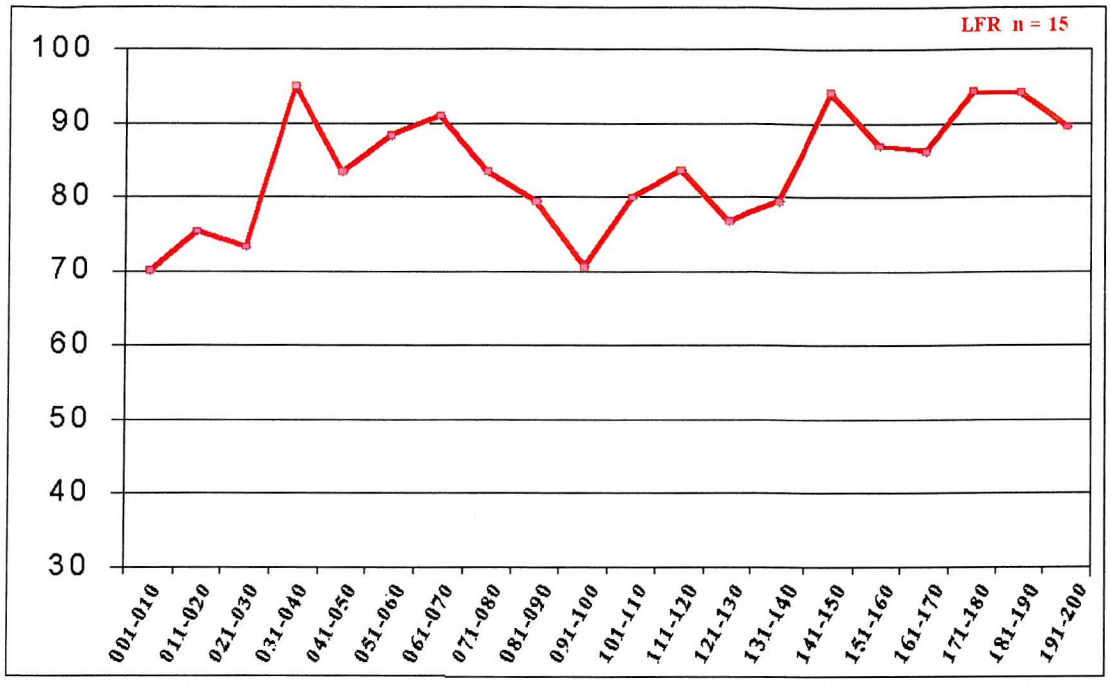


Figure 3.2.11. Shows the subjects performance during a learning task. Y-axis represents the correct answers responses percentage. X axis represents task trials number. Learners in red (L). Thick line with feedback (F), and solid line with rule (R), representing group II (FR).

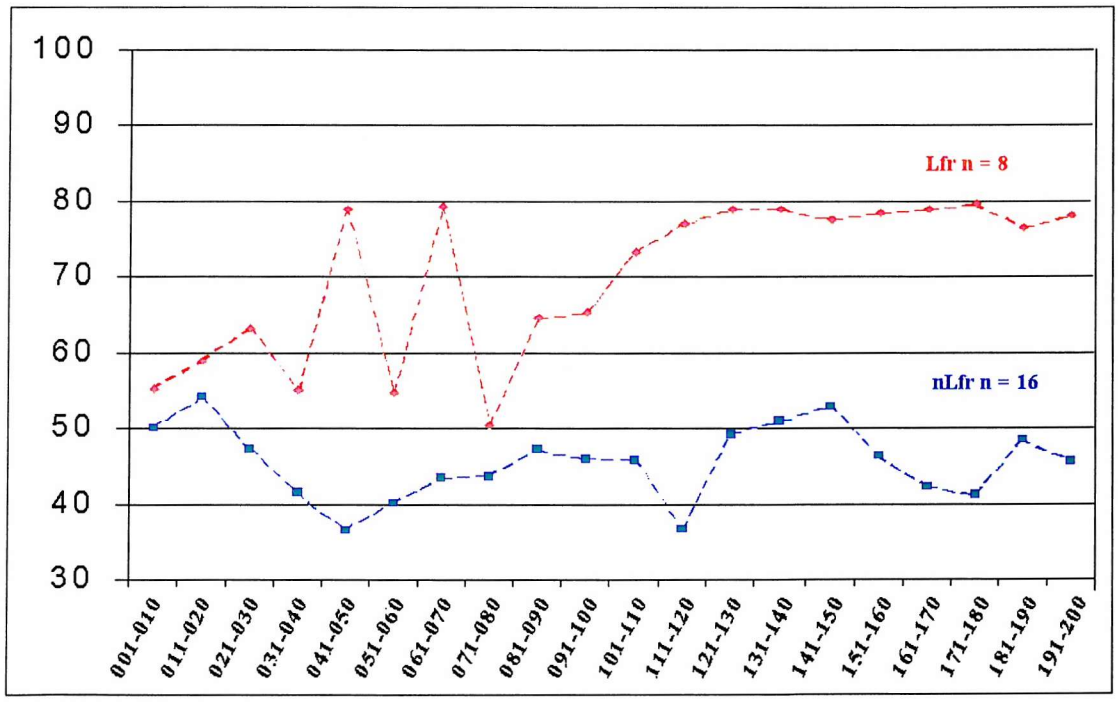


Figure 3.2.12. Shows the subjects performance during a learning task. Y-axis represents the correct answers responses percentage. X axis represents task trials number. Learners in red (L). Non-learners in blue (nL). Thin line without feedback (f) and interrupted line without rule (r) representing group (fr).

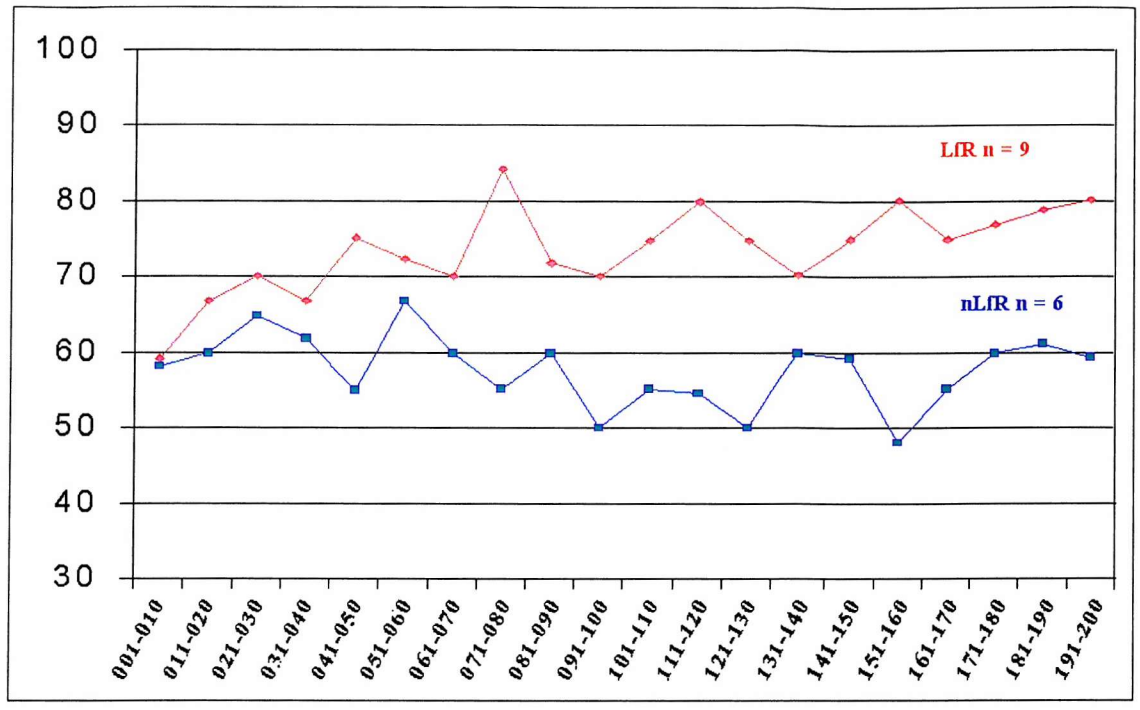


Figure 3.2.13. Shows the subjects performance during a learning task. Y-axis represents the correct answers responses percentage. X axis represents task trials number. Learners in red (L). Non-learners in blue (nL). Thin line without feedback (f), and solid line with rule (R), representing group IV (fR).

RESPONSES	Learners (LFr n= 18)			Non-learners (nLFr n= 16)		
TYPE %	TYPE A	TYPE B	Total	TYPE A	TYPE B	Total
CORRECT	36.5	34.8	70.3	26.9	22.2	49.1
INCORRECT	12.2	14.8	27.0	20.7	25.6	46.3
NO RESPONSE	1.3	1.4	2.7	2.4	2.2	4.6

Table (3.2.2.) shows type A, B and the total responses data comparison for the learners (L) and the non-learners (nL) in the first group (Fr). With feedback (F) and without rule (r)

RESPONSES	Learners (LFR n= 15)		
TYPE	TYPE A %	TYPE B %	Total %
CORRECT	42.1	41.5	83.6
INCORRECT	6.4	6.2	12.6
NO RESPONSE	1.7	2.1	3.8

Table (3.2.3.) shows type A, B and the total responses data comparison for the learners (L) in the second group (FR). With feedback (F) and with rule (R)

In the subjects of group III (fr) who perform the test without rule and without feedback (fr) there was a steady increase in learner's average performance. The non-learners had, as expected, no start to finish difference. The percentage for the correct answers were 71% for learners and were less for non-learners, 45% for whole experiment, but for non-learners incorrect answers were 42.5 % and were less for learners 20.4 % see appendix 5 Table (5.5.3.).

Table (3.2.4.) shows that the learners and non-learners correct answers percentage for type A (38.3 & 23.2%) were more than type B (30.5% & 22.2%). Incorrect answers for both groups were learners and non-learners (8.8% & 20.9%) respectively for type A and were more for type B (15.9% & 21.8%).

The subjects of group IV (fR) performances after giving them full detailed information about the task and they performed it without feedback (WRNF). The non-learners had very good start in the first ten trials (81%) and then the number of the correct answers trials gradually decreased and they tried hard to catch up but they could not get the cut off point and their total average percentage was less than 60 %. The learners started with 65% and then the correct answers trials gradually increased and they get more than 70% in the last fifty trials and their average percentage for the correct answers was 73.9% and their incorrect answer percentage was 13.7%. See appendix 5 Table (5.5.4.).

Table (3.2.5.) shows that the learner's correct and incorrect answer percentage for type A was (40.1 & 3.8%) the percentage was for type B (33.4% & 8.1%) respectively. The non-learners correct answers for both patterns A % B were (26.4% & 31.7%) respectively, and for incorrect answers percentage type A and type B were (16.7% & 13%) respectively. The original patterns were complimentary pattern, type A proved to be easily identified.

RESPONSES	Learners (Lfr n= 8)			Non-learners (nLfr n= 16)		
TYPE %	TYPE A	TYPE B	Total	TYPE A	TYPE B	Total
CORRECT	38.6	31.5	70.1	23.2	22.2	45.4
INCORRECT	8.8	11.8	20.6	20.8	21.8	42.6
NO RESPONSE	3.9	5.5	9.3	5.9	6.1	12.0

Table (3.2.4.) shows type A, B and the total responses data comparison for the learners (L) and the non-learners (nL) in the third group (fr). Without feedback (f) and without rule (r)

RESPONSES	Learners (LfR n= 6)			Non-learners (nLFr n= 9)		
TYPE %	TYPE A	TYPE B	Total	TYPE A	TYPE B	Total
CORRECT	40.2	33.4	73.6	26.4	31.3	57.7
INCORRECT	4.6	9.2	13.8	16.7	14.1	30.8
NO RESPONSE	4.3	8.3	12.6	6.2	5.3	11.5

Table (3.2.5.) shows type A, B and the total responses data comparison for the learners (L) and the non-learners (nL) in the fourth group (fr). Without feedback (f) and without rule (r).

3.3. Decision Time Results:

3.3.1. All trials decision time:

Decision time (DT) was recorded by the pattern generating computer. The mean decision times were measured and compared for all trial answers in every group. The first fifty were compared to the last fifty trial answers. In the same way the correct trials answers were compared to the incorrect trials answers. The trials answers of type A were compared to the type B. Different statistical methods were used as Independent T-test for cross group, and Paired T-test for within group.

Were there statistical significant differences in the decision time between the learners and the non-learners?

Figure (3.3.1.) shows the answer of the previous question. The mean decision time data for learners were shorter compared to the non-learners in group I (Fr), group II (FR) were all learners. In Group III (fr) and IV (fR) the non-learners mean decision time was shorter than the learners were.

All the grand averaged trials answer decision time from table (3.3.1.) show that there was statistical significant difference (P≤0.01) between learners mean decision time (0.94sec) and non-learners mean decision time (1.12sec) in the first group (Fr). Group III (fr) non-learners (nLfr) mean decision time (1.01sec) was shorter than the learners (Lfr) mean decision time (1.27sec) and it was statistically significant (P≤0.01). The learners (LfR) mean decision time (1.16sec) in the fourth group (fR) had a shorter than the non-learners (nLfR) mean decision time (1.47sec) and it was statistically significant (P≤0.001).

GROUP	LEARNERS (L)	NON-LEARNERS (nL)	Differences
Group I (Fr)	0.94 **	1.12	0.18
Group III (fr)	1.01 **	1.27	0.26
Group IV (fR)	1.16 ***	1.47	0.31

Table (3.3.1.) Learners and non-learners means of the mean decision time during all trial answers of the learning task. P value * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001

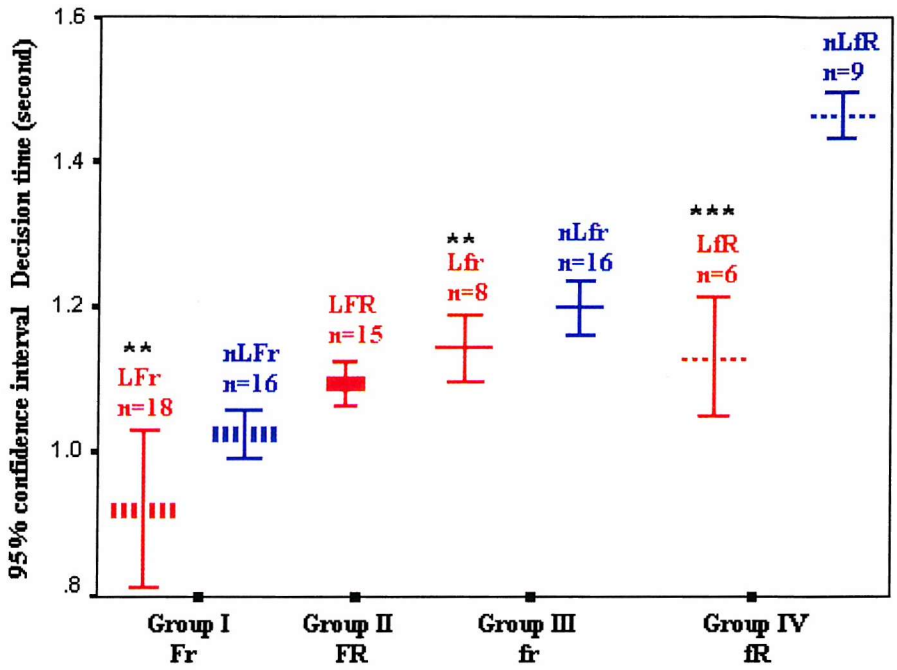


Figure (3.3.1.) shows an error bar chart shows the mean decision time for the learner's (L) in red color and non-learners (nL) in blue color during a learning task. Y-axis represents subjects mean decision time, confidence interval (95%), and the standard errors. X-axis represents different group and experiments conditions. Thick line with feedback (F) thins line without feedback (f). Solid line with rule (R), interrupted line without rule (r). P value: * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001.

3.3.2. The first and last fifty:

The first and last fifty responses percentage were used to compare before and after learning data for the learning curve, but some subjects appeared to have learnt in the beginning, during the first fifty patterns, as shown in appendix 3.

Table (3.3.2.) representing the first fifty trials answers mean decision time for the learners and the non-learners in groups I, III, IV. There was a statistical significant difference ($P<0.002$), between the shorter mean decision time for the learners first fifty answers (0.97sec) as compared to the first fifty mean decision time for the non-learners (1.17sec) in the first group (Fr).

Group III (fr) there was a statistical significant difference ($P\leq0.004$), for the learners last fifty trials answers mean decision time (0.98sec) which was

shorter in comparison with the last fifty mean decision time for the non-learners (1.18sec).

Group IV (fR) the non-learners had longer mean decision time (1.46sec) when compared to the learners means decision time (1.17sec) and it was highly statistically significant (P≤0.001).

Table (3.3.3.) shows that there was a statistically significant difference (P≤0.001), between the mean decision time (DT) which was shorter for learners in group one (Fr) last fifty trials answers (0.89sec) when compared with the last fifty mean decision time (1.13sec) for the non-learners (nLFr).

In group three (fr) there was highly statistically significant difference (P<0.001), between the longer mean decision time (1.23sec) for the non-learners first fifty answers as compared to the first fifty mean decision time for the learners (1.05sec).

Group Four (fR) we found that there was highly statistically significant differences (P<0.001) for the non-learners mean decision time (1.47sec) in comparison with the learners mean decision time (1.18sec).

GROUP	LEARNERS (L)	NON-LEARNERS (nL)	Differences
Group I (Fr)	0.97 **	1.17	0.20
Group III (fr)	1.05 ***	1.23	0.18
Group IV (fR)	1.18 ***	1.47	0.29

Table (3.3.2.) Learners and non-learners means of the mean decision time during the first fifty trial answers of the learning task. P value * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001

GROUP	LEARNERS (L)	NON-LEARNERS (nL)	Differences
Group I (Fr)	0.89 ***	1.13	0.24
Group III (fr)	0.98 **	1.18	0.20
Group IV (fR)	1.11 ***	1.46	0.35

Table (3.3.3.) Learners and non-learners means of the mean decision time during the last fifty trial answers of the learning task. P value * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001

3.3.3. Correct versus incorrect answer decision time:

Table (3.3.4.) shows that there was a statistically significant difference in the first group (P≤0.008) between the mean decision time, which was shorter for the learners correct answers trials (0.92sec), and the non-learners correct answer trials mean decision time (1.121sec).

Group III (fr) we found a statistically significant difference (P≤0.04), for the non-learners shorter mean decision time correct answers trials (1.03sec), as compared to the incorrect answers trials mean decision time for the learners (1.18sec).

Group IV (fR) the non–learners have short decision time (1.47sec) when compared to the learners group decision time (1.16sec) and it is highly statistical-significant (P≤0.001).

Table (3.3.5.) shows that there was a statistically significant difference (P≤0.04), in the first group between the shorter mean decision time for the learners incorrect answers (0.98sec), as compared to the incorrect answers trials mean decision time for the non-learners (1.12sec).

In group three there was a statistically significant difference (P≤0.01), between the shorter mean decision time for the non-learners incorrect answers trials (1.26sec) as compared to the incorrect answers trials mean decision time for the learners (1.00sec).

Group four we found that there was highly statistically significant differences (P<0.001) for the non-learners mean decision time (1.16sec) in comparison with the learners mean decision time (1.55sec) during the incorrect answer trials.

Group	Learners (L)	Non-learners (nL)	Differences
Group I (Fr)	0.92 **	1.13	0.21
Group III (fr)	1.03 *	1.18	0.15
Group IV (fR)	1.16 ***	1.47	0.31

Table (3.3.4.) Learners and non-learners means of the mean decision time during the correct answer trials of the learning task. P value * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001

Group	Learners (L)	Non-learners (nL)	Differences
Group I (Fr)	0.98 *	1.12	0.14
Group III (fr)	1.00 **	1.26	0.26
Group IV (fR)	1.16 ***	1.55	0.39

Table (3.3.5.) Learners and non-learners means of the mean decision time during the incorrect answer trials of the learning task. P value * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001

Both learners and non-learners took consistently longer to reach a decision time when the answer was incorrect than when correct.

3.3.4. Pattern type A versus type B decision time:

A difference in decision times according to whether pattern A or B was on the screen was not expected. Analysis showed that the decision times were longer for the non-learners than the learners when pattern A and B were considered separately.

Table (3.3.6.) shows that there was a statistically significant difference ($P<0.01$), between the mean decision time, which was shorter for the learner's type A trials (0.93sec), and type A trials mean decision time for the non-learners (1.11sec) in group I (Fr).

Group III (fr) in comparison we found that there was highly statistically significant difference ($P<0.001$), for the learner's type A trials mean decision time (1.00sec) where they have been faster than the non learner's type A mean decision time (1.17sec).

Group IV (fR) the non–learners have a longer mean decision time (1.47sec) when compared to the learner's mean decision time (1.18) and it was highly statisticall significant ($p<0.001$).

Table (3.3.7.) representing the decision time in both group's learners and non-learners according to the pattern type (A or B). In group I (Fr) we found that there was a statistically significant difference ($P<0.01$), between the shorter mean decision time for learner's type B trials (1.12sec) as compared to the type B trials mean decision time for the non-learners (0.95sec).

Group three there was no statistically significant difference ($P<0.08$), between the mean decision time for the non-learner's image type B trials (1.02sec) as compared to the image type B trials answers mean decision time for the learners (1.03sec).

Group IV (fR) we found that there was highly statistically significant differences ($P<0.001$) for the non-learner's type B trials mean decision time (1.46sec) in comparison with the learner's mean decision time (1.15sec).

Group	Learners (L)	Non-learners (nL)
Group I (Fr)	0.93 **	1.11
Group III (fr)	1.00 ***	1.17
Group IV (fR)	1.18 ***	1.47

Table (3.3.6.) Learners and non-learners mean of the mean decision time during the image type A answer trials of the learning task. P value * ≤ 0.05; ** ≤ 0.01, *** ≤ 0.001

Group	Learners (L)	Non-learners (nL)
Group I (Fr)	0.95 **	1.12
Group III (fr)	1.03	1.02
Group IV (fR)	1.15 ***	1.46

Table (3.3.7.) Learners and non-learners means of the mean decision time during the image type B answer trials of the learning task. P value * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001

Were there any differences between the first fifty and last fifty trials in the learners and non-learners within every group?

Were there any differences between the correct and incorrect trial answers in the learners and non-learners within every group?

Were there any differences between the trial answers for the pattern type A and Type B in the learners and non-learners within every group?

To answer these three questions we have to look thoroughly through the following figures and tables.

All figures show the learners in red color and the non-learners in blue color. Thick line is for the group, which had feedback and the thin line for those who had not. Solid line for the group that had the rule (full task information) and the interrupted for those who did not.

The first fifty represented by the first bar is compared to the last fifty represented by the second bar from the left-hand side represents the mean decision times. The incorrect answers in third bar is compared to the correct answer trials in the fourth bar. The images of type "A" trials in the fifth bar is compared to the image type B trials in the last bar.

The plotted line represents the mean decision time with standard error for each condition. Confidence intervals of 95% or better are marked.

3.3.5. The learners decision time:

3.3.5.1. The first group (LFR n=18):

Figure (3.3.2.) shows an error bar chart representing the mean decision times, confidence intervals and standard errors for the experiment all conditions; the first fifty versus last fifty; the correct answers is compared to the incorrect answers; the image type A trial answers is compared to the image type B answers.

First row in table (3.3.8.) shows that there was a statistically significant difference (P<0.04) between the mean decision time for last fifty trials answer (0.89sec) and the first fifty the mean decision time (0.97sec) in the first group learners (LFr).

Table (3.3.9.) shows that there was a statistically significant differences (P<0.04) between the correct answers mean decision time and the longer incorrect answers mean decision time (0.92sec and 0.98sec) respectively in the first group learners (LFr).

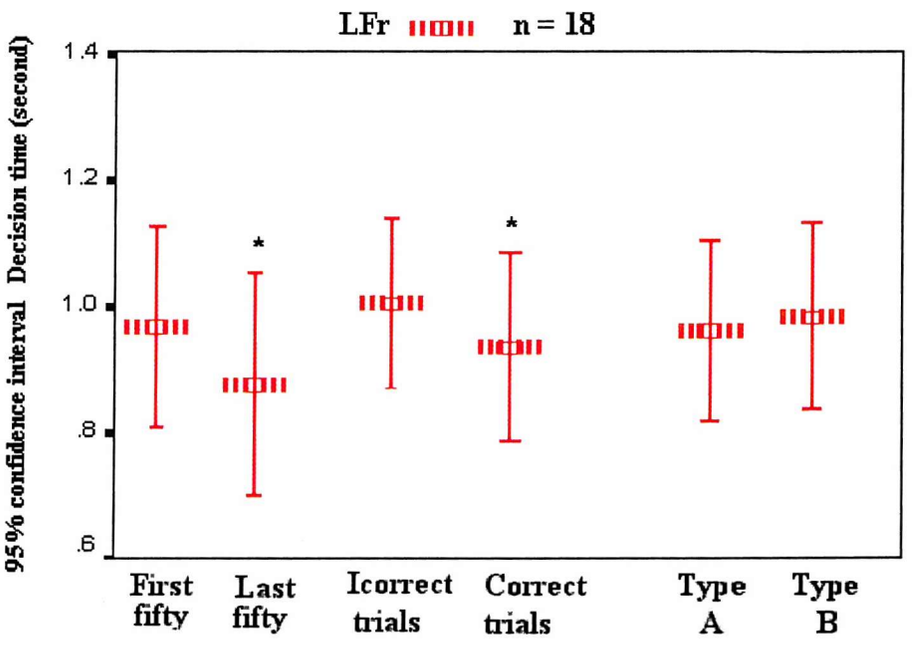


Figure 3.3.2. Error bar chart shows the mean decision time for the learners in red of the first group (LFr) during a learning task. Y-axis represents subjects mean decision time, confidence interval (95%), and the standard errors. X-axis represents different group and experiments conditions. Thick line with feedback (F), interrupted line without rule (r). P value: * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001.

Table (3.3.10.) shows that there was no statistical significant differences (P>0.8) between the image type A answers mean decision time (0.93sec) and the image type B answers mean decision time (0.95sec) in the first group learners (LFr).

3.3.5.2. The second group (LFR n=15):

Figure 3.3.3. Shows the error bar chart representing the mean decision times, confidence intervals and standard errors for the experiment all conditions. The

first fifty versus last fifty. The correct answers is compared to incorrect answers. The image type A trial answers is compared to the image type B answers.

Table (3.3.8.) shows that there was a statistically significant difference ($P<0.01$) between the mean decision time for last fifty trials answers (1.03sec) and the first fifty the mean decision time (1.15sec) in the group II of learners (LFR).

Table (3.3.9.) shows that there was highly a statistically significant difference ($P<0.001$) between the correct answers mean decision time and the longer incorrect answers mean decision time in the group II of learners (LFR) (1.05sec and 1.2sec) respectively.

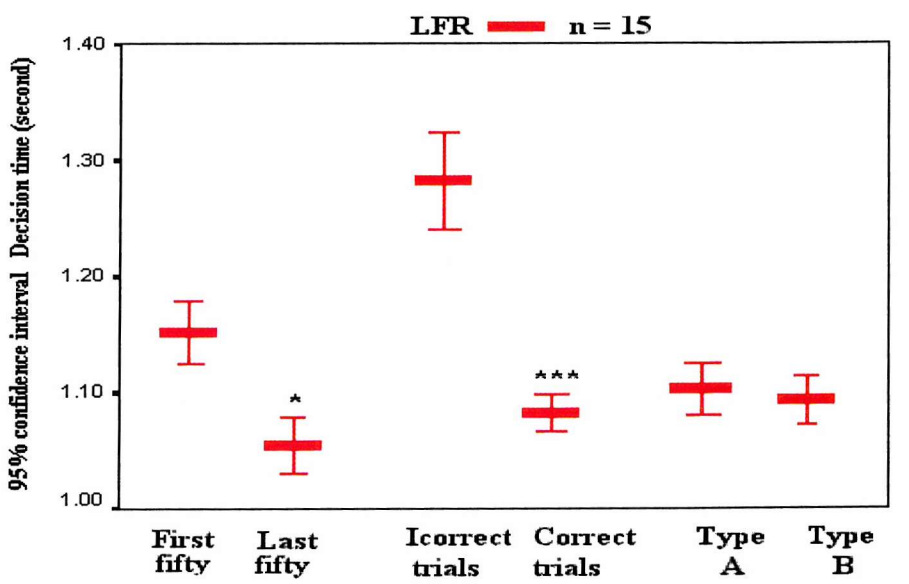


Figure (3.3.3.) shows an error bar chart shows the mean decision time for the learners in red of the second group (LFR) during a learning task. Y-axis represents subjects mean decision time in seconds, confidence interval (95%), and the standard errors. X-axis represents different group and experiments conditions. Thick line with feedback (F), Solid line without rule (R). P value: *≤ 0.05, ** ≤ 0.01, *** ≤ 0.001.

Table (3.3.10.) shows that there were no statistically significant difference ($P>0.1$) between the type A trial answers mean decision time (1.1sec) and the type B trial answers mean decision time (1.07sec) in the learners of group II (LFR).

3.3.5.3. The third group (Lfr n=8):

Figure (3.3.4.) shows the error bar chart representing the mean decision times, confidence intervals and standard errors for the experiment all conditions. The first fifty is compared to the last fifty. The correct answer is compared to incorrect answers. The image type A trial answer is compared to the image type B answers.

Table (3.3.8.) shows that there was no statistically significant difference ($P<0.05$) between the mean decision time for last fifty trials answers (0.98sec) and the first fifty the mean decision time (1.05sec.

Table (3.3.9.) shows the comparison between the correct answers mean decision time and the longer incorrect answers mean decision time in the group of learners (1.00sec and 1.08sec) respectively, and was not statistically significant ($P<0.05$).

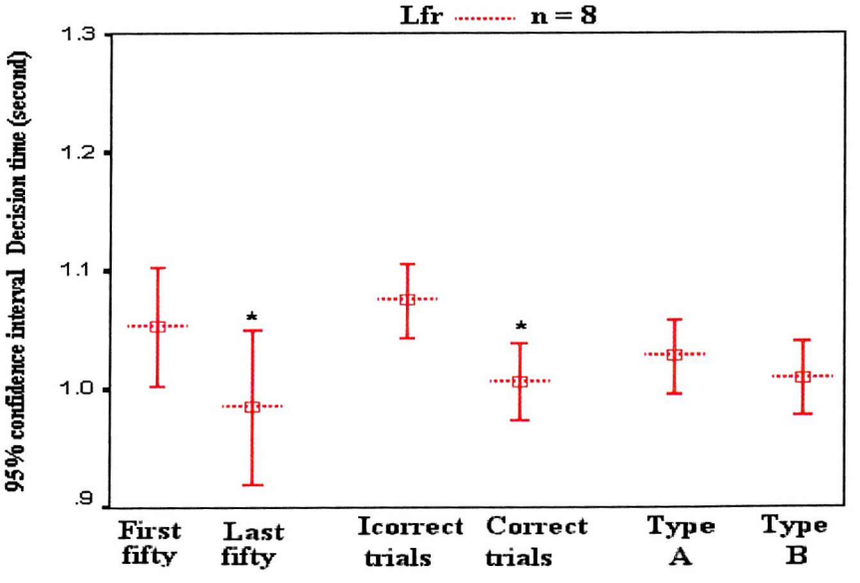


Figure (3.3.4.) shows an error bar chart shows the mean decision time for the learners in red of the third group (Lfr) during a learning task. Y-axis represents subjects mean decision time in second, confidence interval (95%), and the standard errors. X-axis represents different experiment conditions. Thin line with feedback (f), interrupted line without rule (r). P value: * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001.

Table (3.3.10.) shows that there were no statistically significant differences ($P<0.2$) between the trials answers mean decision time for type A (1.00sec) and the type B answer mean decision time (1.02sec) in the learners of group III (Lfr).

3.3.5.4. The fourth group (Lfr n=6):

Figure (3.3.5.) shows an error bar chart representing the mean decision times, confidence intervals and standard errors for the experiment all conditions; the first fifty is compared to the last fifty; the correct answers is compared to incorrect answers; the image type A trial answers is compared to the image type B answers.

Table (3.3.8.) shows that there is no statistically significant difference (P< 0.4) between the mean decision time for last fifty trials answers (1.11sec) and the first fifty the mean decision time (1.18sec) in the learners of group IV (LfR).

Table (3.3.9.) shows that there was a statistically significant difference (P< 0.04) between the correct answers mean decision time and the longer incorrect answers mean decision time in the learners of group IV (LfR), (1.06sec & 1.16sec) respectively.

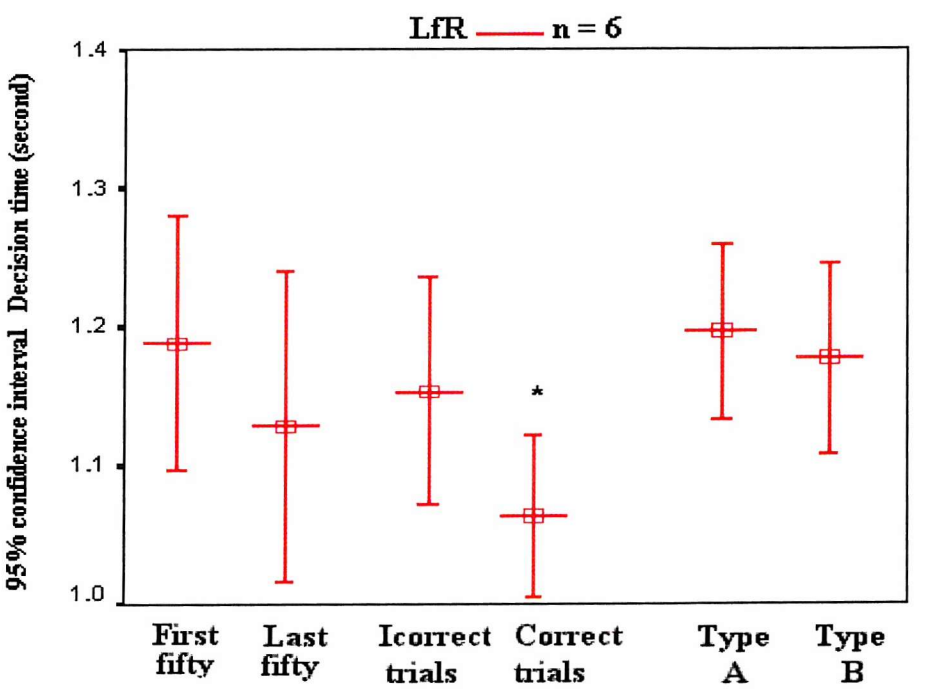


Figure (3.3.5.) shows an error bar chart shows the mean decision time for the learners in red of the fourth group (LfR) during a learning task. Y-axis represents subjects mean decision time in second, confidence interval (95%), and the standard errors. X-axis represents different experiment conditions. Thin line with feedback (f), solid line without rule (R). P value: * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001.

Table (3.3.10.) shows that there were no statistically significant difference (P<0.8) between the trial answer mean decision time for the type A (1.18sec) and the type B answer mean decision time (1.15sec) in the learners of group IV (LfR).

LEARNERS (L)	First fifty	Last fifty	Differences
Group I (LFr n=18)	0.97	0.89 *	0.12
Group II (LFR n=15	1.15	1.03 **	0.12
Group III (Lfr n=8)	1.05	0.98 *	0.07
Group IV (LfR n=6)	1.18	1.11	0.07

Table (3.3.8.) Learners mean decision time of the first fifty and last fifty trial answers during a learning task. P value * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001

LEARNERS (L)	CORRECT	INCORRECT	Differences
Group I (LFr n=18)	0.92 *	0.98	0.06
Group II (LFR n=15	1.05 ***	1.28	0.23
Group III (Lfr n=8)	1.00 *	1.08	0.08
Group IV (LfR n=6)	1.06 *	1.16	0.10

Table (3.3.9.) Learners mean decision time of the correct and Incorrect Trials answers during a learning task. P value * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001

LEARNERS (L)	TYPE A	TYPE B	Differences
Group I (LFr n=18)	0.93	0.95	0.02
Group II (LFR n=15	1.10	1.07	0.03
Group III (Lfr n=8)	1.00	1.02	0.02
Group IV (LfR n=6)	1.18	1.15	0.03

Table (3.3.10.) Learners mean decision time of image type A and image type B trial answers during a learning task. P value * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001

3.3.6. The non-learners decision time:

3.3.6.1. The first group (nLFr n=16):

Figure (3.3.6) shows an error bar chart that represents the mean decision times, confidence intervals (95%), and the standard errors during the different experiment conditions; the first fifty is compared to the last fifty; the correct answers is compared to the incorrect; the image type A trial answers is compared to the image type B answers.

Table (3.3.11.) shows that there was no statistically significant difference between (P>0.06) the first row non-learners last fifty and first fifty mean decision times (1.17sec & 1.13sec), respectively

Table (3.3.12.) shows the comparison between the correct answers trials mean decision time and the incorrect answers trials mean decision time for group one non-learners in the first row (1.13sec & 1.12sec) respectively and it was not statistically significant (P>0.9).

Table (3.3.13.) shows that there was no statistically significant difference (P>0.8) in the first row between the image type A answers trials mean decision time (1.11sec) and the image type B answers trials mean decision time in the non-learners group (1.12sec).

3.3.6.2. The third group non-learner (nLfr n=16):

An error bar chart that represent the result of the mean decision time, confidence intervals (95%), and the standard errors during the different experiment conditions; the first fifty is compared to the last fifty; the correct answer is compared to the incorrect; the image type A trial answer is compared to the image type B answers as shown in figure (3.3.7.).

Table (3.3.11.) shows that there was no statistically significant differences (P>0.09) for the second row non-learners between the last fifty and the shorter first fifty mean decision time (1.23sec & 1.18sec), respectively

Table (3.3.12.) shows the comparison between the correct answers trials mean decision time and the incorrect answers trials mean decision time for the non-learners in group one in the second row (1.18sec & 1.26sec), respectively and it was statistically significant (P>0.05).

Table (3.3.13.) there is no statistically significant difference (P>0.2) in the second row between the image type A trials answers mean decision time (1.17sec) and the nearly similar mean decision time (1.16sec) for type B answers in the non-learners group.

3.3.6.3. The fourth group (nLfr n=9):

Figure (3.3.8.) shows comparison of an error bar chart that summarizes the mean decision times, confidence intervals (95%), and the standard errors during different experiment conditions; between the first fifty and the last fifty; the correct answers and the incorrect. The image type A trial answers and the image type B answers.

Table (3.3.11.) shows that there was no statistically significant difference (P>0.5) for the third row non-learners between the last fifty trials answers mean decision time (1.47sec) and first fifty trials answers mean decision time (1.46sec).

Table (3.3.12.) shows the comparison between the correct answers trials mean decision time and the incorrect answers trials mean decision time for the non-learners in group IV in the third row (1.47sec & 1.55sec) respectively and it was statistically significant (P>0.05).

Table (3.3.13.) shows that there was no statistically significant difference (P>0.4) in the third row between the Image type A trials answers mean decision time (1.47sec) and the image type B trial answers mean decision time (1.46sec) in the non-learners group.

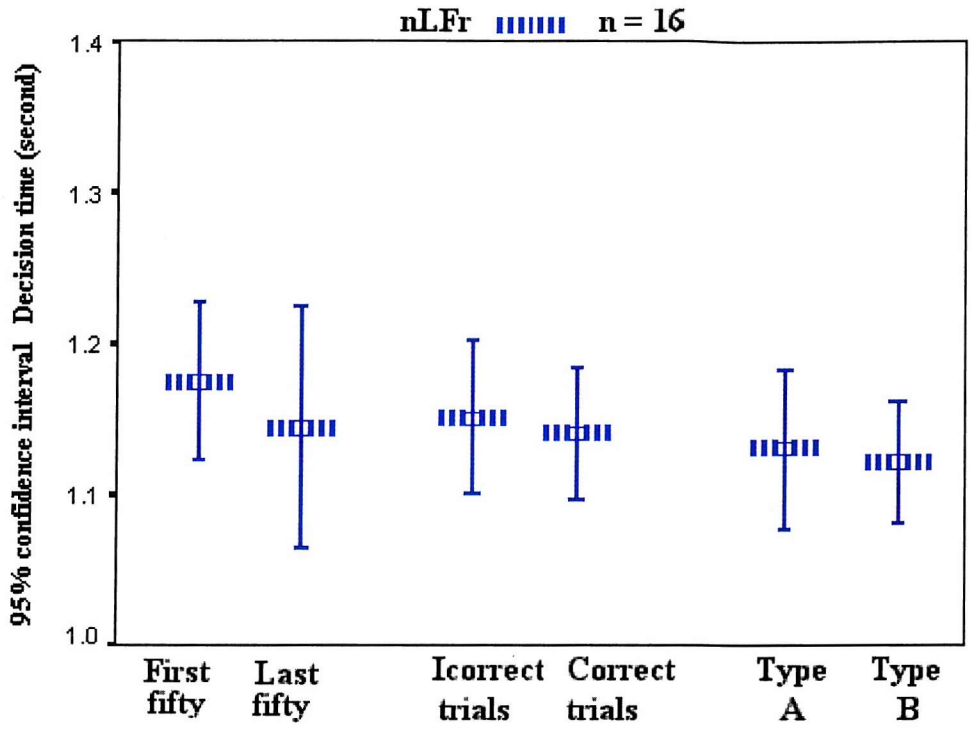


Figure (3.3.6.) an error bar chart shows the mean decision time for the non-learners in red of the first group (nLFr) during a learning task. Y-axis represents subjects mean decision time in seconds, confidence interval (95%), and the standard errors. X-axis represents different experiment conditions. Thick line with feedback (F), interrupted line without rule (r). P value: * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001.

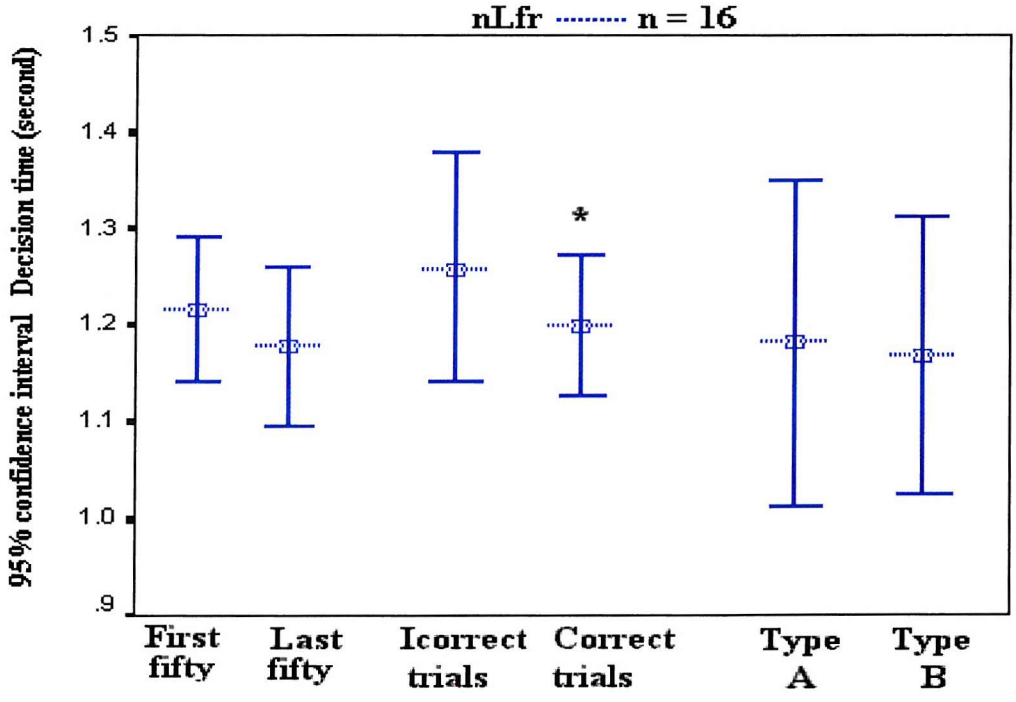


Figure (3.3.7.) an error bar chart shows the mean decision time for the non-learners in red of the third group (nLfR) during a learning task. Y-axis represents subjects mean decision time in second, confidence interval (95%), and the standard errors. X-axis represents different experiment conditions. Thin line with feedback (f), interrupted line without rule (r). P value: * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001.

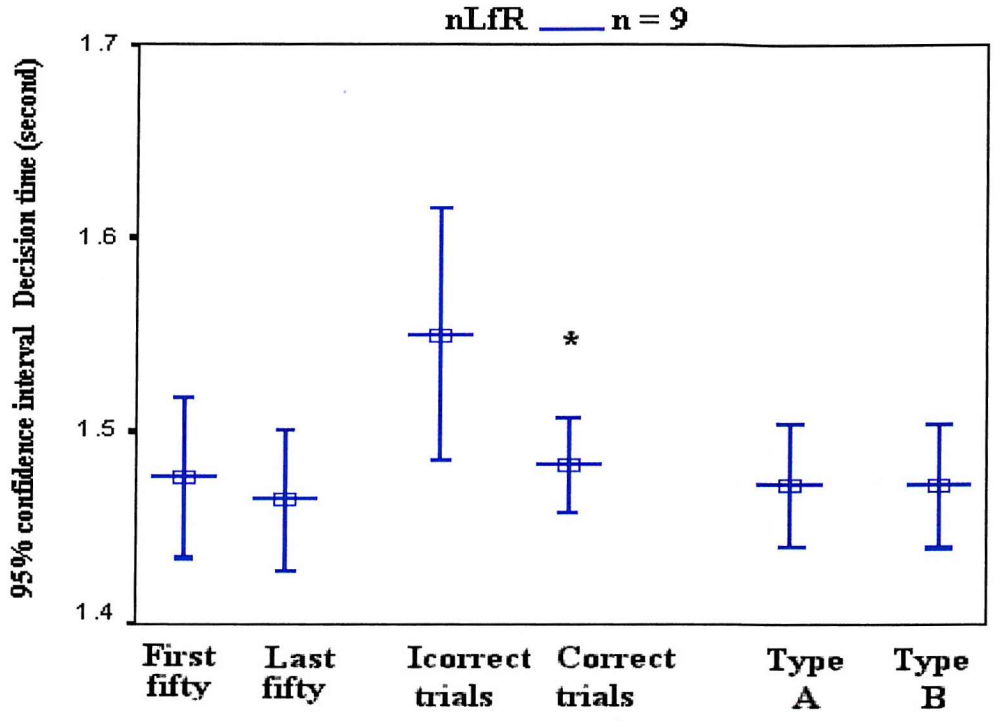


Figure (3.3.8.) an error bar chart shows the mean decision time for the non-learners in red of the fourth group (nLfR) during a learning task. Y-axis represents subjects mean decision time in second, confidence interval (95%), and the standard errors. X-axis represents different experiment conditions. Thin line with feedback (f), solid line without rule (R). P value: * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001.

Non-Learners (nL)	First fifty	Last fifty	Differences
Group I (nLFr n=16)	1.17	1.13	0.04
Group III (nLfr n=9)	1.23	1.18	0.04
Group IV (nLfR n=16)	1.47	1.46	0.01

Table (3.3.11.) Non-learners mean decision time of the first fifty and last fifty trial answers during a learning task. P value * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001

Non-Learners (nL)	CORRECT	INCORRECT	DIFFERENCES
Group I (nLFr n=16)	1.13	1.12	0.01
Group III (nLfr n=9)	1.18 *	1.26	0.08
Group IV (nLfR n=16)	1.47 *	1.55	0.08

Table (3.3.12.) non-learners mean decision time of the correct trial answers and incorrect trial answers during a learning task. P value * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001

Non-Learners (nL)	TYPE A	TYPE B	DIFFERENCES
Group I (nLFr n=16)	1.11	1.12	0.01
Group III (nLfr n=9)	1.17	1.16	0.01
Group IV (nLfR n=16)	1.47	1.46	0.01

Table (3.3.13.) Non-learners mean decision time during image type A and image type B trials during a learning task. P value * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001

3.3.7. Conclusion to this section:

- Learners respond quicker than non-learners
- Both learners and non-learners slightly quicker as trial progress
- Both learners and non-learners tend to have longer decision time over decision that are incorrect
- Pattern types doesn't affect the participants decision times
- Task types does not make much differences
- Even when the participants know the rule (FR) they did not perform quicker.

3.4. Event Related Potentials Results:

3.4.1. The eye movement:

Figure (3.4.1.) shows the averaged of the eye movement potentials and shows that these are negligible. Recordings were all scanned for eye movements and individual sweeps containing blinks were rejected. In this work, eye movements made a negligible contribution and other trace are not shown.

A series of positive and negative components occurred in the all groups' traces for the learners and non-learners with all task-recording conditions. We found that the pre-stimulus baselines of the waveforms are very similar, and the sensory portions of the waveforms are similar too in all groups (Figure 3.4.2.).

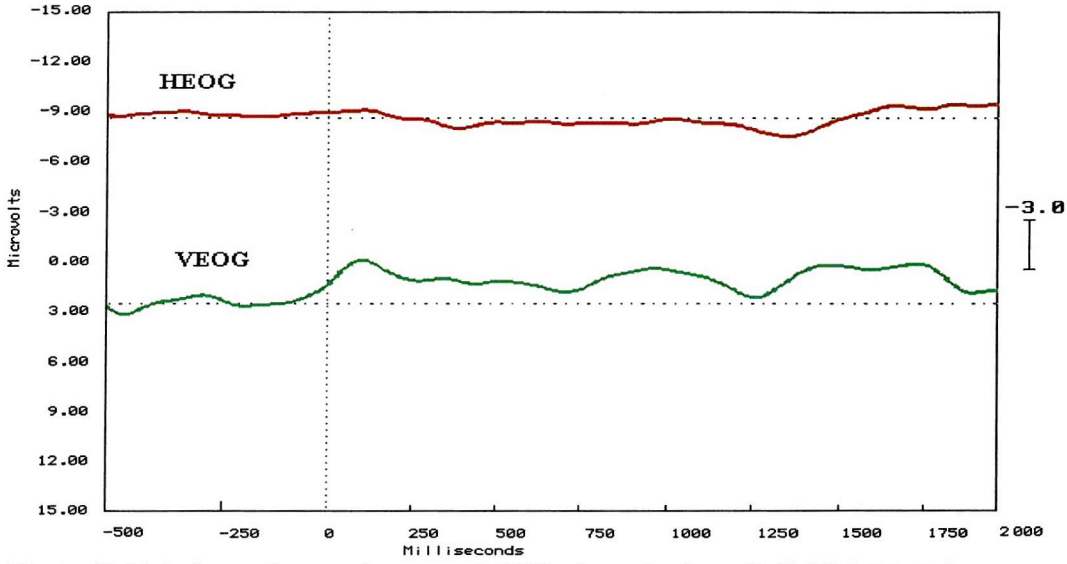


Figure (3.4.1.) shows the grand averaged EOG after rejection of all blinking and eye-movements artefact at HEOG and VEOG representing the horizontal and vertical eye-movement monitor electrodes respectively

3.4.2. Pattern differences:

The complementary pattern used as stimuli, although forming two categories, was very similar visually. This showed in sensory VEP, and the cognitive portion of the traces, the morphology and the latency of ERPs elicited and evoked by either patterns (image type A and image type B) are similar for the both groups (learners and non-learners) pre-stimulus and post-stimulus from

the beginning to the end of the task. There were no statistical significant differences figure (3.4.3.)

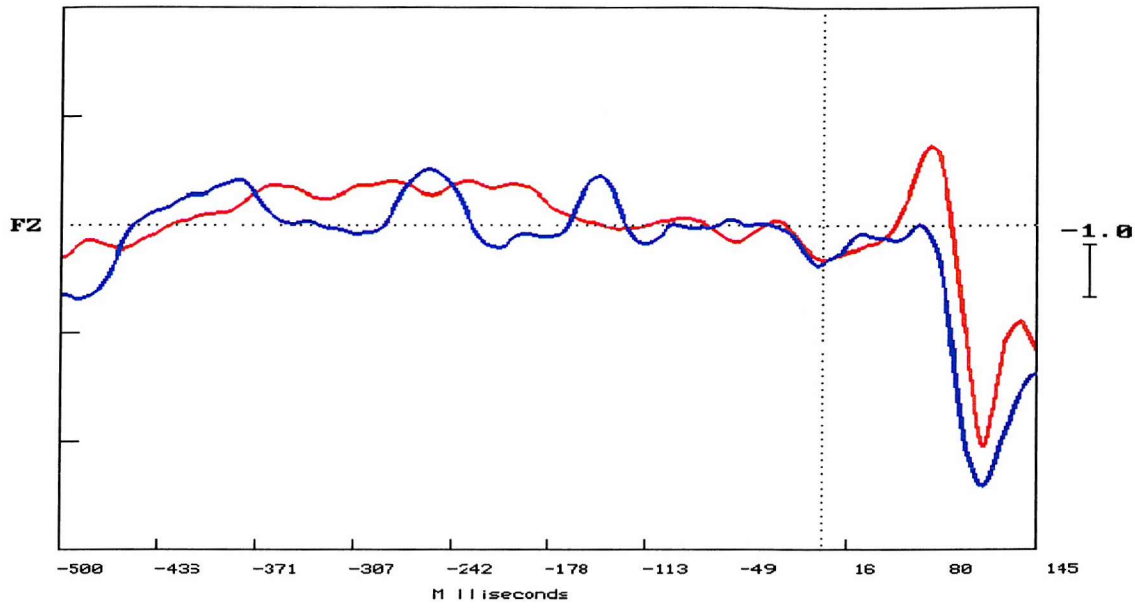


Figure (3.4.2.) shows Zoom grand average ERP waveform elicited by all answers trials for learners in red color trace and non-learners in blue color trace, at FZ site electrode. Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (msec). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

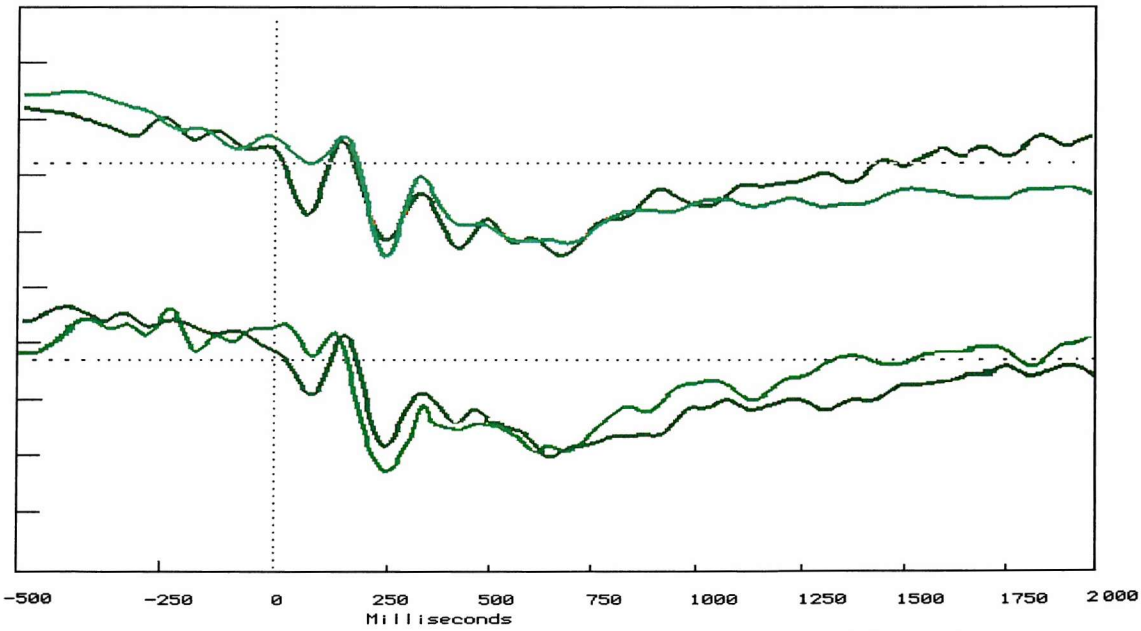


Figure (3.4.3.) shows the grand averaged ERPs elicited by the images type A trial traces in dark green and the images type B trials traces in light green color. The non-learners represented by the top traces and the learners represented by the bottom traces. Recorded from mid-frontal site electrode at FZ, during the learning task. Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

The positive going activity can be called P300 but there is no clear peak. P300 peaks most probably between 300msec and 800msec so it is difficult to see the exact location of it in this graph, but we can see a definite increase in the positivity this time span. Traces begin to change at 250msec and show marked differences from 300msec to 800msec (Figures for fz's ERPs).

Two time windows were chosen to compare between the groups and the subgroups, and were chosen because they encompassed much of the learners and non-learners difference evident in the grand averaged waveform. The first time window is (250msec - 500msec) and the second time window is (500msec - 800msec).

This increased positivity from about 250msec latency and beyond (P3a or P3b) during a learning task for the learners and non-learners correlate with our hypothesis that there is a difference in brain activity as a result of trying to learn.

3.3.3. The learners and non-learners ERPs:

Figure (3.4.4.) shows the superimposed grand average (-500msec to 2000msec) ERPs elicited by subject's performance for the learners in red color traces after in all experimental groups during the last fifty trials of the learning task and the observers in black color trace. Recorded from mid-frontal site electrode (FZ). The trace morphology was very similar from 500msec pre-stimulus to 200msec post-stimulus. The observers trace back to the baseline to the end of the task. There were many peaks positive and negative in every group trace, the learners trace for group (FR) showed two more positive peaks than the other groups traces with differences of the peak latencies at 350msec and 590msec. The learners in peaks at 450msec and 650msec. The learners of group (Lfr) peaks at 440msec and at 690msec. Group (LfR) positive peaks at 500msec and 720msec.

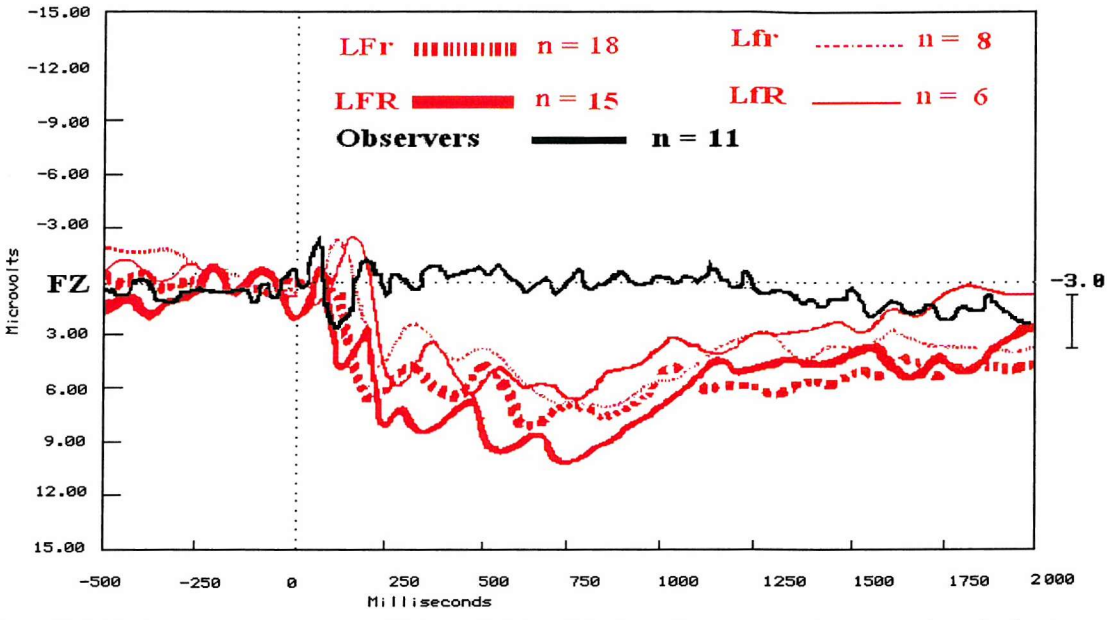


Figure (3.4.4.) shows the grand average ERPs elicited by subject's performance for the learners in red color traces after in all experiments groups during the last fifty trials of the learning task and the observers in black color trace. Recorded from mid-frontal site electrode (FZ), Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (msec). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

Figure (3.4.5.) shows the superimposed grand average (-500msec to 2000msec) ERPs elicited by subject's performance for the non-learners in blue color traces after in all experiments groups during the last fifty trials of the learning task and the observers in black color trace. Recorded from mid-frontal site electrode (FZ). The trace morphology was very similar from 500msec pre-stimulus to 200msec post-stimulus. The observers' trace returns back to the baseline to the end of the task. There were many peaks positive and negative in every group trace, but the positive peaks were not the same amplitude when compared with the learners as shown in (figure 3.4.4.). The non-learners traces showed very clear positive peak at 300 msec for group I (nLFr) and group IV (nLfR), and at 350msec for group III (nLfr). There were more positive and negatives peaks but not strong like the early ones.

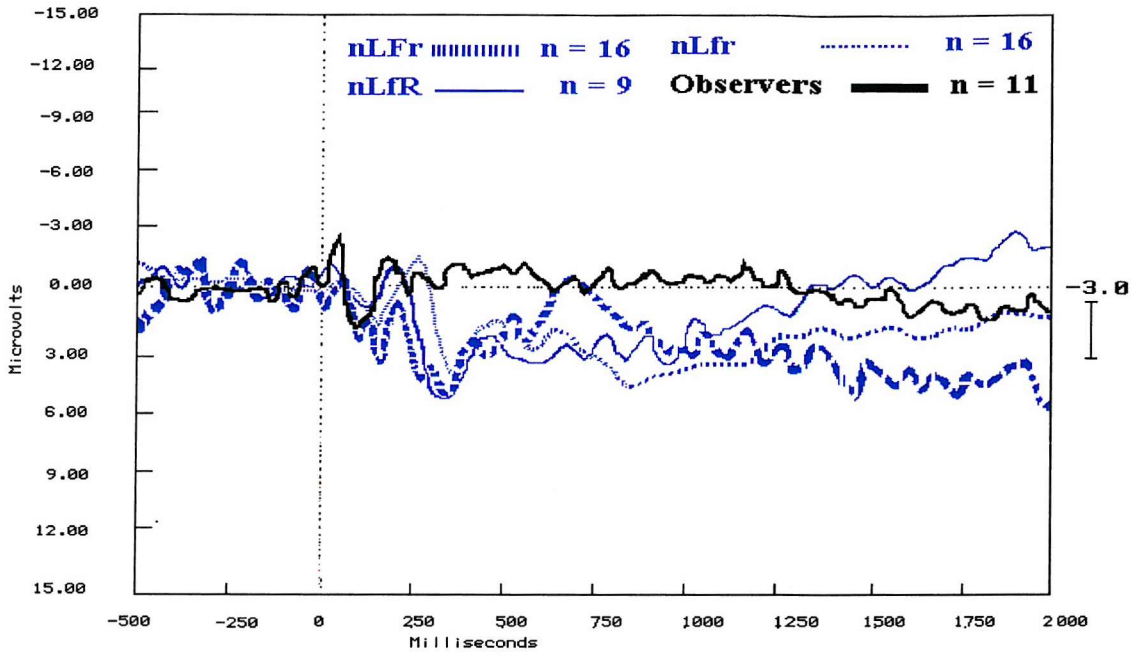


Figure (3.4.5.) shows the grand average ERPs elicited by subject's performance for the non-learners in blue color traces after in all experiments groups during the last fifty trials of the learning task and the observers in black color trace. Recorded from mid-frontal site electrode (FZ), Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (msec). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

The learners mean amplitudes were compared to the non-learners mean amplitudes during the last quartile group by using repeated measures two ways ANOVA (Learners & non-learners) X all electrodes Locations (Loc.). The results revealed that there were statistically significant differences in all groups during both time windows, and there was highly statistically significant difference for group Fr during the first time window. There were no statistically significant differences between the subject's effect in the all groups (Tables 3.4.1. and 3.4.2.).

Experimental conditions	1st window (250msec - 550msec)			
Group	Mean amplitude	DF	F	p
LFr n=18 nLFr n=16	5.99 ± 1.35 3.43 ± 1.12	24, 255	2.346	0.01
Lfr n=8 nLfr n=16	4.30 ± 1.32 2.77 ± 3.48	24, 119	1.93	0.05
LfR n=6 nLfR n=9	4.59 ± 1.30 2.91 ± 1.79	24, 170	3.27	0.03

Table (3.4.1.) shows first time window two ways repeated measures ANOVA test within subject effects of the non-learners and the learners in each group for the all electrodes locations (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ) during last fifty trials (last quartile). * ≤0.05, **≤0.01, *** ≤0.001.

Experimental conditions	2nd window (550msec - 850msec)			
Group	Mean amplitude	DF	F	p
LFr n=18 nLFr n=16	6.12 ± 0.99 2.96 ± 1.35	24, 136	1.99	0.001
Lfr n=8 nLfr n=16	4.88 ± 1.12 2.99 ± 1.09	24, 85	3.08	0.05
LfR n=6 nLfR n=9	4.99 ± 1.23 3.01 ± 0.98	24, 119	2.60	0.01

Table (3.4.2.) shows second time window two ways repeated measures ANOVA test within subject effects of the non-learners and the learners in each group for the all electrodes locations (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ) during last fifty trials (last quartile). * ≤0.05, **≤0.01, *** ≤0.001.

Two ways repeated measures ANOVA were used to compare the brain activity differences between the learners and the observers during two times windows (tables 3.4.3. & 3.4.4.). The non-learners groups were compared with the observers during the time windows (tables 3.4.5. & 3.4.6.). The results revealed that there were statistically significant differences within subjects effect (Groups X all electrodes locations) for the learners and non-learners in all groups. There were no interactions between subject's effect for the all groups.

Experimental conditions	1st window (250msec - 550msec)			
Group	Mean amplitude	DF	F	p
LFr n=18 Observers n=11	5.99 ± 1.35 1.12 ± 0.75	24, 323	12.02	0.0001
LFR n=15 Observers n=11	6.14 ± 1.69 1.12 ± 0.75	24, 187	12.65	0.0001
Lfr n=8 Observers n=11	4.30 ± 1.32 1.12 ± 0.75	24,153	3.32	0.009
LfR n=6 Observers n=11	4.59 ± 1.30 1.12 ± 0.75	24, 170	6.25	0.001

Table (3.4.3.) shows first time window two ways repeated measures ANOVA test within subject effects of the observers and the learners in each group for the all electrodes locations (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ). * ≤0.05, **≤0.01, *** ≤0.001.

Experimental conditions	2nd window (550msec - 850msec)			
Group	Mean amplitude	DF	F	p
LFr n=18 Observers n=11	6.12 ± 0.99 0.94 ± 0.59	24, 170	4.82	0.001
LFR n=15 Observers n=11	6.45 ± 1.09 0.94 ± 0.59	24, 170	4.19	0.001
Lfr n=8 Observers n=11	4.88 ± 1.12 0.94 ± 0.59	24, 119	3.4	0.005
LfR n=6 Observers n=11	4.99 ± 1.23 0.94 ± 0.59	24, 119	3.9	0.003

Table (3.4.4.) shows second time window two ways repeated measures ANOVA test within subject effects of the observers and the learners in each group for the all electrodes locations (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ). * ≤0.05, **≤0.01, *** ≤0.001

Experimental conditions	1st window (250msec - 550msec)			
Group	Mean amplitude	DF	F	p
nLFr n=16 Observers n=11	3.43 ± 1.12 1.12 ± 0.75	24, 187	5.84	0.001
nLfr n=16 Observers n=11	2.77 ± 3.48 1.12 ± 0.75	24, 119	2.08	0.01
nLfR n=9 Observers n=11	2.91 ± 1.79 1.12 ± 0.75	24, 170	4.84	0.01

Table (3.4.5.) shows first time window two ways repeated measures ANOVA test within subject effects of the observers and the learners in each group for the all electrodes locations (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ). * ≤0.05, **≤0.01, *** ≤0.001.

Experimental conditions	2nd window (550msec - 850msec)			
Group	Mean amplitude	DF	F	p
nLFr n=16 Observers n=11	2.96 ± 1.35 0.94 ± 0.59	24, 119	2.64	0.01
nLfr n=16 Observers n=11	2.99 ± 1.09 0.94 ± 0.59	24, 85	3.22	0.04
nLfR n=9 Observers n=11	3.01 ± 0.98 0.94 ± 0.59	24, 119	3.4	0.02

Table (3.4.6.) shows second time window two ways repeated measures ANOVA test within subject effects of the observers and the learners in each group for the all electrodes locations (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ). * ≤0.05, **≤0.01, *** ≤0.001.

Generally, the interpretation of topographic maps is done by pattern recognition. Before any intelligent interpretation can be carried out, it is necessary to have a good understanding of what constitutes a significant pattern, and to be able to differentiate them from artefacts. An important question is: what patterns does one look for?

Due to the way maps are constructed, one should start by analyzing dominant spatial features, and to discern temporal features by following a series of maps, or by inspecting the tracings of the channel of interest. Some of the primary spatial features that ought to be recognized first are peaks, gradients and symmetry. Next, there are secondary features like spread (the pattern of movement of a peak), and regions of persistent hypoactivity. Finally, one should postulate what the configuration of intracranial neuronal generators is that gave rise to this particular potentials map. The objective of this last step is to be able to link particular activity in anatomic structures to an observable electrical feature. While this may not be totally successful, even partial success would provide useful insight under many circumstances.

3.3.4. The learners brainmaps:

3.3.4.1. Group I learners (LFr n=18):

Figure (3.4.6. a, b, c, & d) show the cartoon brainmaps of the grand averaged event related potentials subtraction for the non-learners (nLFr) from the learners (LFr) during the four quartiles of the learning each quartile representing fifty trials.

First quartile (1st fifty) cartoon brainmaps summarize that there was no significant activity over the brain areas from 200 msec prestimulus to the beginning of the stimulus. Then a slight negativity appears frontally, with positivity over the occipital area post stimulus. The positivity starts to distribute forwards to the parietal and central, became clear frontally on the both sides

from 200msec post-stimulus and beyond, and stayed till 1000msec then started to decrease till disappeared. (Figure 3.4.6a)

The second quartile (2nd fifty) cartoon brainmaps shows that it was similar to the first fifty with little changes in the amplitude and latency. Where the positivity distributed faster from the occipital area frontally through the central and parietal areas and stayed for shorter times and started to disappear after 900msec. (Figure 3.4.6b)

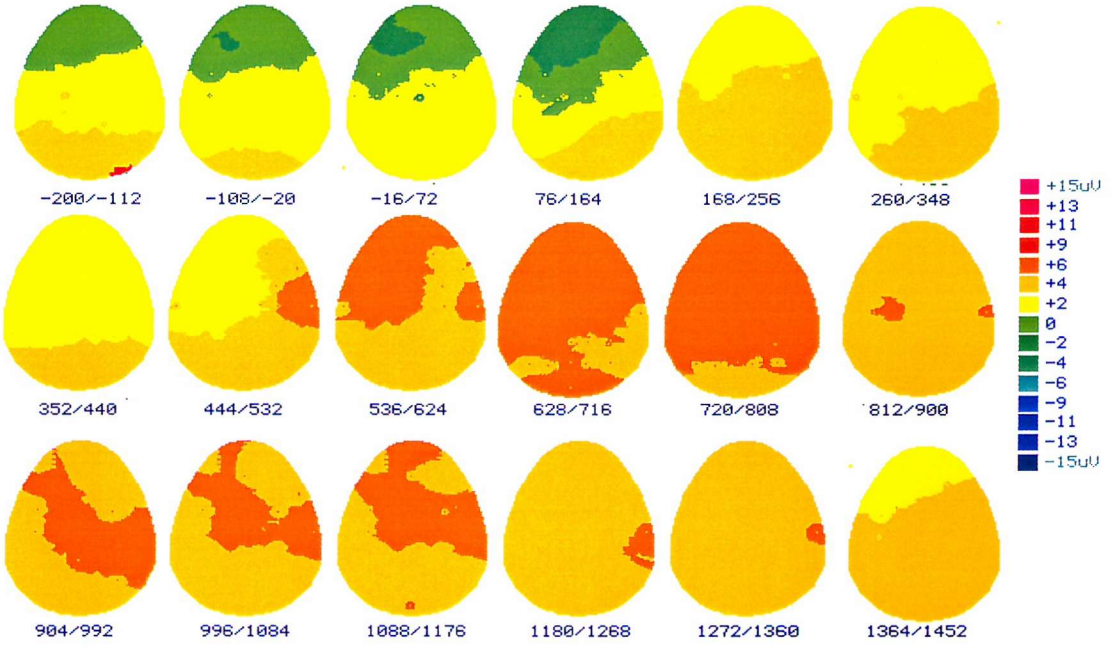


Figure (3.4.6a) shows the top view cartoon brainmaps made from the non-learners (nLFr) subtracted from the learner's (LFr) grand average ERP elicited with the first quartile trial answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

The third quartile trials (3rd fifty) figure 3.4.6c showed the same pattern as the first and the second quartile of learning trial with more positive activity over all brain areas. The positivity was more over the frontal area, temporal bilaterally and centrally. The activities over the brain areas became very low started to diminish gradually about 800msec post-stimulus, and there were some changes over the parietal, the central, and the temporal, but with no significant changes to the end of the task.

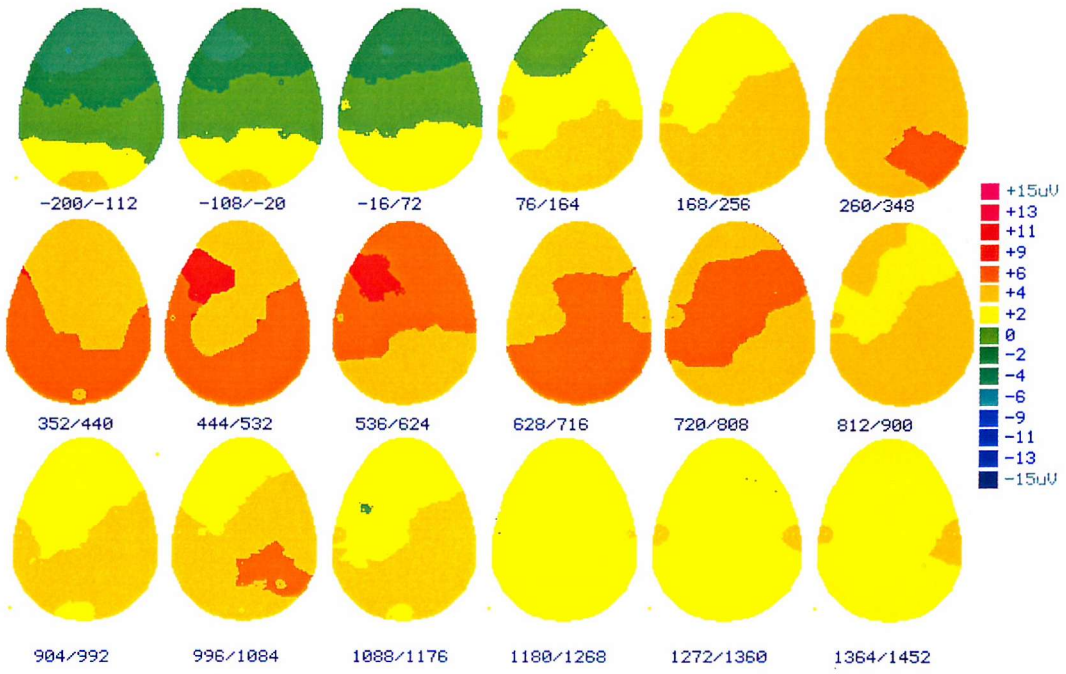


Figure (3.4.6b) shows the top view cartoon brainmaps made from the non-learners (nLFr) subtracted from the learners (LFr) grand average ERP elicited with the second quartile trial answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brainmaps

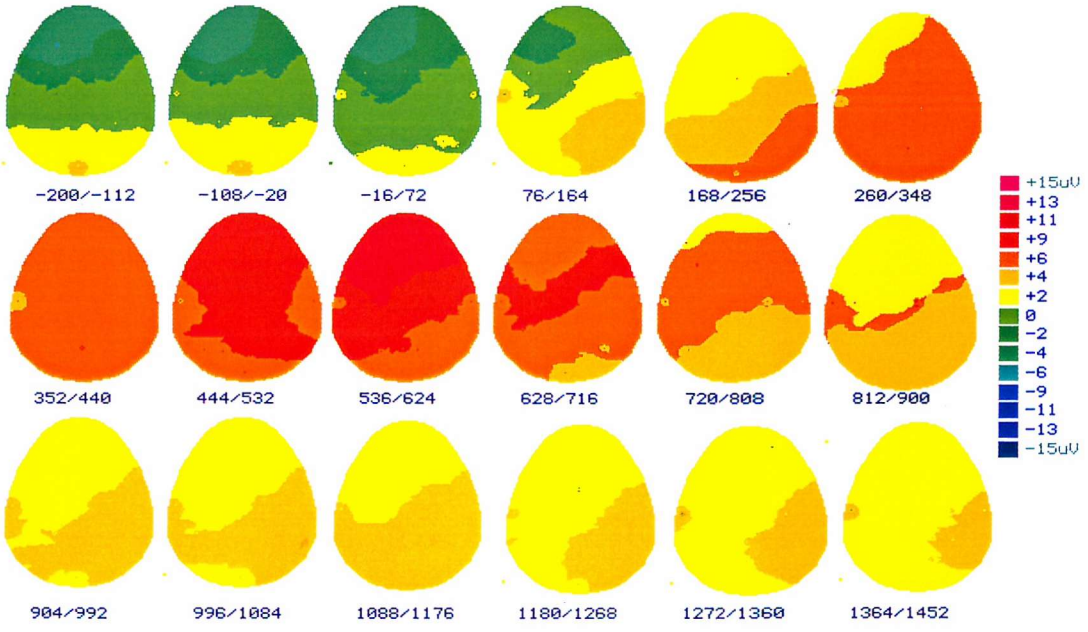


Figure (3.4.6c) shows the top view cartoon brainmaps made from the non-learners (nLFr) subtracted from the learners (LFr) grand average ERP elicited with the third quartile trial answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

The fourth quartile trials (4th fifty) figure 3.4.6d showed the early started positive activities over the occipital area just post-stimulus and extended later to appear all over the brain areas. The parietal, central, occipital and posterior temporal areas showed bilateral positive activity from about 100msec post-stimulus to about 350msec and then the positive activity increased up to 900msec post-stimulus, but there were no too much differences between these areas. The frontal positive activity changes appeared over the right-hand side area from about 200msec and then distributed bilaterally up to about 900msec. The positive activity was localized over the frontal and temporal to the right-hand side from 250msec to 550msec post-stimulus. One second post-stimulus the activities over the brain areas did not show significant changes to the end of the task.

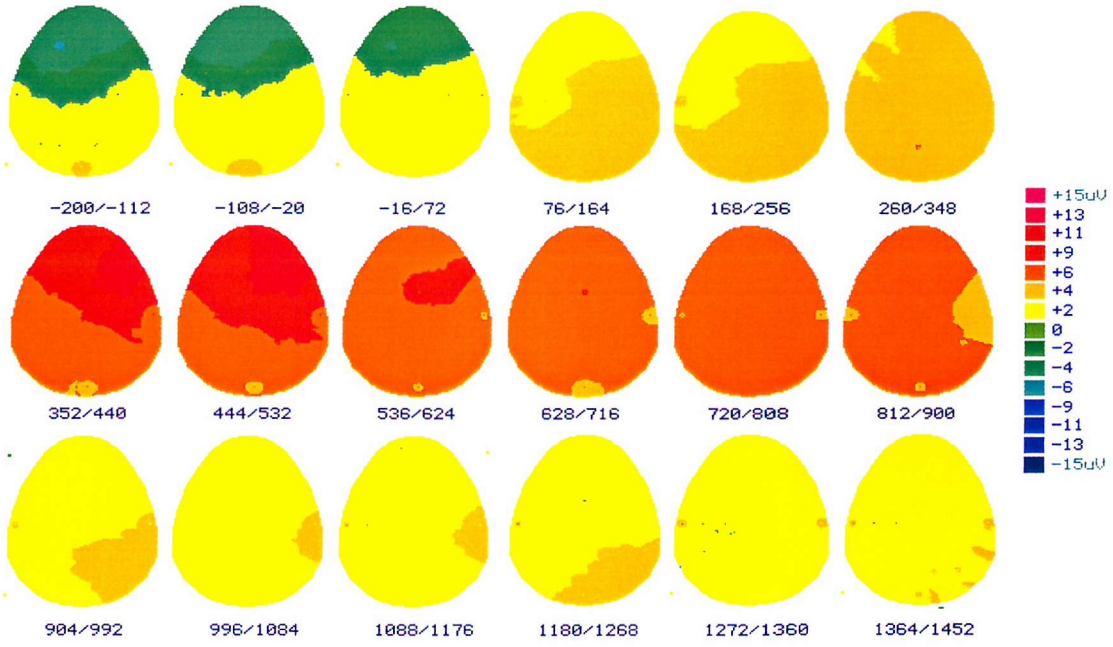


Figure (3.4.6d) shows the top view cartoon brainmaps made from the non-learners (nLFr) subtracted from the learners (LFr) grand average ERP elicited with the fourth quartile trial answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

3.3.4.2. Group II learners (LFR n=15):

Figure (3.4.7 a, b, c, & d) show the cartoon brainmaps of the grand averaged event related potentials subtraction for the non-learners (nLFR) from the

learners (LFR) in the second group during the four quartiles of the learning each quartile representing fifty trials.

The first quartile cartoon brainmaps (first fifty trials) in figure 3.4.7 a showed that there was no significant positive or negative pre-stimulus and then the positivity starts to appear post-stimulus over the occipital area followed by more positivity over the parietal area and distributed forward to be central then frontally where the positivity was stronger and stayed for longer time and bilaterally more to the right-hand side. After about 900msec and beyond the positive activity started to decrease gradually.

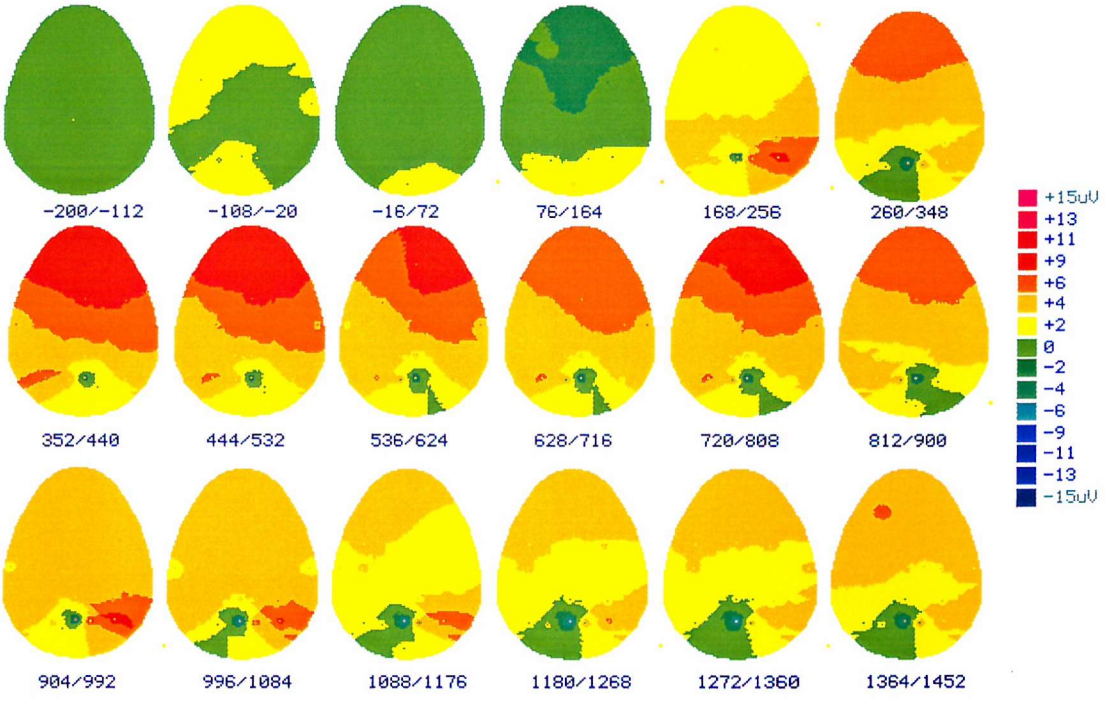


Figure (3.4.7 a) shows the top view cartoon brainmaps made from the group II learners (LFR) grand average ERP elicited with the first quartile trials answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

The second quartile trials (2nd fifty) figure 3.4.7 b showed that there was positive activity appeared occipitally and negative activity frontally. The positive activity became general all over the brain areas about 250msec post-stimulus with more localized positive activity over the frontal area. There were

positive activities over the posterior temporal area especially to the right-hand side. Less positive activity over the central area and it decreased as time progressed. It was bilateral with much deviation and extended more to the right-hand side. The positive activity diminished from about 1000msec to the end of the task.

The third quartile trials (3rd fifty) figure 3.4.7c showed the same pattern as the first and the second quartile of learning trial with more positive activity over all brain areas. The positivity was more over the frontal area and temporal bilaterally and centrally and started to diminish gradually but not as quickly as the first two quartiles.

The fourth quartile trials (4th fifty) figure 3.4.7d showed the early starting positive activities over the occipital area just post-stimulus which extended later to appear all over the brain areas. Generally there was not much change between the first quartile and the last quartile positive and negative activities, but there were little changes in these activities latencies

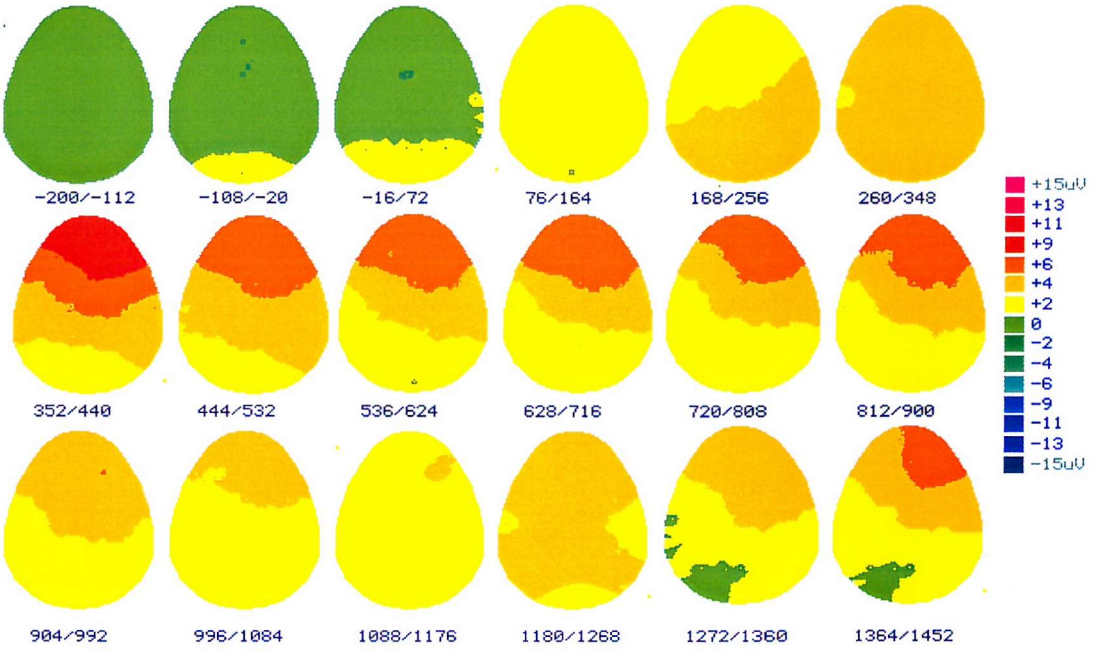


Figure (3.4.7 b) shows the top view cartoon brainmaps made from the learners (LFR) grand average ERP elicited with the second quartile trials answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

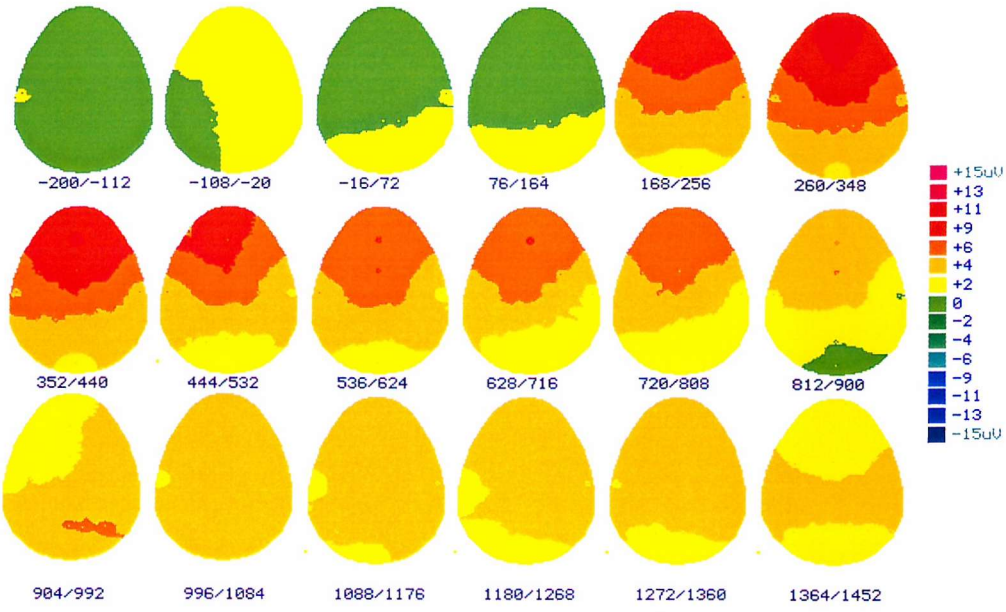


Figure (3.4.7c) shows the top view cartoon brainmaps made from the learners (LFR) grand average ERP elicited with the third quartile trials answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

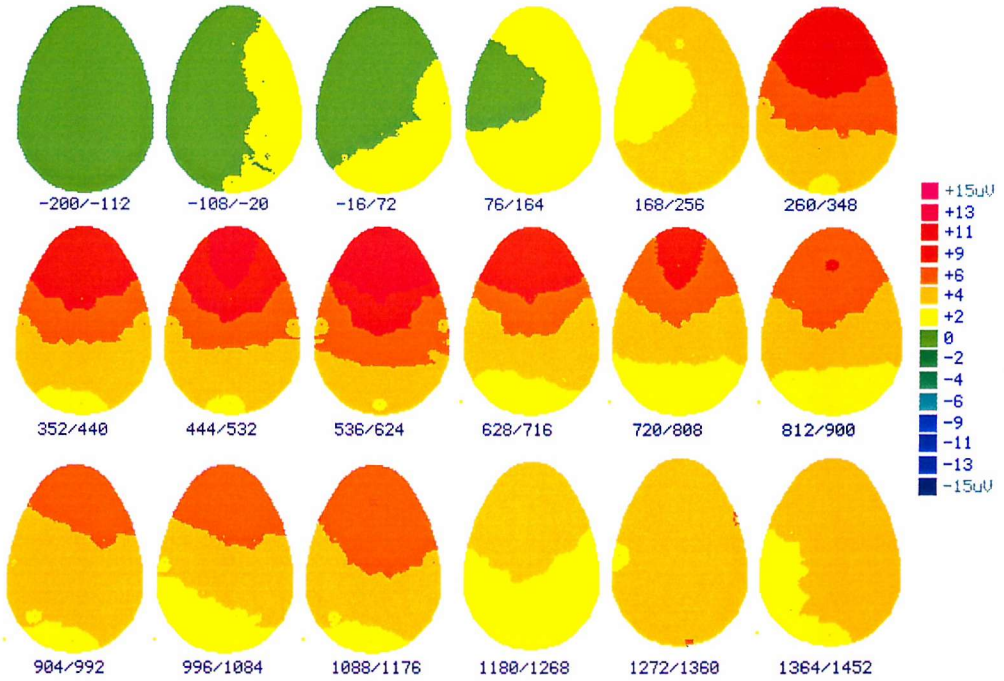


Figure (3.4.7d) shows the top view cartoon brainmaps made from the learners (LFR) grand average ERP elicited with the fourth quartile trials answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

3.3.4.3. Group III learners (Lfr n=8):

Figure (3.4.8 a, b, c, & d) show the cartoon brainmaps of the grand averaged event related potentials subtraction for the non-learners (nLfr) from the learners (Lfr) during the four quartiles of the learning each quartile representing fifty trials.

The first quartile showed in figure 3.4.8a the generalized positive activities all over the occipital, parietal, central, anterior and posterior temporal areas and the maximum was over the frontal area especially to the right-hand side and started to diminish gradually from about 600msec post-stimulus to the end of the trials.

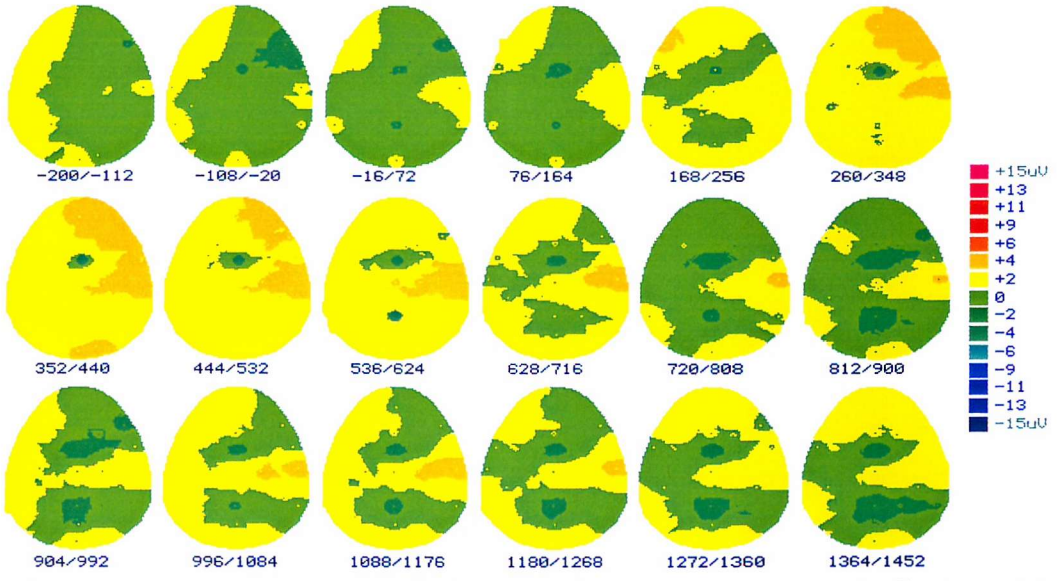


Figure (3.4.8a) shows the top view cartoon brainmaps made from the non-learners (nLfr) subtracted from the learners (Lfr) grand average ERP elicited with the first quartile trial answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

The second quartile showed minimal changes, which means that there was no difference between the non-learners and the learner's brainmap. The positive activity became more from about 350msec to about 750msec and localized frontally to the right-hand side and bilaterally over the parietal, posterior temporal and occipital areas. From about 800msec latency and beyond the

cartoon brainmaps showed that there were no significant positive or negative activity changes which indicate that there were no significant differences between the non-learners and the learners brain activities to the end of the task figure 3.4.8b.

The third quartile trials cartoon brainmaps showed in figure 3.4.8c that there were more differences between the learners and the non-learners brain activity during performing the task. There was a positive activity change starting early over the occipital area and then more positive changes appeared over the frontal area bilaterally from about 150msec and then more localized to the right-hand side. It decreased after about 1000msec. There were no significant differences between over the parietal, central, and temporal areas from the beginning to the end of the task.

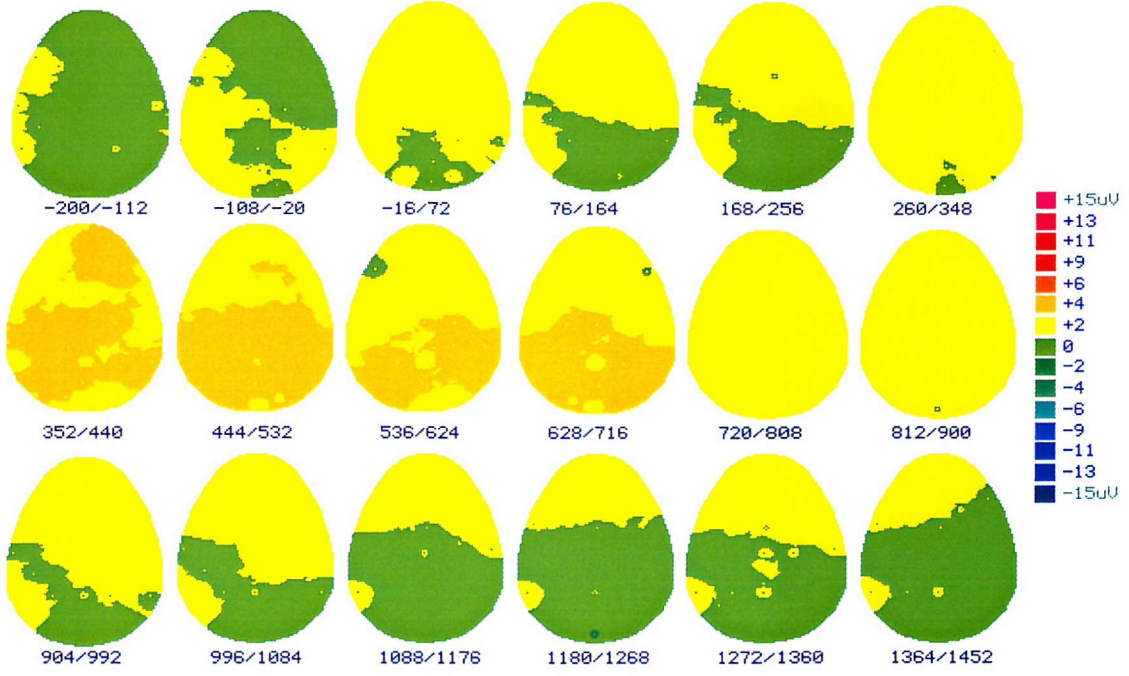


Figure (3.4.8b) shows the top view cartoon brainmaps made from the non-learners (nLfr) subtracted from the learners (Lfr) grand average ERP elicited with the second quartile trial answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

The 4th quartile trials cartoon brainmaps shown in figure 3.4.8d showed more differences between the learners and the non-learners in brain activity. There were positive activity changes starting early over the occipital and the parietal area bilaterally from about 70msec post-stimulus to about 350msec. The frontal positive activity changes appeared over the right-hand side area from about 250msec and then distributed bilaterally to about 900msec. The positive activity became localized to the right hand side again from 900msec to 1200msec when started to decrease. There were no significant differences between the parietal, central, and temporal areas from about 350msec to the end of the task.

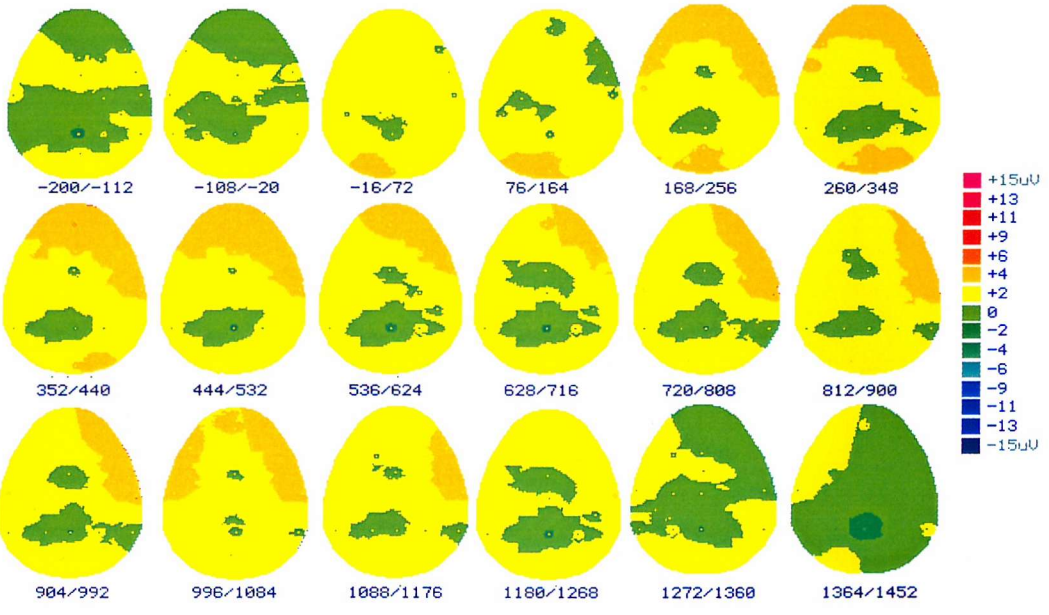


Figure (3.4.8c) shows the top view cartoon brainmaps made from the non-learners (nLfr) subtracted from the learners (Lfr) grand average ERP elicited with the third quartile trial answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

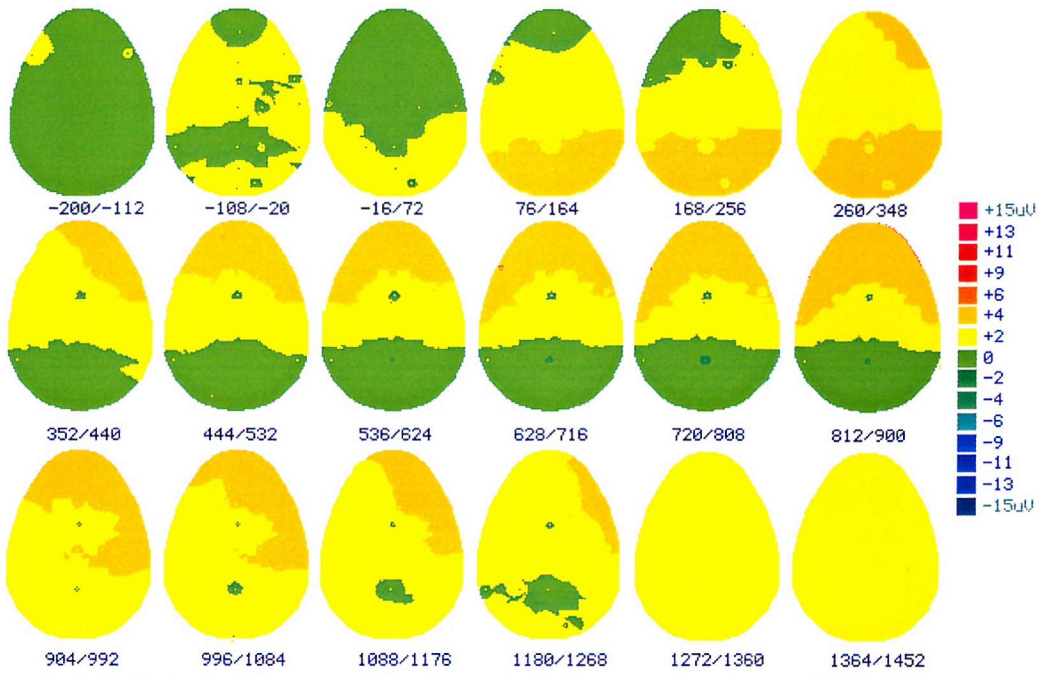


Figure (3.4.8d) shows the top view cartoon brainmaps made from the non-learners (nLfr) subtracted from the learners (Lfr) grand average ERP elicited with the fourth quartile trial answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

3.3.4.4. Group IV learners (LfR n=6):

Figure (3.4.9 a, b, c, & d) show the cartoon brainmaps of the grand averaged event related potentials subtraction for the non-learners (nLfR) from the learners (LfR) during the four quartiles of the learning each quartile representing fifty trials.

The first quartile (1st fifty trials) figure 3.4.9a showed that there was a difference between the learners and the non-learners. The positive activity started early occipital and posterior temporal bilaterally from 100msec post-stimulus. Then extended over the parietal bilaterally and the anterior temporal to the right-hand side from 150msec to 450msec. The frontal area started very late from 550msec to 1200msec and then gradually decreased to the end of the task. Figure 3.4.9b showed the differences between the learners and non-learners. The positive activity over the frontal, central, anterior temporal and

parietal areas bilaterally from 150msec to 1200msec and then decreased gradually to the end of the task.

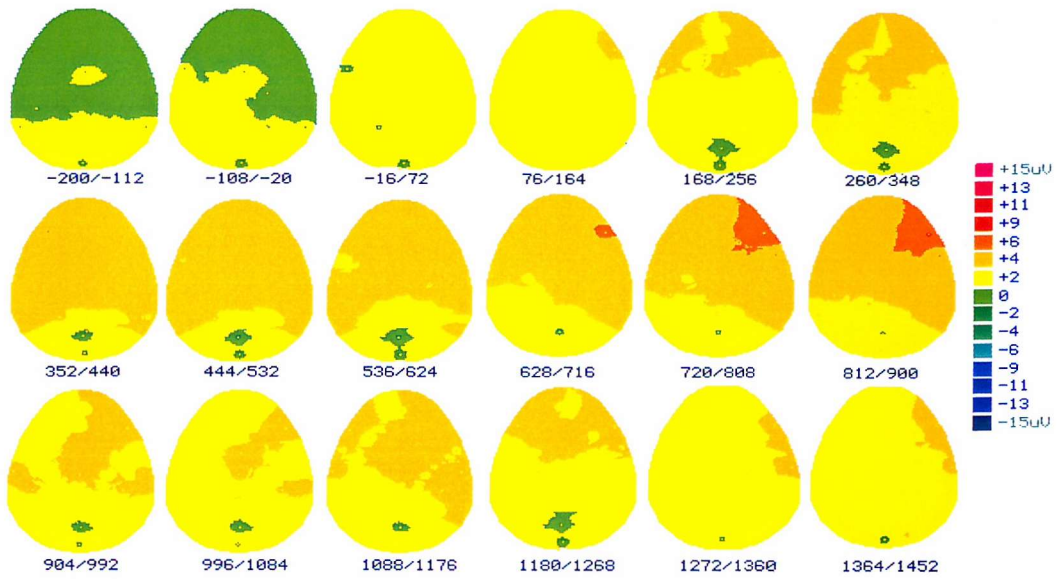


Figure (3.4.9a) shows the top view cartoon brainmaps made from the non-learners (nLfR) subtracted from the learners (LfR) grand average ERP elicited with the first quartile trial answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

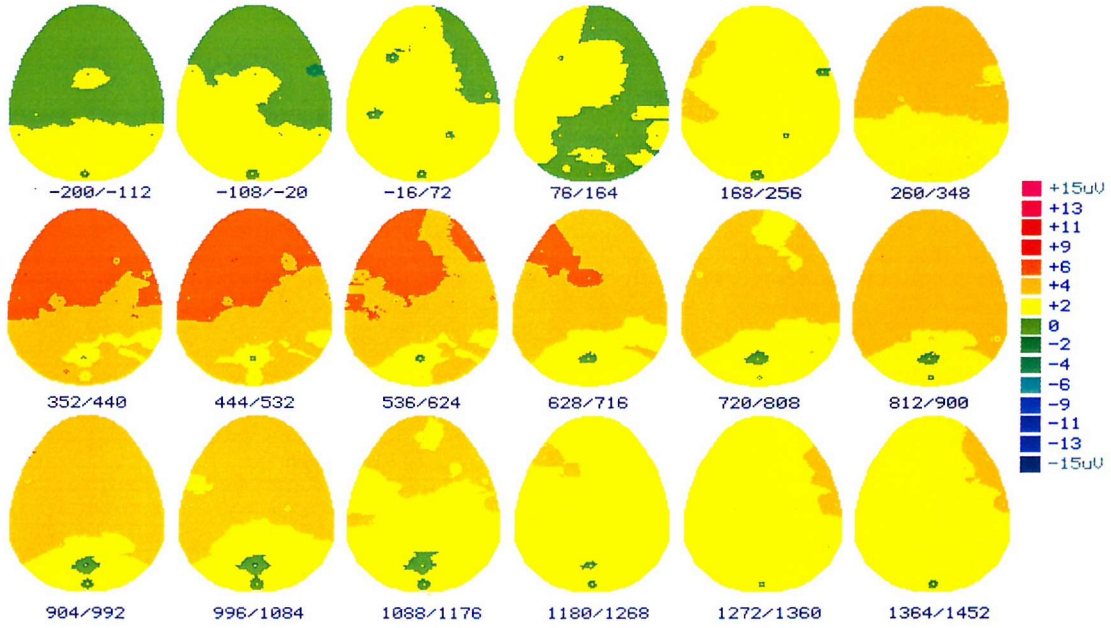


Figure (3.4.9b) shows the top view cartoon brainmaps made from the non-learners (nLfR) subtracted from the learners (LfR) grand average ERP elicited with the second quartile trial answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

The third quartile (3rd fifty trials) figure 3.4.9c showed frontal positive activity bilaterally and then showed more positivity from 350msec to 700msec and localized to the left-hand side. The positive activity over the parietal, posterior temporal started from 350msec to 1000msec. Decrease the positive activity from 1000msec to the end of the task.

The last fifty (4th quartile) showed that there were changes between the learners and the non-learners where the positive activity started at about 100msec over the occipital, parietal, posterior temporal areas bilaterally. The positive activities were over the central, anterior temporal bilaterally from 350msec. The positive activity over the frontal area was more than the other areas and it was bilateral at the beginning and more localized to the right-hand side to the end of the task figure 3.4.9d.

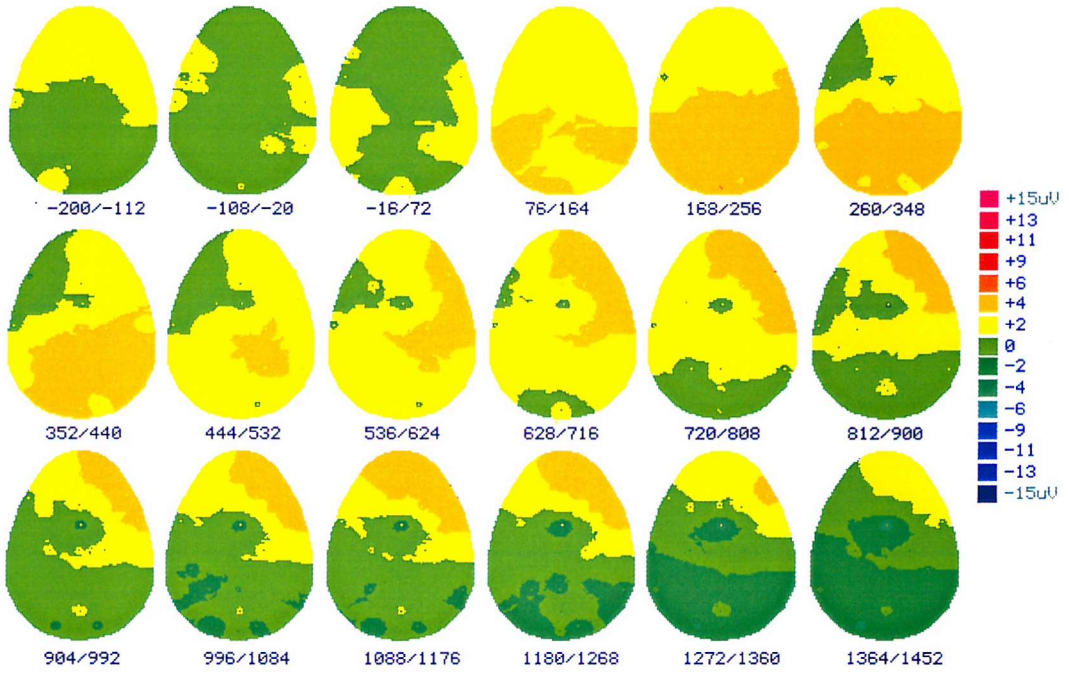


Figure (3.4.9c) shows the top view cartoon brainmaps made from the non-learners (nLfR) subtracted from the learners (LfR) grand average ERP elicited with the third quartile trial answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

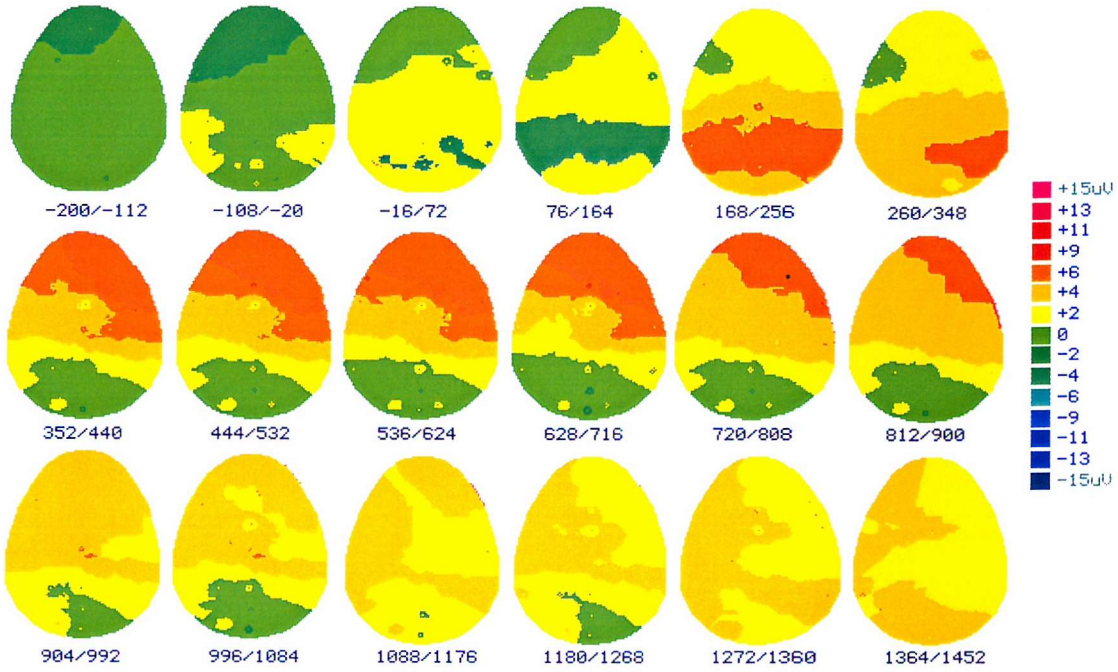


Figure (3.4.9d) shows the top view cartoon brainmaps made from the non-learners (nLfR) subtracted from the learners (LfR) grand average ERP elicited with the fourth quartile trial answers. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

3.3.4.5. Inter groups brainmaps comparison :

The above Figure (3.4.6d, 3.4.7d, 3.4.8d, 3.4.9d) show the cartoon brainmaps of the grand averaged event related potentials subtraction for the non-learners from the learners during the fourth quartiles of the learning each quartile representing last fifty trials in every group. The comparison between the learners of the all groups showed that the positive activity was localized in general to the frontal lobe and mainly to the right-hand side. The positive activity as well was well distributed over the parietal, central, anterior temporal, and occipital. All these positive activities were different from group to group in start point and their duration. Group II learners (LFR) showed the strongest positive activity in frontal area bilaterally, and especially to the right-hand side followed by the group I (LFr & nLFr) and group IV (LfR & nLfR) and on the least one is group III (Lfr & nLfr).

Figure 3.4.7a cartoon brainmaps showed the grand averaged event related potentials subtraction for the learners during the first quartiles of the learning (1^{st} fifty trials). These subjects performed very well from the beginning of the task similar to their performance in last quartile of the task in the same group. When comparing figures (3.4.6d, 3.4.7d, 3.4.8d, and 3.4.9d), we found that there were no great differences between all these cartoon brainmaps.

We compared between the subjects effect for the brain activity elicited by the learners last quartile in every group and the learners first quartile in the second group (LFR) X all electrodes locations (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ). The results revealed that there were no statistically significant differences for any of the groups (Table 3.4.7.)

Learning Group	Amplitude	df	F
LFr n=18 (4^{th} quartile) LFR n=15 (1^{st} quartile)	6.12 ± 0.99 5.22 ± 1.01	(1,14)	62.41
LFR n=15 (4^{th} quartile) LFR n=15 (1^{st} quartile)	6.45 ± 1.09 5.22 ± 1.01	(1,14)	53.37
Lfr n=8 (4^{th} quartile) LFR n=15 (1^{st} quartile)	4.88 ± 1.12 5.22 ± 1.01	(1,7)	33.17
LfR n=6 (4^{th} quartile) LFR n=15 (1^{st} quartile)	4.99 ± 1.23 5.22 ± 1.01	(1,5)	21.86

Table (3.4.7.) shows two ways repeated measures ANOVA test between subjects effect during the last quartile for the learners in each group and the learners first quartile in the second group (LFR) for all electrodes (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ). * ≤0.05, **≤0.01, *** ≤0.001

3.4.5. Group V: Observers (Passive)

Grand average event related potentials were inspected visually for amplitude peaks and troughs. It can be seen that electrical activity was very similar in all parts of the brain pre-stimulus

All over the scalp the waveforms from all the electrodes superimposed for ERPs elicited by the all-trial stimuli show series of positive and negative peaks occurred with similar morphology and almost the same latency. The positive

and negative waves beyond 200msec disappeared and the trace returned to the baseline and looks like the baseline (Figure 3.4.10.).

The top view cartoon brainmaps (Figure 3.4.11.) shows that there is no positive or negative activity before the stimulus. We could see the usual changes in the color with image perception. This activity was around the start point up to 200msec post-stimulus all over the brainmap especially frontal, parietal and occipital sites. Then the color changed again to the baseline level. From the color scale it can be seen that the amplitude was around zero μV ± 2 μV.

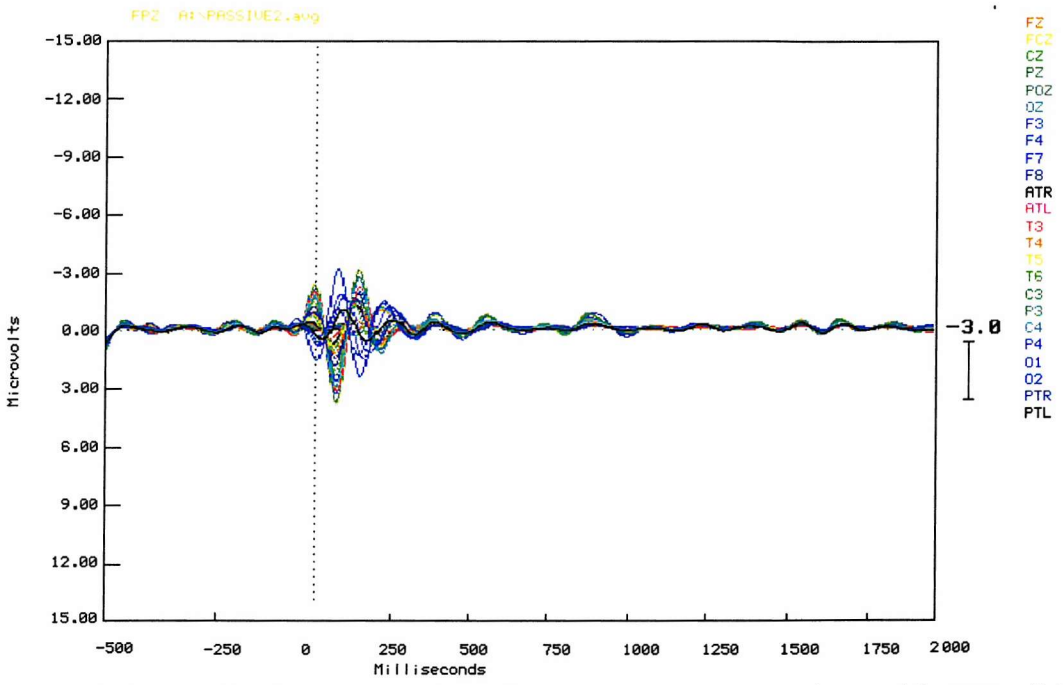


Figure (3.4.10.) shows the observers waveforms from all the electrodes superimposed for ERPs elicited by the all-trial stimuli. Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Downward deflection represents the positivity. Upward deflection represents the negativity.

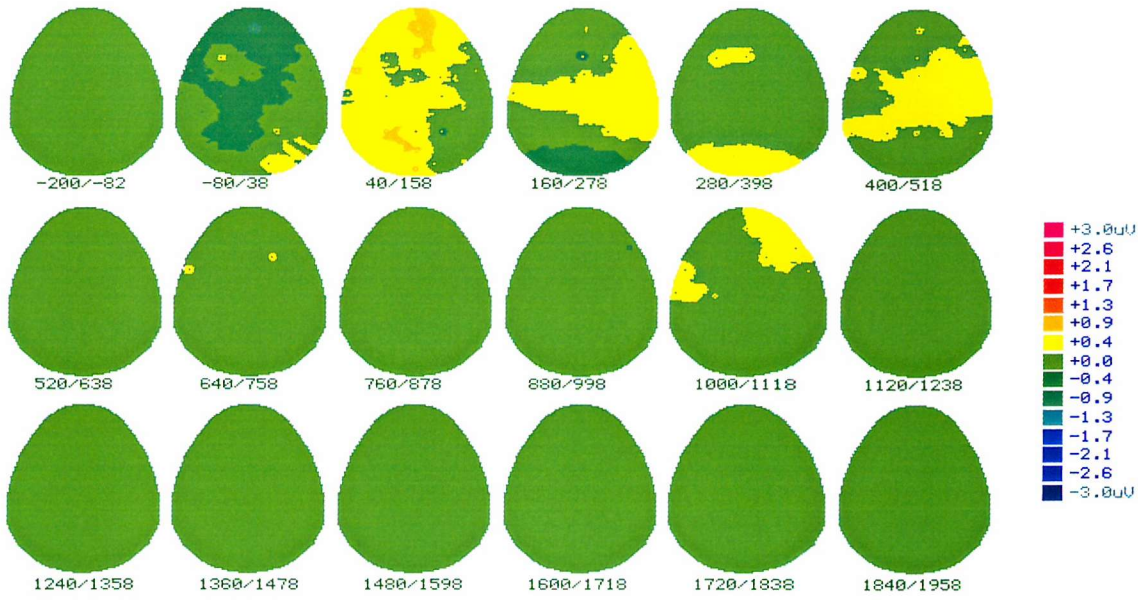


Figure (3.4.11.) shows the top view cartoon brainmaps of made from grand average ERP elicited with the all observers' trials. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

Statistical analysis of the difference between subjects brain activity while performing the task for each quartile (50 trials). Between the subjects effect for the inter learner's group fourth quartile. The learner's groups by the electrodes locations during first versus last quartiles, and the correct answer trials versus the incorrect answers trials (See tables in appendices 5.5.2.)

3.5. Group I with feedback and without rule (Fr n=34)

All subjects showed a characteristic positive peak about 250msec onwards in all trial displays for both groups learners and non-learners. The positive activity peaks were greater for the learners group than the group of non-learners

All traces are shown with reference to linked mastoids. Positivity at the named electrode denoted by downward deflection of the trace.

3.5.1. First fifty and last fifty trials:

In figure (3.5.1.) we are comparing the learners and non-learners first fifty trials out of the two hundred trials versus the last fifty trials. In the first fifty we expect they are guessing, as they have not had the chance to learn yet, and the last 50 as we can assume that they either have or have not learned.

The learners start-to-end trials comparison showed that they were different with increase in the positivity occurring from 200 msecs onwards in the last fifty displays. The last fifty traces deviated in the cognitive part from 200msecs to 900msecs. Whereas in the case of non-learners group, the activity appeared to be similar throughout the all task with insignificant differences

Figure (3.5.2.) shows that there are very clear positivity differences for the learners more than the non-learners group after learning (during the last fifty trials) started around 300msecs and ended about 1300msecs. Comparing this to the equivalent traces for the last fifty traces. The first fifty traces for both groups showed the same morphology and the learners first fifty was more positive going than the non-learners trace. This means that in the learners brain potentials for the first fifty answers provoke a more positive potential during both time windows.

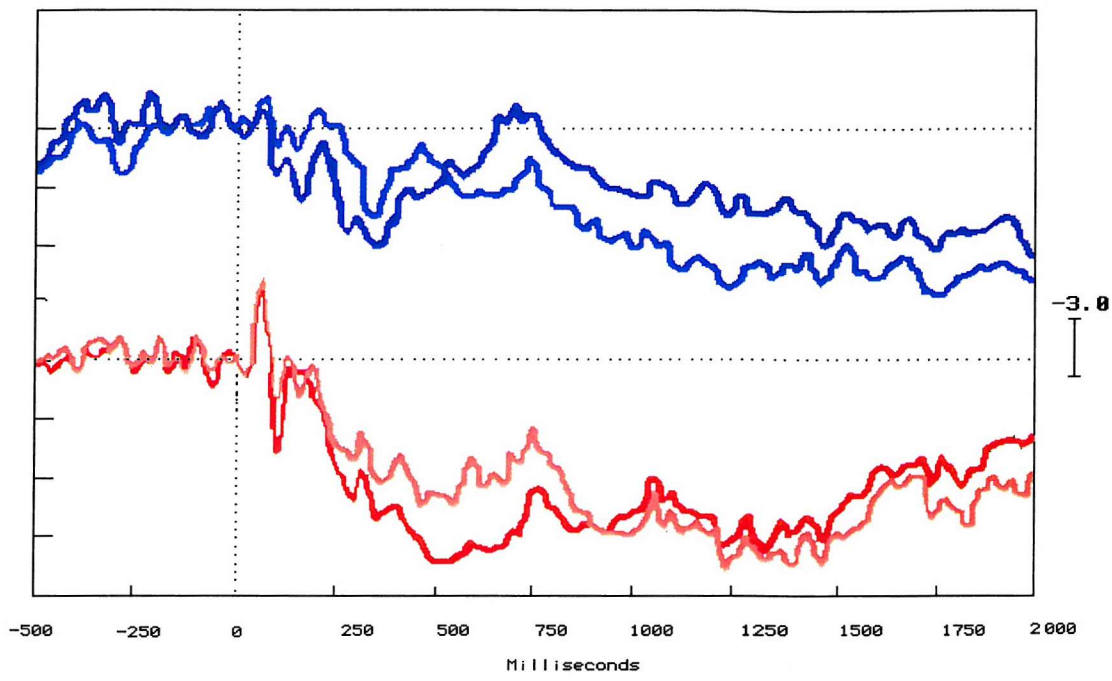


Figure (3.5.1.) Grand average ERPs elicited by the learners first fifty trace in light red color and the last fifty traces in red color and the non-learners first fifty trace in light blue color and the last fifty in blue color. Recorded at FZ mid-frontal site electrode. Y-axis shows amplitude in Microvolts (μV) and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

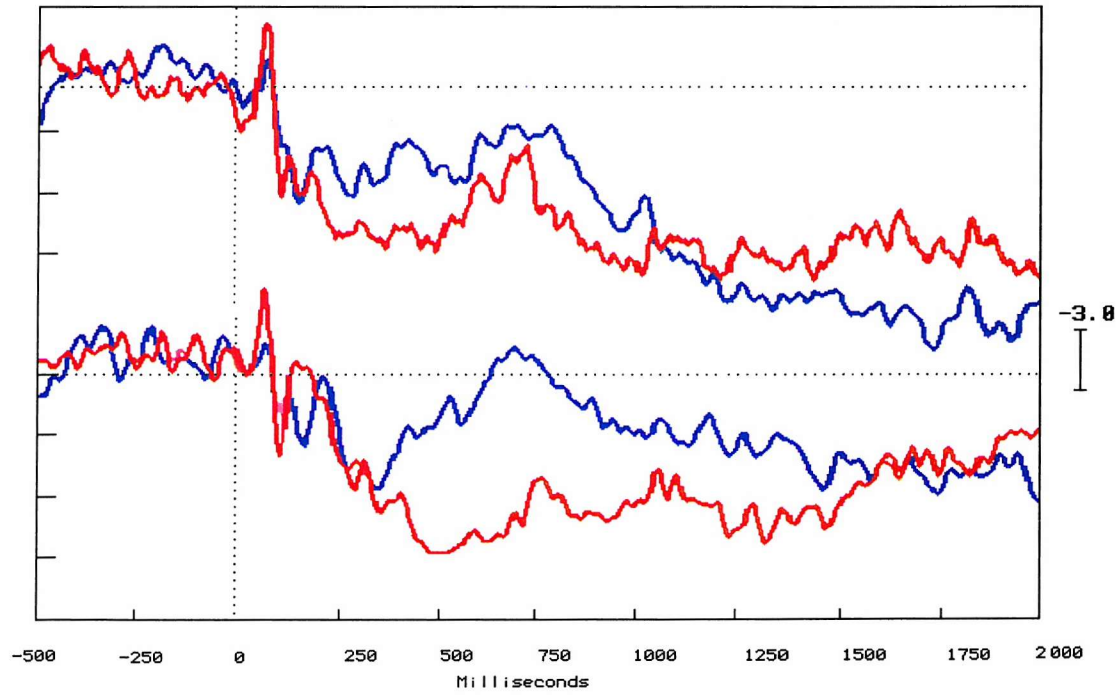


Figure (3.5.2) shows the grand averaged ERPs elicited by the learners trace in red color and the non-learners trace in blue color and the first fifty represented by the top traces and the last fifty represented by the bottom traces. Recorded at FZ mid-frontal site electrode, Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (msec). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

Individual electrodes gave us limited information as they reflect localized brain activity. For this reason brainmaps are useful in showing more widespread effects. Figure 3.5.3a shows the learners' top view cartoon brainmaps of made from subtraction of the first fifty trials from the last fifty trials (LFr). There were no differences recorded pre-stimulus and up to 160msec post-stimulus. The positive activity was distributed over the parietal, the temporal and occipital areas and then distributed forward to the frontal and anterior temporal areas bilaterally, and more deviated to the right-hand side. The positive activity back to decrease gradually after 500msec and localized to the left hand side posterior temporal and parietal areas and then there were no recorded differences about 900msec and beyond.

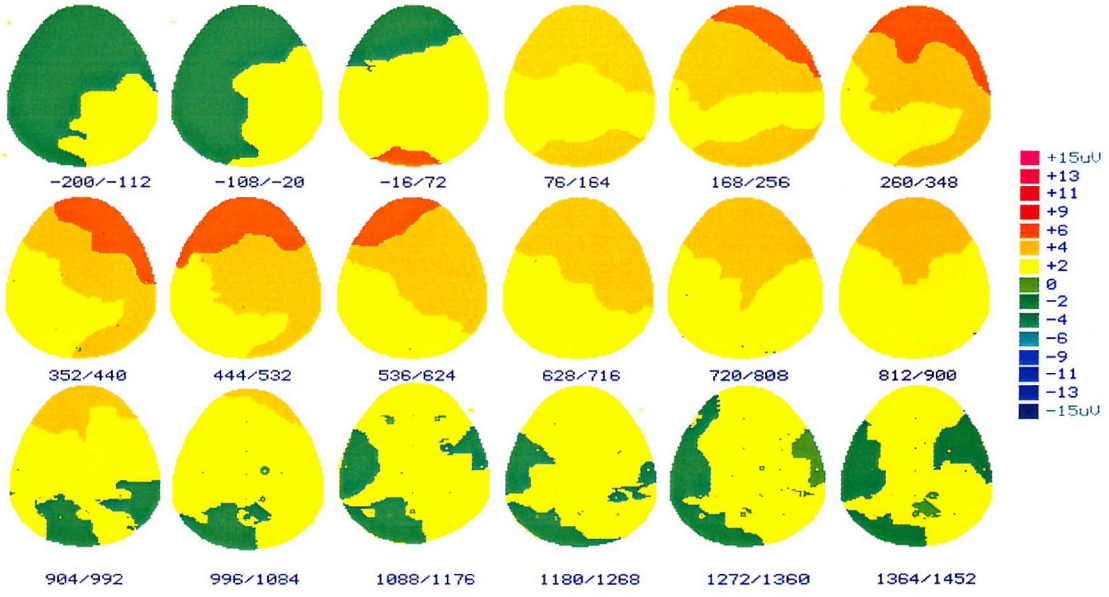


Figure (3.5.3a) shows the top view cartoon brainmaps of made from subtraction of the first fifty answers trials from the last fifty answers trials grand average ERPs elicited by the learners performance in group three (LFr). The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1452msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal area to the top and occipital to the bottom of the brainmaps.

Figure 3.5.3b shows the non-learners top view cartoon brainmaps of made from subtraction of the first fifty trials from the last fifty trials (nLFr). There were no

differences recorded pre-stimulus and up to 200msec post-stimulus. The positive activity started to appear frontally and deviated to the right-hand side. The brain activity differences did not show the same positive or negative activity distribution or latencies when compared with the learners brain maps.

Independent-Sample t-Tests for within group analysis to compare the mean amplitude for in the learners group and the non-learners group separately, and between both of them. There were high statistically significant differences between the learners start to end trials during the two time windows; the first time window learners first fifty mean amplitude was (3.02μv) and for last fifty was (5.3μv); the second time window learners first fifty mean amplitude was (3.17μv) and for the non-learners was (5.63μv); (Table 3.5.1.), but there were no statistically significant difference for the non-learners during the both time windows (Table 3.5.1.)

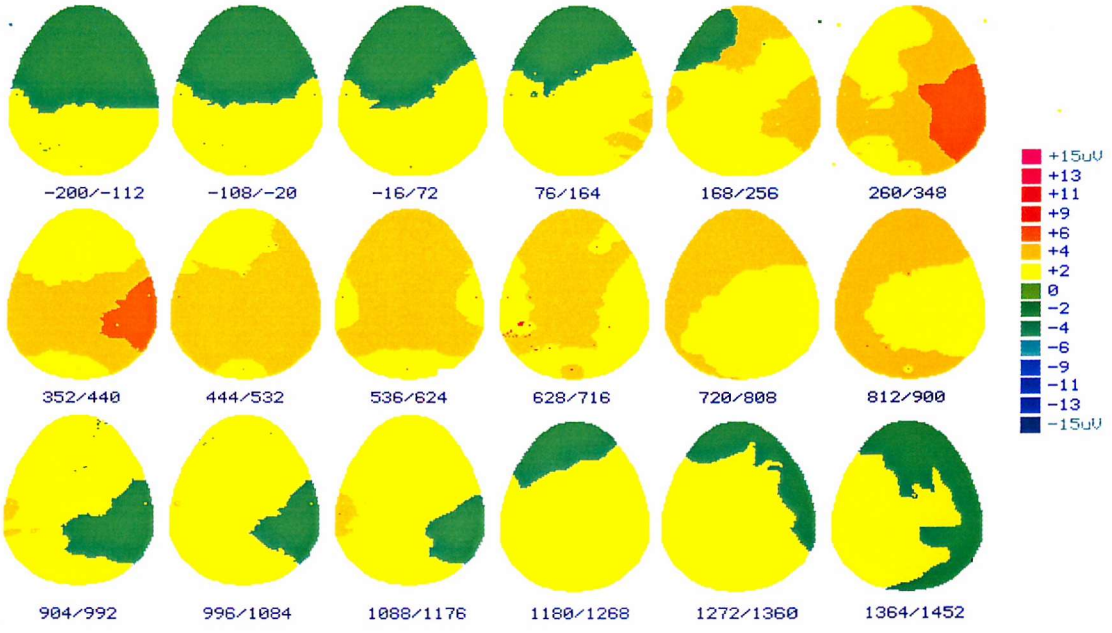


Figure (3.5.3b) shows the top view cartoon brainmaps of made from subtraction of the first fifty answers trials from the last fifty answers trials grand average ERPs elicited by the non-learners performance in group three (nLFr). The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1452msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal area to the top and occipital to the bottom of the brainmaps.

Comparing the learners and the non-learners mean amplitude during the first quarter (first fifty trials) there were no statistically significant differences (Table 3.5.2.), but after learning (last fifty trials) there was highly statistically significant difference (Table 3.5.2.).

Paired t-Tests were used for, subjects within the same group analysis to compare between the active individual electrodes. Table (3.5.3.) shows that there were statistical significant differences results in the learning group during the two time windows the last fifty answer trials versus the first fifty answer trials for these two frontal electrodes F3 & F4, and the frontal midline electrode FZ. The non-learning the last fifty versus the first fifty answer trials did not show any statistical significant differences for any of the compared electrode site during the two time windows.

Group	Learners (LFr n=18)		Non-learners (nLFr n=16)	
Time window	1st window	2nd window	1st window	2nd window
First fifty (Amplitude μv)	3.02	3.17	3.50	3.30
Last fifty (Amplitude μv)	5.30 ***	5.63***	3.70	3.81

Table (3.5.1.) Independent T-test results of the first fifty versus the last fifty answer trials mean amplitude during the both time windows for the Learners and the non-learners. * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001.

Experiment condition	First fifty (Amplitude μv)		Last fifty (Amplitude μv)	
Group / windows	1st window	2nd window	1st window	2nd window
Non-learners (nLFr n=16)	3.50	3.30	3.70	3.81
Learners (LFr n=18)	3.02	3.17	5.30 **	5.63 **

Table (3.5.2.) Independent T-test results of the learners versus the non-learners mean amplitude during the both time windows for first fifty and the last fifty answer trials. * ≤ 0.05, ** ≤ 0.01, ***≤0.001.

Group	Learners (LFr n=18)		Non-learners (nLFr n=16)	
Electrodes sites	1st window *t taild value*	2nd window *t taild value*	1st window *t taild value*	2nd window *t taild value*
C3	0.59	1.2	1.2	0.89
C4	1.2	1.4	1.3	0.53
CZ	1.23	1.3	2.1	0.54
FCZ	1.88	1.77	1.98	0.97
F3	3.30*	3.54 **	2.1	0.48
F4	3.8*	3.60 *	2.3	0.52
F7	1.17	1.11	1.8	1.4
F8	1.57	1.13	1.7	0.74
FZ	3.89**	3.94 **	2.3	2.4
P3	2.3	2.3	0.90	0.64
P4	2.5	2.1	1.1	0.98
TPL	1.26	1.3	1.1	2.20
TPR	1.65	1.80	1.3	2.3
PZ	1.12	1.46	0.98	0.58
POZ	1.11	1.56	0.99	0.87
T3	1.25	1.30	1.3	1.5
T4	1.03	1.5	1.2	1.6
T5	1.15	1.7	1.7	1.20
T6	1.12	1.5	2.1	1.9
ATL	1.07	1.12	0.89	0.90
ATR	1.61	1.8	1.1	1.30

Table (3.5.3.) shows Paired T-test results of the start versus the end answers trials at the individual electrode sites during both time windows for the learners and the non-Learners. * ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001.

3.5.2.Correct versus incorrect trial answers:

The learners ERPs correct answer trials versus the incorrect answer trials seem to be different with a very clear increase in the positivity for the correct answers. These cognitive deviations start at 200msecs and end about 1200 msec (Figure 3.5.4.). Table (3.5.4.) shows that these mean amplitude differences are highly statistically significant during both time windows.

For the non-learning group both waves for the correct and incorrect answers look similar to each other (Figure 3.5.4.), but there was a minimal increase in the positivity for the correct answers starting at 400msec and ending around

700 msec. These differences are shown in the Table (3.5.4.) and these are not statistically significant during time window.

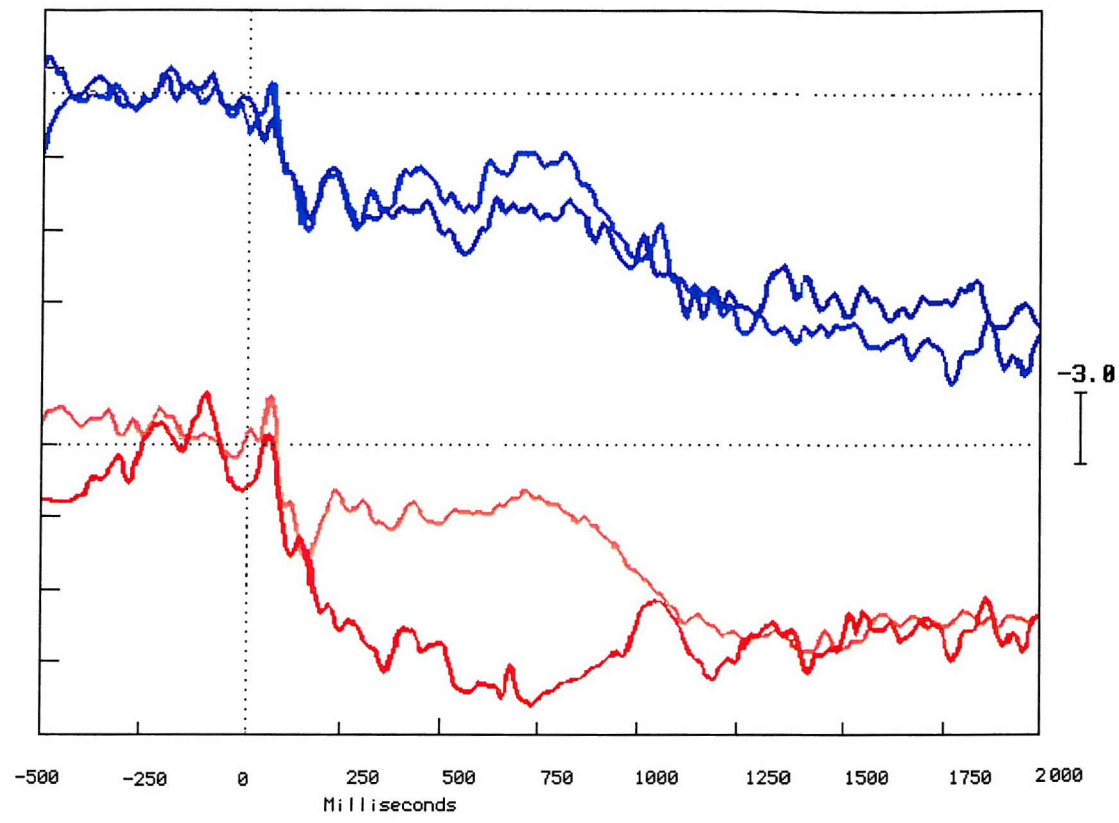


Figure (3.5.4.) the grand averaged ERPs elicited by the learners' correct answers trace in red color and the incorrect answer trace in light red color represented by the bottom traces and the non-learners correct answers trace in blue color and the incorrect answers in light blue color. Recorded at FZ mid-frontal site electrode, Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (msec). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity

Group	Learners (LFr n=18)		Non-learners (nLFr n=16)	
Experiment condition	1st window	2nd window	1st window	2nd window
Incorrect (Amplitude μv)	2.53	2.32	2.26	1.14
Correct (Amplitude μv)	5.55 **	5.70 **	2.38	2.70

Table (3.5.4.) Independent T-test results for incorrect versus correct answers during both time windows for the learners and non-learners group. * ≥ 0.05, ** ≥ 0.01, *** ≥ 0.001.

Comparing the correct answer trials trace of both groups, the learners group starts to show positively about 200msec and that deviation ends by 1100msec (Figure 3.5.5.),

Table (3.5.5.) shows that there are mean amplitude statistical significant differences between both groups, and that statistical differences were highly significant during the two time windows. The incorrect answer trial traces comparison between both learners and non-learners (Figure 3.5.5.) shows that the wave morphology looked very similar throughout the trial. Table (3.5.5.) confirms that there were no statistical significant differences between the mean amplitudes during the two time windows.

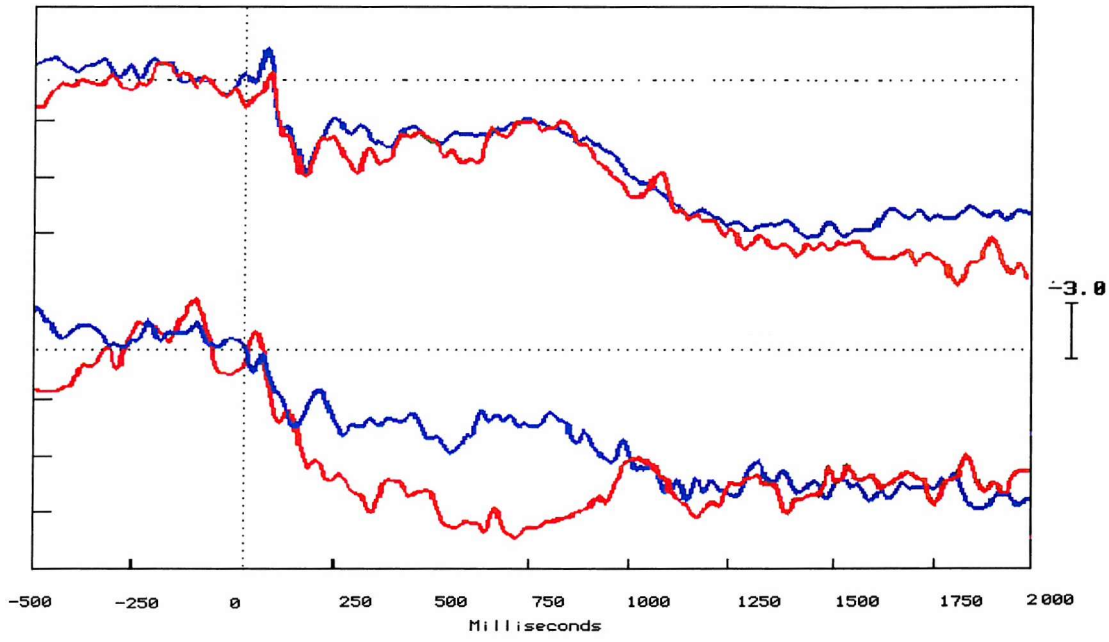


Figure (3.5.5.) Grand average ERPs elicited by the learners' traces in red color and the non-learners trace in blue color and the incorrect answer trials represented by the top traces and the correct answer trial represented by the bottom traces. Recorded at FZ mid-frontal site electrode, Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (msec). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

Experiment condition	Incorrect (Amplitude μV)		Correct (Amplitude μV)	
Group / windows	1st window	2nd window	1st window	2nd window
Non-learners	2.26	1.14	2.38	2.70
Learners	2.53	2.32	5.55 ***	5.70 ***

Table (3.5.5.) Independent T-test results of the learners versus the non-learners group in the incorrect and correct answers mean amplitudes during the first and second times windows.
* ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001.

Figure (3.5.6.) shows the cartoon brainmaps of the correct answer trials concludes that there were no significant brain activities over all the brain areas from 500msec pre-stimulus. The post-stimulus the positive activity appeared over the occipital and parietal areas bilaterally. The positive activities extended forward from the right-hand side of the brainmaps over the frontal, central and anterior temporal areas from about 200msec and the positivity increased gradually over the frontal area especially to the right-hand side. The posterior temporal and occipital areas bilateral negative activities appeared from about 300msec up to 800msec post-stimulus. The positive and negative activities back to decrease gradually to the end of the task. The brain activity was greater for the correct answer trials than the incorrect answer trials.

Figure (3.5.7.) shows the cartoon brainmaps of the incorrect answers trials where there was no remarkable significant positive or negative brain activity 500msec pre-stimulus. Up to 200msec post-stimulus there was negative activity located frontally followed by positive activity bilaterally and positive activity over the occipital and parietal area bilaterally. The positive activity then distributed forward centrally and to the right. The significant positive activity very obvious over the frontal area from about 200msec to the right-hand side and then distributed bilaterally and to the anterior temporal area. The negative activity localized to the right-hand side over the frontal and the temporal areas from about 1000msec and beyond onward. Generally the brain significant activity started to decrease gradually from 1100msec to the end of the task. The overall brain activity was less than the brain activity for the correct answer trial

brainmaps. Comparison with the learners correct answers cartoon brainmaps in figure (3.5.6) shows that there is a stronger and more frontal positivity.

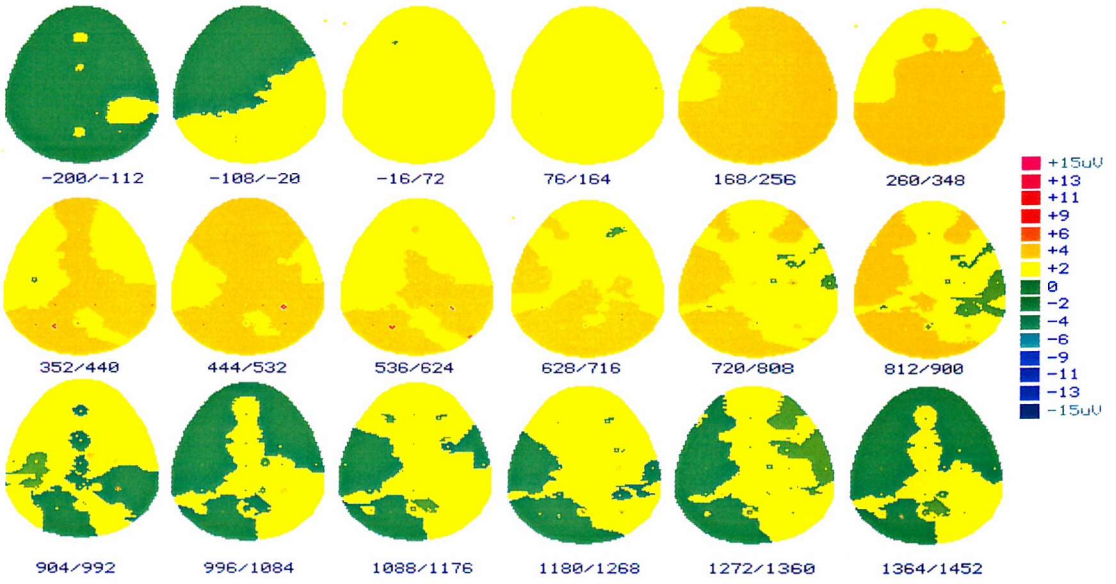


Figure (3.5.6.) shows the top view cartoon brainmaps made from the grand average ERPs elicited by the learners correct answer trials. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1452msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal area to the top and occipital to the bottom of the brainmaps.

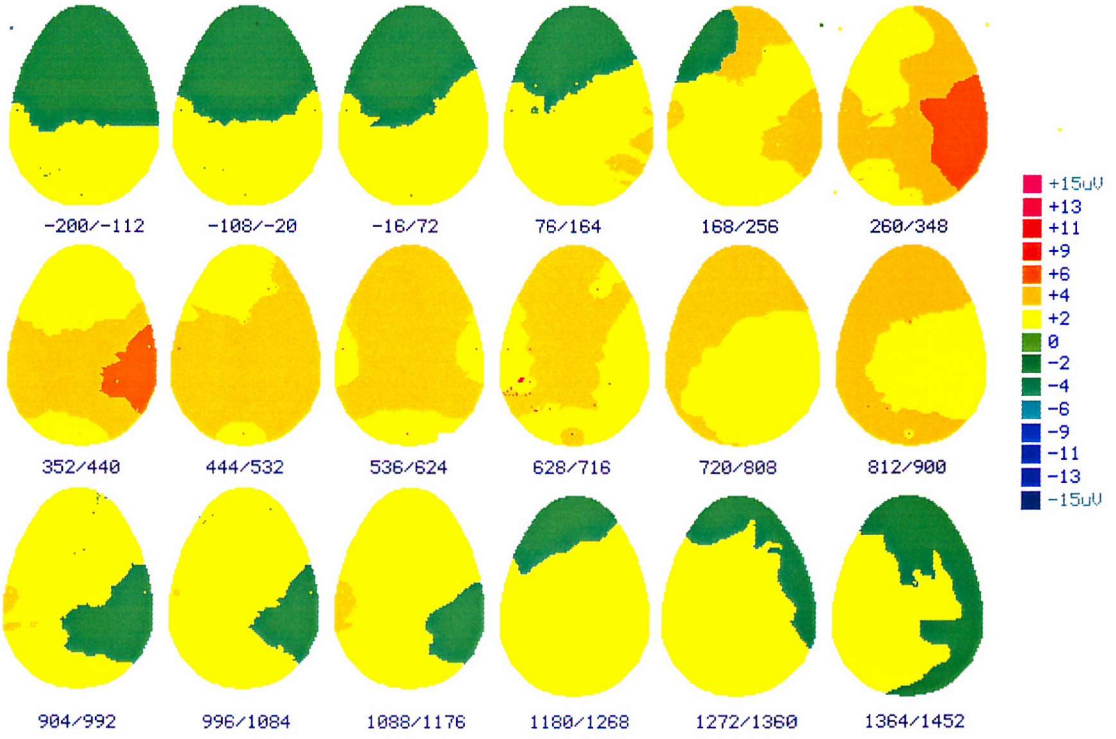


Figure (3.5.7.) shows the top view cartoon brainmaps made from the grand average ERPs elicited by the learners incorrect answer trials. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1452msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal area to the top and occipital to the bottom of the brainmaps.

Table (3.5.6.) shows that there were statistically significant differences results in the learning group during the two time windows the correct answer trials versus the incorrect answer trials mean amplitudes for these two frontal electrodes F3 & F4, one right tempro-parietal electrode TPR, and two frontal and parietal midline electrodes FZ &PZ. The non-learners for the correct versus the incorrect answer trials were not statistically significant different for any of the compared electrodes site during the two windows, except only for the frontal midline one FZ during the second time window between the correct and incorrect answers.

Group	Learners (LFr n=18)		Non-learners (nLFr n=16)	
Electrodes sites	1st window *t value*	2nd window *t value*	1st window *t value*	2nd window *t value*
C3	0.61	0.44	1.54	1.3
C4	1.35	1.30	1.3	1.4
CZ	0.23	1.17	1.22	1.17
FCZ	2.03	1.90	1.34	1.29
F3	3.31 *	3.43 *	1.54	2.4
F4	4.82 *	3.70 *	1.94	1.2
F7	0.17	0.15	1.64	2.6
F8	0.61	0.67	1.26	2.1
FZ	3.63 *	3.54 *	1.5	2.67
P3	0.38	0.47	0.5	1.08
P4	0.94	1.15	0.215	0.56
TPL	1.4	1.70	1.3	2.2
TPR	2.34*	2.40 *	1.34	1.92
PZ	2.35*	2.30 *	1.07	0.34
POZ	2.20	1.99	1.58	0.45
T3	0.57	0.47	0.65	1.14
T4	0.15	0.60	1.27	1.13
T5	0.04	0.42	1.35	2.40
T6	1.25	1.16	1.8	2.20
ATL	0.34	0.44	2.05	1.19
ATR	1.2	1.3	1.4	2.1

Table (3.5.6.) shows Paired T-test results of the incorrect answer versus the correct answers trials at the individual electrode sites during the both time windows for the learners and the non-Learners group.* ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001.

3.5.3.Regional differences:

The learners' right-hand side compared with the left-hand side electrodes sites over all the brain areas. The trace morphology looks very similar 500msec pre-stimulus and 200msec post-stimulus. The positive and negative peaks started to appear about 200msec post-stimulus onward to about 1000msec with some differences from site to site (Figures 3.5.8a, b & c).

Paired t-Tests were used to compare the subjects within the same group. Table (3.5.7.) shows the comparison between the right-hand side with the left-hand side electrodes for the learners during the last fifty answer trials. There were highly statistically significant differences for the central area C4-C3, Frontal area F4-F3 & F8-F7, and Parietal area P4-P3 during the two time windows. The non-learners did not show inter-regional statistical significant differences.

Group	Learners (LFr n=18)		Non-learners (nLFr n=16)	
Electrodes sites	1st window *t value*	2nd window *t value*	1st window *t value*	2nd window *t value*
C4 - C3	1.145 ***	1.657 **	0.125	0.614
F4 - F3	0.674 **	1.732 **	0.058	0.155
F8 - F7	1.904 ***	1.773 ***	1.600	1.837
O2 - O1	0.506	0.631	1.000	0.627
P4 - P3	0.665**	0.549 **	0.550	0.895
TPR - TPL	0.021	0.447	0.445	0.970
T4 - T3	0.073	0.431	1.030	0.545
T6 - T5	0.407	0.792	1.370	1.223
AT - ATL	0.343	0.331	1.631	1.333

Table 3.5.7. Paired T-test results of the right-hand side versus the left-hand side electrodes for the last fifty trials (4th quartile) during both time windows in the Learners and the non-learners group.

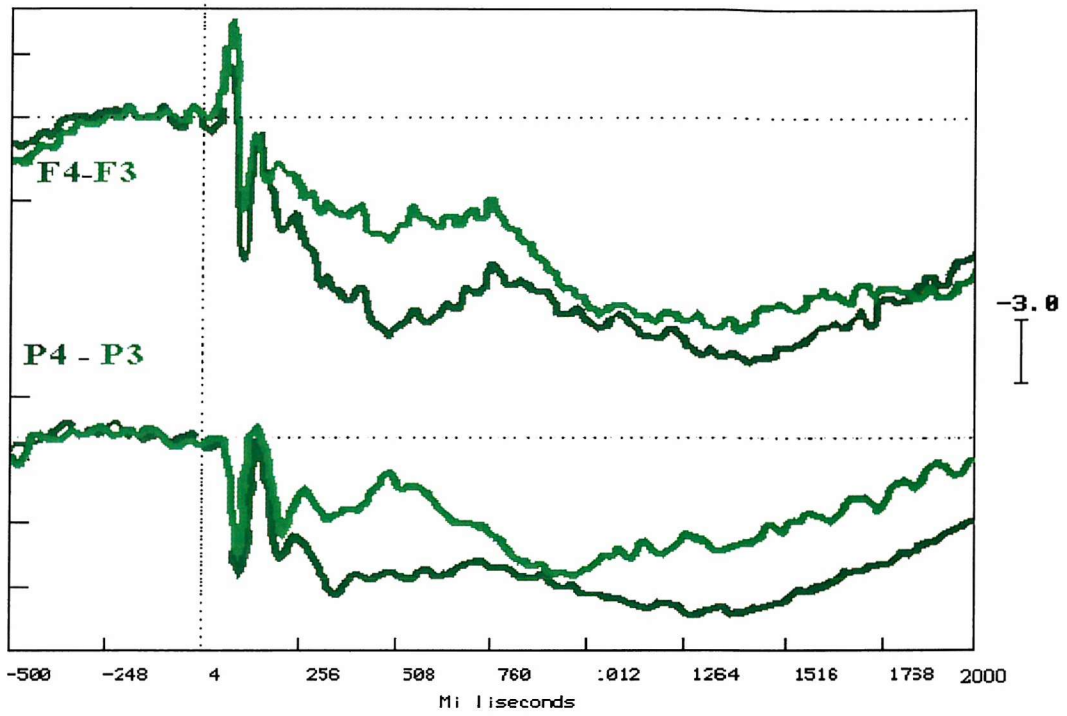


Figure (3.5.8a) shows the grand average ERPs elicited during the last fifty trials of the learning task. The right-hand site electrode site trace in dark green color and the left-hand site electrode site trace in light green color. Recorded at F4-F3, & P4-P3, refer to linked mastoids. Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (msec). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

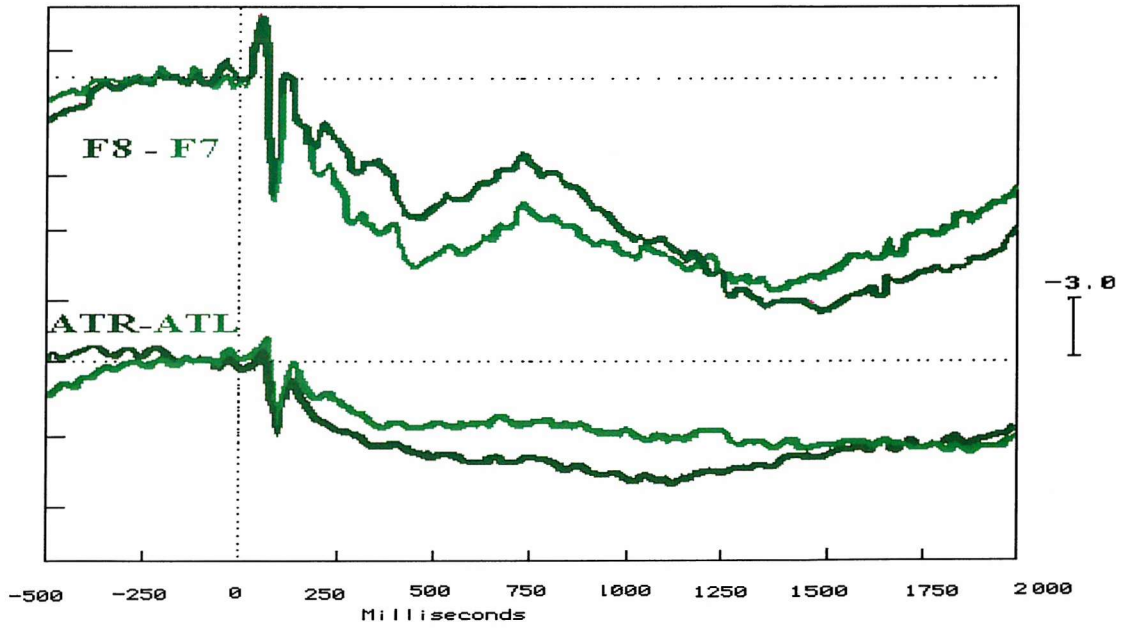


Figure (3.5.8b) shows the grand average ERPs elicited during the last fifty trials of the learning task. The right-hand site electrode site trace in dark green color and the left-hand site electrode site trace in light green color. Recorded at F8-F7, & ATR-ATL, refer to linked mastoids. Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (msec). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

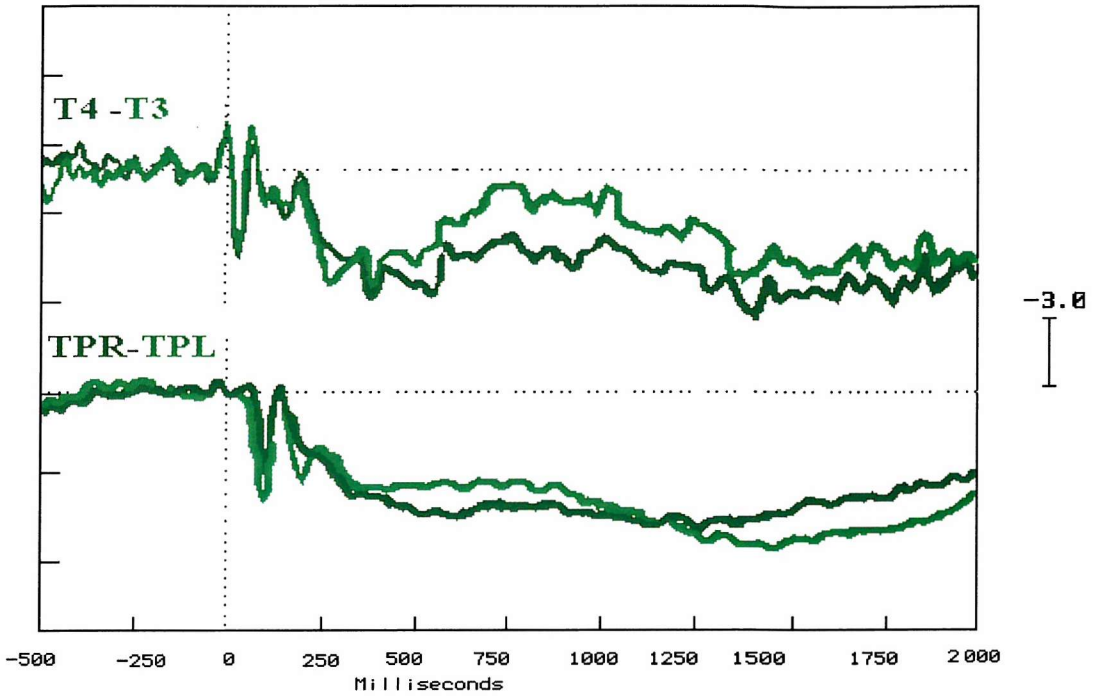


Figure (3.5.8c) shows the grand average ERPs elicited during the last fifty trials of the learning task. The right-hand site electrode site trace in dark green color and the left-hand site electrode site trace in light green color. Recorded at T4-T3, & TPR-TPL, refer to linked mastoids. Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (msec). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

Figures 3.5.9a & b showed the comparison between cartoon brainmap the right-hand side view versus the left-hand side view for the correct answers trials during the two time windows 250msec-550msec and 550msec-850msec. The positive activity was localised frontally and distributed backward to the anterior temporal and was more for the right-hand side view brainmaps during both time windows when compared to the left-hand side view. The activity equally distributed over the parietal, the central, the posterior temporal and the occipital areas for the correct and the incorrect answers trials and during the both windows. The positive activities were more for the second time interval window 550msec to 850msec than the first time interval window250msec to 550msec.

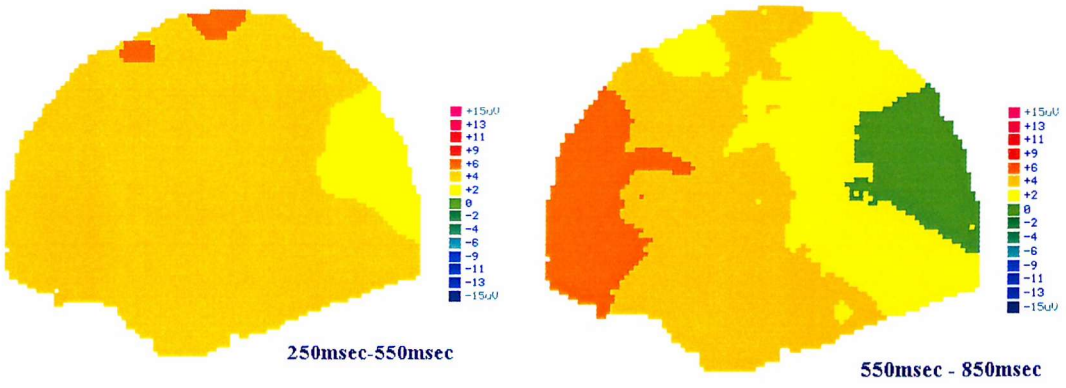


Figure (3.5.9a) shows the left-hand side view brainmaps made from the grand average ERP elicited with last fifty stimuli in the learners. The numbers below each large map indicates the time in milliseconds when the map was computed. The first time interval 250msec to 550msec and the second time interval 550msec to 850msec post-stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue.

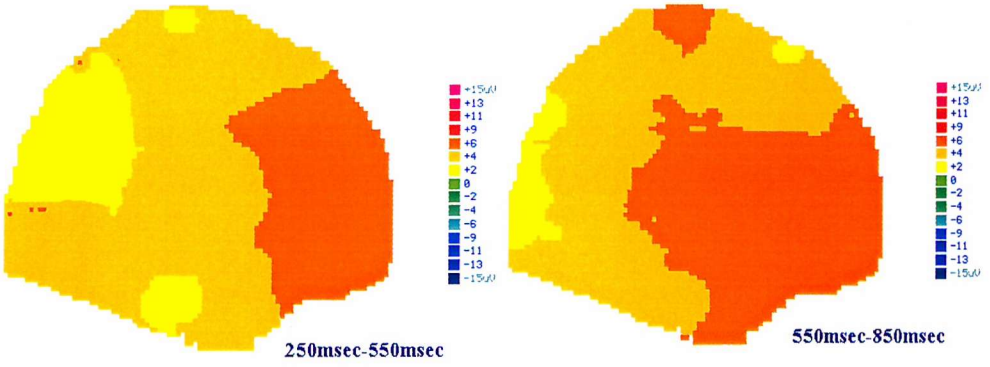


Figure (3.5.9b) shows the right-hand side view brainmaps made from the grand average ERP elicited with last fifty stimuli in the learners group. The numbers below each large map indicates the time in milliseconds when the map was computed. The first time interval 250msec to 550msec and the second time interval 550msec to 850msec post-stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue.

3.6. Group II with feedback and with rule (FR n=15).

Group II subjects had been taught the differences between the patterns but had not practiced the task. All achieved the learning level quickly and there were no non-learners.

The grand average ERP showed a similar morphology to those of group I (Fr). The positivity began at 200msec and was frontally and centrally located with emphasis on the right side. Overall the positivity was of lower amplitude.

3.6.1. First fifty and last fifty trials:

The initial potentials were the same with first fifty, last fifty, correct answers, incorrect trial waveforms up to 230 msec.

Figure (3.6.1) compares the first fifty and the last fifty trials. These subjects were already performing above 70% correct for the first fifty and achieved over 80% during the last fifty trials. The last fifty trials trace was more positive going than the fifty trial traces starting from 200msec to beyond about 1100msec.

The last fifty trials elicited a first positive peak at 220msec and another positive peak at 350msec, and the biggest one at 650msec. The first fifty elicited the same positive peaks but they were less in amplitude and earlier in latency.

The first fifty trial cartoon brainmaps subtracted from the last fifty trials showed the difference between the subjects who knew the task and when the subject knew how to perform it. There was not much difference between the first fifty and the last fifty pre-stimulus and post-stimulus till about 150msec. The positivity was more localized frontally to the right-hand side. The positive activity was distributed bilaterally over the anterior temporal areas and the frontal areas from about 200msec and extended backward over the central area. Some positivity was

obvious in the posterior temporal area to the right-hand side of the brainmaps (figure 3.6.2).

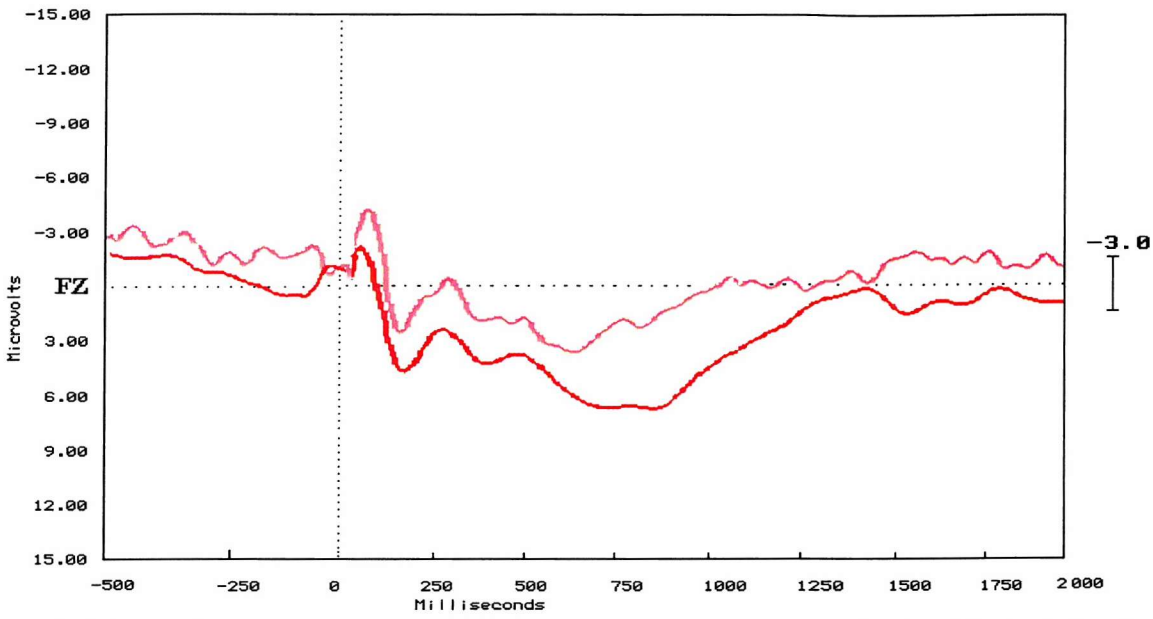


Figure (3.6.1) Grand average ERPs elicited by the first fifty in light red and the last fifty in dark red. Recorded at (FZ), Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

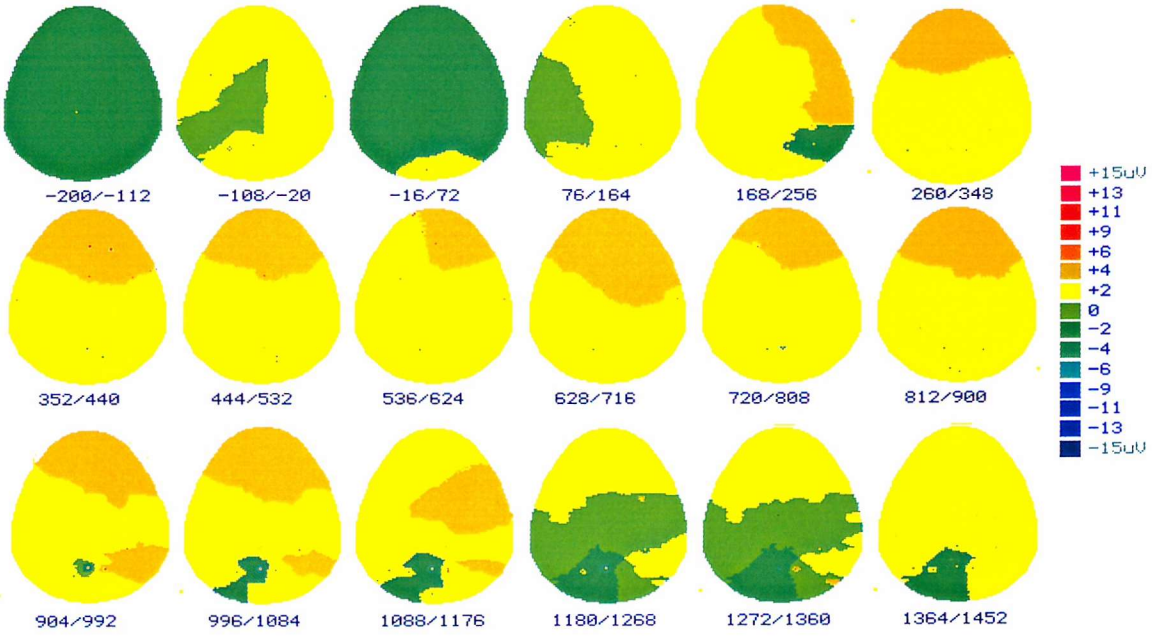


Figure (3.6.2) shows the top view cartoon brainmaps made from grand average ERP elicited by the first fifty trials subtracted from the last fifty trials stimuli. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200 msec before stimulus to 1452 msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

3.6.2. CORRECT VERSUS INCORRECT:

The correct answer trials were more positive going than those were to the incorrect answer trials starting from 200msec to about 1200msec.

Figure (3.6.3) shows that the incorrect and correct answers wave were very similar pre-stimulus and post-stimulus till about 250msec. The correct answers and the incorrect answers elicit positive peak at 480msec but more positive for the correct answers. The second positive peaks were about 750msec and more positive for the correct trace.

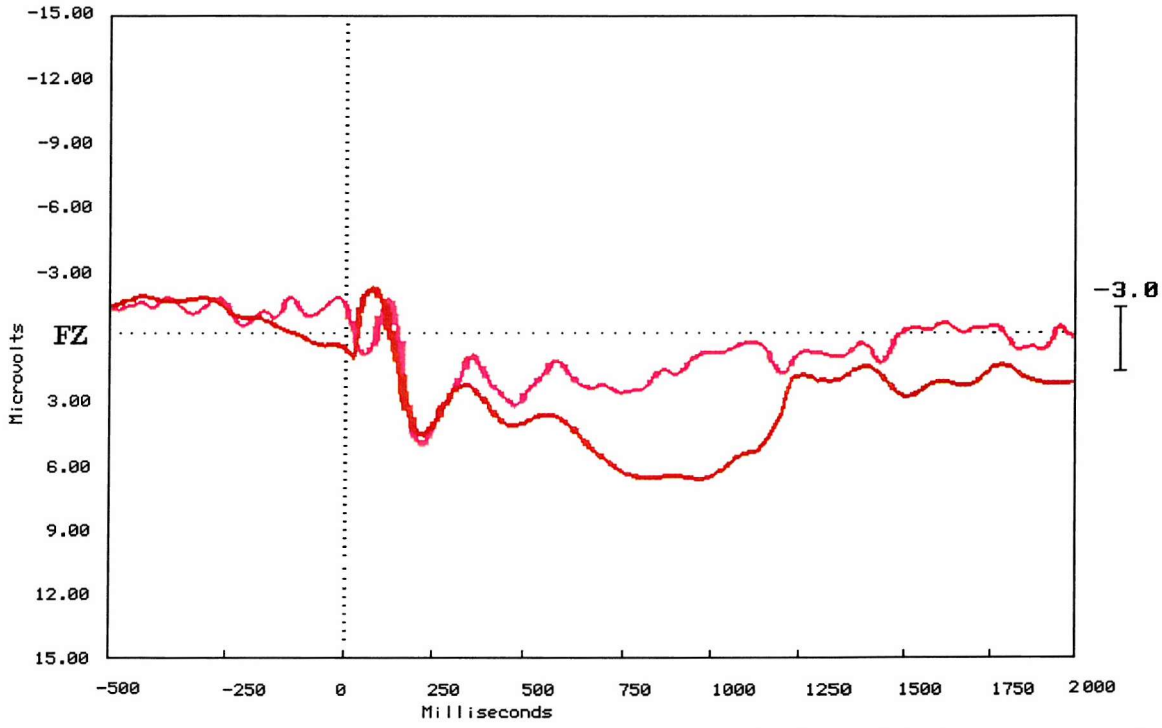


Figure (3.6.3.) Grand average ERPs elicited the correct answers in red color, and the incorrect answers in light red color. Recorded at (FZ), Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

The cartoon brainmaps (Figure 3.6.4) of the incorrect answers trials showed that there was no significant positive or negative brain activity pre-stimulus. Post-stimulus there was negative activity located frontally and positive activity over the occipital and parietal area bilaterally from 200msec and then distributed forward

centrally and to the right. The significant positive activity very obvious over the frontal area from about 500msec to the right-hand side and then distributed bilaterally. The negative activity bilaterally over the occipital and the parietal area. The brain activity started to decrease gradually from 1200msec to the end of the task.

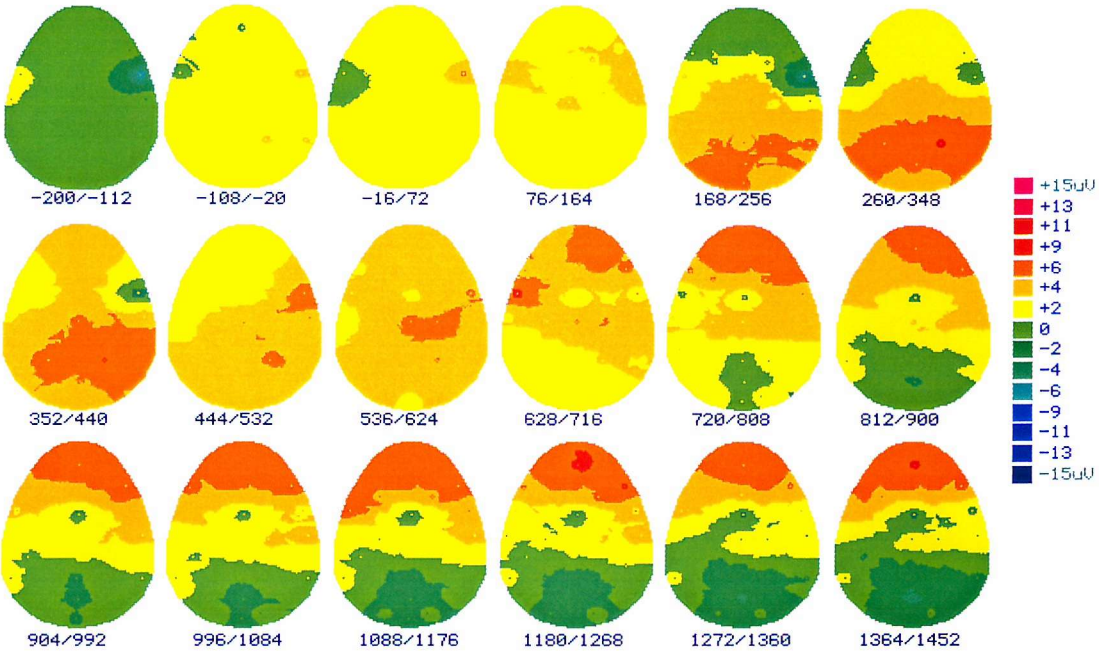


Figure (3.6.4) shows the top view cartoon brainmaps made from the grand average ERP elicited with the incorrect trials stimuli. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps.

Figure 3.6.5 showed that the brainmaps of the correct answers conclude that there were no significant brain activities over all the brain areas pre-stimulus. The post-stimulus the positive activity appeared over the occipital and parietal and the negative activity over the frontal areas bilaterally. The positive activities extended forward from the right hand side of the brain maps over the frontal, central and anterior temporal areas from about 300msec and the positivity increased gradually over the frontal area especially to the right-hand side. The parietal, posterior temporal and occipital bilateral negative activities appeared from about 700msec. The positive and negative activities back to decrease gradually to the end of the

task. Generally the brain positive activity was more for the correct answers trials than the incorrect answers trials.

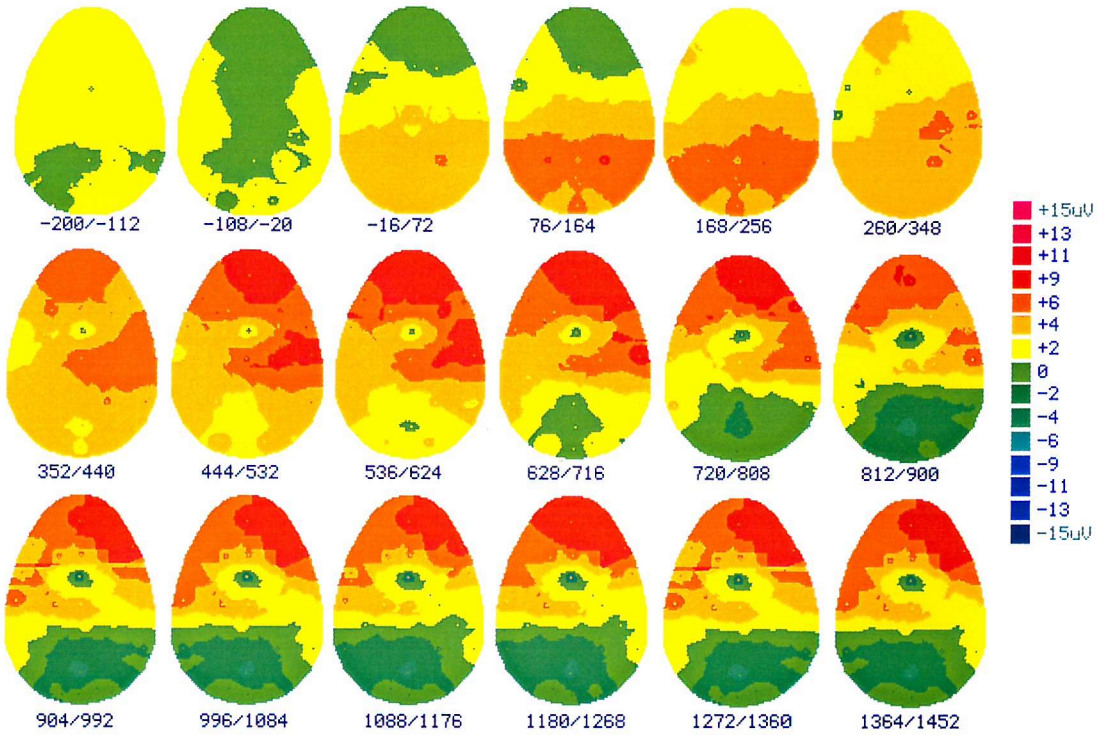


Figure (3.6.5) shows the top view cartoon brainmaps made from the grand average ERP elicited with the correct trials stimuli. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps.

3.6.3. Regional differences:

Multiple equal numbers of electrodes on each side of the scalp were used to record the ERP. Comparison between ERP elicited by the correct versus the incorrect and last fifty versus the first fifty trials answers showed the differences were more prominent in the frontal right-hand side than the left-hand side. These differences begin around 250msec post-stimulus and persist beyond the recording epoch of 1000msec in the right-hand hemisphere. The central electrodes shows differences started around 300msec and end very quickly at 500msec which I considered from my inspection and comparisons with other sides electrodes not significantly different where the traces were similar throughout the task. The parietal area

electrodes showed positive differences starting around 450msec to beyond 1000msec. Amplitude of P300 was maximal in frontal and higher for the correct and last fifty trial answers and P600 showed maximal amplitude for correct last fifty in the parietal locations (Figure 3.6.6).

Table (3.6.1.) shows the comparison between the right-hand side with the left-hand side electrode for the learners during the last fifty trials. There was statistically significant difference for the frontal area electrodes F4-F3 during the two time windows.

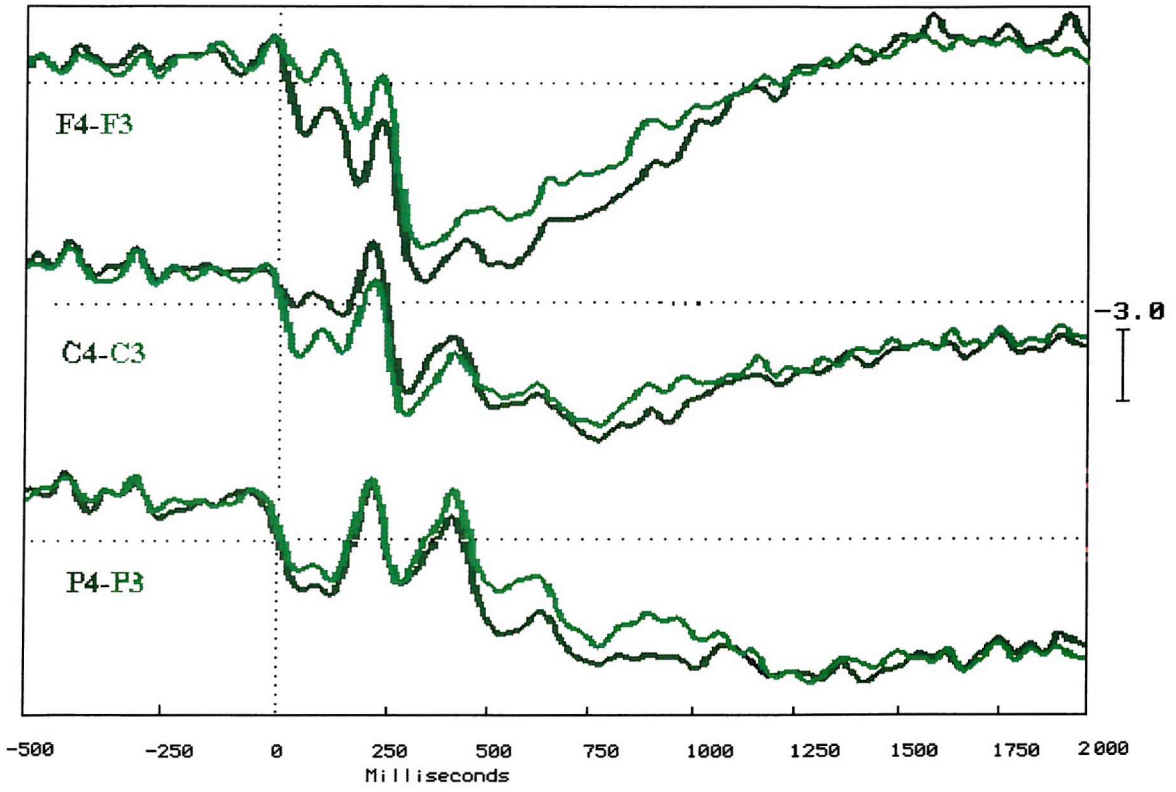


Figure (3.6.6) Grand average ERPs elicited by all subject's performance in group II, recorded at F3-F4, C3-C4, and P3-P4 refer to linked mastoids, during the last fifty trials, Right-hand side traces represented in dark green color and left-hand side represented in light green color. Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

Group	Learners (LFR n=15)	
Electrodes sites	1st window *t value*	2nd window *t value*
C4 - C3	1.46	2.008
F4 - F3	2.11 *	2.89 **
F8 - F7	1.66	1.56
O2 - O1	1.27	1.63
P4 - P3	1.65	2.01
TPR - TPL	1.28	1.88
T4 - T3	1.78	0.99
T6 - T5	1.29	0.87
AT - ATL	1.23	1.09

Table (3.6.1.) Paired T-test results of the right-hand side versus the left-hand side electrodes for the last fifty trials (4th quartile) during both time windows

Figures (3.6.8a & b) showed the comparison between the right-hand side view versus the left-hand side view for the subtraction of the incorrect answers trials from the correct answers trials brainmaps during the two time windows. The positive activity was localized frontally and distributed backward to the anterior temporal and central areas. The activity distributed over the parietal, the central, the posterior temporal and the occipital areas which means that these areas were involved in the trials performance by the same value during both conditions task correct and incorrect answers trials. These positive and negative activities were more for the first time interval window 250msec to 550msec than the second time interval window 550msec to 850msec.

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3.7. Group III without feedback and without rule (fr n=24)

3.7.1. First fifty and last fifty trials:

Figure (3.7.1.) shows the top view cartoon brainmaps for the subtraction of the grand averaged ERPs elicited by the learners last fifty answer trials minus the first fifty answer trials. There were no significant differences from 500msec pre-stimulus and up to 200msec post-stimulus. The positivity for the last fifty subtractions is all over the right-hand side of the brainmaps over the frontal, temporal, central and parietal areas from 200msec. The positive activity localized over the frontal area bilaterally and central area, by the time changed to be right-hand side of the frontal and anterior temporal areas of the brainmaps. 1000msec post-stimulus the brain activity did not show significant changes.

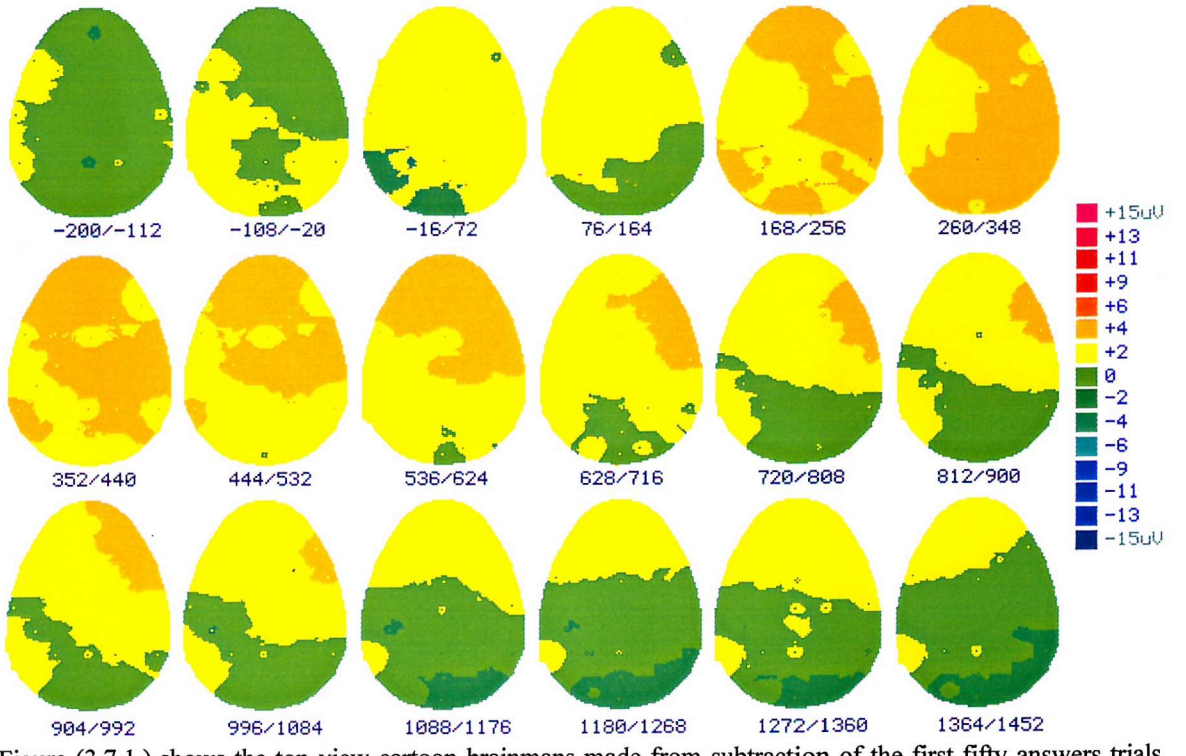

Figure (3.7.1.) shows the top view cartoon brainmaps made from subtraction of the first fifty answers trials from the last fifty answers trials grand average ERPs elicited by the learners performance in group three (Lfr). The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200 msec before stimulus to 1452 msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal area to the top and occipital to the bottom of the brainmaps.

Figure (3.7.2.) shows the top view cartoon brainmaps made from subtraction of the first fifty answers trials from the last fifty answers trials grand average ERPs elicited by the non-learners performance (nLfr). These results indicate 200msec pre-stimulus where we did not notice any significant brain activity. There was not much difference between the first fifty and the last fifty post-stimulus up to about 250msec. There was little significant positive brain activity pre-stimulus until 250msec post-stimulus located over the frontal area, the parietal area, and the occipital area bilaterally and the posterior temporal area. The activity differences were gradually decreased from about 500msec. The positive and negative activity over the brain areas from 500msec up to the end of the task did not show any significant differences.

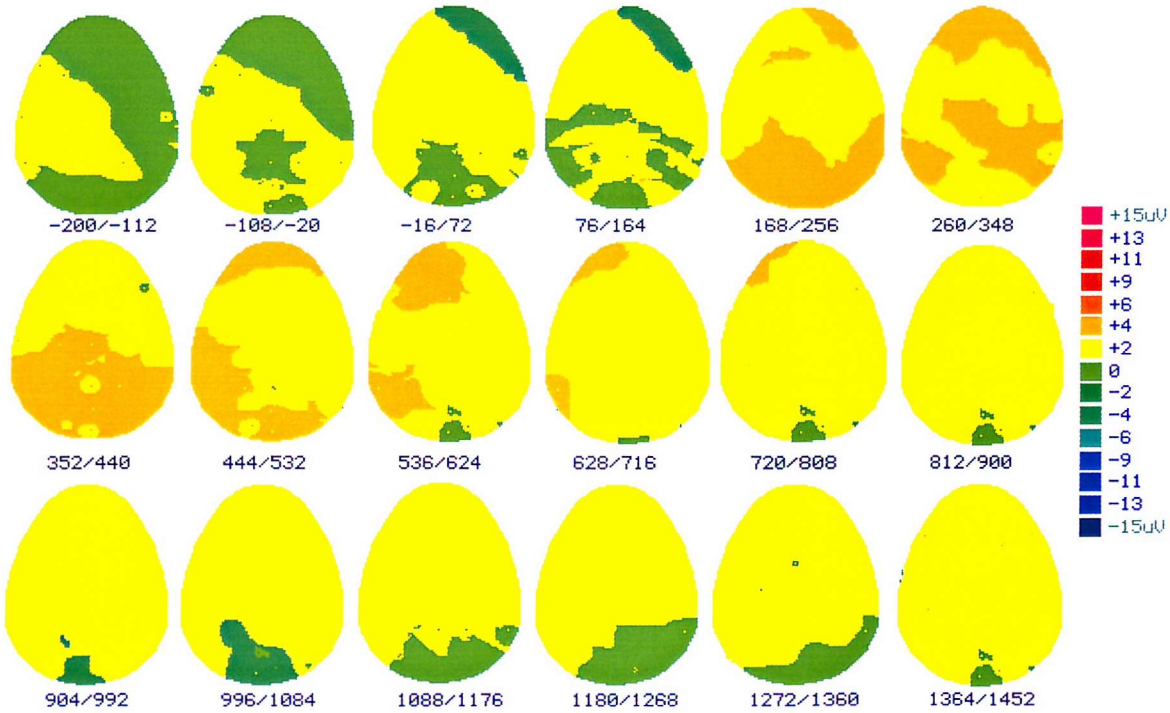

Figure (3.7.2.) shows the top view cartoon brainmaps made from subtraction of the first fifty answers trials from the last fifty answers trials grand average ERPs elicited by the non-learners performance in group three (nLfr). The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1452msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal area to the top and occipital to the bottom of the brainmaps

A comparison was made of the grand averaged event related potential waveforms for the last fifty trials and the first fifty trials in the learners (Lfr) and the non-learners (nLfr). The waveforms showed quite clearly the similarity of the waveform before the onset of the stimulus, and then the differences in ERPs. The initial potentials were the same up to 220msec post-stimulus in particular with respect to amplitude. The learners showed that the waveforms from about 250msec of the last fifty answer trials showed more positivity than the first fifty trials. The positive peak amplitudes were higher for the last fifty stimuli than for the first fifty stimuli. The non-learners traces for the first fifty answer trials and the last fifty answer trials did not show obvious significant differences. The trace morphology showed that both traces had the same positive and negative peaks (Figures 3.7.3a).

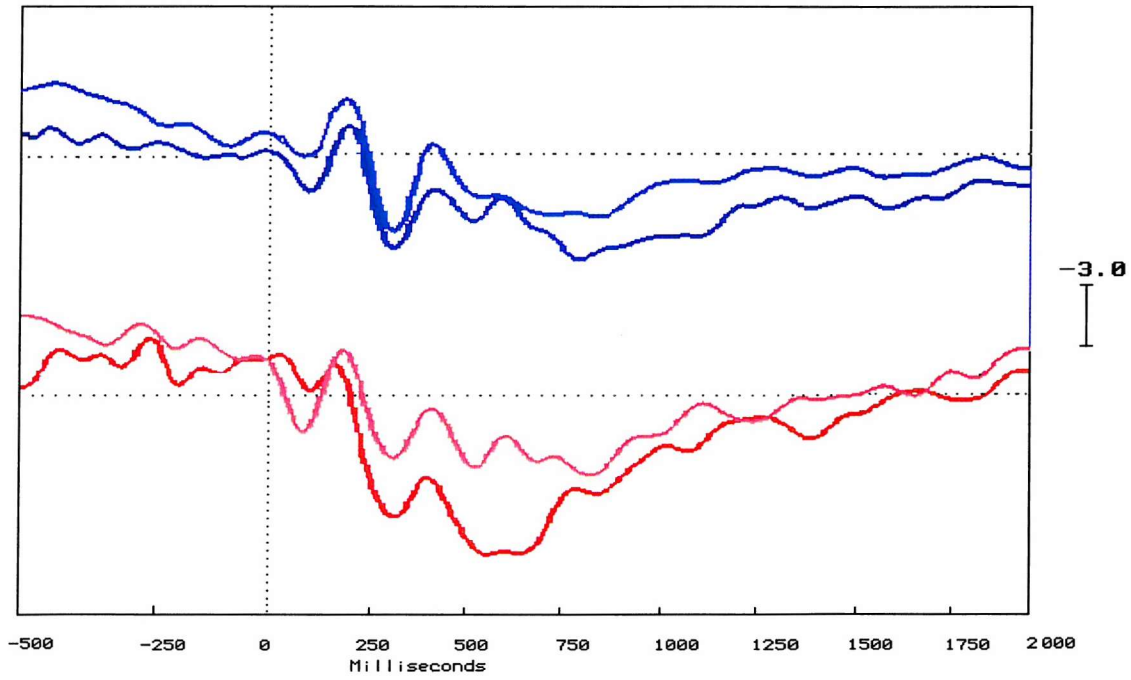

Figure (3.7.3a) Grand average ERPs elicited by the non-learners last fifty trials in blue color and the first fifty in light blue color represented by the top traces and The learners' last fifty trial traces in red color, the first fifty trials in light red color presented by the bottom traces. Recorded at FZ, Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

Figure 3.7.3b shows that the learners and non-learners last fifty answer trials traces were similar pre-stimulus and up to 250msec post-stimulus. The positive going peak were very clear and looked significantly different (Top traces). The learners and non-learners first fifty answer trials were quite similar pre and post stimulus in positive and negative peaks morphology and amplitudes.

There were numbers of other significant observations. Firstly, the differences in the positive peak amplitudes between the last fifty and first fifty stimuli were more persistent in the right hemisphere. Secondly, the maximum amplitude for the positive peaks were recorded at the frontal electrode Fz and the positive peak component for last fifty stimuli showed a more enhanced positivity than for first fifty stimuli. Finally, the peak latencies of positive components were slightly later for the last fifty-answer trial.

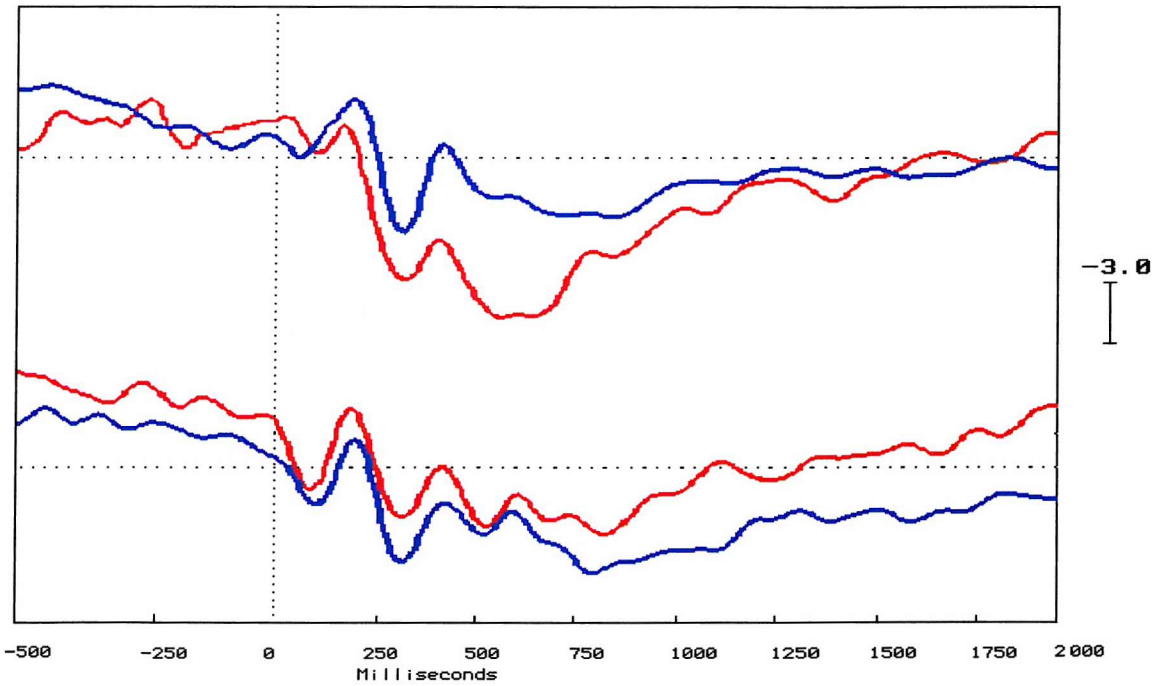

Figure (3.7.3b) Grand average ERPs elicited by the non-learners trial traces in blue color and the learners' trial traces in red color. The top traces represent the last fifty; the bottom traces represent the first fifty. Recorded at FZ, Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

3.7.2. Correct versus incorrect answer trials

Figure 3.7.4a shows the grand average event related potential traces elicited by the learners and non-learners subject's performance during the correct and the incorrect answer trials. The pre-stimulus part was similar and did not show any significant differences. Post-stimulus and up to 280msec did not show significant differences and the traces were similar in positive and negative deflections. The learners correct answer trials trace showed more positive differences than the non-learners. Incorrect answers trial traces for the both groups did not show any differences.

The learners correct and incorrect answer trials compared together and showed a more positive going peak from about 300msec up to 800msec post-stimulus when they return back to be similar to the first stage of recording and pre-stimulus. The non-learners correct answer trials trace and the incorrect answer trials showed no morphological or amplitude differences.

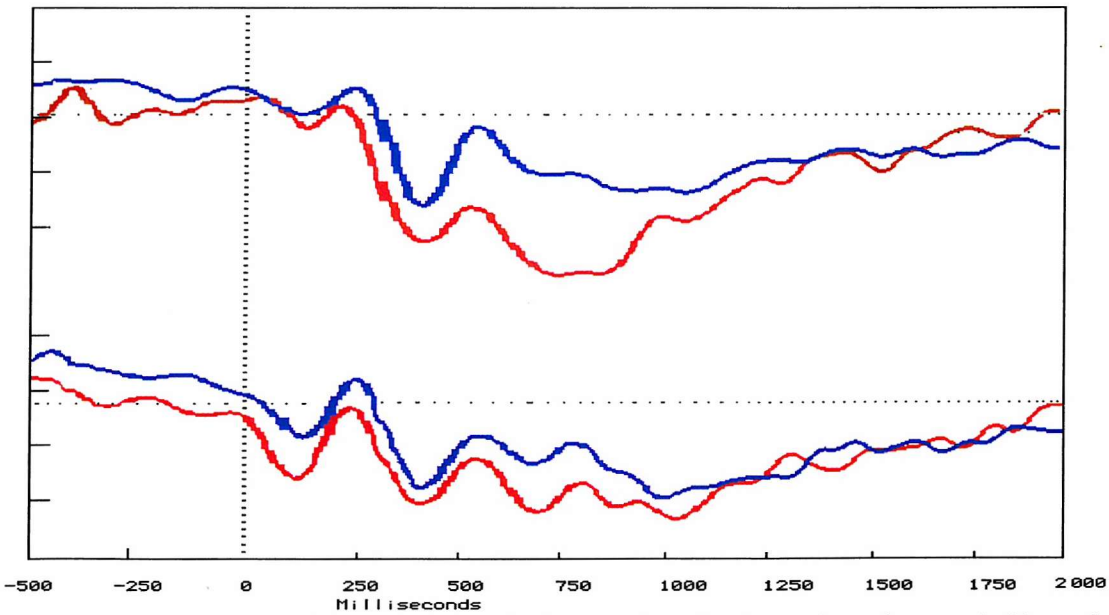

Figure (3.7.4a) Grand average ERPs elicited by the learners in red color and non-learners in blue color. The correct answer trials represented by the top traces and the incorrect answers trials represented by the bottom traces. Recorded at FZ, Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

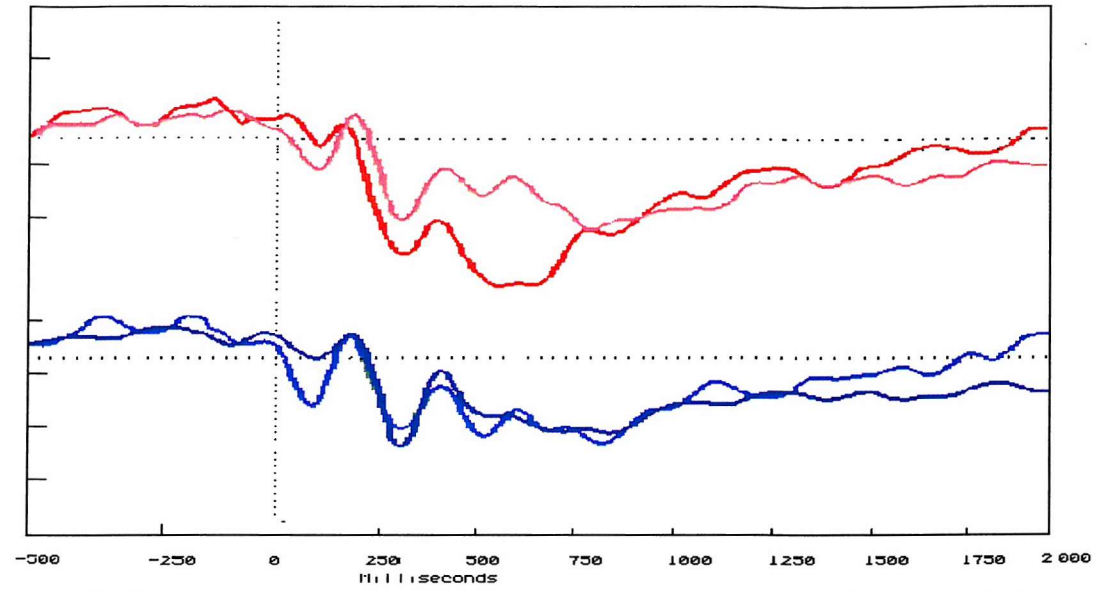

Figure (3.7.4b) Grand average ERPs elicited by the learners correct answer trials in red color, the incorrect trials in light red color represented by the top traces and the non-learners correct answer trials in blue color, the incorrect trials in light blue color, represented by the bottom traces. Recorded at FZ, Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

Figure 3.7.5a shows the learners correct answer trials cartoon brainmaps where there were no significant brain activities over all the brain areas from 200msec pre-stimulus. The post-stimulus positive activity appeared over the occipital and parietal and the negative activity over the frontal areas bilaterally.

The positive activities became frontally bilateral especially to the right-hand side and over the anterior temporal area from about 350msec. The negative activity replaced the positive activity over the parietal, occipital and the posterior temporal areas bilaterally about 350msec up to 900msec post-stimulus. The positive and negative activities decrease gradually to the end of the task. Generally the brain activity was more for the correct answers trials than the incorrect answers trials.

Figure 3.7.5b shows the cartoon brainmaps of the learners incorrect answers trials where there was no remarkable significant positive or negative brain activity 500msec pre-stimulus to about 200msec post-stimulus. There was frontal

negativity then positivity from 250msec up to 900msec post-stimulus especially to the right-hand side.

Parietal, occipital, and posterior temporal positivity changed to negativity bilaterally about 350msec post-stimulus. The brain significant activity decreased gradually from 1000msec to the end of the task, and was less than the correct answer trials activity

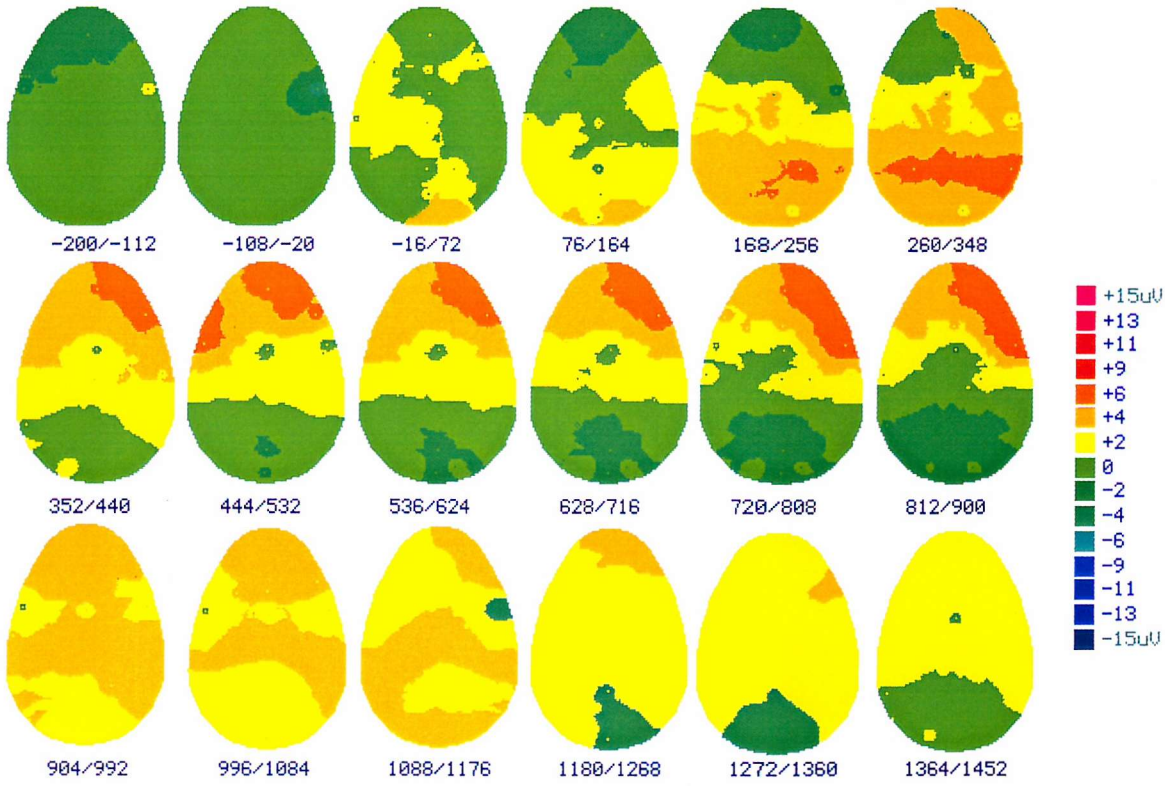

Figure (3.7.5a) shows the top view cartoon brainmaps of made from the grand average ERPs elicited by the learners correct answer trials. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1452msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal area to the top and occipital to the bottom of the brainmaps

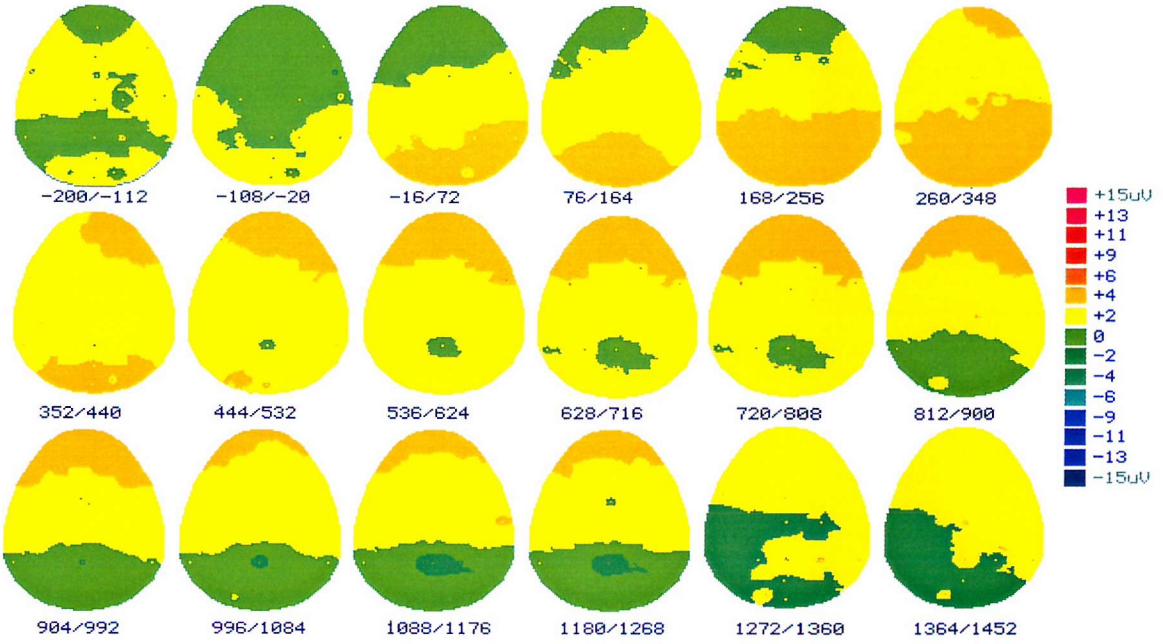

Figure (3.7.5b) shows the top view cartoon brainmaps of made from the grand average ERPs elicited by the learners incorrect answer trials. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1452msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal area to the top and occipital to the bottom of the brainmaps

3.7.3. Regional differences

Furthermore, these figures clearly show a very marked front-occipital difference. The activity was more positive going over the frontal, the parietal, and the temporal areas especially on the right-hand side electrodes.

The brain potentials elicit more positive activity on the right hemisphere at frontal sites and propagated to the central and parietal sites on both hemispheres.

Figures (3.7.6a & b) shows the right-hand side and the left-hand side view cartoon brainmaps of the event related potentials elicited with the learners group during the last fifty answers trials. The positive activity started occipitally post-stimulus and then propagated over the parietal lobe area. The frontal area shows more positive activity at 200msec post-stimulus but it did not stay longer than

800msec. The frontal area on the right hand side view cartoon map shows more late positivity and stayed longer than the left-hand side.

Figures (3.7. 7a & b) showed the comparison between cartoon brainmap the right-hand side view versus the left-hand side view for the last fifty answer trials during the two time windows 250msec-550msec and 550msec-850msec.

The positive activity was localized frontally and distributed backward to the anterior temporal and was more for the right-hand side view brainmaps during both time windows when compared to the left-hand side view. The activity distributed over the parietal, the central, the posterior temporal and the occipital areas which means that these areas were involved in the trials performance by the value during this experiment condition trials and during the both windows. The positive activities were more for the right-hand side view large map during the first time window and for the left-hand side view large map during the second time interval window 550msec.

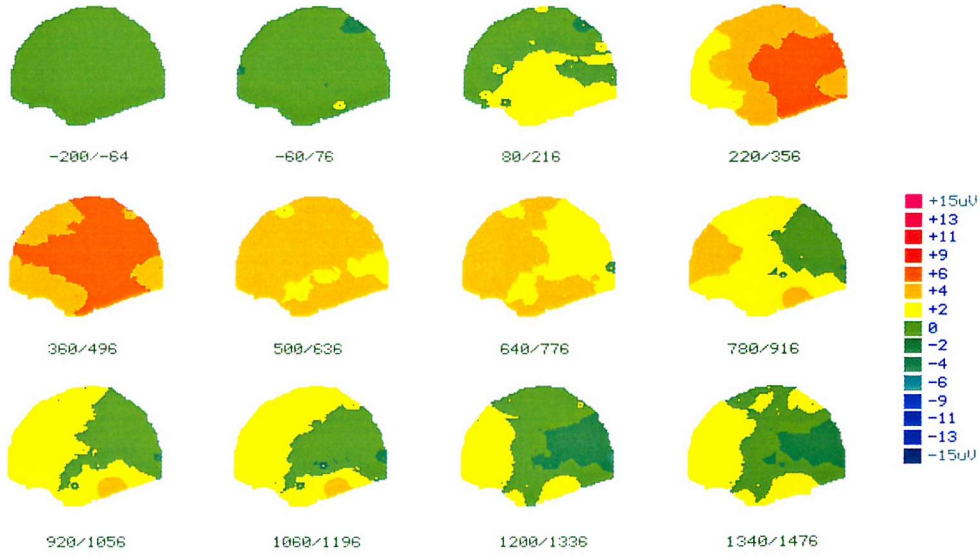

Figure (3.7.6a) shows the left-hand side view cartoon brainmaps of the ERP elicited with the learners group last fifty answers trials. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue.

Table (3.7.1.) shows the comparison between the right-hand side with the left-hand side electrodes for the learners during the last fifty trials. There were statistically significant differences for the frontal area electrodes F8-F7 and the anterior temporal area electrodes ATR-ATL during the two time windows.

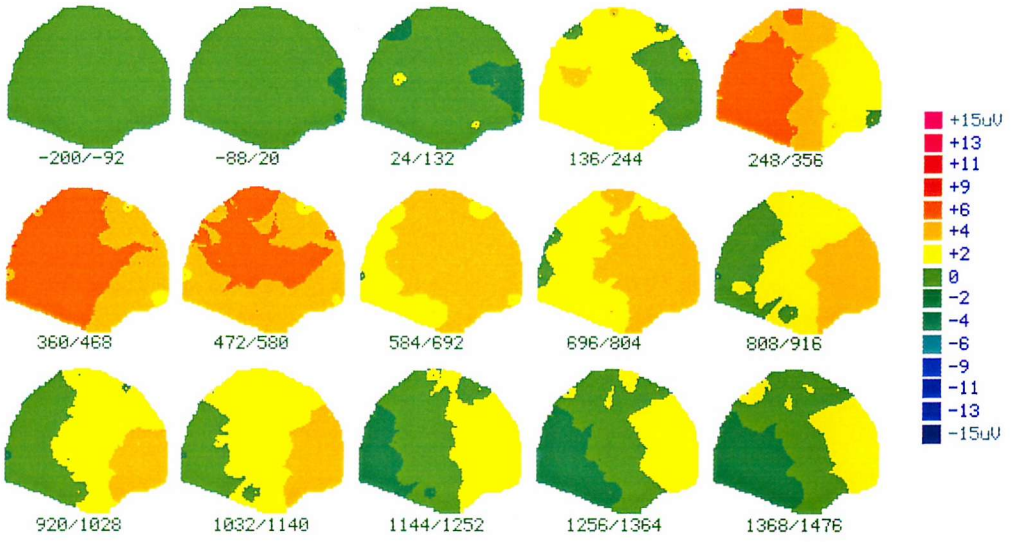

Figure (3.7.6b) shows the right-hand side view cartoon brainmaps of the ERP elicited with the learners group last fifty answers trials. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1500msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue.

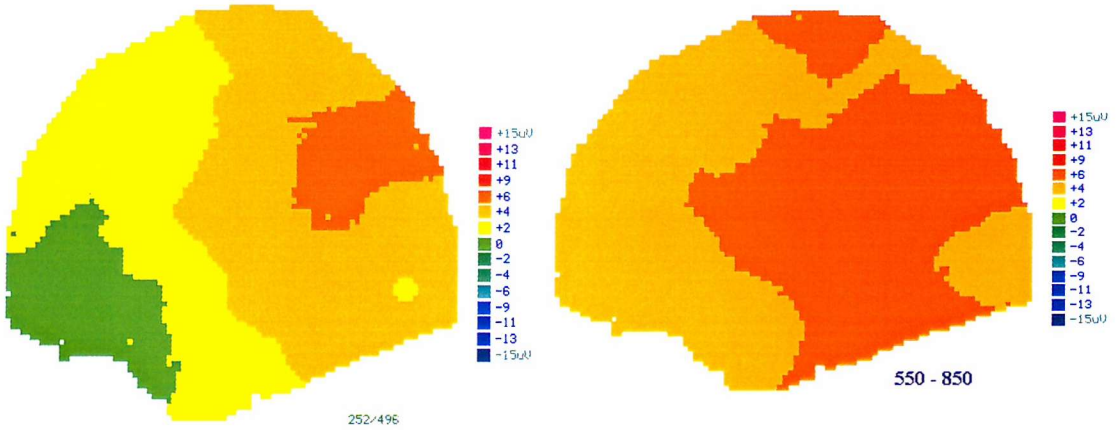

Figure 3.7.7a. Shows the left-hand side spatial maps made from the grand average ERP elicited with last fifty answer trials for the learners. The numbers below each large map indicates the time in milliseconds when the map was computed. The first time interval 250msec to 550msec and the second time interval 550msec to 850msec post-stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue.

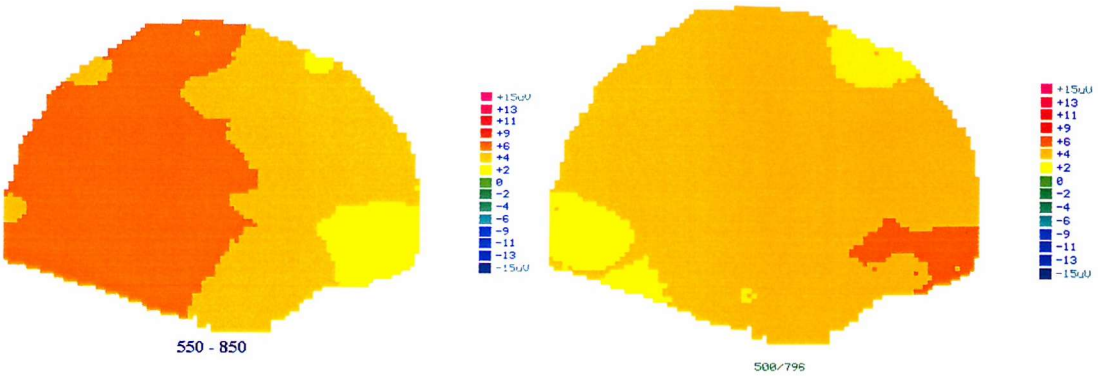

Figure (3.7.7b) shows the right-hand side spatial maps made from the grand average ERP elicited with last fifty answer trials for the learners group. The numbers below each large map indicates the time in milliseconds when the map was computed. The first time interval 250msec to 550msec and the second time interval 550msec to 850msec post-stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue.

The comparison between the individual right-hand side versus the left-hand side electrodes for the learners during the last fifty answer trials. The frontal, lateral central and parietal lateral electrodes (Figure 3.7.8a). The lateral frontal and the anterior temporal electrodes (Figure 3.7.8b). The temporal and the temporal-parietal (Figure 3.7.8c)

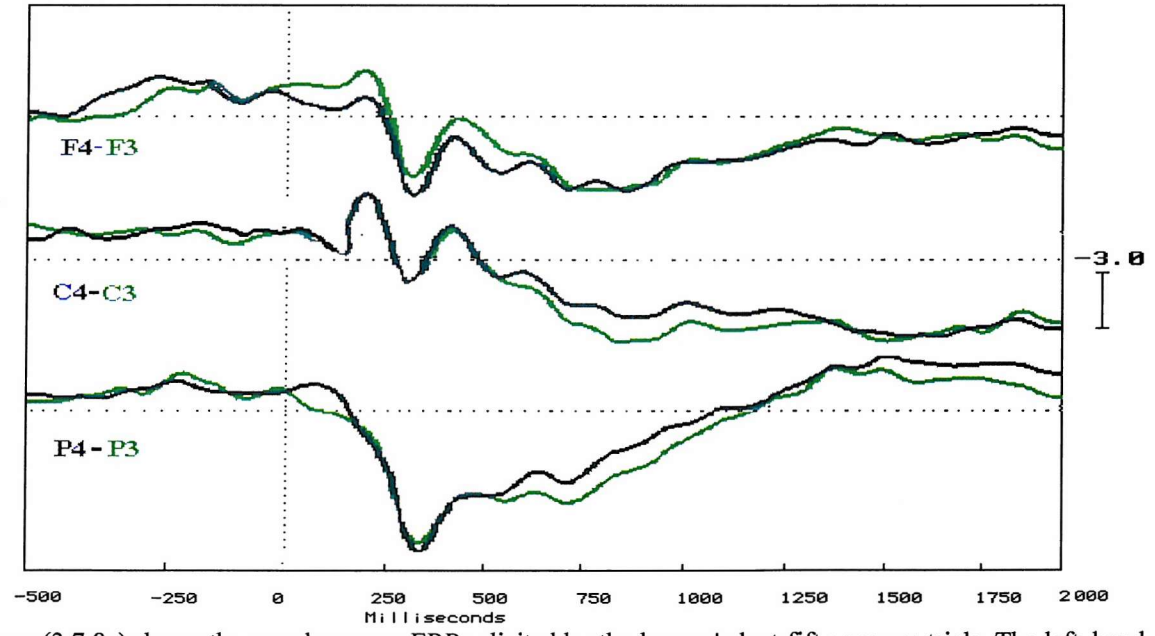

Figure (3.7.8a) shows the grand average ERPs elicited by the learner's last fifty answer trials. The left–hand side electrodes sites traces in light green color, the right-hand side electrodes sites traces in dark green color. Recorded at F4-F3, C4-C3, and P4-P3 Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

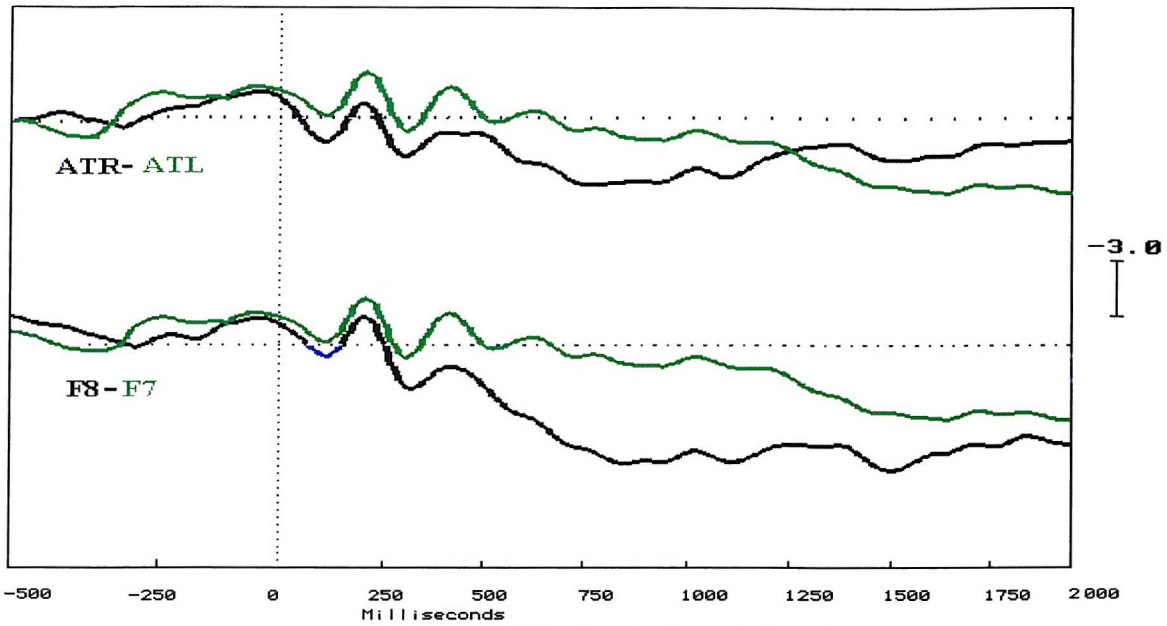

Figure (3.7.8b) shows the grand average ERPs elicited by the learner's last fifty answer trials. The left–hand side electrodes sites traces in light green color, the right-hand side electrodes sites traces in dark green color. Recorded at F8-F7 and ATR-ATL, Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

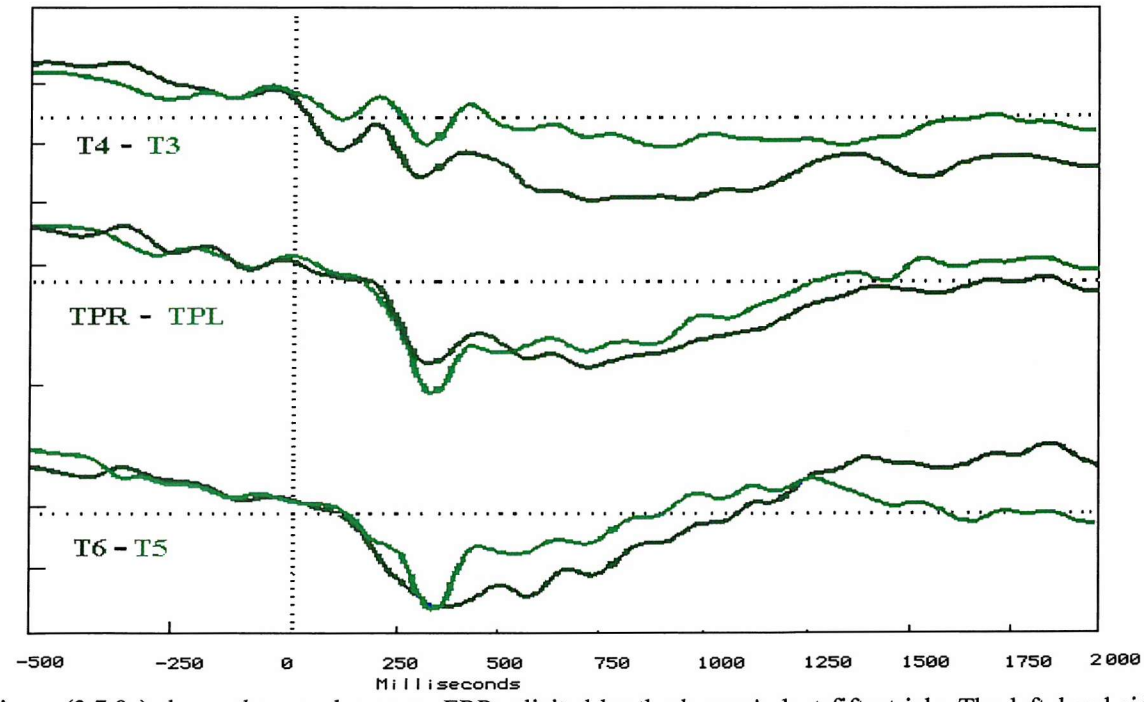

Figure (3.7.8c) shows the grand average ERPs elicited by the learner's last fifty trials. The left–hand side electrodes sites traces in light green color, the right-hand side electrodes sites traces in dark green color. Recorded at T4-T3, TPR-TPL and T6-T5, Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

Group	Learners (LFR n=15)	
Electrodes sites	1st window *t value*	2nd window *t value*
C4 - C3	0.88	0.97
F4 - F3	1.06	1.59
F8 - F7	2.91 *	3.15 **
O2 - O1	1.01	0.99
P4 - P3	1.02	1.33
TPR - TPL	1.18	1.08
T4 - T3	0.93	1.20
T6 - T5	1.65	0.95
AT - ATL	2.38 *	2.99 **

Table 3.7.1. Paired T-test results of the right-hand side versus the left-hand side electrodes for the last fifty trials (4th quartile) during both time windows

3.8. Group IV without feedback and with rule (fR n=15):

3.8.1. First fifty and last fifty trials:

All responses from individual trials were visually inspected and all uncontaminated by marked muscle or eye-movements artefacts were averaged.

Figures (3.8.1.a &b) show that the morphology was similar during the first fifty and the last fifty. As reported before the learners group elicited more positive going traces than the non-learners subjects did. 500msec pre-stimulus was similar in both groups, and up to 200msec post-stimulus.

Positive peaks were elicited by both conditions, the first fifty answer trials and the last fifty answer trials and the latencies were similar for each group separately. The last fifty answer trial stimuli elicited more positive going component than the first fifty answer trials.

The ERPs produced by the last fifty answer trials for the learners were distinguished from the non-learners by two more prominent positive peaks around 400msec and 680msec. The first fifty for the learners and non-learners were similar.

Cartoon brainmaps figures (3.8.2a & b) show that the both groups were similar pre-stimulus and at the beginning till about 150msec. About 200msec the learners and non-learners showed different brainmaps. In the group who trying to learn the task the positivity at the beginning at the occipital and parietal sites and then moved forward with time to the frontal sites. In the learning group brain positive activity at the beginning was frontal and distributed afterward to the occipital. It looks like the group of non-learners goes the opposite way of the brain active areas while performing the task. The learners brain activity for the last fifty differs from the first fifty appeared over the frontal, the anterior temporal, and the central area

bilaterally from about 250msec and up to 700msec post-stimulus then localized over the frontal and the anterior temporal especially to the right-hand side. The non-learners brain activity was over the parietal and the posterior temporal bilaterally from 150msec and up to 350msec, then changed to be frontally especially to the right-hand side up to 700msec. Gradually the brain activity decreased from about 900msec for the learners and from 700msec for the non-learners up to the end of the task where there were no remarkable significant activity

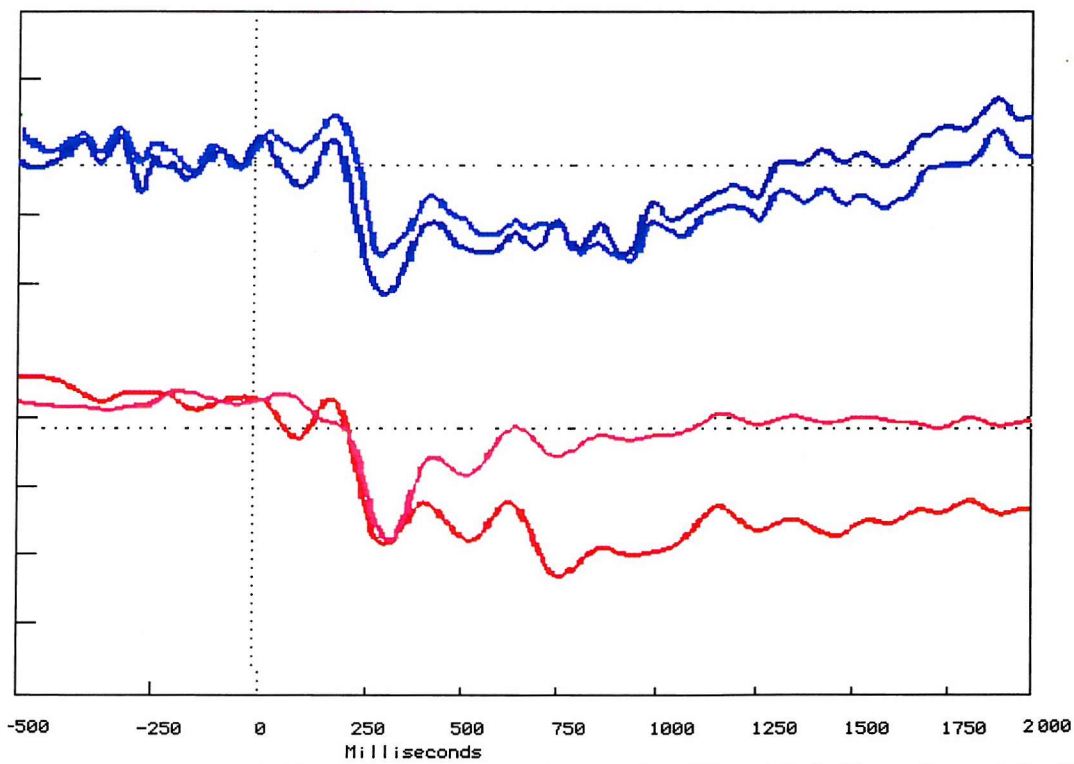

Figure 3.8.1a. Grand average ERPs elicited by the non-learners last fifty trials in blue color and the first fifty in light blue color represented by the top traces and the learners' last fifty trial traces in red color, the first fifty trials in light red color presented by the bottom traces. Recorded at FZ, Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

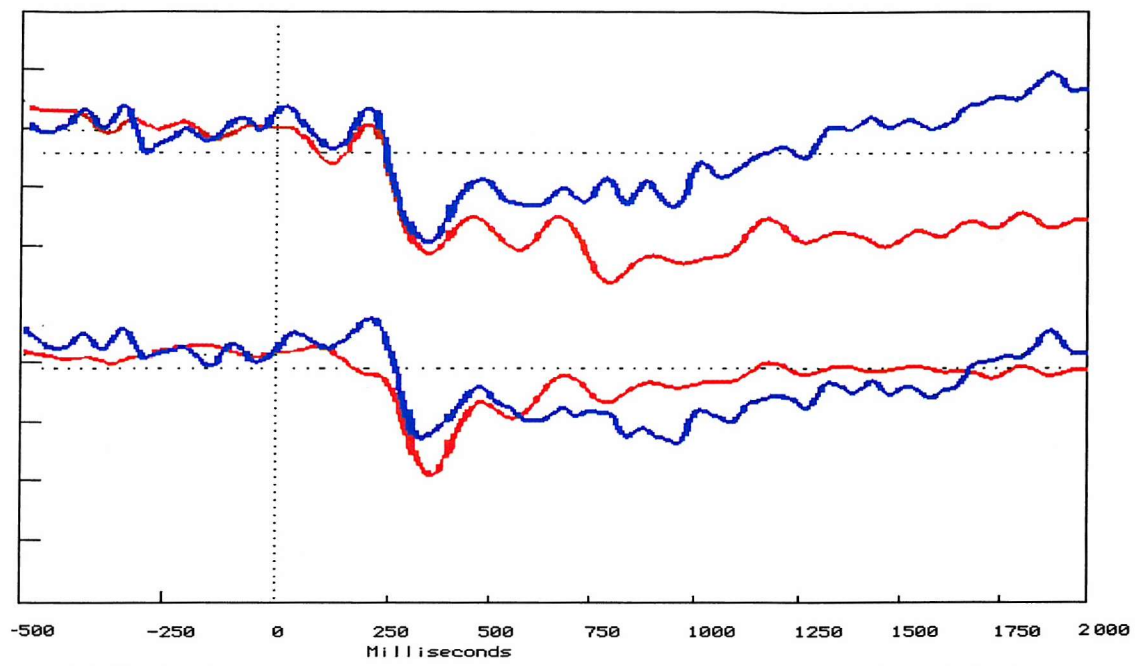

Figure 3.8.1b. Grand average ERPs elicited by the non-learners trial in blue color and the learners' trial traces in red color. The top traces represent the last fifty; the bottom traces represent the first fifty. Recorded at FZ, Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

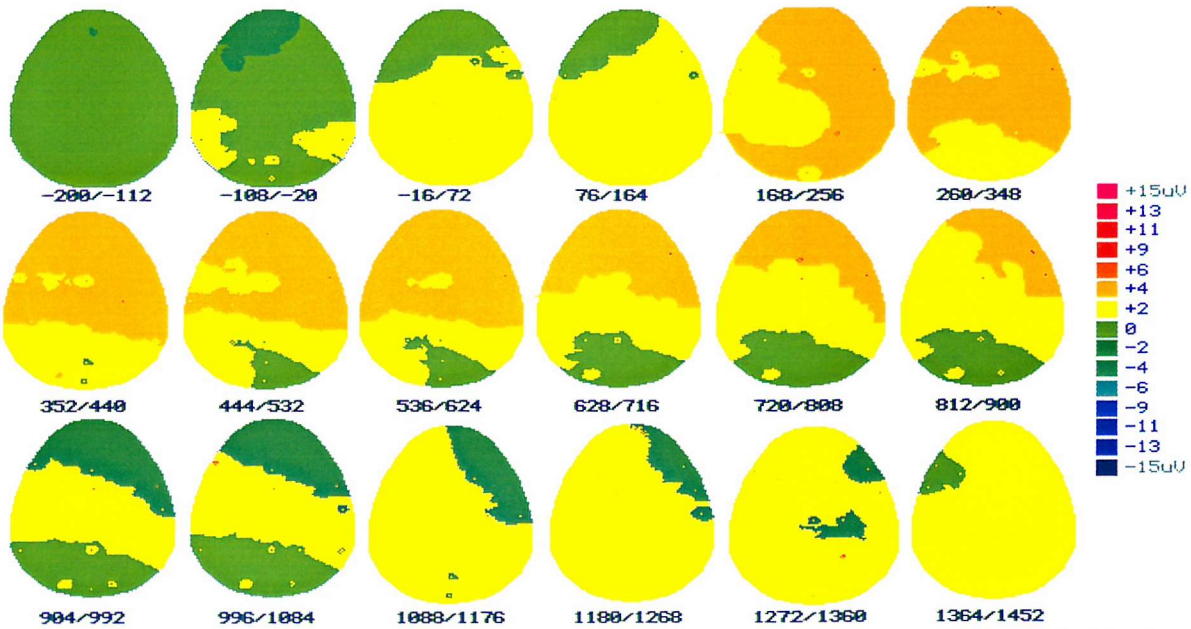

Figure (3.8.2a) shows the top view cartoon brainmaps made from the grand average ERPs elicited by the last fifty trials of the learners minus the first fifty. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1452 msec post-stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

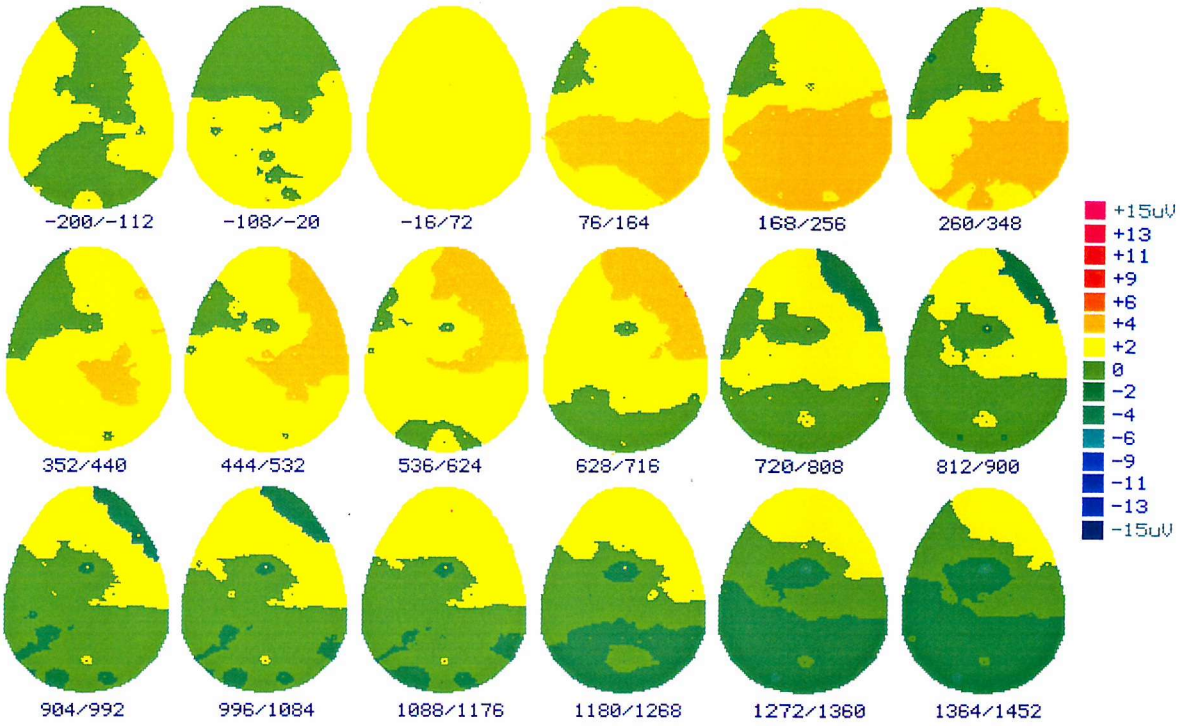

Figure (3.8.2b) shows the top view cartoon brainmaps made from the grand average ERPs elicited by the last fifty trials of the non-learners minus the first fifty. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1452msec post-stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. Frontal to the top, occipital to the bottom of the brain maps

3.8.2. Correct and incorrect answers trials:

The group of learners brain activity stayed similar up to 200msec, then the correct answer trace showed positive peaks deflections stayed for about 1000msec. The group of non-learners stayed similar up to 450msec, then the positive deviation just stayed for 100msec, then the two traces were similar again up to the end of the task. A comparison between the learners and the non-learners showed that the pre-stimulus was the same in both of them up to 200msec and beyond 1200msec. The ERPs showed two positive peaks with latency of 300msec and 600msec in both groups. The positive amplitude was bigger for the learners group when compared with the non-learners, and the latencies were almost the same in the two conditions. In the learners group the positivity was more for the correct answers

trials but the positive peaks latency was not similar where were delayed in case of the correct answers trials. The brain potentials elicit more positive activity on the right hemisphere at frontal sites and propagated to the central and parietal sites on both hemispheres.

The brainmaps are useful in showing more widespread effects, as we mentioned before that the individual electrodes gave us limited information as they reflect localized brain activity.

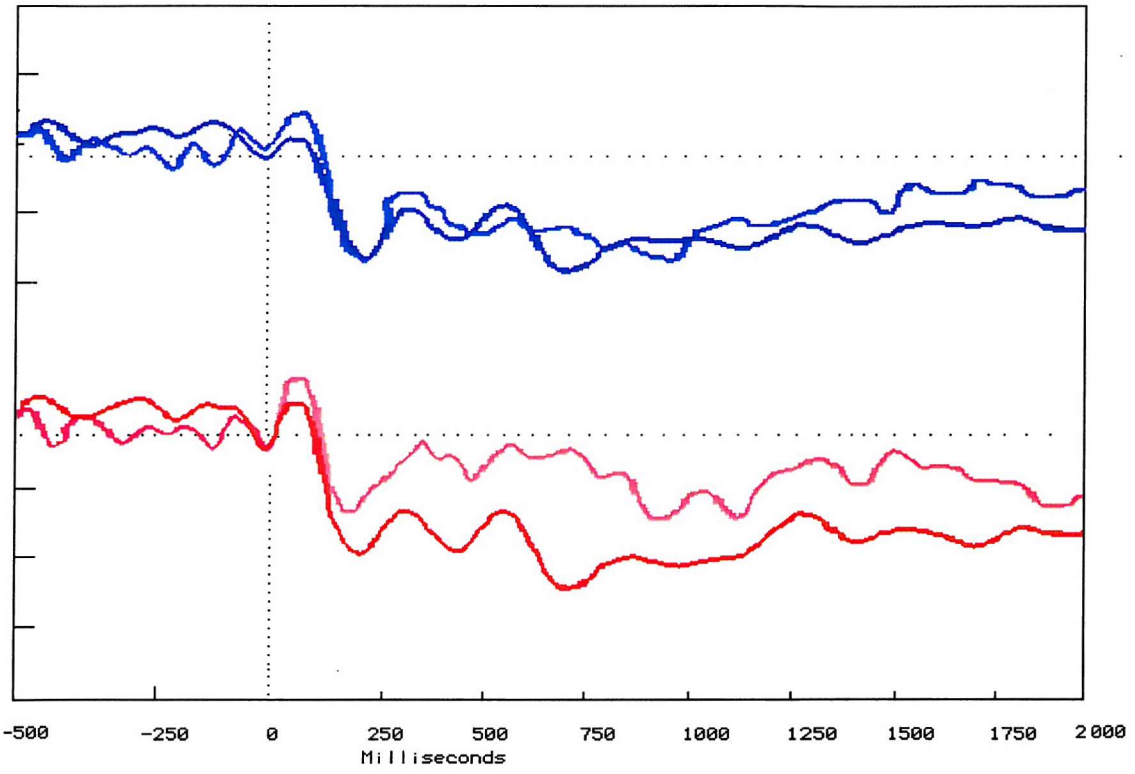

Figure 3.8.3a. Shows the grand averaged ERPs elicited by the non-learners correct answer trials in blue color and the incorrect answer trials in light blue color represented by the top traces and the learners correct answer trials traces in red color, the incorrect answer trials in light red color presented by the bottom traces. Recorded at FZ, Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

Figure (3.8.4a) shows the learners' top view cartoon brainmaps of made from the correct answer trials (LfR). There were significant brain activity recorded pre-stimulus and up to 50msec post-stimulus. The positive activity was distributed

over the occipital, the parietal, the temporal areas and then distributed forward to the frontal and anterior temporal areas bilaterally, and more deviated to the right-hand side. The positive activity decreased gradually after 1100msec and beyond.

Figure (3.8.4b) shows the non-learners top view cartoon brainmaps of made from the correct answer trials (nLfR). There were no differences recorded pre-stimulus and up to 200msec post-stimulus. The positive activity started to appear parietally, and over the temporal areas bilaterally. Then the brain activity distributed over the frontal area and the temporal area especially to the right-hand side. The brain activity showed less positive amplitudes and different latencies when compared with the learners brain maps.

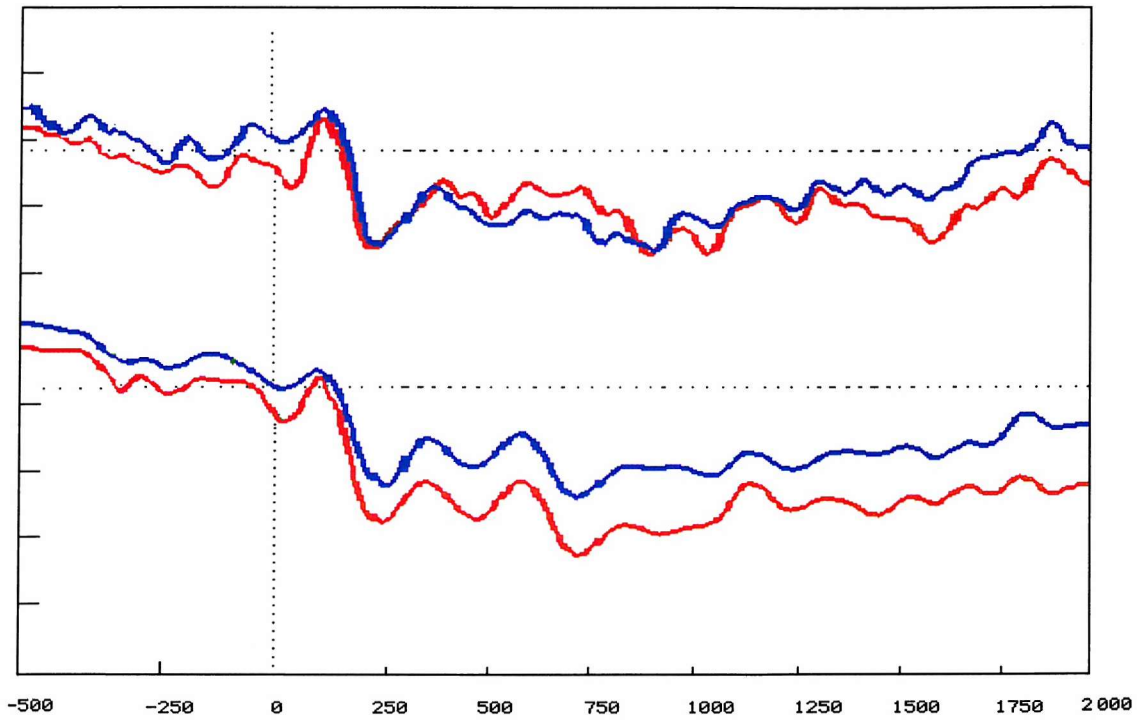

Figure (3.8.3b) shows the grand averaged ERPs elicited by the non-learners trial traces in blue color and the learners' trial traces in red color and the top traces represent the incorrect answer trials; the bottom traces represent the incorrect answer trials. Recorded at FZ, Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

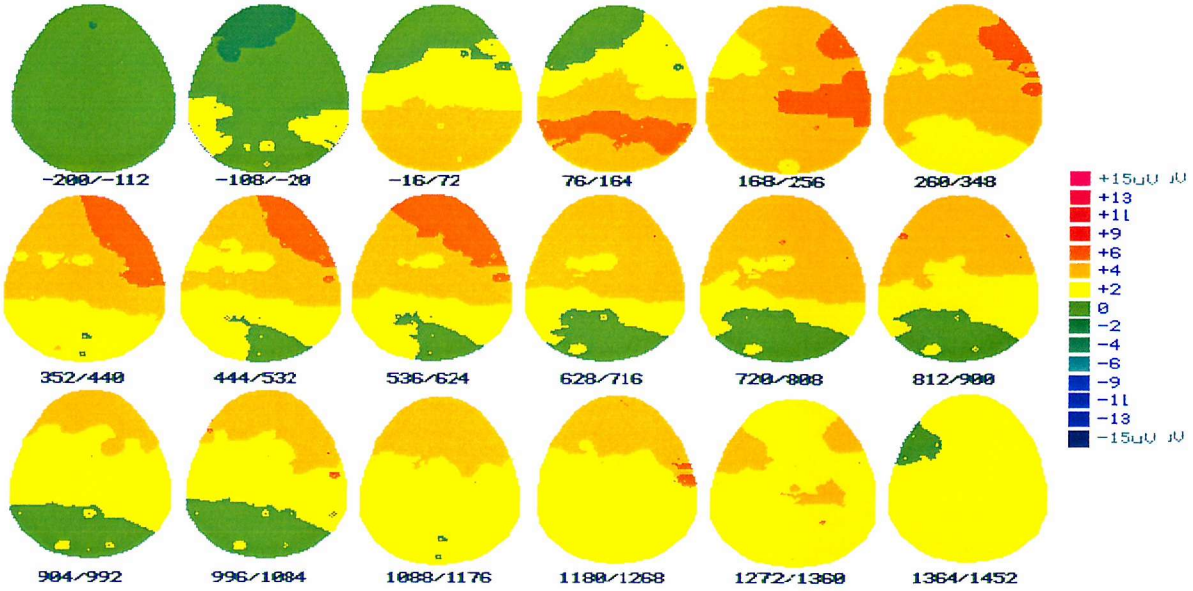

Figure (3.8.4a) shows the top view cartoon brainmaps made from grand average ERP elicited by the learners' correct answer trials. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1452msec after stimulus. Color scale displays brain potentials from +15 μν in pink color, and –15 μν in dark blue. Frontal to the top, occipital to the bottom of the brain maps

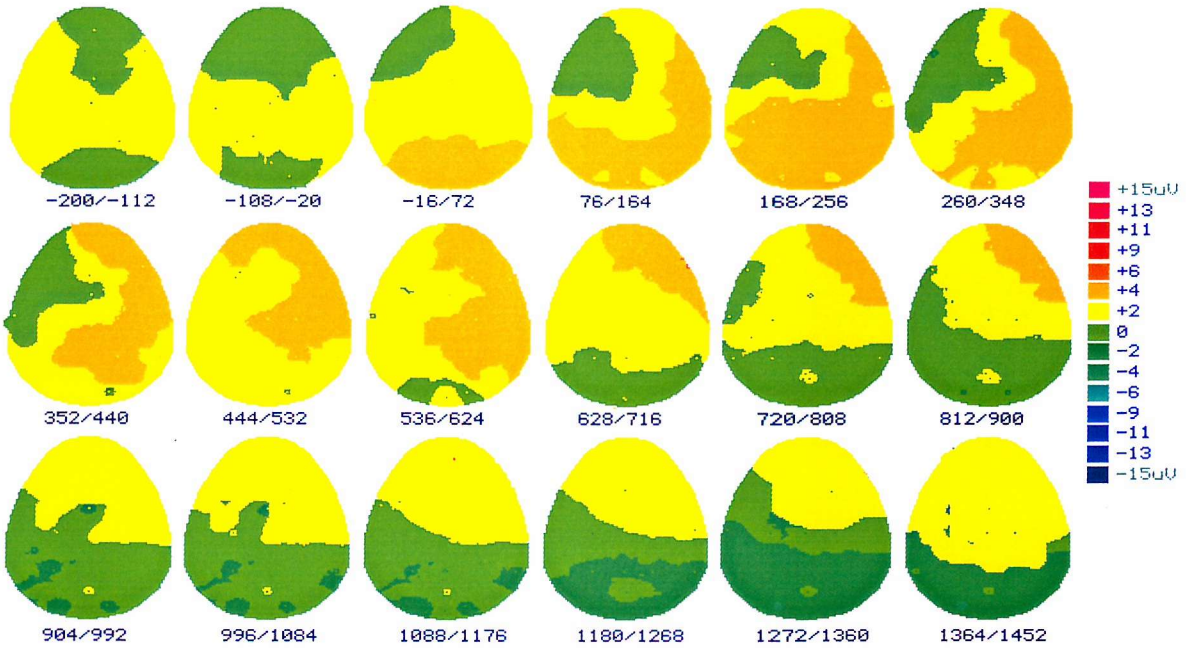

Figure (3.8.4b) shows the top view cartoon brainmaps made from grand average ERP elicited by the non-learners correct answers trials. The numbers below each brainmap indicates the time in milliseconds when the map was computed. These results indicate 200msec before stimulus to 1452 msec after stimulus. Color scale displays brain potentials from +15 μν in pink color, and –15 μν in dark blue. Frontal to the top, occipital to the bottom of the brain maps

3.8.3. The regional differences:

The electrical activity was very similar in all parts of the brain pre-stimulus.

Furthermore, these figures clearly show a very marked front-occipital difference. The activity was more positive going over the frontal, the parietal, and the temporal areas especially on the right-hand side electrodes.

The comparison between the individual right-hand side versus the left-hand side electrodes for the learners during the last fifty answer trials. The frontal, central, and parietal lateral electrodes (Figure 3.8.5a). The lateral frontal and the anterior temporal electrodes (Figure 3.8.5b). The temporal and the temporal-parietal (Figure 3.8.5c)

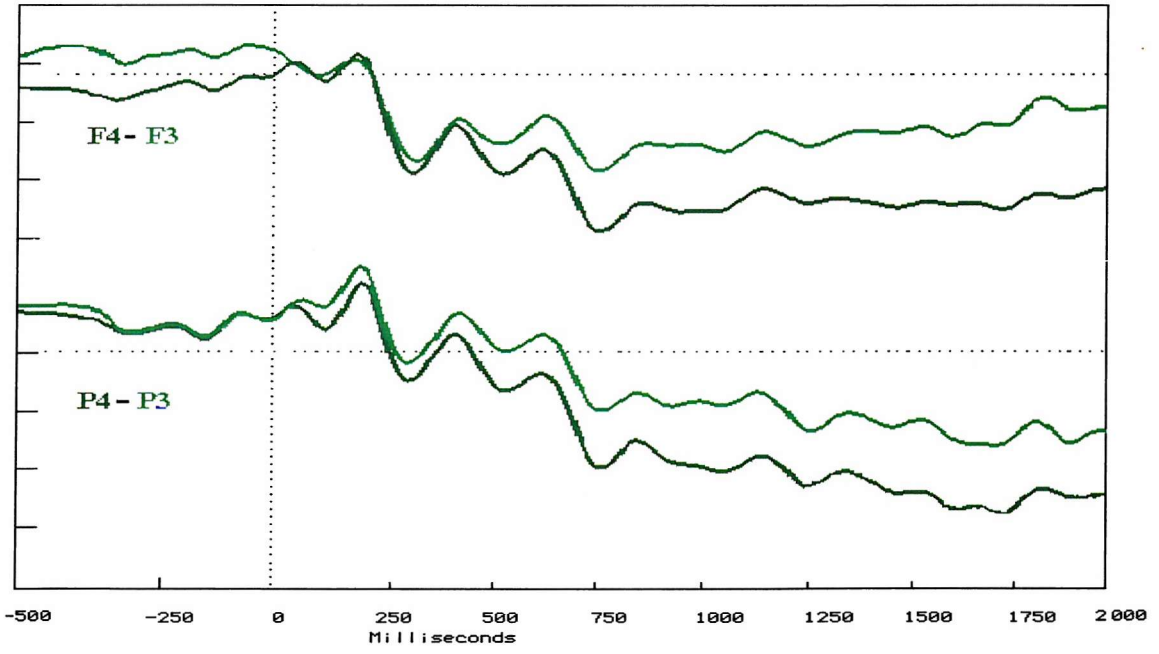

Figure (3.8.5a) shows the grand average ERPs elicited by all subjects' performance in group four. The right–hand side electrodes traces in dark green color, and the left-hand side electrodes traces in light green color. Recorded from the lateral frontal at F4-F3, and, the parietal area at P4-P3. Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (msec). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

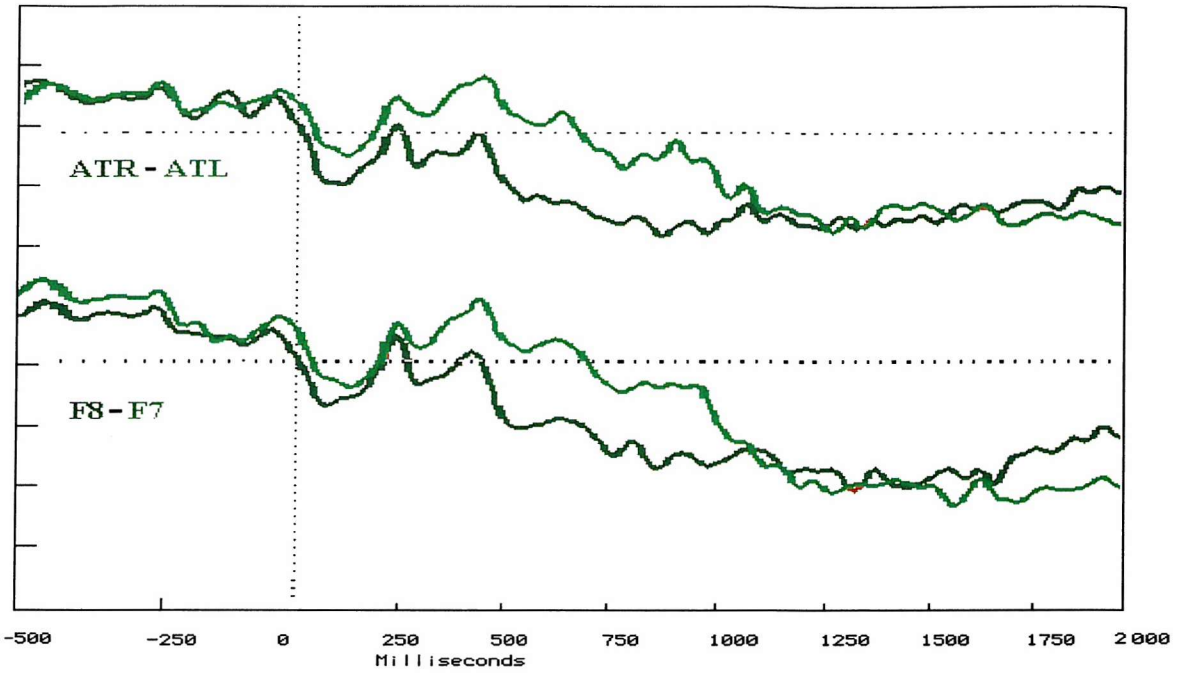

Figure (3.8.5b) shows the grand average ERPs elicited by all subjects' performance in group four. The right–hand side electrodes traces in dark green color, and the left-hand side electrodes traces in light green color. Recorded from the lateral frontal at F8-F7 and the anterior temporal area at ATR-ATL. Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

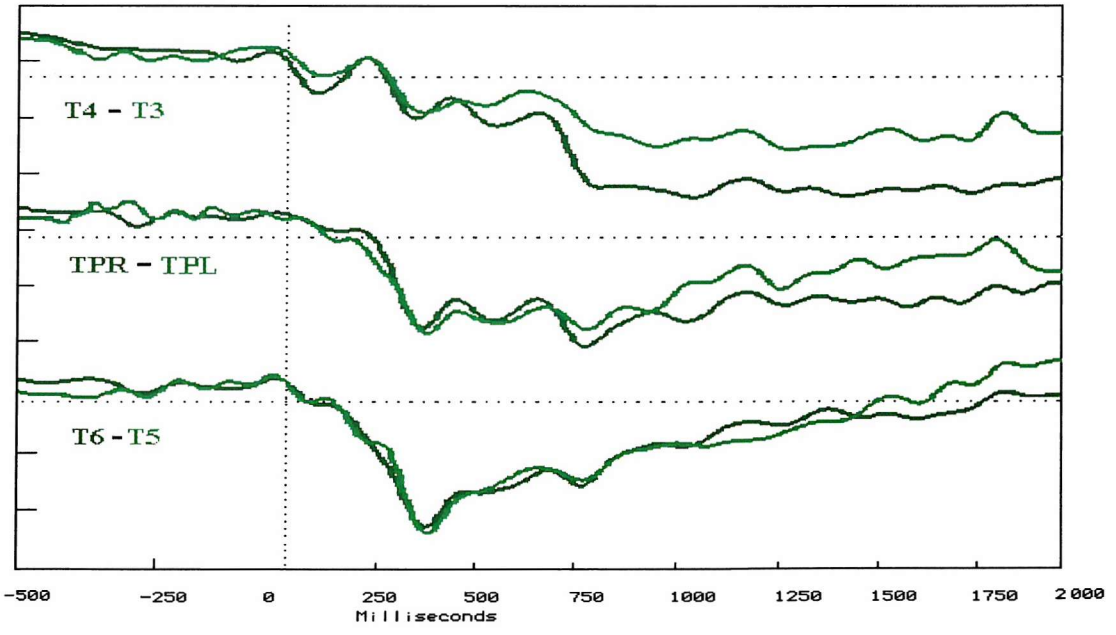

Figure (3.8.5c) shows the grand average ERPs elicited by all subjects' performance in group four. The right–hand side electrodes traces in green color, the left-hand side electrodes traces in blue color. Recorded from the tempro-parietal at TPR-TPL, the temporal at T4-T3 and the posterior temporal at T6-T5. Y-axis shows amplitude in Microvolts (μv), and X-axis shows latency in milliseconds (ms). The black vertical dotted line marks the point of stimulus onset, and the horizontal black dotted line represents the baseline. Upward deflection represents the negativity.

Figures (3.8.6a &b) show the comparison between cartoon brainmap the right-hand side view versus the left-hand side view for the last fifty answer trials during the two time windows 250msec-550msec and 550msec-850msec. The positive activity was localized frontally and distributed backward to the anterior temporal and was more for the right-hand side view brainmaps during both time windows when compared to the left-hand side view. The activity distributed over the parietal, the central, the posterior temporal and the occipital areas which means that these areas were involved in the trials performance by the same value during this experiment condition trials and during the both windows. The positive activities were more for the large map right-hand side view during the first time window and the second time window.

The brain potentials elicit more positive activity on the right hemisphere at frontal sites and propagated to the temporal, the central and parietal sites on both hemispheres.

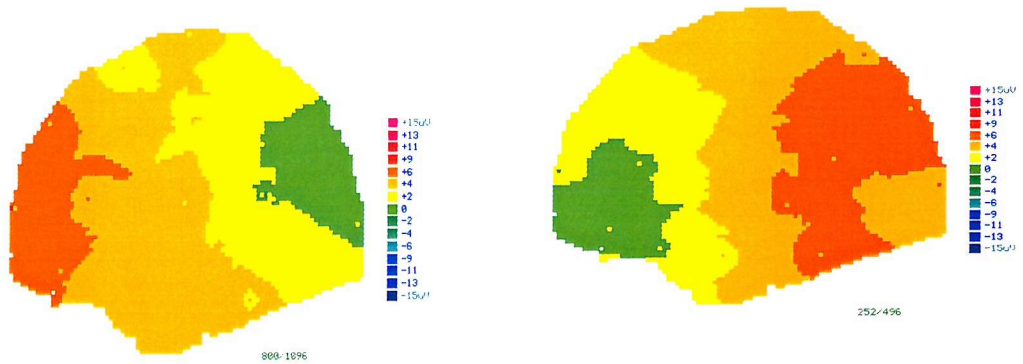

Figure (3.8.6a) shows the left-hand side view spatial maps made from the grand average ERPs elicited by the learners group last fifty stimuli. The numbers below each large map indicates the time in milliseconds when the map was computed. The first time interval 250msec to 550msec and the second time interval 550msec to 850msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and –15 μv in dark blue. The frontal area to the left-hand side and occipital area to the right-hand side of the brainmap

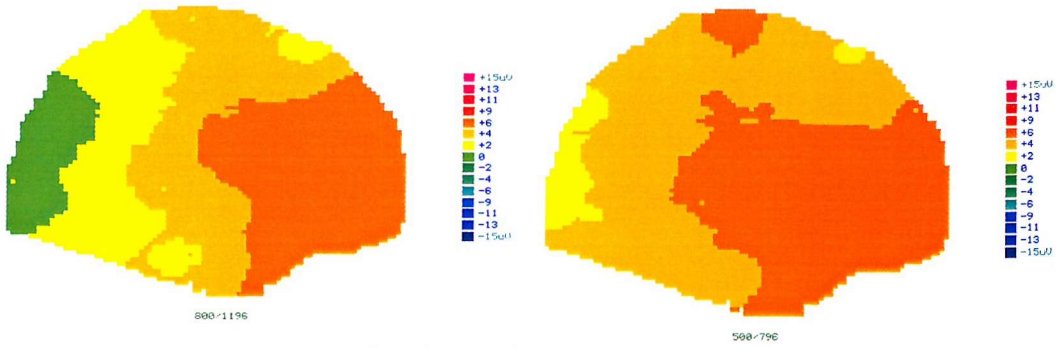

Figure (3.8.6b) shows the right-hand side view spatial maps made from the grand average ERPs elicited by the learners group last fifty trials. The numbers below each large map indicates the time in milliseconds when the map was computed. The first time interval 250msec to 550msec and the second time interval 550msec to 850msec after stimulus. Color scale displays brain potentials from +15 μv in pink color, and – 15 μv in dark blue. The frontal area to the right-hand side and occipital area to the left-hand side of the brainmap

Table (3.8.1.) shows the comparison between the right-hand side with the left-hand side electrodes for the learners during the last fifty trials. There were statistically significant differences for the frontal area electrodes F4-F3 and the parietal area electrodes P4-P3 during the second time window. There was statistically significant difference for the frontal area electrodes F8-F7 and the anterior temporal electrode ATR-ATL during both time windows

Group	Learners (LFR n=15)	
Electrodes sites	1st window *t value*	2nd window *t value*
C4 - C3	1.03	1.08
F4 - F3	1.77	2.31**
F8 - F7	2.87 **	3.66**
O2 - O1	1.43	1.52
P4 - P3	1.79	2.77 **
TPR - TPL	1.68	1.51
T4 - T3	1.09	0.96
T6 - T5	0.99	1.78
AT - ATL	2.22 **	2.75 **

Table 3.6.1. Paired T-test results of the right-hand side versus the left-hand side electrodes for the last fifty trials (4th quartile) during both time windows

CHAPTER 4: DISCUSSION

4.I. GENERAL DISCUSSION

The aim of this study was to record in parallel a subject's performance during a learning task and changes in event related potentials ERPs. It has to said that two aspect of this work were unforeseen during planning phase

1) The learning task chosen happens to be difficult. Only about half the subjects succeeded in learning to do it. Fortunately there was a clear difference in performance between those who learned and those who did not.

2) The learning was implicit. That is debriefing revealed that the learners could not declare what they had learned.

"I think therefore I am", but "I am, therefore I think". We are not who we are simply because we think. We are who we are because we can remember what we have thought about.

The scientific literature of similar experiments is sparse.

4.1.1. Learning and Memory:

Learning is acquisition of new information or knowledge, and memory is the retention of learned information for the future.

Psychologists have studied learning and memory extensively. As a result, they have distinguished what appear to be different types. Several schemes have been proposed distinguishing different categories of memory. Cognitive psychological studies have shown that there are at least two distinct types of memory storage: the conscious recall of information about people, places, and things (explicit or declarative forms of memory) and recall of information about

motor skills and perceptual strategies (implicit or procedural forms of memory). These two forms of memory have been localised to different neural systems within the brain. Explicit memory requires regions within the temporal lobe of the cerebral cortex, including the hippocampus; implicit memory involves the specific sensory and motor systems recruited for the particular task.

Memory for facts and events is called "declarative memory" and it is usually what is meant by the word "memory" in every-day usage and can be assessed by conscious recollection. Memory for skills or behaviour is called procedural memory that cannot be assessed by conscious recollection and it is more like "habit". These procedures can be performed without conscious recollection. Working memory is a more general term for temporary information storage that allows several types of information to be held at the same time.

How do we learn? "Practice" in a continuous regular way and you will have much progress. "Study" practice study-practice and learning takes time, and effort. Learning of anything continues over the entire life span. There is no end to the learning of any topic.

How does one learn? There can be no definite answer, with intellectual activities one problem of learning is simply the size of the task, few ideas seem difficult when examined in isolation. The task is not easy; the difficulty seems to lie in the interrelationships among the ideas that must be acquired. It is the totality of the topic that requires time and mental effort.

How do we remember? Some events are easy to remember and some not. Sometimes remembrance comes only with difficulty. Learning a person's new name, telephone number, vocabulary of foreign language, etc.

To remember is to have managed three stages successfully. The "acquisition" when a sensory impression is registered as a memory. The "retention" once a

memory is registered, it retained and can be recalled. The "retrieval" recall what registered and retained of the information. Failure at managing one of these three stages means failure to remember. Learning is very close to understanding, you learn how to play a game of chess when you understand the moves.

Early last century, Karl Lashley, a pioneer neuro-psychologist, set out to find the engram, the hypothetical unit of memory or permanent memory trace. He concluded that memories are distributed, and he had an important and lasting impact on the study of learning and memory because he led other scientists to consider ways in which memories might be distributed among the many neurons of cerebral cortex.

Hebb was the most famous student of Karl Lashley and father of cognitive psychobiology (1904-1985). He proposed in his published remarkable book in 1949 entitled "The Organization Of Behaviour" that the internal representation of an object consists of all the cortical cells that are activated by this stimulus. He immagined that all these cells were connected one to another by reciprocal connections and he called all these stimulatenously active neurons a cell assembly. The internal representation of the object was held in the short term memory as long as the activity reverberated through the connections of the cell assembly.

At the physiological level of the learning spectrum this seminal idea of Hebb (1949) argued that the formation of permanent memory must involve structural changes to cellular networks in the brain, and that this must take time. Consequently, there must be some form of temporary storage mechanism to allow immediate recall of learned information. This notion became known as the consolidation hypothesis.

Was the first formal enunciation of the biological stage of the concept of memory formation. The permanent memory is probably a form of passive store which involves relatively permanent alterations to the connectivity between synapses in a neural network, while a shorter term active representation must be present, involving transient electrochemical events in the network.

The most complex biological system known to us is the brain and among the most complex questions concerns the mechanisms of learning and memory. Since we believe that learning/memory mechanisms occur at synaptic connections (Bailey and Kandel, 1993; Jessel and Kandel, 1993), the site of information transfer between neurons has become an interesting area for research.

Learning occurs in many ways. At the most basic level, the level of the neuron, learning is associated with the production of more glial cells, better blood supply, more acetylcholinesterase and thus acetylcholine (Rosenzweig, 1984), as well as more synapses per neuron (Turner & Greenough, 1985) and more complex dendritic trees (Greenough & Volkmar, 1973). While these changes could result from a number of factors, such as better health, they must be related to learning (Carlson 1991). Further, while it may not be safe to say that these changes necessarily represent learning, it is safe to say that they may be associated with learning.

4.1.2. Long-term potentiation:

Long-term potentiation is operationally and typically expressed as a long-lasting increase in synaptic efficacy (lasting from hours to days) following brief tetanic (high-frequency) stimulation of an afferent pathway (fibers). Thus, following LTP induction, a fixed amount of presynaptic stimulation induces a " potentiated" post-synaptic response, e.g., an increase in excitatory post-synaptic potentials (EPSPs). In 1966 Terge Lomo, working in the laboratory of Per

Anderson initially observed the phenomenon of LTP. In 1973, the first full article described LTP in the hippocampus of the rabbit, a collaborative effort between Lomo and Timothy Bliss (Bliss & Lomo 1973), (Bliss & Gardner-Medwin 1973). Exploration of the mechanisms underlying LTP induction has been one of the most active areas of research in neuroscience. LTP was discovered after it was found that electrical stimulation of the perforant path, which connects the entorhinal cortex with the dentate gyrus of the hippocampus, resulted in "stronger" excitatory post-synaptic potentials in the ipsilateral dentate gyrus. This effect may last several months and thus represents a relatively long term strengthening, or potentiation, of neurons and their multiple synapses.

By 1989, the U.S. National Library of Medicine listed 312 articles with the term "long-term potentiation" in the title. In the 1990's alone, over 700 additional articles have appeared. This search vastly underestimates the research effort, because many articles that address LTP do not contain LTP in the title phrase or refer to the same phenomenon with a different name (e.g., "long-term enhancement" (McNaughton et al. 1986).

The concerted attention that LTP attracted over time is perhaps of no surprise to those familiars with the search for the engram (a neural memory store) and the associated mechanism that could account for its formation. Prior to the observation of LTP, the search had produced virtually no viable candidate mechanisms, at least in the vertebrate nervous system (Kandel & Tauc 1965a, 1965b). In this regard, LTP was and still may be the best candidate. In several recent reviews, different authors have concluded that not only is LTP a viable mechanism for the induction and storage of memories, but also is the most promising candidate (Morris et al. 1991).

The most well studied synaptic pathway exhibiting LTP is the termination of the Schaffer collateral system of axons, projecting from pyramidal cells in hippocampal area CA3 and synapsing on the dendrites of pyramidal cells in hippocampal area CA1. This pathway has been implicated in the storage of declarative perceptual memories in humans and spatial learning in rodents. The most extensively studied form of LTP requires the activation of postsynaptic N-methyl-D-aspartate (NMDA) type glutamate receptors. The influx of $Ca2^+$ ions through NMDA receptors triggers a partly understood cascade of enzyme activity which results in a long-term strengthening of the synapse (Lisman, 1994). The form of NMDA receptor dependent LTP which is expressed immediately following induction is called early LTP (E-LTP), which after about an hour is replaced by a late form of LTP (L-LTP) which depends on postsynaptic protein synthesis. This paper focuses on NMDA receptor dependent, early LTP at CA3-CA1 synapses, and refers to this phenomenon simply as LTP unless mentioned otherwise.

4.1.3. NMDA Receptors and Post-synaptic Calcium:

One defining feature of LTP is its dependence on high levels of postsynaptic calcium, a common feature of most learning-induced neuronal modifications. In and of itself, a definition which includes "calcium dependence" provides little insight since a wide range of cellular functions require calcium and still more are dependent on elevations of intracellular $Ca2^+$ above basal levels. Although the exact role of calcium in LTP induction is a matter of debate, elevation of post-synaptic calcium is clearly necessary, and may even be sufficient for the induction of hippocampal LTP. Induction of LTP is prevented by a pre-tetanus injection of calcium chelators into the post-synaptic cell (Lynch et al. 1983; Malenka et al. 1988), and induction occurs when the postsynaptic cell is artificially loaded with the ion (Malenka et al. 1988). A great deal of evidence (Jahr & Stevens 1987) indicates that the primary source of calcium influx

during the induction of hippocampal LTP occurs through an ion channel that is coupled to the NMDA subtype of glutamate receptor. This receptor is unique in that stimulation of the channel ionophore requires glutamate binding as well as a moderate level of depolarisation. At normal resting potentials (-70 mV), the channel is blocked by magnesium, and glutamate binding is insufficient to open it. However, at depolarised membrane potentials (> -40 mV), magnesium is expelled from the channel, which can then be opened by glutamate and which displays a high selectivity to calcium ions. Thus, the NMDA receptor complex is said to be dually regulated by two factors: ligand and voltage. These cofactors can be recruited through several means.

First, a relatively long, high intensity pre-synaptic burst of activity (such as a high-frequency train of stimulation) can induce LTP by releasing glutamate onto the postsynaptic receptor, while depolarising the postsynaptic cell through stimulation of the non-NMDA type of glutamate receptors (AMPA).

Second, shorter and more physiologically relevant levels of pre-synaptic activity can induce hippocampal LTP by stimulating the NMDA receptor with glutamate, while the postsynaptic cell is depolarised via an alternative means such as an input from a second afferent pathway.

Other forms of LTP, such as that induced in CA3 pyramidal cells following mossy fiber tetanization, occur independently of the NMDA receptor, and are instead dependent on $Ca2^{+}$ influx through voltage-gated channels, with some debate as to whether the critical $Ca2^{+}$ signal occurs pre- synaptically (Castillo et al. 1994), post-synaptically (Johnston et al. 1992). As alluded to earlier, even in area CA1, LTP can be induced without the participation of NMDA receptors, provided that the tetanus (or post-synaptic depolarisation) is of sufficient intensity to activate voltage-dependent calcium channels (Kullman et al. 1992). Thus, activation of the NMDA receptor is critical to many forms of LTP, but it

is not necessary for all. In contrast, intracellular calcium appears to be a necessary element for the induction of LTP. A necessary role for calcium in LTP is consistent with LTP's presumed role in learning; calcium plays a critical role in many cellular modifications thought to underlie conditioned behavioural responses (Abrams & Kandel 1988, Matzel & Rogers 1993).

Long-term potentiation (LTP) is a long-lasting increase in synaptic strength (larger excitatory post-synaptic potentials or EPSPs) induced by high frequency, high intensity stimulation of the pre-synaptic neuron. LTP is exciting to memory researchers because it provides empirical support for the hypothetical strengthening of connection hypothesised by Hebb. It is a phenomenon most widely studied in vitro in the rat hippocampus slice, but it has also been recorded in cortex - both the cortex and hippocampus are considered to be possible sites for memory processing. In addition, LTP is popular because it has many of the characteristics expected of a memory mechanism, in that it:

- is triggered by a very brief event
- is persistent
- can be associative (dependent on the NMDA glutamate receptor's properties)
- Appears to depend on similar mechanisms as memory and learning.

Changes in the brain are recorded as plasticity whereas changes in behaviour or cognition are the result of learning. Psychologists have their own problems with learning, instrumental conditioning, impinting, recall, forgetting curves as well as learning curves.

Do both disciplines have the same aims? Not always, one wishes to understand behaviour and other the brain tissue. When they have come together in the past their joint findings have been most insightful. One might mention the much

quoted case of HM (Scoville and Milner 1957) who underwent bilateral temporal lobe resection. In the context of these experiments HM learned how to solve several perceptual-motor puzzles but denied he had even seen the puzzle let alone solved it on previous occasion (quoted in Churchland P.S. 1986)

There are many interesting cases in the world literature beginning with Pheneas Gage who survived frontal lobe damaged which rendered a skilled worker into a feckless individual. Much work has been a careful psychological examination of individuals with specific and well documented brain lesions. This gives a psychological picture of deficits but there are pitfalls in integrating these observations into a theory of brain function.

Now things are changing - by the build up anatomical psychological maps of deficits, it is possible to build pictures of "facits". New techniques PET and fMRI give pictures of which parts of the brain are hard at work during a psychological task. Event related potentials give only poor spatial information but have very accurate temporal discrimination

It would have been very exciting and worth while to do these experiments with contemporary ERP and PET but that was not possible.

4.2. PERFORMANCE

We divided the participants in each of the experimental groups into two subgroups according to their performance as learners and non-learners. In the second group (FR) all were learners. Males and females contributed equally to both groups. Due to selection of medical undergraduate and postgraduate students no real initial intelligence difference was present. As it happened all were right handed.

4.2.1. Levels of learner performance:

Learners can be described and classified according to their level of performance in the learning process.

The five levels identified by Pacific Crest are as follows (in increasing level of performance):

Trained Individuals, who have developed a specific knowledge base, with specific skills for a specific context.

Learned Individuals, who have acquired a broad base of general knowledge and can apply it to related contexts.

Lifelong Learners, who have developed the skills and motivation to self-facilitate their ongoing learning and can, apply it to a variety of contexts.

Enhanced Learners, who have developed a higher level of performance skills and actively seek new knowledge and contexts for application in a constantly changing environment.

Self-growers, who continually grow by using strong self-assessment skills to improve future performance

This highest level of learner performance is characterised by the following:

- Seek to improve their own learning performance with every experience.
- Create their own challenges.
- Serve as a leader and mentor to others.

- Take control of their own destiny — "there are no bounds."
- Self-assess and self-mentor to facilitate their own growth.

My subjects were all being trained to be lifelong learners and some would be expected to develop enhanced learners and self-growers. Reasons have been given earlier why all subjects tried and were attentive to the task. Debriefing gave some insights into their inner mental life during the task.

Since 1972 the researchers have studied the subject's performance and ERPs accompanying feedback. They conclude that the feedback provides information relevant to past behaviour which may be used to modify behaviour in the future trials (Jenness 1972; Poon et al. 1974; Johnson and Dochin 1978, 1982, 1985; Stuss and Picton 1978; Perrault and Picton 1980; Ruchkin et al. 1980, 1981, 1982; Stuss et al. 1980; DeSwart et al. 1981; DeLisle et al. 1986; Papkostopoulos et al.1986; Warren and McDonough 1995). During debriefing, motivation and frustration seemed to contribute to performance. Certain individuals appear to be over competitive or to try too hard, resulting in incorrect answers provoking frustration. The ideal subject seemed to be a moderately motivated and competitive individual. No formal psychological testing was employed and these subjective views are based on observation and questioning. A further group seemed less motivated and therefore contributed to the non-learning group. These people perhaps didn't want to be there and were thinking of other things and couldn't focus on the task. Thus they were in a situation not conclusive to learning.

Task performance was virtually perfect with fewer than 2% of target trials missed across the learners in general. Less than 10% were missed across the non-learners and they reported that they could not make their decisions in the allowed time (2000msec). The subjects included some comments about their strategies for performing the task: Some divided the image on the screen into

four quadrants and then tried to concentrate on one of these four quadrants and follow it from one image to the next trying to find the differences between them. Others tried to do the same but with modification like choosing another quadrant and if they gave incorrect answers, they moved directly to another quadrant.

Another group of the subjects did not divide the image and dealt with it as one part, by having a quick look at it searching out for the differences. Then by the time they become more able and much quicker in making an accurate decision. The learners reported that they have been confident about their judgement and decision.

Some of them divided the image into centre and periphery and they concentrated at the beginning on the periphery but they found no differences at all. Then they directed their concentration around the centre of the image and found differences.

The subjects get a clue after few trials. Some of them get the idea of the distributed elements. They understand that these features are distributed in different percentage, from one image to another. They found as well that these elements (features) look like a tuning fork facing different directions.

Few of them reported that they could not make a decision within the allowed time in the very first trials. Another group of the subjects reported that they were pressing the button without intention and they got the feeling of pressing the button automatically (unconsciously).

The non-learners reported that the task was very difficult and they got the feeling before they knew the result of their performance that they had not reached the cut off percentage to be classified as learners.

An interesting observation was into our subject's strategies and beliefs. Only two out of eighteen learners were close in their explanations of the pattern of the correct difference between patterns. A further two explained left to right or waterfall effects, although were unsure. The rest of them claimed to ' just know', and one subject reported to hearing a voice that coincided with pattern presentation calling 'left', or 'right'. The overall impression was that the classification task was at subconscious level or could not be expressed in words.

Only two of the learners developed explicit knowledge of the task; they could use this knowledge to form attentional experiences regarding the next image in the task. This developed explicit knowledge did not improve the procedural knowledge per se but facilitated the behaviour used to measure procedural knowledge. Mishkin and Appenzeller (1987) reported that "behaviour could be a blend of automatic responses to stimuli and actions guided by knowledge and expectation"

Non-learners also suggested guesses about orientation and employed a multitude of tactics including tilting the head. Some attempted to visualise three dimensionalities to the image as in the 'magic eye'.

Because the subjects were unable to declare the differences between the patterns the learning task is considered "non-declarative" or " procedural skill learning).

The learning curves for the learners and their correct performance throughout the all trials for each group shows that, in the first group (LFr) there was a steady increase in average performance. Although they started between 50% to 60% correct responses their curve during the first 100 trials shows that they have been moving up and down, but finished above 80%. The feedback gives good understanding about the performance and everyone of the learners tried to

modify his/her performance according to the feedback. Over the two hundred they were able to develop a method for success. This is learning.

The explicitly instructed subjects with the given feedback in this study performed better than did those given the neutral instruction. Reber (1989) concluded that the explicitly instructed perform poorly compared with those given the neutral instruction and he claimed that his conclusion was related to the explicitly instructed subjects who took longer to memorise the exemplars, and they were poorer at determining well-formedness of test string. I suggest that the explicit processing of complex materials has an advantage over implicit processing

The "learners" in group LFR were strictly not learners at all as they had been told the rule of operation. However they had never performed the task and needed to develop their skill. From the start they achieved learner status (>70% correct answers). There was a slight drop in the middle of the task but they finished with the highest score of all. They were not perfect however, indicating the difficulty of the task even when the rule is known.

It would have been of interest to take subject from Fr and FR groups and put them through the task again to seek further improvement. This would have taken the experiments away from the learning task into the realms of skill development and I decided against this.

The third group learners (Lfr) performed the task with neither information nor feedback. Their start was very interesting as expected for someone guessing, about 50% correct answers. During the middle of the first hundred trials their curve wavered between 50% and 80% giving a zigzag shape. At the end they finished in the learning category very close to the subjects who had no feedback but had a rule. I relate that performance to the strong challenge they had and

their hard and serious effort to get the clue. They seemed even surer than others of their responses did as their learning was unaided and totally self generated.

Finally the fourth group (LfR) which I gave the subjects all information and the feedback was not given after they made decision. After a little while they showed an up and down curve which indicates that they have been getting correct responses and then they lost the clue again and that was repeated at the end they finished well within the learning group.

Generally all learners achieved the criterion by the middle of the task. Improvement was rapid during the first 100 trials and continued at a lesser rate thereafter.

As expected those who knew the rules in advance performed best and were performing well from the beginning of the task. The other groups had a similar performance to one another. I did not expect group (fr) to do good performance as well but there were only 8 learners out of the 24 subjects in the group.

The learning curves of the non-learners have around 50% correct, which is to be expected. Group fR are interesting in that they know the rule, and for the first 100 trials (first two quartiles) or so they perform better than chance. Thereafter performance declines to chance level.

The learning process appeared to go through three phases, with individual subjects taking varied times on each stage. Firstly subjects were guessing resulting in 50% performance with strings of three or four similar answers at most.

During the second stage a seesawing of collections or strings of right or wrong answers was seen. The resultant runs extended to as many as 15 patterns correct in some cases. At this point the subject's tactic was to compare a past sensory image with the present stimuli. Subjects were only able to distinguish between

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4.3. DECISION TIME

Decision time is the time taken from the onset of a stimulus or signal to the initiation of response. Since nineteenth century the decision time has been recognised as a potentially powerful means of relating mental events to physical measures.

The learners in debriefing reported that the task at the beginning was very hard and then became much easier by the time when they started to learn the differences between the two patterns. One of the most firmly established findings in some studies of discrimination, is that as some measure of the difference between two stimuli is decreased (hard task). The time taken to discriminate between them increases.

Barrett (1996) found that there are some subjects considered the task complex and others considered it as a piece of trivia, and when the complex cognitive function would be hard to achieve the increased complexity leads to increased work load and increased response time.

Naturally it takes more time to distinguish two very similar stimuli than two which differ greatly. The time to react in a situation in which any one of several signals may occur, each calling for a different response, must include four processes (Decision time includes four processes):

(1) Reception of the signal by a sense organ and conveyance of data by afferent nerves to the brain.

(2) Identification of the signal.

(3) Choice the corresponding response.

(4) Initiation of the action that constitutes the response.

First and fourth steps are relatively short taking a few tens of milliseconds to receive the signal and give the response action like a simple button press. Second and third steps take longer for identification and choice and it depends on each subject performance.

The subjects were asked to respond within 2000msec. There was no encouragement for them to be quick or as quick as possible. The prize or goal was correctness, not speed. Most decision time experiments in the literature encouraged subjects to respond as fast as possible.

4.3.1. Learners and non-learners decision time:

The decision time was quicker for the learners than non-learners. The reduced decision times for the learners during the last quartile of the attempt and during the correct answers suggested that knowing the answers and responding is a quicker process than guessing answers.

The non-learners showed no improvement in the decision times from the beginning to the end of the trials. The non-learners (nLfr & nLfR) showed minimal improvement in the decision time for the correct answers which was significantly shorter than the decision time for the incorrect answers. Other two groups (Fr) did not show statistical significant changes between the correct and the incorrect trials answers, variance reinforced the hypothesis that, once learning mechanisms were effective, this increased processing speed.

Corresponding with a start and end ERPs difference, learners showed a significantly shorter decision time to non-learners at the beginning and the end of the trial. The decrease in the learners decision time is related to my explanation that the decision or the response time is affected by the self-confidence which subjects reported, after making a particular judgement.

There were no significant differences between the subjects decision time either in the learners group or the non-learners group for type A and Type B patterns as expected. The decision times for the learners during type A & type B were quicker than the non-learners resulted in from the differences in each of these groups' strategies and tactics.

For the correct and incorrect answers decision time were significantly different, for the learners but not for the non-learners. That finding is in line with the findings of Fernandez, et al 1998, that the reaction time is significantly different between the correct and incorrect answers for the group with good performance. Fujihara, 1998, found that the decision time for the target category was quicker than the non-target. Thus learning results from tactic employed within this extra exposure time of the stimuli.

On the level of each group separately, group one (Fr) the learners as a general conclusion I found were quicker than the non-learners. During the last fifty trials in particular the learners were quicker than the non-learners were.

Group two (FR) who got the all instructions for good performance had unfortunately no non-learners to compare. We can compare the learners in that group (LFR) with the rest of the learners. I found that the learners decision time during the last quartile in this group (LFR) were not quicker than the decision time of the learners of group (LFr) and they are quite similar to group three (Lfr) and four (LfR). I believe the decrease in the decision time was according to the given feedback to the group one subjects, which helped them to make a quicker decision. In the same time the more instruction the slower decision time, perhaps they take more time to be surer that they made accurate decisions.

Group three learners (Lfr) were quicker than the non-learners were. This group performed the task without either feedback or instructions. The subjects decision time for the learners, and even for the non-learners were slower than

group (LFr) who performed the task with given feedback and no instructions given as well.

Group four (fR) the learners were quicker than the non-learners and I believe that it is related as mentioned before in the previous paragraph to the given feedback and could be related as well to the instructions and the information which have been given before involved in the task.

The learners built up their own explicit knowledge and by using the given feedback in this study they improved their performance and the time taken to make their decision. Willingham et al. (1989) found that at least some participants with high amount of explicit knowledge used this knowledge to anticipate the following stimulus, and as a result had reaction time much faster than could have been achieved if they had waited for the stimulus before beginning the finger movement.

4.3.2. The subjects co-operation:

It might be argued that those who did not learn were not trying. Perhaps they decided the task was too difficult and they were mentally "switched off" perhaps their attention wandered or drowsiness set in.

According to the debriefing this did not happen but subjects may deny the experimental access to their inner mental life. There were several reasons against non-co-operation.

- Debriefing did not reveal it. Some may have done but probably not all as there was censure applied
- They were motivated to try and not attain a secondary goal such as payment. No reward was offered.

- Inattention and drowsiness would lead to missed responses. There were very few of these (about 2%). These sweeps were excluded from analysis

- Decision times were consistent. A subject trying to bluff his way rather than concentrating would perhaps be more likely to press the button early, without thought. This did not happen.

- Observation during the test showed alertness and careful visual concentration. Recorded eye movements were minimal.

All these features suggest that the subjects were co-operative and entering fully into the challenge of the task.

Although the decision time for non-sense stimuli in the present study was not available, a measure of accuracy was. Since the accuracy of responses must depend on the availability of sufficient information about the stimuli, one might expect to find a relation between response accuracy and the timing of response relative to the P300/P600.

Indeed Coles et al (1985) found such a relationship and suggested that the P300 latency is dependent on response accuracy. In a related vein, Kutas et al (1977) found that the correlation between P300 latency and the decision time is higher when subjects are told to concern themselves with accuracy rather than speed. Both these findings suggest an association between the accuracy and latency of P300.

4.4. Event Related Potentials (ERPs)

4.4.1. Event Related Potentials

Generally the brain ERP results reflect several findings related to the impact of learning on the underlying brain circuitry.

Establishing the functional significance of cognitive ERPs requires the identification of both their cognitive correlates and their neural origins. Progress on each of these fronts is accelerating rapidly and it is important to note that work on event related potential is beginning to connect psychological ideas with brain activity. At present the cognitive event related potential research is more closely integrated with midstream cognitive psychology than before. Although the absence of comprehensive information about the neural basis of an ERP places strong constraints on the conclusions that could otherwise be drawn, the importance of ERP recording in normal subjects and patients is now clearly recognised and much research is being devoted to elucidation of the processes underlying it. Consequently, when a significant body of knowledge concerned with the cognitive and neural origins of event related potential has been accumulated, ERP studies of human will have come of age.

Studies have demonstrated that P300 amplitude and latency can be used as indices of the nature and timing of a subject's cognitive response to stimulus since P300 discovery by Sutton and his colleagues (Sutton, et al 1965 and Sutton et al 1967).

It is well established that P300 is elicited by unexpected events, and that the lower the subjective probability of an event the larger will be the P3 it elicits (Duncan-Johnson and Donchin 1977). A larger positive wave occurring sometime after 300msec post-stimulus onset is variously termed P300, P3, or

Late Positive Component LPC (Sutton, et al 1965 and Sutton et al 1967; and Donchin et al 1987).

Reports of visual and auditory modalities in normal subjects show that there are two types of P300. These two positive component are sometimes seen in simple targets detection tasks consisting of a fronto-central P3a and P3b. Correctly detected targets elicit a large P3b and non-targets elicit fronto-central P3a. Picton et al 1984 reported age-related changes in the ERPs that there were decreases in P3 component amplitudes (-0.25 micro-volt/year) and P3 latency (1.41 msec/year). This small change will not affect my results, as the subjects were all young adults.

Its amplitude (size) and latency (timing) measure the positive peak. Amplitude (μV) is defined as the voltage difference between a pre-stimulus baseline and the largest going positive or negative peaks of the ERP waveform.

Latency (msec) is defined as the time from stimulus onset to the point of maximum positive amplitude within the latency window.

P3 scalp distribution is defined as the changes in component amplitude across the midline recording sites from the frontal (FZ), central (CZ), parietal (PZ) locations. Amplitude and latency are very important and effective on the scalp distribution, since variation in P3 measures from the manipulation of task or subject variables has been used to infer information about the underlying neural generators (Johnson 1993; Polich and Heine 1996)

The P100, N100, N200, P200, and P250 peaks are considered as early sensory components, which is consistent with findings in a variety of studies using visual stimuli (Mangun and Hillyard 1988).

4.4.2. Learning process and ERP positivity

The idea was to see if the event related potentials were associated with learning or not

Through my research many experiments were performed to explore and study the morphology and characteristics of positive components of cognitive event related potentials in order to investigate the neurophysiological and neuropsychological processes underlying cognition.

Is there any ERP components related to the task?

It is apparent that subjects attempting the task show a positive shift over frontal areas. Those merely observing the patterns have no positive shift.

The positivity is a long duration change with no clearly defined onset at about 200msec. It decreases towards the end of the time window. Pattern A and B produced the same effect. There was no reason to suspect the two patterns should produce anything different.

When subjects who learned or who made correct responses are compared it was clear that there is no unique waveform associated with learning. The difference between the groups of subjects is one of degree. To measure this degree the mean amplitude during two time windows was determined. The positivity has been referred to as P300 and P3 because it clearly developed at 300msec. It is not intended to imply that it is the same as the classical P300 associated with oddball stimuli.

Perhaps a better term for it would be ***"Positivity Associated with Learning"*** or (PAL).

In the present study I selected two time windows 250msec to 550msec and 550msec to 850msec. These cover positive peaks occurring during both time

windows. The group FR was the most positive in the learning groups during the last fifty trials. Others groups of learners waveforms showed similar peaks of less amplitude. P300 has been associated with increased memory effect, depth of processing and comparisons of stimuli (Fiztgerald and Picton, 1981, Donchin 1981). This is a representation of the processing involved in comparing the stimuli to previous patterns. The increased P300 after learning is agreement with previous studies (Karis et al, 1984). The ease of pattern to category assignment, an initial categorical perception step for learning will contribute to the increased P300 amplitude (Duncan-Johnson, 1981). Mecklinger and Ullsperger (1995) showed that P300 increases in amplitude with ease of stimulus categorisation.

Further experimentation is needed to see if the positivity decreases when the category can be easily distinguished, as hypothesised. A parallel can be drawn with Friedman and Sutton's 1987 experiment, which used different task hardness, showing increased P300 to categorical memory task.

Positivity is present at the start of the task when there has been no learning but gets bigger and stronger in learners, so part of it may be due to learning.

Positivity is still present in non-learners so parts of it are related to attention and trying.

I am trying a logical and synthetic approach. The striking differences between the passive (observers) and all these who were trying to learn is a late positivity seen most strongly over the frontal areas. There is no unique waveform associated with learning and giving correct answers, but there is a change in the quality of the underlying wave.

The beginning of the trial for most of learners showed different ERP's morphology from the non-learners. The unique feature of this ERP is the

negative peak; the learner's waves had more negativity than the non-learners waves. This initial negativity could be hypothesised to be the result of a process that is essential for later learning. For example a foundation block for a robust model of learning. This would insinuate that a prediction could be made from an ERP at the beginning of the trial as to whether a subject will learn, possibly reflecting a difference in tactics involved.

The learners and the non-learners in all groups in my research experiments showed more positive activity compared with the passive group (observers), but the positivity was more still for the learners than non-learners. The learners in all four groups showed nearly the same trace (waveform) morphology.

The non-learner's slow decision times were associated with much more prominent negative going peak at latency of 200msec whereas for the learner's fast decision time the negative going peak appears as much as smaller potential at the same latency.

The learners in group two (LFR) had more positive going ERPs and if we arranged according to the positive activity we could have that classification group two first (LFR), followed by group one (LFr), then group four (LfR), and at the end group three (Lfr), and I claim that the information given played a very important role. At the same time the feedback was not less important to induce positivity. When we mixed the rule with the feedback the learners have got more positive going waves than when we gave just the feedback without rule as group two which is more positive going as well as the waveform for the learners who have got just the rule without feedback and the less positive group waveform was the third group where they have no rule and no feedback.

The positive peaks were earlier for group two (LFR) and group four (LfR) than group one (LFr) and group three (Lfr) and I explained that the learning processes was quicker for the groups who have got the rule and slower for the

groups did not. The group two positive peaks were earlier than group four which means that the feedback could be responsible for the differences and that is confirmed by looking at the group two which was earlier than group three who have not neither the feedback nor the rule.

The non-learners in group two (nLFr) and group four (nLfR) had the same positive peak with the same amplitude and both groups positive peaks were earlier than the less positive peak in case of group three (nLfr) and that confirms the effect of the feedback and rule in the processes of learning even in the non-learners which means by another means that the groups of non-learners had the similar processes but it was not complete for them to make them able to succeed.

The differences between the non-learning ERP traces at the beginning and end of the trial are due to many interactive factors. Firstly partial learning could be responsible. Some of the processes needed for learning could be in place but not perfected resulting in ERP changes. A different way of dealing with the stimuli will have evolved through the trial. Boredom and/or frustration are other contribution.

Standard components can be identified from event related potentials. This is especially true for the learning group traces figures showed P100, P300a/b, N100 and N200a/b (Czigler, 1995; Polich 1990). The pre-stimulus baseline and sensory portion, until 200 msec. are very similar in all subjects, suggesting pattern induced matching brain processes. The P200 was increased for the learners after learning due to correctly recognised target stimuli (Czigler, 1995). From 200msec to 300msec the learning groups end ERP, showed an increased N200b. A positive peak was visible around 300msec. For the learners group when compared with the observers group, the observers did not show any positive activity around the same latency. That changes in ERPs most probably

related to the learning processes, and the decision-making processes in the learners and non-learners group. But not applicable to the observers group who did not ask to learn or to make any decision. This finding is in the agreement with the finding of (Cutmore and Muckert 1998), who found a relationship between P300 amplitude and word distance on the underlying metric, was found only for the decided group. This was interpreted in terms of previously documented relationship between P3 and the constructs of decision confidence task difficulty.

4.4.3. The Correct Answers:

The positivity is stronger for the correct answers, and there is a negative wave.

The correct answer trial potentials in the learners group were more positive from about 300msec and up to about 900msec post-stimulus than the incorrect answer trial potentials for the learners in all groups. The same comparison done for the non-learners in all experimental groups and there was no difference between the correct answer trials and incorrect answer trials for the non-learners. One of the most interesting finding when I compared between the learners incorrect answers and the non-learners incorrect answer was showed no statistically significant difference and with the non-learners correct answers showed no differences which gave me impression that the brain learning processes and the ERPs elicited by the brain in these three conditions were similar. I could conclude that the more correct answers the more early positive peaks, and was due to learner's early correct decisions matching. The learning processes, is represented by positivity. The negative peaks within the selected time windows were larger for the non-learners than the learners and that as well related to the learning processes and the decision making for both groups. We might explain that by looking at the correct and incorrect answers waves, where

we found that more negative activity the more incorrect answers, and vice versa the more correct answers the less negative activity.

The building block that is essential for a robust model of learning would be a direct association of pattern to the left or right mouse button, similar to Braida's (1969) context parameter. This process is partly responsible for the longer reaction time at the start. This would imply that the comparison to previous stimuli and association to mouse button has components that are dependent on each other. The resolution of this secondary process produces positivity at 830 mescs.

Both fragile and robust learning models are acting concurrently and rely on categorical perception. Knowing which group each pattern is in, or at least discriminating between them is essential for any sort of success.

Subtraction brainmaps for the elicited ERPs during the four quartiles of the learning task showed over all voltage changes starting from 200msec to 1000msec. these are related to the learning processes and decision making. The learner's cartoon brainmaps of subtraction showed a major frontal and temporal positivity that was especially predominant on the right-hand side. The subtraction for the four quartiles showed that the positive activity increased gradually throughout the task to reach the maximum during the last fifty (the fourth quartile) due to cumulative changes. The role the parietal and tempro-parietal area brain activities remain unclear and it has been shown that the activity within this region can be modulated by voluntary attention. The unique findings in that comparison was the unremarkable differences between the brainmaps during the first fifty in group two (LFR) when compared with the last fifty for the experimental groups, and I conclude that the learners in group two performance was nearly the same from the beginning to the end because

they have been able to learn the differences and get the task clue from the start point.

4.4.4. The Event Related Potentials Generators:

The brain structures generating the ERPs are unknown, despite efforts using extracerebral MEG topography, scalp recording EEG recording in brain-lesioned subjects, animal models, and recording directly from the depth of the human brain (Halgren et al 1986; Paller et al, 1992).

Efforts to locate the neural generators of the P300 component of the event-related potentials have focused on studies using intractable epileptic seizures. These experiments have consistently revealed the presence of P300-like potentials in medial temporal lobe structures (i.e., amygdal, uncus, and hippocampus) in response to stimuli in the oddball task (Halgren et al., 1980, Stapleton & Halgren. 1987). Such reports have prompted efforts to determine whether temporal lobectomy surgery has any effect on the lateral symmetry or overall amplitude of P300, because this operation results in the unilateral removal of these medial temporal lobe structures. Unilateral removal of one of two symmetrical P300 generators should result in either asymmetrical and/or reduced overall P300 amplitude. However a number of experiments have failed to find any statistically significant differences between these patients and normal controls (Stapleton, Halgren & Moreno, 1987). Unlike shorter-latency components' of the ERP, the P300 is considered to be sensitive to the cognitive processes elicited by a stimulus, but relatively insensitive to its physical properties. It is therefore generally accepted that the P300 arises from a modality-independent neural generator. Whereas the early intracranial electrode studies relied exclusively on auditory stimuli, more rescent studies have found that both auditory and visual P300-like components are generated bilaterally in

the same medial temporal lobe structures (Stapleton & Halgren, 1987). Such results are consistent with the modality-independent generator hypothesis.

Eric Halgren et al (1995) recorded from 537 sites (121-left hemisphere, 416 right) in the superior temporal plane and parietal cortex of 41 patients. Depth electrodes were implanted to localise seizure origin prior to surgical treatment. Subjects received an auditory discrimination task with target and non-target rare stimuli (standard oddball paradigm).

They distinguished three response patterns:

(1) In the posterior superior temporal plane, a large positivity peaked at 150msec after stimulus onset superimposed on an early component and inverted in sites superior to the Sylvian fissure. Subsequent components could be large, focal and/or inverting in polarity, and usually included positivity, at 230msec and negativity at 330msec. All components at this area were specific to the auditory modality. The early endogenous activity in auditory cortex may embody activity that is antecedent to the other patterns in multimodel association cortex.

(2) In the posterior cingulate and supramarginal gyri, a sharp 'triphasic' negative-positive-negative waveform, which peaks at about 210msec-300msec-400msec, was observed. This waveform was of relatively small amplitude and diffuse, and seldom inverted in polarity. It was multi-model but most prominent to auditory stimuli, appeared to remain when the stimuli were ignored, and was not apparent to repeated words and faces. The 'triphasic' pattern may embody a diffuse non-specific orienting response that is also reflected in the scalp P3a.

(3) A broad, often monophasic, waveform peaking at about 380msec was observed in the Superior parietal lobe, similar to that which has been recorded in the hippocampus. This waveform could be of large amplitude, often highly

focalised, and could invert over short distance. It was equal to visual and auditory stimuli and was also evoked by repeating words and faces. This broad pattern may embody the cognitive closure that is also reflected in the scalp P3b or late positive component. In summary, depth recording supported by other data clearly demonstrated that a P3 is locally generated in the hippocampus. Furthermore, scalp recording after hippocampal lesions clearly implies the existence of other P3 generators. The location of these generators has been suggested by depth recording, but such recording has been limited in scope.

Event-related potentials were recorded by Baudena et al (1995) from 991 frontal and peri-rolandic sites (106) electrodes in 36 patients during a discrimination task with target and non-target (distracter) rare stimuli. Variants of this task explored the effects of attention, dishabituation and stimulus characteristics (including modality). Rare stimuli evoked a widespread triphasic waveform with negative, positive and negative peaks at about 210msec, 280msec, 390msec, respectively. This waveform was identified with the scalp ERP complex termed the N2a/P3a/SW (slow wave) and association with orienting. It was evoked with rare target and distracter auditory and visual stimuli, as well as by rare stimulus repetition or omissions. Across most frontal regions, N2a/P3a/SW amplitude changes only slowly with distance. In summary this study demonstrated an early P3a-like activity that polarity inverts over short distances in the medial frontal lobe, and that it has a significantly shorter latency than similar potentials recorded in the temporal and parietal cortices. It is clear from the results of several investigators that rare stimuli evoke multiple overlapping components over the 100-600msec latency range and that each component has many generators, so to search for exact correlation between depth and scalp peaks would be fruitless. It must be pointed out that even across different scalp sites, that components bearing the same name often do not have identical latencies or task correlates. Further research is necessary to determine

the exact locations of ERPs' generators. With reference to the findings above about the generators of the ERPs so far, 1 could not confirm with confidence which parts of the brain were involved in generating ERPs obtained in

Ji et al. 1999 were examined the topographic relation of P3 between the visual and auditory modalities, especially to examine whether there were any modality-specific hemispheric differences of P3 in normal adults. They were used auditory oddball task and visual paradigm with novel stimuli. They concluded that the topographic similarities between P3s recorded in the visual and auditory modality out number the differences. Profile analysis of P3 topography support the hypothesis of multiple generators of P3 that were differentially active in processing stimuli for different sensory modalities and were not symmetrically distributed between the two hemispheres.

1 may suggest that the frontal lobe and also the temporal lobe have an important role in eliciting positive components. To validate these finding with more confidence 1 need to record ERPs from subjects with learning disabilities and a much bigger group of normal volunteers.

We found that the positive activity was not symmetrically distributed between the two brain hemispheres for all groups in who learned or even in who tried but did not. Different brain area were involved in the task from the beginning to the end of the task by different percentage especially the parietal lobe which involved during the early stages and these results supported by the findings of Walsh et al 1998. The learning of perceptual skills is thought to rely upon multiple regions in the cerebral cortex Poldrack et al 1998. Reber and his colleagues 1998 conclude that the decrease activation of visual cortex when categorical patterns were being evaluated suggest that these patterns could be processed in a more rapid processing categorical patterns could be related to

any of several processes involved in retrieving information about the learned exemplars.

4.4.5. Regional differences

Dipole analysis assumes only a very limited number of localised dipoles. We are dealing with widespread brain activity so, it does not work because there is no dipole solution for the dipole fitting equation, and it will be misleading to give dipole, so we did not use it.

Comparing the hemisphere data showed major differences. The right-hand side hemisphere, in conjunction with other visual and categorical perception tasks, shows increased positivity from 300msec onwards (Berlteson, 1982). The positive event related potential (ERPs) is considered to be closely related to cognitive processes, scalp positive activity latencies increase, parietal positive activity scalp amplitude decrease and the scalp potential field shift to relatively more frontal distribution (Anderer et al. 1998). The ERPs to pictures, but not to words, also demonstrated frontally distributed Old/New effects, which shifted over time from a left to a right-sided maximum (Schloerscheeidt & Rugg, 1997). Mecklinger and Meinshausen, 1998, found that the effects in the second time intervals may play a functional role in post-retrieval processing, such as recollecting information from the study episode or other processes operating on the products of the retrieval process, and presumably were mediated by right frontal cortical areas. Thus cognitive learning processes are predominantly a right hemisphere.

Studies of children learning to read or learning a language with novel script find a right hemisphere advantage at early stages of learning that shift to a left hemisphere advantage as reading became skilled (Silverberg et al 1979), and 1980). Behavioural research indicates that the right hemisphere performs

memory judgement about specific visual items more quickly and accurately than the left hemisphere (Marsolek et al 1994, and Metcalfe et al 1995).

The right hemisphere also is more responsive to novel stimuli than the left hemisphere (Bradshaw and Nettleton, 1983). Conversely, The left hemisphere performs judgements about prototypical examples of a visual concept more rapidly than the right hemisphere (Marsolek 1995)

There were no statistical significant differences for any of the individual electrodes for the recorded ERPs from the temporal lobe, anterior temporal and parieto-temporal lobe. But from the brain maps the over all brain activity showed that the temporal area especially the anterior part to the right-hand side was more active like the frontal area early and late during the task which lead to the conclusion that these areas were involved in the learning processes.

Discriminating the target from a standard stimulus processing could initiate right frontal engagement, because such a processing requires the consistent application of attentional focus a major attribute of frontal lobe function (Pardo et al. 1991 and Posner 1992)

Positivity continues after button press and the given feedback appearance.

Is this the same neural process or not- it may be something different.

The additional or continuing positivity in the ERPs waves after the feedback, which was given to the subjects, was seen especially in the learners giving correct answers. Result in using the information given to the subjects by the feedback to modify them coming responses, and it is more positive in the learning group due to the expected feedback which was correct for most of the trials. The differences between the learners and the non-learners groups were not statistically significant at that latency (after button press). Johnson 1986, in

his review of the ERPs feedback studies, noted involvement of additional cognitive processes after the stimulus categorisation as a result of feedback.

The present observation strongly supports the view that the learning processes takes place in neural regions located in the human frontal and temporal areas of both hemisphere especially on the right-hand side. The results suggest that the elicited positive activity depends on the processes taken by every subject trying to learn the differences between images type A and type B and depends on the memory search necessary to obtain the meaning of the stimuli and the meaning of each different category.

This is supported by Pouthas et al (2000) where they assume that the right frontal area plays a specific role in the formation of temporal judgements. Monfort et al (2000) reported that both left and right hemispheres especially the frontal lobe involvement is necessary for recognition of temporal information.

Research into this should pose interesting questions. To do this the task will need to be modified. Further studies into ERPs changes after the learning task has been competently dealt with are needed. Changing the task will show whether the ERPs are faithful to learning or depend on the stimuli.

4.5. Comparing of my results with Seger

4.5.1. Seger C. et al 2000 studied brain activity while people learned to distinguish between two novel visual prototype stimuli taken from Fried and Holyoak (1984) using functional magnetic resonance imaging (fMRI). They displayed total of 98 categorisation trials and were broken into four quartiles (four groups of 24) for purposes of analysis. During the scan the stimuli were presented for 2500msec, during which participants responded by pressing optical switches, with feedback given "smith" or "Jones" appeared for 500msec.

They had 6 learners and 4 non-learners out of the subjects participating in the task. They decided the cut off score for the learners and non-learners was 83% correct answers. Learners got 64%, 82%, 79%, 79% during the four quartiles, and their mean classification score was 91% in the final quartile. The non-learners got a classification score 61% in the final quartile.

Functional MRI shows increased metabolic activity during the task and Seger et al's task was similar to mine. She is able to report better spatial information; table (4.1.) summarises those areas of cortex showing increased activity during the classification than baseline across trials. While this is interesting spatial data, she gave no indication of how much metabolism in these areas increased. Her subjects learned quickly and frontal activity fell away later in the test, learning was accomplished.

There was prominent activation of right dorsolateral prefrontal and bilateral parietal regions, areas associated with reasoning and working memory. In addition, activation was found in the bilateral middle occipital cortices, bilateral inferior frontal areas, and the anterior cingulate. Changes in activity in frontal and parietal brain areas were found across the four quartiles of visual concept learning

Activation in the classification task relative to the baseline task was limited to right hemisphere area of the frontal and the parietal lobes. Beginning of the second quartiles a high level of classification ability was attained, and left hemisphere activation was present in addition to right hemisphere activation

Left parietal activation was present in quartiles 2-4. Left dorsolateral and prefrontal activation was present in quartiles 2 and 3, and was present but did not reach threshold of significance quartile four, which probably due to insufficient power attributable to the low numbers of participants. The right frontal activity did not increase significantly across quartiles

In addition to frontal and parietal areas, activation in both right and left occipital gyri increased across quartiles.

Activations in the left prefrontal cortex for learners were increased across quartiles, but activation in non-learners remained constant across quartiles.

The consistency of right hemisphere (both frontal and parietal) activity during learning implies that the right hemisphere play a role in stimulus processing (such as visual working memory or feature analysis) that is independent of learning

Left parietal activity increased across quartiles, indicating learning related change, but was not significantly more active in learners than in non-learners.

Left side changes	Right-hand side changes
1st quartile not involved occipital gyri	1st quartile Parietal Frontal
2nd quartile Dorsolateral prefrontal Parietal occipital gyri	2nd quartile Parietal Frontal
3rd quartile Dorsolateral prefrontal Parietal occipital gyri	3rd quartile Parietal and frontal involved but not significant occipital gyri
4th quartile Dorsolateral prefrontal significantly involved Parietal occipital gyri	4th quartile Parietal and frontal involved but not significant occipital gyri

Table 4.1. Shows the learning related brain activity change during learning in Seger et al 2000 study

The presence of left frontal activation as a marker for classification learning indicates that analytic reasoning may be involved in induction of pattern

knowledge. The left frontal areas may play a crucial role in gaining expertise in classification

The only group of subjects similar to Seger experimental group is group one (Fr) with feedback without rule, 18 learners out of the 34 subjects.

4.5.2. Learning brain activity changes in my study:

During the first quartile the occipital lobe the first showed positive activity, the parietal lobe and the central involved from the beginning about 200msec post-stimulus and even after the subject made responses. The frontal lobe and temporal lobe showed negative activities pre-stimulus and then not involved as much as the other areas, around 400msec post-stimulus showed greater positivities bilaterally than other areas.

In the second quartile the areas did not show too much changes from the first quartile. All the brain areas were involved by different amount of positive and negative activities.

In the third quartile the occipital area first showed positive activity and all other areas showed negative activity. The all areas showed positive activity and the frontal lobe showed more positive activity bilaterally.

In the fourth quartile there was not much difference from the beginning of the third quartile and then around 500 msec post-stimulus the frontal lobe area showed greater positivity especially to the right-hand side.

My study results give interesting time data in that the learning associated with positivity begins at 200msec and continues, but in an attenuated form, even after feedback. This strongly supports the idea that learning involves anticipation and planning for the next trial. The performance differences between learners and non-learners were associated with one reliable brain activation difference.

The main positive amplitude appears at the occipital sites at 100 to 200msec, which represents the sensory portion of the ERPs and this did not increase across quartiles.

Left-hand side	Right-hand side
1st quartile Frontal (+++) Anterior temporal (+++) Temporal (+) Central (+) Parietal (++) Occipital (++)	1st quartile Frontal (++) Anterior temporal (++) Temporal (++) Central (++) Parietal (++) Occipital (++)
2nd quartile Frontal (++) Anterior temporal (+++) Temporal (+) Central (+) Parietal (+) Occipital (+)	2nd quartile Frontal (++) Anterior temporal (++) Temporal (+) Central (+) Parietal (+) Occipital (+)
3rd quartile Frontal (+++) Anterior temporal (+++) Temporal (+) Central (+) Parietal (+) Occipital (+)	3rd quartile Frontal (+++) Anterior temporal (++) Temporal (+) Central (+) Parietal (+) Occipital (+)
4th quartile Frontal (+++) Anterior temporal (++) Temporal (++) Central (+) Parietal (+) Occipital (+)	4th quartile Frontal (++++) Anterior temporal (+++) Temporal (++) Central (+) Parietal (+) Occipital (+)

Table 4.2 shows the learning related brain activity changes during learning in my study (+ = 2μv) As many of + sign means how much the area was actively involved in the learning task.

The ERPs traces start to increase the positivity at 250msec and end nearly about 1000msec post-stimulus after the button press which may lead me to say that

the brain activation appear to be related to the constant processes of visuo-spatial analysis of stimulus and categorical learning processes

There are significant difference between the learners and the non-learners. We have two peaks of positivities: the first one latency range 350msec to 480msecpost-stimulus; the second positive peak latency range 550msec to 750msec post-stimulus, which is more, delayed for the learners than the non-learners.

The temporal lobe area showed significant activities bilaterally, the parietal and the central areas did not reach the threshold of significance changes from the first quartile to last one, but both were present from the beginning and persist throughout the learning task. They did not differ reliably in learner and non-learners

For the learners there are differences from the start to end, and for the non-learners it stays constant.

I could conclude that the frontal lobe was significantly involved throughout the task and the right-hand side frontal hemisphere activity increased significantly across the quartiles. The left-hand side hemisphere activity was present over all the quartiles but did not increase significantly.

4.6. CONCLUSION:

1. Subjects attempting to learn, regardless of whether they learn or not, show a Positivity Associated with Learning (PAL) unlike those who just observe without making decisions

2. These was no unique waveform associated with learning but positivity was more pronounced in learners than non-learners. More positivity follows correct than incorrect answers

3. The PAL was distributed over the frontal lobes with more positivity on the right side than left

4. Learners made quicker decision

5. Comparison of different groups showed learners develop more PAL than non-learners

6. More PAL was associated with better performance.

7. The evoked potential technique can usefully be applied to study the learning process in patients and subjects with learning difficulties.

Chapter 5: APPENDIXES

The following pages contain several appendices related to the thesis.

5.1. SUBJECTS INFORMATION SHEET

COGNITIVE EVENT RELATED POTENTIALS DURING A LEARNING TASK

- We asked you to volunteer for an experiment which records your brain waves during learning to distinguish between one pattern and another projected on a TV screen. We want to know how the brain responds while you are trying to learn because this will increase our understanding of brain mechanisms.

- The procedure lasts about an hour. During it you will have a cap with electrodes placed on your head and you will be asked to sit comfortably in front of a TV screen and press a button according to the type of pattern you see. All these recording techniques are well established and there is no real risk. The learning task is quite difficult and you may feel frustrated at first that you are not getting the right answers. Wearing the cap of electrodes maybe slightly uncomfortable and you will need to wash your hair afterwards to get rid of the electrode paste, which we use.

We ask you to take part in this project entirely voluntarily. You can withdraw at any time, even after the recording has started, if you wish.

You are, of course, entitled to ask for more information but we cannot, obviously, tell you the difference between the two patterns you will be looking at, but you will give us your comments.

Continue ----------

- The result of the experiment will be pooled with that of other subjects.

- We will not be able to tell you anything special about your learning abilities and the outcome will not be of any particular benefit to yourself.

- The results will eventually be published in basic psychological journals and will help our understanding of the learning process.

- In overall charge of the project is Professor E M Sedgwick, University of Southampton, Department of Clinical Neurological Sciences, Room LF73B, F Level, South Block, Southampton General Hospital, Tremona Road, Southampton. SO16 6YD. Tel: 01703 796617/796951. The research worker directly is Dr. Mohamed Fath El-Bab, contactable at the same address and telephone numbers as given above.

5.2. QUESTIONAIRE

NEUROLOGICAL ASPECT OF COGNITIVE RELATED POTENTIALS IN A LEARNING TASK

ID: ----------

Initials: ---------- **Surname:** ----------

Age: **Sex:** Male Female

Address: ----------
-

-

Occupation: ----------
-

Special Habits: ----------
-

Hand: Right ------- Left ------- Mixed -------

Height: ------- **Weight:** -------

Medical History:

Date of the Test: ----/----/ 19

Continue ----------

1. How Hard Was the Task?

Easy ------- Moderate ------- Difficult ------- Very Difficult ----

2. What Was Your Strategy throughout the Task?

---

3. Did you notice any differences between pattern A & B?

---

4. Comments:

THANK YOU

5.3. Edinburgh Handedness Inventory

Please indicate your preferences in the use of hands in the following activities by putting + in the appropriate column.

When preference is so strong that you would never try to use the other hand unless absolutely forced to, put ++.

If in any case you are really indifferent put + in both columns.

Some of the activities require both hands. In these cases the part of the task, or object, for which hand preference is wanted is indicated in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all of the object of task.

		Left	Right
1	**Writing**		
2	**Drawing**		
3	**Throwing**		
4	**Scissors**		
5	**Toothbrush**		
6	**Knife (without fork)**		
7	**Spoon**		
8	**Broom (upper hand)**		
9	**Striking match (match)**		
10	**Opening Box (lid)**		

Points scored = Sum of the number of (+) signs for each side.

Calculate the laterality percentage (%) as follow:

LP = (Number Of Points For Right - Number Of Points For Left) / Total No. Of Points Scored X 100

5.4. The CuSum

5.4.1. The cusum method:

The CUSUM starts at zero, declining in the cusum trend indicate success, and an increasing in the cusum trend indicate failure.

This may be express mathematically as: -

$$\text{CUSUM (i)} = \sum (\text{Result (i)} - \text{Tolerance})$$

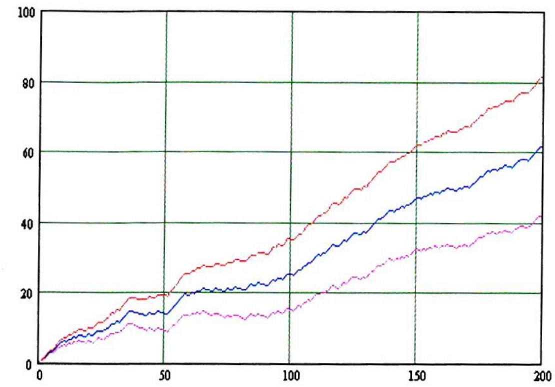
The performance of the subject is seldom perfect; it is usual to allow a certain tolerance 10% (0.1) failure rate (red line). A subject performance with 90% success will generate a horizontal and the line will move above horizontal for a worse performance. Individual increments for the cusum would then be 1.0 - 0.1 = 0.9 for each failure, and 0 - 0.1 = -0.1 for each success, and the same equation for tolerance 20 % (blue line), and tolerance 30% (pink line).

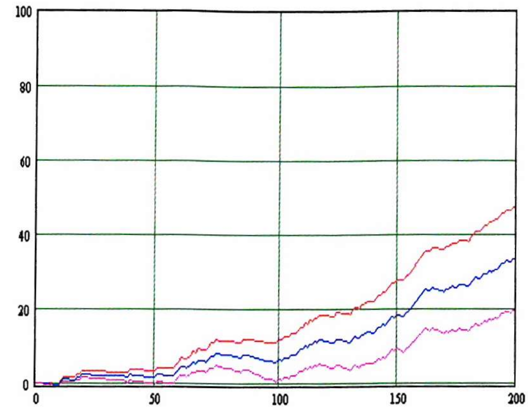
For each graph:

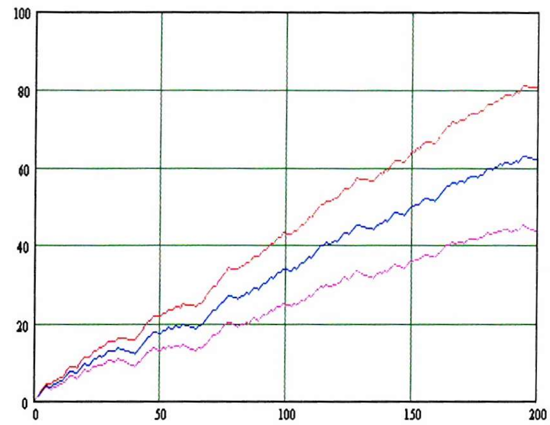
Y-axis: represents the performance

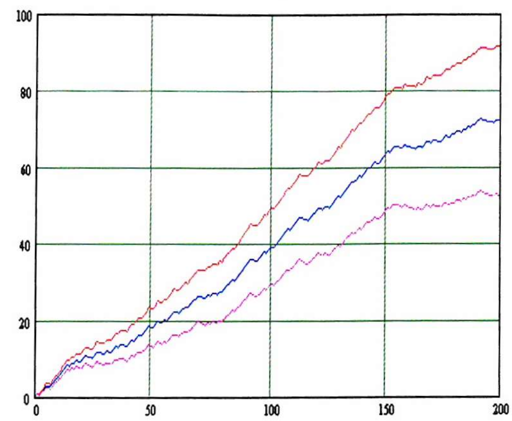
X-axis: represents the 200 trials.

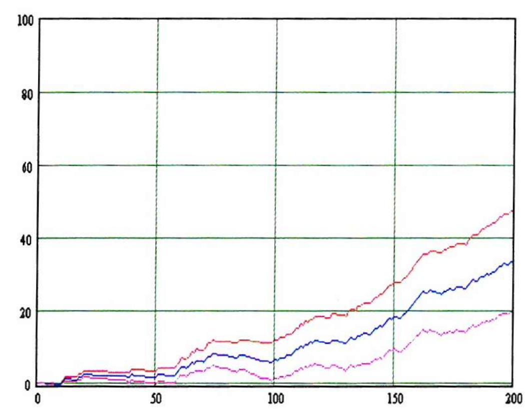
5.4.2. Cusum charts for the learning subjects

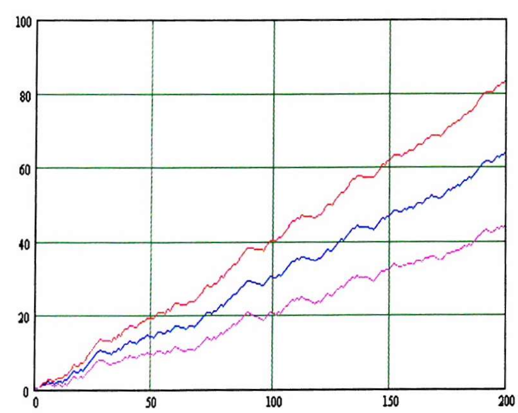


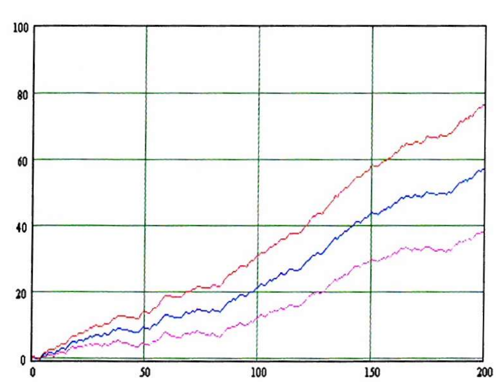


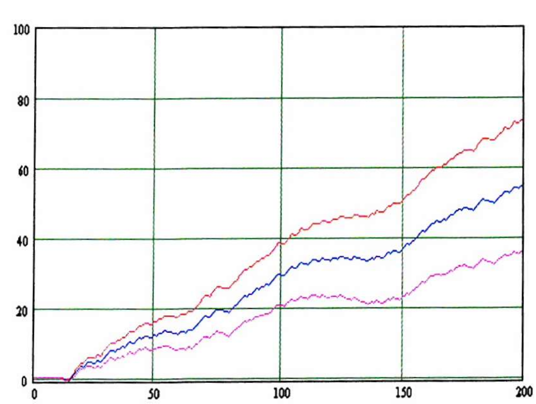


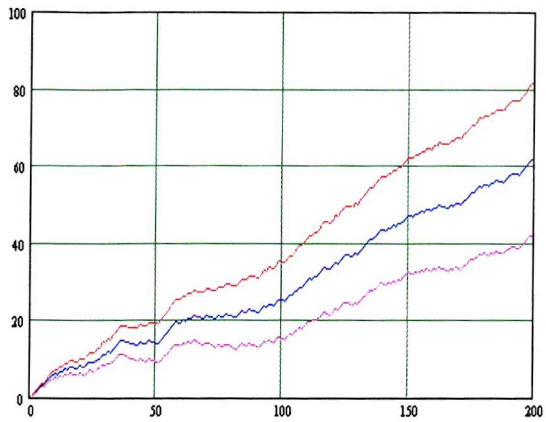








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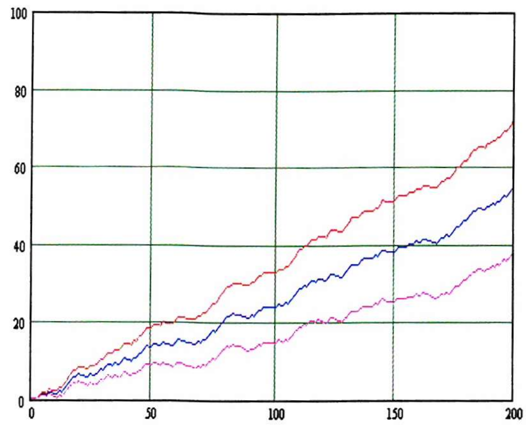
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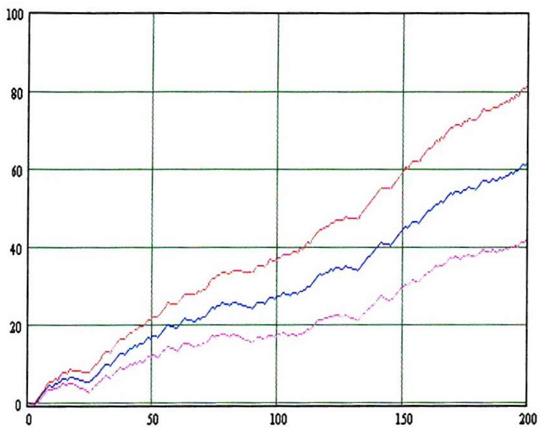
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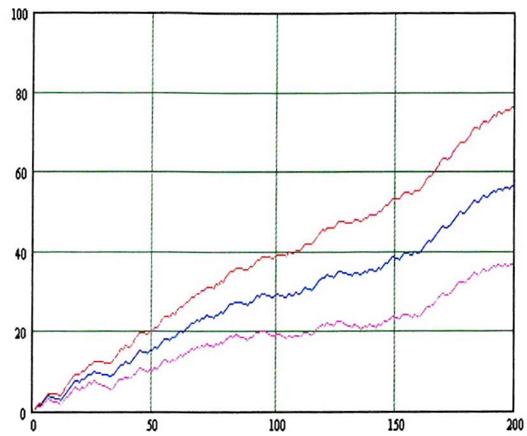
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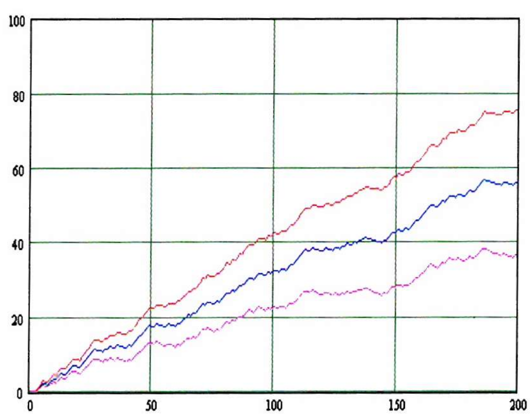
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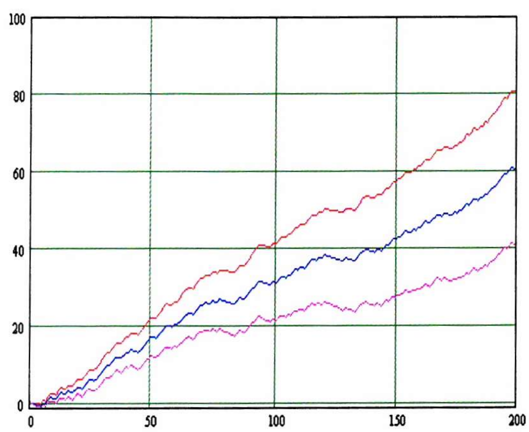
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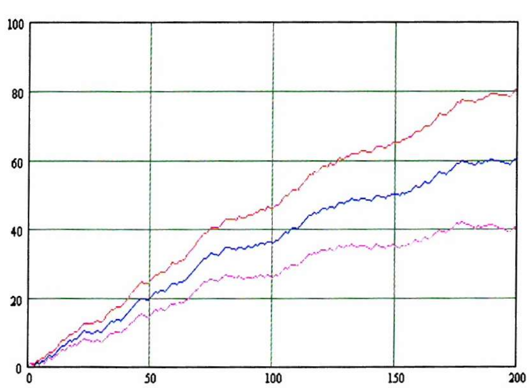
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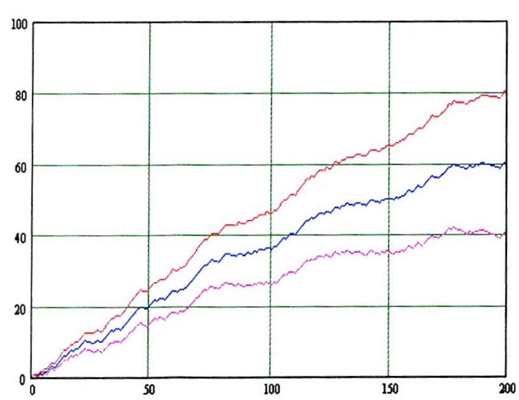
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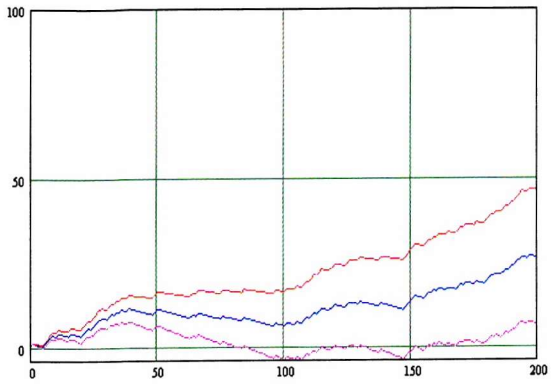
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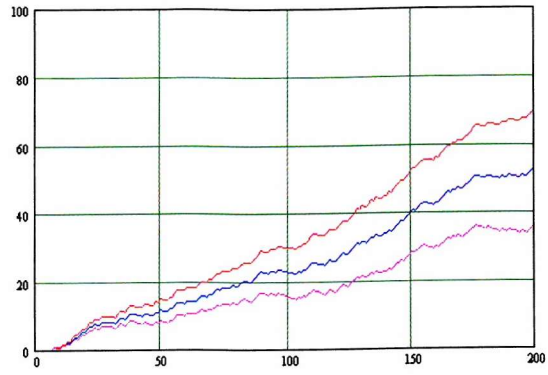
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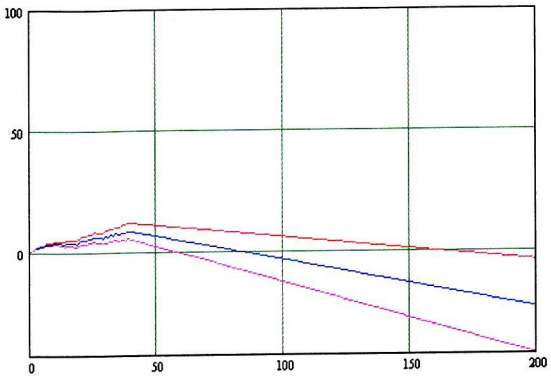
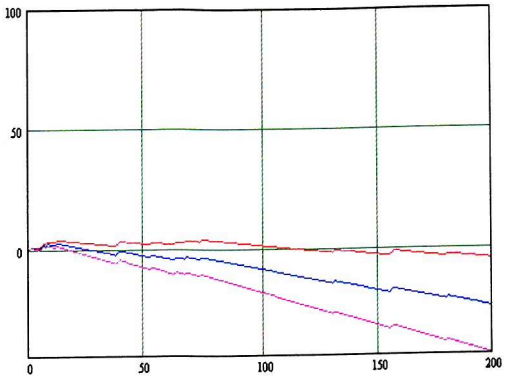
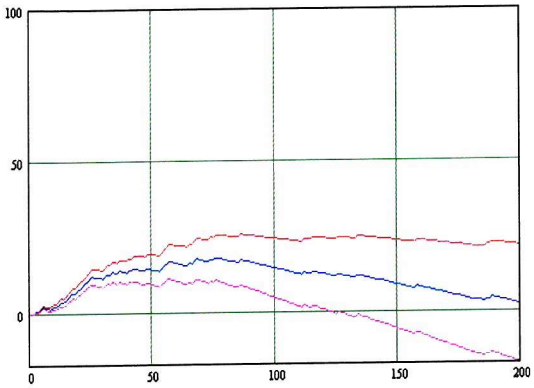
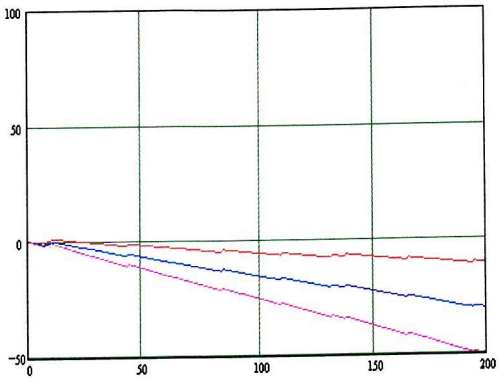
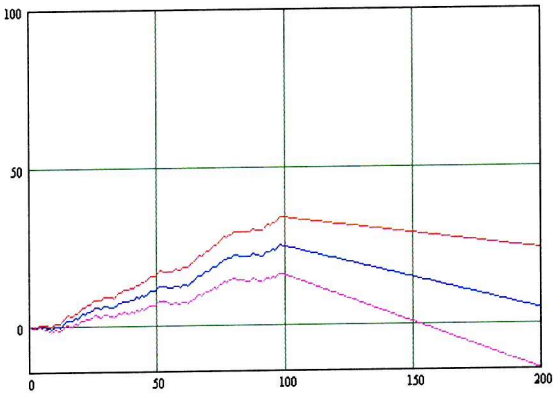
5.4.3. Cusum charts for the non-learning subjects:

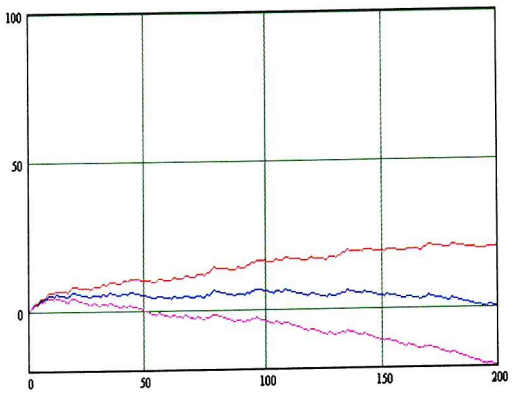


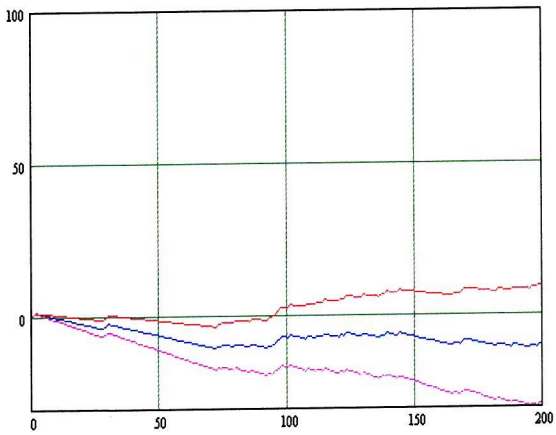


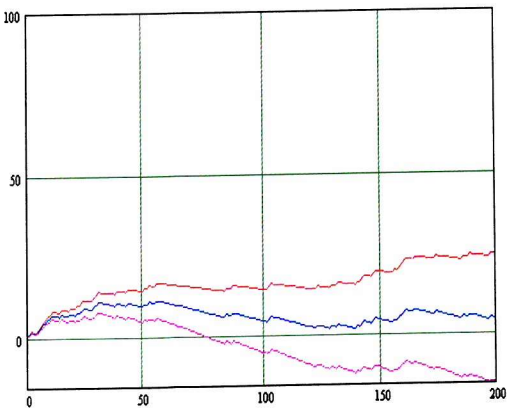


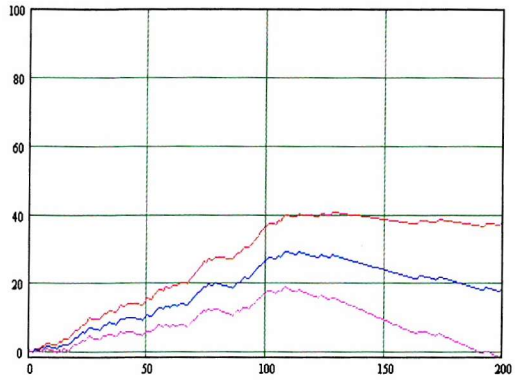








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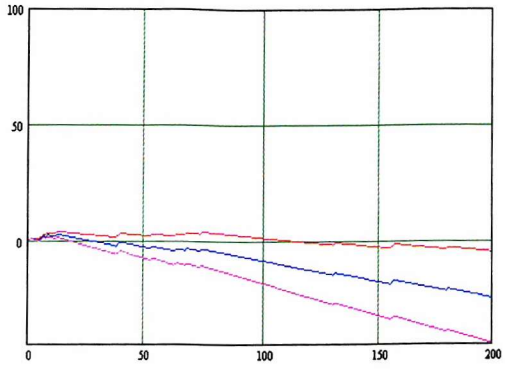
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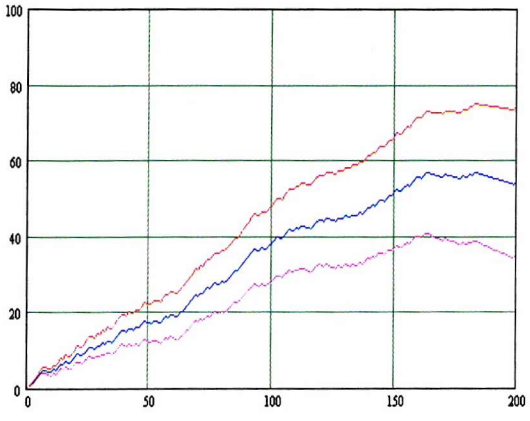
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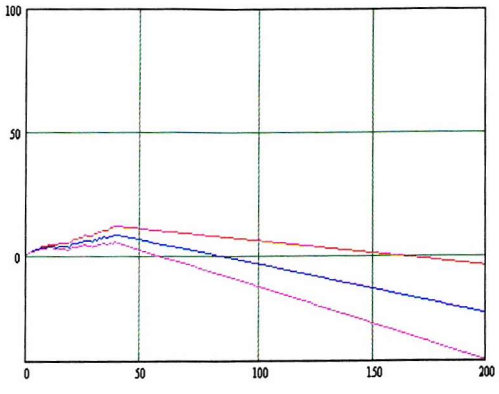
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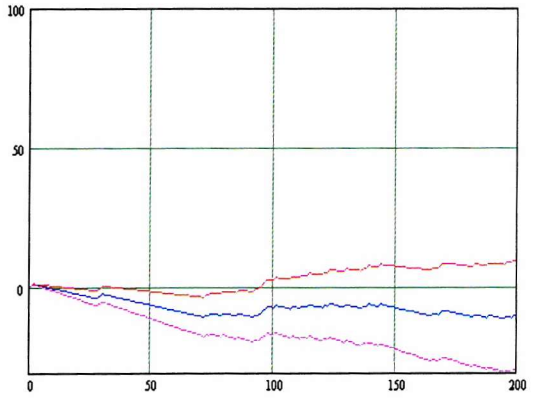
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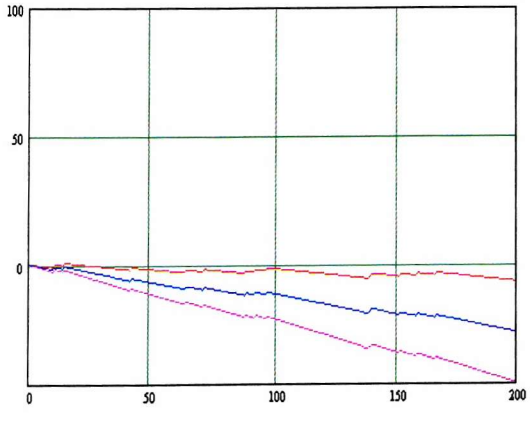
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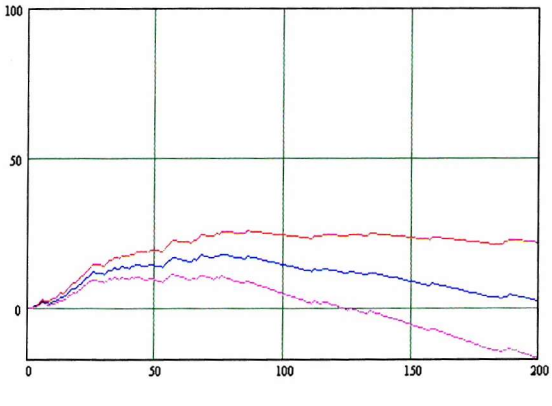
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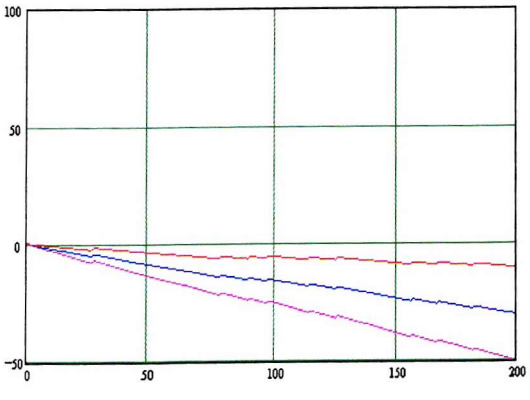
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5.5. Extra Results:

5.5.1. Subjects performance

GROUP	Learners (LFr n=18)		Non-learners (nLFr n=16)	
TRIALS	CORRECT %	INCORRECT %	CORRECT %	INCORRECT %
01-010	57.5	38.0	39.4	51.3
11-020	58.9	39.4	46.3	46.3
21-030	60.4	36.2	43.1	48.8
31-040	61.5	33.4	51.9	44.4
41-050	64.9	34.4	46.3	49.4
51-060	68.9	27.8	51.9	46.3
61-070	68.9	32.9	46.9	51.3
71-080	64.3	33.9	54.4	42.5
81-090	64.4	36.7	51.3	45.0
91-100	74.4	23.3	50.0	46.9
101-110	76.7	23.1	49.4	45.0
111-120	70.9	22.4	47.5	50.6
121-130	77.2	21.1	51.9	45.0
131-140	75.7	24.3	58.8	40.6
141-150	78.7	20.2	49.4	49.4
151-160	78.6	20.8	50.6	46.3
161-170	78.6	20.9	50.6	40.6
171-180	78.6	20.3	45.6	46.9
181-190	80.4	18.0	46.3	46.9
191-200	85.6	14.4	50.0	41.9
TOTAL	71.3	27.0	49.1	46.3

Table 5.5.1.1. Shows the performance data comparison for the learners (L) and non-learners (nL) in the first group (Fr). With feedback (F) and without rule (r).

TRIALS	Learners (LFR n= 5)	
	CORRECT %	INCORRECT %
01-010	70.0	15.5
11-020	75.2	14.2
21-030	73.1	19.2
31-040	94.9	4.2
41-050	83.3	12.5
51-060	88.2	10.1
61-070	90.8	7.5
71-080	83.3	15.0
81-090	79.3	16.0
91-100	70.6	21.0
101-110	79.8	17.6
111-120	83.5	15.7
121-130	76.7	20.8
131-140	79.3	16.7
141-150	94.0	5.1
151-160	86.9	9.8
161-170	86.2	13.8
171-180	94.2	3.8
181-190	94.1	3.9
191-200	89.5	9.8
TOTAL	83.6	12.6

Table 5.5.1.2. Shows the performance data comparison for the learners (L) in the second group (FR). With feedback (F) and with rule (R)

TRIALS	Learners (Lfr n = 8)		Non-learners (nLfr n = 16)	
	CORRECT %	INCORRECT %	CORRECT %	INCORRECT %
01-010	55.2	27.1	50.1	36.8
11-020	58.9	15.2	54.1	33.5
21-030	63.2	24.9	47.2	38.7
31-040	54.9	40.3	41.5	37.9
41-050	78.9	10.9	36.5	48.8
51-060	54.6	35.2	40.1	46.8
61-070	79.3	19.8	43.4	47.8
71-080	50.4	30.1	43.7	46.5
81-090	64.5	25.9	47.2	43.2
91-100	65.3	30.1	45.9	44.1
101-110	73.3	21.0	45.8	39.5
111-120	76.9	20.0	36.7	52.7
121-130	78.9	20.1	49.2	42.1
131-140	78.9	21.3	50.9	38.9
141-150	77.5	11.2	52.9	35.9
151-160	78.3	12.2	46.3	43.8
161-170	78.9	13.5	42.3	49.1
171-180	79.7	17.6	41.1	47.9
181-190	76.4	10.9	48.5	40.1
191-200	78.1	4.8	45.6	39.5
TOTAL	70.1	20.6	45.4	42.6

Table 5.5.1.3. Shows the performance data comparison for the learners (L) and non-learners (nL) in the third group (fr), Without feedback (f) and without rule (r)

TRIALS	Learners (LfR n = 6)		Non-learners (nLfR n = 9)	
	CORRECT %	INCORRECT %	CORRECT %	INCORRECT %
01-010	59.2	20.0	58.1	13.2
11-020	66.9	7.5	60.0	29.9
21-030	70.1	10.0	64.9	29.9
31-040	66.9	20.0	61.9	10.2
41-050	75.2	12.5	54.9	30.2
51-060	72.3	7.5	66.8	30.1
61-070	70.1	12.5	60.0	5.2
71-080	84.2	7.3	55.1	29.9
81-090	71.9	20.0	60.0	34.8
91-100	70.1	15.0	50.0	25.9
101-110	74.9	12.0	55.2	34.9
111-120	79.9	10.0	54.6	45.6
121-130	74.8	7.3	50.0	40.4
131-140	70.2	7.5	60.0	25.8
141-150	75.1	20.0	59.3	18.3
151-160	80.1	15.0	48.1	50.2
161-170	75.1	18.0	55.2	40.6
171-180	76.9	15.0	60.0	55.5
181-190	78.9	20.0	61.2	35.2
191-200	80.1	18.0	59.5	30.2
TOTAL	73.6	13.8	57.7	30.8

Table 5.5.1.4. Shows the performance data comparison for the learners (L) and non-learners (nL) in the fourth group (fR). Without feedback (f) and with rule (R)

5.5.2. Learner's Event related potentials

In each group we investigate the electrodes locations for within the learners during two different set of experimental conditions (First quartile (Q1) with the fourth quartile (Q4) and (Correct answer trials with the incorrect answers trials during) by using two ways ANOVA repeated measures (experiment conditions X electrodes Locations) tables (5.5.2.1, 2, 3, & 4.) The results revealed that there were statistically significant differences for the central, right-hand side, and all electrodes locations in all four groups (Fr, FR, fr, fR). There was no statistically significant difference for the left-hand side locations except in group FR.

For the experiment conditions correct answers and the incorrect answers the results revealed that there were statistically significant differences when compared by the central, right-hand side, left-hand side, and all electrodes locations

Experimental condition	Correct / Incorrect answers			First Quartile / Fourth Quartile		
Group	DF	F	p value	DF	F	p value
LFr n=18	(1,17)	132.41	0.001	(1,17)	65.44	0.001
LFR n=15	(1,14)	97.70	0.001	(1,14)	103.22	0.001
Lfr n=8	(1, 7)	7.98	0.03	(1, 7)	8.49	0.03
LfR n=6	(1,5)	5.16	0.05	(1,5)	4.49	0.06

Table (5.5.2.1.) shows two ways repeated measures ANOVA test within subject effects of the learners in each group for the central electrodes locations (FPZ, FZ, FCZ, CZ, PZ, POZ, OZ)

Experimental condition	Correct / Incorrect answers			First Quartile / Fourth Quartile		
Group	DF	F	p value	DF	F	p value
LFr n=18	(1,17)	89.63	0.001	(1,17)	56.60	0.06
LFR n=15	(1,14)	57.92	0.01	(1,14)	70.52	0.01
Lfr n=8	(1, 7)	20.91	0.03	(1, 7)	14.20	0.07
LfR n=6	(1,5)	7.05	0.11	(1,5)	8.70	0.09

Table (5.5.2.2.) shows two ways repeated measures ANOVA test within subject effects of the learners in each group for left-hand side electrodes locations (F3, F7, ATL, C3, T3, T5, TPL, P3, O1,)

Experimental condition	Correct / Incorrect answers			First Quartile / Fourth Quartile		
Group	DF	F	p	DF	F	p
LFr n=18	(1,17)	142.2	0.001	(1,17)	118,30	0.001
LFR n=15	(1,14)	129.45	0.001	(1,14)	81.16	0.001
Lfr n=8	(1, 7)	14.48	0.007	(1, 7)	9.36	0.01
LfR n=6	(1,5)	6.62	0.03	(1,5)	6.38	0.03

Table (5.5.2.3.) shows two ways repeated measures ANOVA test within subject effects for the learners in each group by the right-hand side electrodes locations (F4, F8, ATR, C4, T4, T6, TPR, P4, O2).

Experimental condition	Correct / Incorrect answers			First Quartile / Fourth Quartile		
Group	DF	F	p value	DF	F	p value
LFr n=18	(1,17)	134.3	0.001	(1,17)	99.90	0.01
LFR n=15	(1,14)	92.11	0.005	(1,14)	53.37	0.04
Lfr n=8	(1, 7)	11.53	0.01	(1, 7)	10.24	0.02
LfR n=6	(1,5)	5.98	0.05	(1,5)	5.43	0.01

Table (5.5.2.4.) shows two ways repeated measures ANOVA test within subject effects of the learners in each group for the all electrodes locations (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ).

Tables (5.5.2.5, 6, 7, & 8) show the Statistical analysis of the difference between subjects brain activity while performing the task for each quartile (50 trials), (Q1, Q2, Q3, Q4) X Electrodes locations using two ways repeated measures ANOVA revealed a significant differences of brain activity during quartiles X location. Inspection of these results suggests that the bulk of the within quartile learning effect was restricted to the Fr, and FR groups especially during the last quartile.

Analyzing each group separately supported this impression when the effect of learning across the quartiles was analyzed for group FR. Group fr only showed

that there was no significant increasing in the brain activity across the quartile. There was significant increasing in the brain activities of Fr, FR and fR groups from Q1 across to Q4. The ERP for the all-individual electrodes were entered into experiment conditions (Q1, Q2, Q3, and Q4) ANOVA: Significant differences emerged between the ERP elicited by learning processes for each quartile. We can infer that any improvement and changes in the brain activity was transferred from previous learning rather than constituting new learning within that quartile.

	1st Quartile		
Q2	F (1,17) = 56.46 p ≤ 0.01	2nd Quartile	
Q3	F (1,17) = 76.18 p ≤ 0.001	F (1,17) = 77.3 p ≤0.01	3rd Quartile
Q4	F (1,17) = 99.90 p ≤ 0.000	F (1,17) = 98.78 p ≤ 0.02	F (1,17) = 90.65 p ≤ 0.01

Table (5.5.2.5.) shows two ways repeated measures ANOVA test within subjects effect of the learners (LFr) four quartiles (Q1, Q2, Q3, Q4), for all electrodes (group X locations), (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ).

	1st Quartile		
Q2	F (1,14) = 53.38 p ≤0.05	2nd Quartile	
Q3	F (1,14) = 37.7 p ≤0.05	F (1,14) = 37.7 p ≤0.001	3rd Quartile
Q4	F (1,14) = 53.37 p ≤ 0.04	F (1,14) = 67.07 p ≤0.002	F (1,14) = 39.47 p ≤0.001

Table (5.5.2.6.) shows two ways repeated measures ANOVA test within subjects effect of the learners (LFR), four quartiles (Q1, Q2, Q3, Q4), for all electrodes (group X locations), (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ).

	1st Quartile		
Q2	F (1,7) = 3.94 p ≥ 0.08	2nd Quartile	
Q3	F (1,7) = 9.26 p ≤ 0.04	F (1,7) = 7.11 p ≤ 0.05	3rd Quartile
Q4	F (1,7) = 10.24 p ≤ 0.02	F (1,7) = 2.06 p ≥ 0.11	F (1,7) = 7.71 p ≤ 0.05

Table (5.5.2.7.) shows two ways repeated measures ANOVA test within subjects effect of the learners (Lfr), four quartiles (Q1, Q2, Q3, Q4), for all electrodes (group X locations), (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ

	1st Quartile		
Q2	F (1,5) = 1.28 p ≤ 0.07	2nd Quartile	
Q3	F (1,5) = 3.55 p ≤ 0.05	F (1,5) = 2.99 p ≤ 0.06	3rd Quartile
Q4	F (1,5) = 5.43 p ≤ 0.01	F (1,5) = 4.98 p ≤ 0.03	F (1,5) = 4.56 p ≤ 0.04

Table (5.5.2.8.) shows two ways repeated measures ANOVA test within subjects effect of the learners (LfR), four quartiles (Q1, Q2, Q3, Q4), for all electrodes (group X locations), (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ). * ≤0.05, **≤0.01, *** ≤0.001.

Inter learner's group mean amplitudes (amp.) during last fifty (Q4) comparison revealed that there were statistically significant differences between group last fifty trials mean amplitude (LFR amp.) and all groups during the first, but was no statistically significant difference only with group Fr during the second time window. There were no significant differences between group Fr when compared with group FR both time windows. There was statistically significant difference between group fr and Fr during the first time window. There were no significant differences between Group fr and group fR during both time windows (tables 5.5.2.9 & 5.5.2.10.)

LFr amp. 5.99 ± 1.35			
LFR amp.	F (1,14) = 57.6 p ≤ 0.01	LFR amp. 6.14 ± 1.69	
Lfr amp. 4.30 ± 1.32	F (1,7) = 50.62 p ≤ 0.01	F (1,7) = 21.49 p ≤ 0.005	Lfr amp. 4.30 ± 1.32
LfR amp. 4.59 ± 1.30	F (1,5) = 4.93 p = 0.07	F (1,5) = 7.52 p ≤ 0.04	F (1,5) = 0.96 p = 0.22

Table (5.5.2.9.) shows two ways repeated measures ANOVA test within subjects effect for the last quartile for the learners in each group during the first time window, for all electrodes (group X locations), (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ)

LFr amp. 6.12 ± 0.99			
LFR amp. 6.45 ± 1.09	F (1,14) = 22.5 p = 0.11	LFR amp. 6.45 ± 1.09	
Lfr amp. 4.88 ± 1.12	F (1,7) = 12.27 p = 0.06	F (1,7) = 16.92 p ≤ 0.01	Lfr amp. 4.88 ± 1.12
LfR amp. 4.99 ± 1.23	F (1,5) = 13.2 p = 0.09	F (1,5) = 14.22 p ≤ 0.03	F (1,5) = 4.71 p = 0.32

Table (5.5.2.10.) shows two ways repeated measures ANOVA test within subjects effect for the last quartile for the learners in each group during second time window, for all electrodes (group X locations), (F3, F4, F7, F8, ATL, ATR, C3, C4, T3, T4, T5, T6, TPL, TPR, P3, P4, O1, O2, FPZ, FZ, FCZ, CZ, PZ, POZ, OZ)

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