LITERATURE REVIEW

Because my research contains 3 different concepts and each of them needs a specific concentration, I have separated the subjects to make it more categories. At the beginning I have explained the concept of information load and how literatures define information load. Then I briefly showed how internet increase information load and how internet affect costumers shopping behavior. After that I have talked about the literature related to the role of information load on decision making and I have described why this concept should be consider as an important issue in designing e-commerce websites. So, first part of my literature is about the role of information load and the importance of this concept. Second part of my literature is about the method I used for measuring information load. Because I have used EEG device and this device is a tool in neurology science and that area has its own terminology, I have explained the concept of working memory which I have used in the other part of my research. Working memory is a system which I believe information overload during shopping will occur on that. Then I have explained about EEG device and its terminologies and at the end I bring the literatures which support the relationship between brains signals and working memory, which I measured.

Part 1:

i. Concept on information overload

ii. Electronic Market place

iii. Information overload and decision making

Part 2:

i. Working Memory

ii. EEG Devices

iii. Brain signals and Working memory

THE CONCEPT OF INFORMATION OVERLOAD

In the ordinary language information overload is, receiving too much information. Actually the performance (decision making) of individual change with the change in amount of information he/she receive. In general definition researchers have found that the quality of decisions of an individual has positive correlation with the amount (number of piece of information)of information he or she receives—up to a certain point. With providing more information beyond this point, the performance (quality of decision or doing task) of the individual will decline (Chewning & Harrel, 1990). The information provided beyond this point will no longer be integrated into the decision-making process and information overload will be the result.

Scammon, (1977) define information overload as the limitation which consumer will face on their ability to analyse and deal with large amount of information, within limited time period.

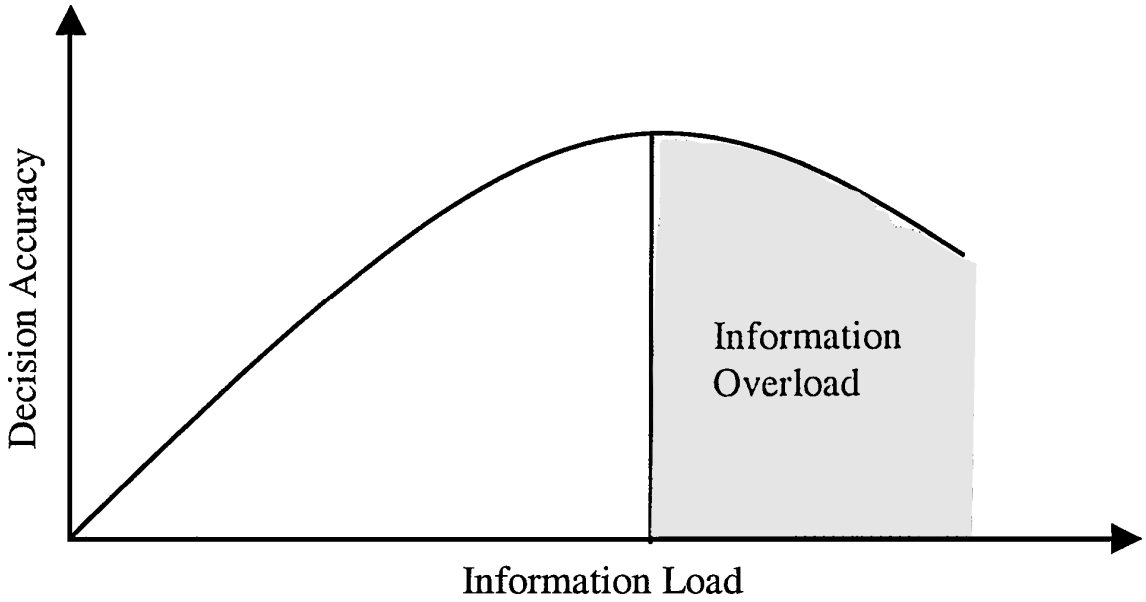

Figure 2- Information overload as the inverted U-curve (Schroder et al., 1967)

(Eppler & Mengis, 2004) did a review on the information overload literature and analyze the problem of information overload across different areas of management such as organization science, accounting, marketing and management information system (MIS). From gathering all the literature they found that different synonyms in this area such as cognitive overload, sensory overload, communication overload, knowledge overload and information fatigue syndrome. These terms are applied to different areas of business and management from auditing to strategizing and even super market shopping. Eppler and Mengis found five reason for information overload though the literature, first is amount of information(such as quantity, frequency, intensity and quality) second is the person who is receive the information third is task process that need to be completed by a person forth is organizational structure or design and final one is using of information technology.

Concept of information overload in the marketing area is defined as a comparison between volume of supplied information (number of available

brand or attributes for each choice) and individual capacity for processing information. If the supplied information was greater than processing capacity, then overload may become the result and because of this overload dysfunctional consequence may happen.

Although some researchers believe that there is a relation between information load and processing capacity and with increasing amount of information the processing capacity will increase simultaneously but they also found that this increase in the processing capacity has also a limitation. So they are agreeing with problem of overload in the same way (Schultze & Vandenbosch, 1998)

Different studies find different elements which effect on the information overload. For example Schick et al. (1990) mention about the time as a crucial factor which effect the information overload problem.

One of the other factors which affect on information overload is characteristics of information. Variation in information type can be in terms of information attributes or intensity or complexity and each of these types can contribute to overload information or to reduce that (Keller & Staelin, 1987).

The amount of information could be defined in terms of dimensions of data which is available for each brand (attributes). Literature suggested 2 type of information overload first in the number of brands presented to the customer; second one is number of attributes for each option. Companies and especially marketers have the control over the amount of information per brands while consumer or store seller has the control over the number of brands to

considering (Wilkie, 1974). But now a day online store have both control in term of the number of attributes and also number of brand they want to promote in their website.

In marketing or consumer research area with explosion in the number of brands, customers are facing so many choices and as a result of this explosion consumer may become overload. Jacoby, Speller and Kohn are the first researchers who tested the effect of amount of information on customer decision making in the supermarket environment. They design a 3×3 factorial study, and then they test the effect of quantity of brand information on brand choice decision. Their results support the information overload phenomenon.

Actually in marketing area the importance of information overload is because of the impact of this phenomenon on the customer choice quality, on decision time and on the number of information that can be processed by customer in a purchase situation.

One important issue is measuring the amount of information which humans mind are able to process. (Miller, 1956) try to find what the number is.

We can see that for many reasons people may become overloaded and one of the factors which affect this (information overload) problem, is IT. Using information technology can help to reducing the ambiguity in the information and also can help to filtering the information and reducing the amount of irrelevant information. But it is also can increase amount of information by facilitating the process of acquiring information. In the next section I will show how internet can affect on the information load problem:

INTERNET AND INFORMATION OVERLOAD

Nowadays everyone use internet as a source of information and with a little IT skills everyone can get huge information (related or unrelated depend on using search engines expertise), about anything they want so we can look through the internet as a phenomena which change the business environment.

The special opportunity which online environment gave to the seller is that the sellers and companies are able to create very interactive features. These interactive features are help to reduce the load of information and also improve the decision making process. The reason of growing these interactive tools is a drastically increase in the number of companies and sellers who want to use WWW as a new way to attracting new customers. With existing these tools and other options online environment is totally new shopping environment which shopping behaviour in this area is fundamentally different from traditional market (Haubl & Trifts, 2000)

Internet and online environment gave this capability to the both sellers and buyers to take advantage of free, huge and easy information. But it seems there are still problems with this new product as an example:

In ideal market all the seller charge a single price so there is no need to search. But in reality price is higher than marginal cost and because of that buyers are faced with search cost and this is different from buyer to buyer. So sellers take advantage from this and charge the customers.

(Fama, 1998) talk about market efficiency term which based on economic theory of price equilibrium which is come from the interaction of forces of supply and demand. In his efficient market the information are accessible and with low cost for everyone. In traditional market, market efficiency term cannot easily reachable but it seems with use of internet and World Wide Web technology it should be easy to reach. But (Grover, Lim, & Ayyagari, 2006) who are discussed about the market efficiency in e-market, argue that steel in e-market is suffer from price dispersion.

It shows that Internet cannot solve the problem with providing information. Researchers believe that there is a problem with this easy and free

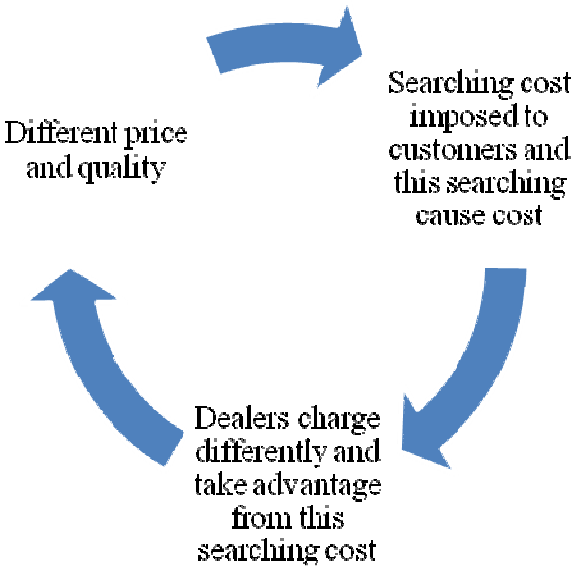

Figure 3-price and information flow in online environments

information follow.

Electronic marketplace is useful for vertical relation between seller and buyer and its major impact is reduction in search cost about the price and also product offerings available in the market. It must have major role in building market efficiency. There is one assumption for simplification in microeconomic in which they assume that buyers must incur cost for obtaining full information about prices and product offerings of the sellers in a market. With help of e-market we can reduce this cost and going toward more realistic assumption in terms of “full information”. (Bakos, 1991)

(Bakos, 1991) introduce 5 major characteristics of electronic market systems, one of them that related to my research is: An e-market place can reduce both buyer and seller costs. In buyer side with reducing cost of obtaining information about the price and also products alternatives and in seller side with reducing cost of communicating.

With increasing usage of internet the costs of obtaining information dramatically decrease, so it lead to reduce information asymmetry and opportunistic behavior and so leading to efficient e-markets. In this case we should see some changes in causes of this, for example about the price dispersion we may hope to don’t see price dispersion in e-market but wee steel have a lot of previous issues same as traditional market. One reason could be the nature of information in this new market such as uncertainty, overload and equivocality (Grover, Lim, & Ayyagari, 2006). (Ackoff, 1967) named it as “dark side of information” it is not necessarily negative but it means unknown side and effect of information.

Search cost by itself has some impact on the market which (Bakos, 1991) categorize them in 4 group: (1) selling price will decrease as cost of searching information decreases; (2) the amount of search increases with reducing the searching cost; (3) the amount of search increases with increasing price dispersion and (4) with increasing price dispersion, buyer finally can find better deals however their searching amount increase but we can conclude that total search cost decrease if all other variables be fixed (ceteris paribus).

Information uncertainty in (Grover, Lim, & Ayyagari, 2006) definition means when information is unavailable to make transaction. Information overload is when information is more than required. Information equivocality arises in ambiguous situations with multiple conflicting views among stakeholders.

With increasing web shopping suppliers start to increase the amount of product related information. It lead to information overload, and because of human limitation in processing the data, so consumers must start to filter the information and it causes additional cost. So it reduces one type of cost and incurs another type.

(Grover, Lim, & Ayyagari, 2006) mention that overload is form of incomplete information that crushes the decision maker so he/she cannot easily decide on relevant information. In this case authors conclude that consumers are willing to pay more (higher price) to get rid of this ambiguity.

They also mention about the effect of information in customers preferences which customers could perceived differently about same product with only different information about the products.

Information itself is just like row materials they require synthesis and analysis to create knowledge or help to make decision, but the quality of raw material is important of quality of resultant knowledge and/or decision made. (Fornaciari, Loffredo, & Maria, 1999)

(Fornaciari, Loffredo, & Maria, 1999) discusses about factors affect web effectiveness and they found three major problems when dealing with web effectiveness:

1- Knowledge of the technology
2- Data Relevance and information overload
3- Evaluating web site for quality

They propose some solutions for these problems (solutions steps for effectively finding and evaluating internet based information):

1- Make a research a mindful activity
2- Define the problem effectively
3- Define information needs
4- Identify the proper information sources
5- Evaluations in terms of credibility, quality, interpreting

As we can see all the solutions are not appropriate for a simple buyer, and also cannot help to non experts to solve their problems they are issues that we can look at them as barriers for everyone who wish to take advantage from online shopping.

From the above literatures we can see how internet affect on information and make information overload, it cannot help to reach an ideal and efficient market and steel people in online market face the old problems such as price dispersion, from the reasons counted above my focus is on information overload and the effect of it on the decision making in the internet buying.

Another aspect of information overload is effect of information overload on the decision making which as follows.

INFORMATION OVERLOAD AND DECISION MAKING

With considering the “right to know” for the consumers, (Jacoby, Speller, & Kohn, 1974) found positive, linear relationship between amount of product information and subjective feeling of satisfaction a negative linear relationship with confusion, and a curvilinear (information overload) relationship between amount of information and the accuracy or the "correctness" of the purchase decision.

(Iyengar & Leppe, 2000) stated that for many years the assumption of having more choice is more desirable, and for year’s psychological theories and research demonstrated this supposition, across many domains, such as life satisfaction, intrinsic motivation with increasing in choice and so on and so forth. But this satisfaction is up to specific point and after that more choices and so more information may lead to confusing and purchase mistakes and as a consequence decreasing on satisfaction. (Owen, 1992)

Increasing the product information lead to information overload and so decreasing customer satisfaction and loyalty. (Lee, 2004)

In managerial environment, (Ackoff, 1967) pointed to some major factors affecting to decision making with relation to management information system issues. One was lack of relevant information the other is management needs all information they want, and third was managers assume that with having all the information the decision making process will improve. He mentions that for coping the first deficiencies which lack of relevant information most of the time lead to information overload. Then managers will suffer from information overload. They must spend a great deal of time separating the relevant from irrelevant and searching for the basic and main documents. For the second factor the assumption is managers know what they want. In real world knowing all the information needed meaning well understanding the phenomena. But in most of the time managers (and also everyone who search around a case) don't know phenomena very well so tend to more variable (i.e. as much as possible) this one lead to information overload too. For the third one which is says "if manager has the information he/she needed his/her decision making will improve" this one strongly depend on the managers capability, it depend on how well managers can used needed information effectively.

As we can see form what Ackoff done in 1967 we will find some similarity among what happen in the organizations and what happen in our daily decisions. We want as much as information we can gather, most of the time we don't know what type of information we exactly want and finally our decision quality depend on our capacity in analyzing all the received information.

Now it is well accepted that human minds have limitation on processing the information. Memory models which proposed by researchers such as “multiple-store concept” and “level of processing” and the “activation model” are all consistent with this “limited processing capacity” (Malhotra, 1982)

When we want to deal with information quality (Iselin, 1993) counted three factors:

1- Uncertainty experienced by decision maker
2- Information load experienced by decision maker (information load)
3- The quantity of irrelevant data affecting by decision makers (data load)

These factors are depend on the nature of decision (i.e. what is the type of decision tasks) and so depend on type of information we need for our decision.

Information overload occurs when the amount of input data exceeds from the processing capacity, so this situation is likely that a reduction in decision quality will occur. Researches shows that information overload lead to decrease decision quality and also increase the time required to make decision, also increase confusion regarding the decision. (Speier, Valacich, & Vessy, 1999); (Jacoby, Speller, & Kohn, 1974)

(Milgram, 1970) explores the effect of information overload and how people confront of it. In his study he found that there is six common reactions on information overload situations, which are 1) allocation less time for each input, 2) disregard the low-priority inputs, 3) redrawing of boundaries in some social transactions to shift the burden of overload to the others, 4) reduction

the input by filtering, 5) refusal of communication reception, and finally 6) use the help of specialized institution.

In marketing area the effect of information overload on whether decision accuracy, decision time and general performance is inconsistent especially in terms of methodology. But all of the literature agrees on that heavy information load can affect the performance of an individual negatively (in terms of accuracy or speed). The negative performance come from personal difficulties in identifying the relevant information so it become highly selective and maybe ignores a large amount of information or maybe facing with some problems in identifying the relationship between details and so need more time to reach decision or maybe sometimes at the end does not reach a decision of adequate accuracy. (Eppler & Mengis, 2004)

A marketer reported his observation that consumers were choosing the wrong product when asked to compare too many features or too many product alternatives. Humans processing capacity system just like the other information processing systems subject to some constraints and have limited capacity so exhibits problems of reliability with approaching to those capacity limitation. (Owen, 1992)

(Owen, 1992) argues about what he call in as “purchasing mistakes” he mention that knowing about customers maximum processing ability by its own is not helpful for sellers because it vary from one customer to another and so there is nothing to do with it but there is another point of view to help customers in choosing their needed and to decreasing information overload unsatisfactory effect, and that is increasing the customers processing quality.

He argues that theoretical and managerial interest should not be focuses so much on information quantity issues, but more towards to changing processing quality as consumers mental work load is increased.

(Owen, 1992) claim that redline for comparing data is the magic number which (Miller, 1956) introduce a magic number seven is the redline for the number of items and number of attributes for each item, that can still analysis correctly with respect of humans processing capacity. But this claim cannot be correct because the capacity change with humans past experience and also mental ability someone is stronger and someone is weaker. Also the nature of data is important in this case. So there is not an exact number that we can introduce for maximum. Maybe in the future researcher can propose an optimal number in which marketer can use it as average comparison capacity for buyers.

Overload redline could differ not only among individuals, but within individuals depend on aging, environmental factors like food intake, noise, temperature and clothing the overload redline may change. (Owen, 1992)

Another point that we can not exactly detect information overload is overload may occur at different points, depend on what combinations of data are engaged for the decision task.

Owen (1992) proposes tow different qualitatively, information processing form: 1) objective or “systematic” forma of processing, 2) heuristic based mode of processing. He also adds another form of processing named “peripheral” when decision maker faced with non-issue relevant information. If we put an

assumption that each consumers will to attempt to make satisficing (refer to the next page) choice, in all situation even when they confronting to information overload and they don't have enough processing capability, then we cannot conclude that they would make random and incorrect choice in this case consumers mostly use some simplifications on heuristics based and also use peripheral clues to product quality to make decision. This type of selecting in overload times different with type of purchasing for example for buying a house or car, in most of the time buyer think about the alternatives for days and try to find best solution.

Owen (1990) introduce tow processing model which attempt to integrate issues of capacity first is consumer memory and second is attitude. Attitude and capacity based theories recognize the influence of motivation and ability on human information processing, information overload affect both model.

(Hunter, 2004) express that the ability in processing the information is varying among the types of information for example for telephone numbers although it has 9 or 10 digit but humans still can memorize more than one number. He also argues that the one weakness of research on information overload is inability to identifying the criteria of error, so he believe that the effective way to measuring the constructs is to have individuals self report, so self reports can developed and used for investigate information overload.

It is obvious now that with providing huge information about products we make the consumers faced with overload but we cannot reduce the information because in searching around purchasing behaviors, marketing researchers find that having more choice and more alternatives in most of the

times can lead to human motivation in buying. Although they faced by choice overload but still work as a motivator. (Iyenger & Lepper, 2000)

Iyenger & Lepper (2000) also argues that what happen when the range of alternatives becomes larger and so the differences among the options become relatively small. They found that people start to simplify their choices and more relying on heuristics.

Now I want to explain behavioral model in rational choice (reminder I explained above that we assume that buyers tend to do rational choice). (Simon, 1955) bounded rationality theory is most usable theory especially in marketing analysis.

In the past, before Simon (1955) bounded rationality theory, there was tow different mathematical algorithms to predict purely rational or optimal human decision making process, he explained these two theories as bellow:

1- Economic man. This man assumed to have enough knowledge about the environment and also has adequate capability in analyzing this information's. He also assumed also to have well- organized and stable system of preference and all of the alternative courses of actions are available to him. Actually in recent environment this kind of definition is not appropriate for the foundation of the research.
2- In contrast there is another definition which is psychological concept, they concerned with rational behavior. It cannot be helpful in analyzing people behavior especially in marketing.

Simon (1955) bounded rational theory is an accepted model in describing humans decision method. He rejects the mathematical algorithms to predict purely rational or optimal decision making. He claims that because of time limitation and also cognitive limitation humans can not consider all decision outcomes. So he defined rationality inside a specific boundaries contain time and cognitive barriers.

There is a big gap between these two aspects so Simon proposed a half way between these two, and he named it rational choice, he reject the other pervious methods, named them optimal choice, because he believe on human limitation and so he suggest his theory on bases of two limitation which human faced with them in decision making process, one is time and second cognitive limitation with respect of processing information. He mentions that because of these limitation people tend to use simplification in their choices and just choosing the outcomes which are suited their needed. He used word “satisficing” which a Scottish origin word and is a combination of sufficing and satisfying.

In classic rational theory researches assumes that humans in decision position has the ability to mathematical operation to identify the probable range of offers and can find better offer among them with higher value. This kind of assumption is so optimistic because the big percentages of buyers or decision makers don’t have this computational capacity. That’s why Simon predicts some simplification on decision making process from the decision maker. This simplification in Simon opine is up to satisficing point and that point is where the outcome is good enough to suit decision makers, but not

necessary best decision. Satisficing act as a stop rule which once an acceptable alternative is found, the decision maker concludes the decision process. Simon also contended that satisficing generally leads to choices roughly equal in quality to choices predicted by optimizing algorithms.

In case of using internet which helps us to find at least some relevant information with correspondingly minimal investment of time and effort, it can be some sort of satisficing. In the other word we continue our searching until because of time limitation or information overload we stop searching although we are not completely satisfy yet.

(Agosto, 2002) tested Simons behavioral decision making theories of bounded rationality and satisficing in young people's in the web based decisions, not only rely on buying but more is on to selection decision among web sites. His research is based on qualitative research methodology… In the past researchers test Simons theory in traditional market. But yet there is no study on how this theory affect on shopping in the market. That's what I want to test. In the next section I am going to explain the concept of working memory. It seems that the term of "working memory" which neurologist are using is the place of occurring information overload. So to measuring information load I have to measure working memory. In the next section I explained why I should measure working memory for finding information load.

WORKING MEMORY:

Working memory is a process for storage information in our short term memory and adding this information with information retrieved from long term

memory and then with analyzing these two types of information we can do a cognitive task.

Cognitive process or memory processes are using working memory systems and also long-term memory system to complete the tasks. For example task of friend recognition. First part is our sensors receive the information and then with using long-term memory we can identify our friend only when the codes in our long term memory matching to what we received. These processes need a place to be done and that place is short-term memory or working memory (Klimesch, Russegger, Doppelmayr, & Pachinger, 1998)

One of the pioneers in this area is Baddeley who is a professor in York University. Alan Baddeley and Graham Hitch (Baddeley & Hitch, 1974) proposed a Model of Working Memory in 1974, in an attempt to describe a more accurate model of short-term memory. (Baddeley A, 1986) define the concept of working memory as a "limited capacity system", for keeping and saving information in short-term, and this system support human decisions and thinking process by providing a relation between short-term and long-term memory.

(DeJang & Das-Smaal, 1995) discuss that working memory is critical for different cognitive tasks such as reasoning, and (Kyllon & Christal, 1990) find the relationship between working memory and problem solving tasks.

The term of working memory mostly use when we talking about cognitive tasks. It is related to that part of memory which is active for a short period of time, around seconds.

We should notice that the concept of working memory has less relation to storage and retrieval process but more relation to online mental

representation of information and the ability to change and manipulate those information to come up to an action. (Welsh, 1988)

(Jensen, Gelfand, Kounios, & Lisman, 2002) believe that “Working memory is the process by which the brain sustains the activity of cells whose firing represents information derived either from brief sensory input or readout from long-term memory.”

Studies shows that working memory process is mostly generated from prefrontal cortex. (Cohen, et al., 1997) shows that prefrontal cortex has a critical role in maintenance of information.

Prefrontal cortex (PFC) involve in working memory and inhibitory process. With this view we can say that working memory is important to maintain goal relevant information and behavioural inhibition relies on the ignoring irrelevant information or inappropriate responses. (Bunge, Ochsner, Desmond, Gloverm, & Gabrieli, 2001) and (Klimesch, 1996)

(Bunge, Ochsner, Desmond, Gloverm, & Gabrieli, 2001) use fMRI (functional MRI) to test the relationship between working memory and behavioural inhibition while they use Sternberg test.

EEG (ELECTROENCEPHALOGRAPHY) DEVICE AND SIGNALS

EEG, or electroencephalogram, is a tool to imaging the brain activities during its performance. We can detect the location and magnitude of brain activity involved in the various types of cognitive functions we study. EEG allows us to view and record the changes in your brain activity during the time you are performing the task. By using 3 electrodes (2 sits on ears and one has to fix

on the head) we can monitor the amount of electrical activities related to different cognitive tasks.

EEG provides an electrophysiological method of investigating cognitive processes. (Elul, 1972) explain the physiological basis of the EEG, which is "synaptic functional units" that are composed of thousands of synapses. Within each functional unit, the synapses share the same presynaptic input, resulting in the depolarization or hyperpolarization of an immense number of neurons as a unit. It is the activity within these functional units that is recorded by surface electrodes.

(Klimesch, 1996) believe that intelligence has appositive correlation to cortical volume and thickness and then he evolved that EEG power is somehow related to cortical layers, this assumption has a result and that is recording EEG's signal can reflects the capacity and performance of cortical information processing. But this conclusion is not straight forward because the measurement is depend on the thickness of the skull and the volume of cerebrospinal fluid and also some factors such as age and cognitive task which should perform.

Carlo Matteucci (1811–1868) and Emil Du Bois-Reymond (1818–1896) were the first researchers who record electrical signals emitted from brain nerves. After them Richrd Caton (1842-1926) uses electrodes on the scalp of human subjects to record the brain activity and only after his work the term EEG was used. The discoverer of the existence of human EEG signals was Hans Berger (1873–1941).He began his study of human EEGs in 1920 (Sanei & Chambers, 2007)

Sanei and Chambers in their book “EEG signal processing” explain about Central nervous system (CNS) and how CNS activities create signals. They mention that the activities in CNS are related to synaptic currents transferred between the junctions of axons and dendrites. This activity produces a potential of 60-70 µV with negative polarity.

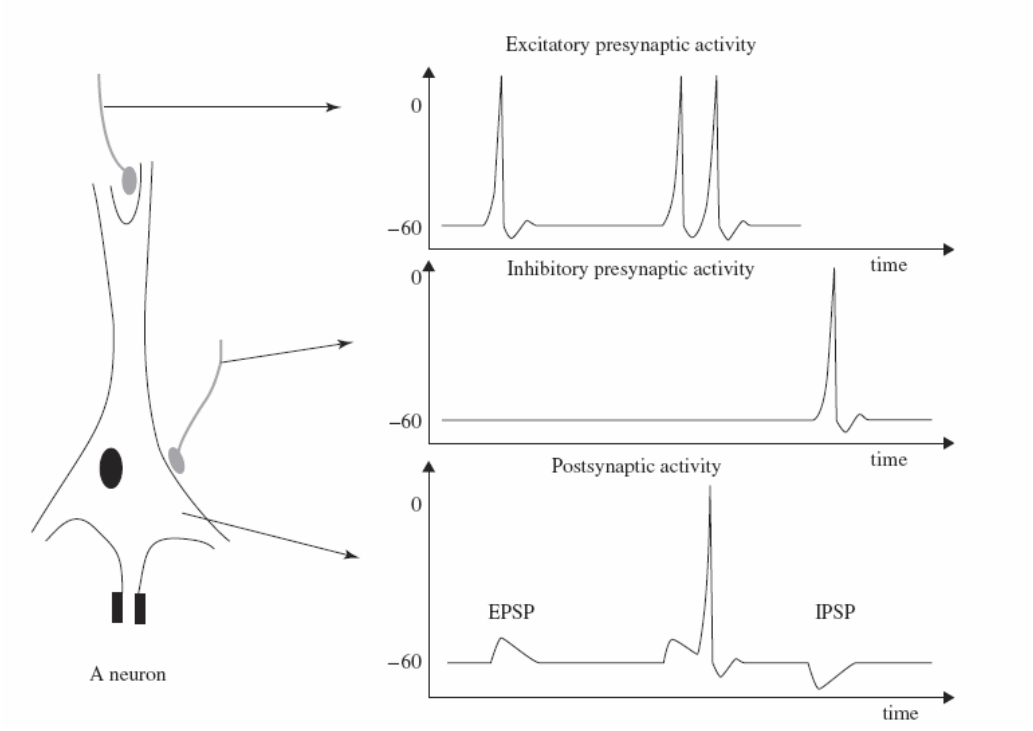

Figure 4- Neurons produce EEG signals

After explaining how human brain can produce electric signals now I am going to explain brain rhythms or signals:

(Shaw, 1984) mention that the EEG signal can be considered as “the sum of *many* components of different frequencies surnrnating to produce the resultant complex pattern of fluctuation”. EEG frequencies are subdivided to 5 major frequency bands. These frequency bands form low to high frequencies are include delta *(0.5* to *4* Hz), theta *(4 to 8* Hz), alpha (8 to 13 Hz) and beta (13 to *30* Hz) and gamma were refer to waves of above 30 Hz. The alpha and

beta waves was introduced by Berger in 1929. Alpha wave is the most prominent rhythm in brain activities. A beta wave is the usual waking rhythm of the brain associated with active thinking, active attention, focus on the outside world, or solving concrete problems, Gamma is the term that Jesper and Andrews (1938) used for the waves above 30 Hz. The first person who introduce delta was Watler in 1936, he use this term to distinguish rhythm below the alpha frequency. These waves are associated with deep sleep and waking state. Finally the concept of theta was introduced by Wolter and Dovey in 1944. Theta waves are associated with consciousness slips towards drowsiness, theta also associated with access to unconscious material, creative inspiration and deep meditation. (Sanei & Chambers, 2007)

(Klimesch, Schimke, & Schwaiger, 1994) and Klimesch, (1996) believe that different frequencies should be the result of different mental process or states. Figure 5 shows a brain signal with its subdivision. Figure 6 shows each of this sub signals separately.

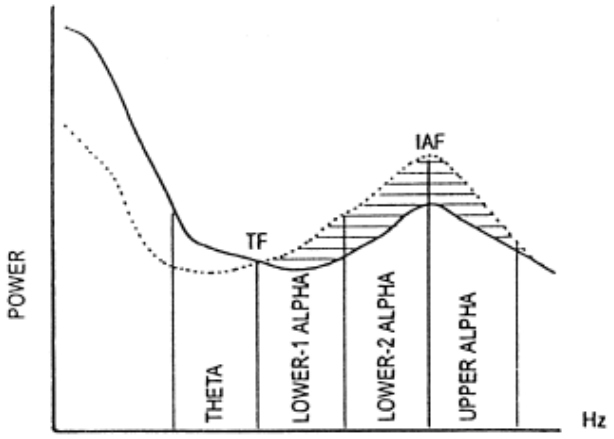

Figure 5- Single brain signal include different frequencies

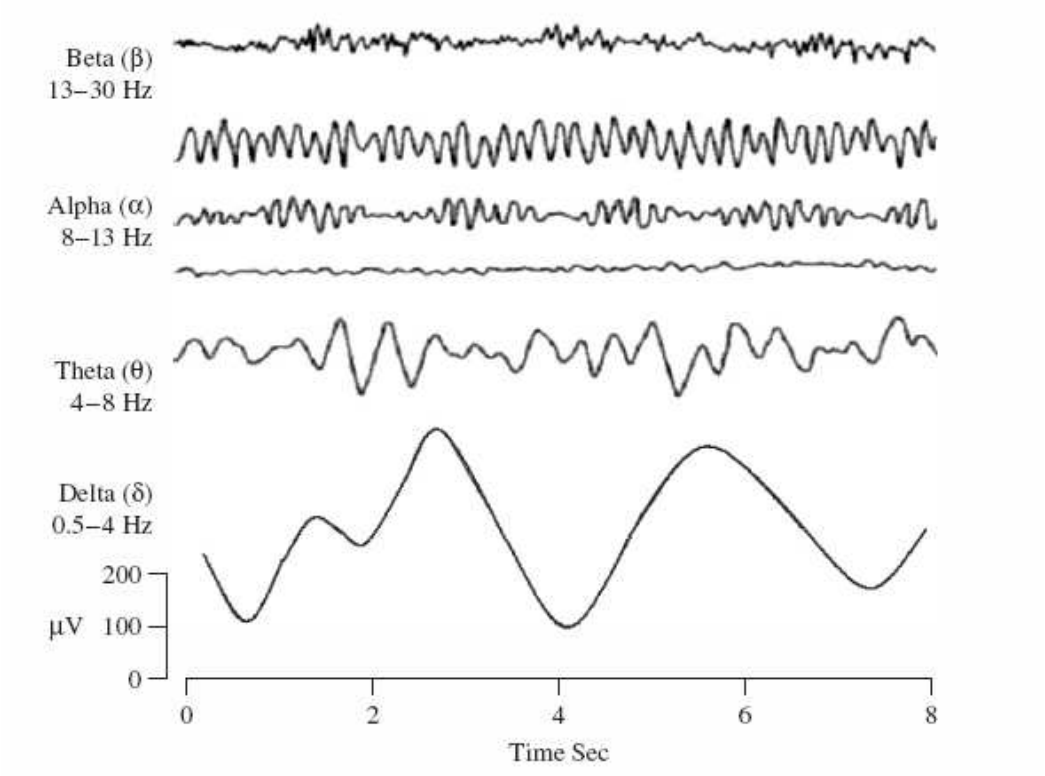

Figure 6-- Four typical dominant brain normal rhythms, from high to low frequencies.

The relations between brain function and EEG measures have commonly been investigated by comparing regional c*hanges* in the amount of EEG activity within these particular frequency bands and at particular scalp regions (Ray, 1990)

BRAIN SIGNALS AND WORKING MEMORY

(Jensen, Gelfand, Kounios, & Lisman, 2002) discuss about the role of brain oscillations on working memory, for this purpose they recorded the scalp electroencephalogram (EEG) during the retention interval of a modified Sternberg task. They particularly test theta and alpha frequency band. They use mean reaction time as a function of memory load. They found that reaction time increased systematically as a function of load. They found that

activity in 9-12Hz area called alpha band reflect working memory state and also the power of the band depend on the number of items being stored. They did not detect a peak in the theta band, except in one subject. They found that theta activities are stronger in frontal area but alpha band shows stronger effect in posterior area of mind.

For testing brain oscillation there is two common task one is Sternberg task which used by Jensen and the other in n-back task which is used by Gevins and colleagues. By using n-back test subjects are present with a continuous stream of items and they have to indicate whether the displayed item matches the one presented n positions back. But by using Sternberg test items are present simultaneously at the center of a computer monitor subjects should press a mouse button to indicate that which item is presented before, subject also should define where the item was in first presented picture.

One of the sample of n-back test is a research which (Krause, et al., 2000) had done. They tested the effect of memory load on EEG signals and bands by means of EDR (event-related desynchronization) and ERS (event-related synchronization). Same as Klimesch *et al.* (1997, 1999) they found that with increasing memory load EEG theta power increase and at the same time EEG alpha power decrease. In the 6-8Hz (include theta and low alpha band) they observed greatest ERS caused by high memory load, 2-back.

(Kahana, Seeling, & R, 2001) have summarised reviewed literature and researches about the role of theta in memory and cognitive tasks. They mention that studies with using cortical surface electrodes in humans have shown that theta oscillation increase during verbal and spatial memory tasks.

From studying role of theta in cognitive functions and different type of information processing they conclude that theta's role can be seen as a function of task demand.

The amount of EEG power for theta and alpha signals is indeed reflected cognitive task and memory performance, but in a non-linear way. Small power of theta plus large power of alpha will show good task performance. In the same way increase in theta and decrease in alpha is an indicator of cognitive task and memory performance. It means that there is a positive correlation among alpha frequency and cognitive performance and also negative correlation among theta and cognitive task and memory performance (Klimesch W. 1998).

A recent MEG study reports on a systematic increase in frontal theta activity with memory load (Jensen and Tesche, 2002).

However, additional investigations will be needed in order to draw any general conclusions about the role of this frequency band in association with human information processing.