EXPLORING HUMAN ERROR

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Certified that the Thesis entitled: ***Exploring Human Error*** submitted by me for the award of the Degree of Doctor of Philosophy in Arts at Jadavpur University is based upon my work carried out under Supervision of Dr. Lopamudra Choudhury and that neither this thesis nor any part of it has been submitted before for any degree or diploma anywhere / elsewhere.

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PREFACE

Human error is a large subject. It has been studied in heterogeneous disciplines. Errors mean different things to different people. In philosophy errors are discussed in epistemological context. Psychologists concentrate on the influence of it to the human behavior. For cognitive theorists error provides important clues to the underlying factors of human action. According to applied practitioners, they remain the main threat to the safe operation to high-risk technologies. This thesis has proceeded with a mixed readership in mind. This thesis did not provide any specialist knowledge. It explores the common people attitude towards error. Its approach is highlight the issue that ignorance about error is a main cause behind error induced adverse event. It has analyzed the phenomenon of error, investigates origin of error, the myths about error, the taboos associated with it. Our aim is to analyze the views on errors and arrive at a proper understanding about it.

In the introductory chapter *Introduction* provides the general view on error. Until now we have discussed some popular quotes on error. It may give us a basic conception of common attitude towards error. We all are concern about error in many ways. Primarily we refer to error as an unwanted fact which we compel to face every day. In this chapter we would show that there may be options to handle our error in positive way. This chapter would depict a summary of our whole study. It explains the concept and context of our dissertation.

In the second chapter *Views on Error: Some Perspectives* we will explain the traditional meaning of the term 'error'. In this chapter we will take a look on the literal meaning of error. According to the literal meaning, error means wrong judgment. But we use the term 'error' in different senses: as action, as cause and as effect. At the same time in this chapter we are going through different established views on error. We will follow the different studies on error from different background. We will follow Rene Descartes' view on error from philosophical point of view. From psychological background we will discuss error following Sigmund Freud. Cognitive science highlights error from different points of view. We will point out Douglas and David's (1989) view on speech error in this context. They discussed error following cognitive science tradition. Finally Understanding the modern view on

human error we will pursue the definitions of human error given by Meister (1986), Swain and Guttman (1983), Reason (1990), Holnagel (1993), and Whittingham (2004). Discussing these literatures on error we would try to provide some general characteristics of human error.

In the third chapter *Types of Human Error* we will consider different patterns of human error occurring in our everyday life. In this framework collecting different examples of error we will try to provide a wide taxonomy on human error. In this context we would take a view on the underlying mechanism of different types of error. Though much works have been done on the taxonomy of human error so we have surveyed the literatures and collected some of those errors in this context. We will classify human error from two basic points of view:

i) The different underlying factors of error and
ii) The different outcomes of human error.

Under first type of classification we will highlight different cognitive factors behind error. In the second type of classification we will consider the result of errors. Here we will classify human error from different point of views. Considering human error as an individual action we will classify human error into two types: genotype and phenotype. We will further classify each genotype and phenotype. Genotype error may be classified into two important categories: intentional and unintentional. For a clear conception we discuss types of error dividing in five subchapters. After categorizing individual action error we will divide human error in a system into two types: active and latent.

In the fourth chapter *Examples of Human Error: A Quest for Rectifying Measures* we will provide a brief discussion of human error with lots of practical examples. In this chapter mainly we will talk about human error as a factor of adverse events. Human error is the most concerned issue as a factor of accident. We will discuss human errors in background of four different fields: medical, aviation, marine and mining. With a general view about basic medical process we will describe different steps of medical treatment. We will describe what types of medical error may take place. We will mention some precautions as measure to reduce human induced medical error.

In the field of aviation we have observed that there are some typical types of human errors responsible for aviation accident. Analyzing some incidents of aviation

accident we will try to find human errors behind that specific accident. We will give importance in finding cognitive factors behind aviation errors. We will also try to find some remedies in reducing errors in this field.

After the aviation error we will go through the human error in the sector of marine. We will discuss some incidents selected from the worldwide marine accident list. We will analyze these accidents to point out human error behind these. We will also try to identify the typical human errors in marine industry. We will take an effort to find some measure which may be useful in reducing human error in this field.

Finally in the fourth section of this chapter we are going to discuss human induced mining error. In this perspective we will follow the reports of some accidents that took place in Indian mining in the post independent period. We will try to find the common human errors in Indian mining. We will take a look on how we may reduce human error in mining.

Our fifth chapter is *Errors in Learning and Pedagogical Reasoning*. This chapter emphasizes on the importance of error in learning. We have collected some examples of different types of learning errors from relevant literature. In this context we will go through in three different fields. We will follow the learner's errors in conducting experimental procedure, learning mathematics, and error in learning language. We will try to find out main sources of these errors. After that we will discuss about how we can handle these errors. In this framework we will discuss knowledge based effective pedagogy. This chapter discusses pedagogical reasoning. Pedagogical reasoning is the new comprehension of the teacher which makes learning meaningful to the learner. We will try to justify that developing own pedagogical reasoning teacher can handle learners' errors and endowed the learners with significant knowledge.

In the sixth chapter *Breaking some Myths and Exploring Utilities of Human Error* we will give importance to finding some positive aspects of human error. This chapter will try to justify that we may also treat human error in a useful way; for that it is needed to change our attitude towards both of our errors and its committers. That chapter will break some traditional myths on error and will venture toward a new view on human error. We wish that it helps us in reducing error induced adverse event in future.

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Any research work in the field of social science cannot be really completed without the help, cooperation and support of different people of the allied fields. The present study is also not an exception. I humbly seek to acknowledge the immense contributions of those persons without whom this work would not have been possible.

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Chapter1

INTRODUCTION

Chapter 1

INTRODUCTION

'To err is human" is a century old saying; at the same time, a sense of shame, guilt and inferiority all go with error. We are immensely influenced by error many times. Ramayana begins with an error when the king Dasharatha mistakenly killed the son of Shantavan (Andhamuni), Shravan Kumar. Hunting in a forest hearing the sound of filling a pitcher (the king failed to identify the actual cause of the sound) hoping to hit an animal the king unleashed an arrow. While the king went for collect his kill, he was shocked to find that his arrow had fatally struck a teenage boy. The boy told the king that he had come to the lake to collect water for his parents. Though his parents were both blind and aged they had lived on his dependency. With his dying breath, Shavran requested the king to take water to his parents and make them to know what happened. After saying his tale, the boy died. Dasharatha took water for Sravan Kumar's parents and told them of his tragic mistake. They were too shocked for this incident that despite acknowledging that it was an accident, they cursed Dasharatha that he too would experience "Putrashoka". Thus the entire epic follows as a consequence. On the other hand human psychology of error is also very strange. We may compare it with the greatest wonder explained in another Indian epic Mahabharata. In Mahabharata a critical question asked by Dharma the king of Morality that, what the greatest wonder in the mortal world is. Wise Yudhisthira answers that, day after day countless people die, yet the living wish to live forever; people believe they will never die.[1] In the context of human error also it is indisputable that everybody commits error; in addition it may be said that each one among us generates uncountable errors in a day; even after that everyone tries to justify that he is not responsible for any error. More or less every human being has a common tendency to cover up his/ her error. It is to be noted that this error hiding mentality is an important issue behind most of the accidents. It is also true that socio-

[1] Roy, P. C. (1983).The Mahabharata of Krishna-Dwaipayana Vyasa, Translated into English Prose from the Original Sanskrit Text. (2nd Edition), Calcutta, Oriental Publishing Co.

cultural background is mainly responsible for this kind of attitude. A large part of our society considers error as negative occurrence or bad luck. This thesis attempts to study the phenomenon of error, the myths about error, the taboos associated with it and our aim is to analyze the views on errors and arrive at a proper understanding of it.

In our daily life we all feel sad in committing error mainly because we do not intend to commit it. It just takes place as our unintended action. The following saying by US politician Hugh White (1773 - 1840) may heal our pain with a hopeful assurance "When you make a mistake, don't look back at it long. Take the reason of the thing into mind and then look forward. Mistakes are lesson of wisdom. The past cannot be changed. The future is yet in your power." [2]

It indicates that, errors may be recoverable if we can find out the reason of its occurrence. We can gain experience from our error and it may help us to make future actions flawless. For that we have to change our attitude towards error. In accepting error in an unprejudiced sense we need to know what error is.

There are many synonyms for error. When we do something stupid or when our carelessness leads us to a very awkward situation, we refer to it as 'blunder'. As an example 'The Government had blundered in its handling of affair'. Likewise sometimes we say 'It was his fault that we were late'. Here 'fault' means the 'failure in commit responsibility for something/some incident'. Sometimes we use error as 'mistake'. As an example, 'it would be a mistake to ignore his opinion'. We also consider 'forgetting' as an error.

In this context it is quite reasonable to ask that why are we going to explore error? In answering this question we may say that we commit uncountable errors in our day to day activity. Each of them is different according to their background and consequences. In finding the underlying causes of error we observe different cognitive factors behind them. The positive side is that, by handling these underlying factors we may reduce our error.

[2] Quote of Hugh White cited in *The Quotations Page* Retrieved on (12.12.2015) from http//www.quotationspage.com/quote/2726.html

Another point is that, we often withhold most of our errors. We give importance to errors only which results harmful adverse events. But this attitude provides us fake overconfidence in thinking that we are almost perfect. This mentality of common people often leads us to do erroneous action in future. On the other hand if we think that our every action may lead to error that will make us conscious in doing a work; it will make us properly attentive to our activity.

In most literature on error it is accepted that, attention failure is an important factor of error; but when we think analytically we observe that attention failure may take place due to many reasons. It may occur due to some external occurrences or for some internal cognitive factors. In finding grounds of errors we may search from two perspectives: external and internal. Memory span, limit of intelligence, habits are examples of internal factors behind human error while fatigue, working pressure, lack of communications are external factors behind it. So, these findings about error show that we may categorize error from different perspectives. And a wide taxonomy of error may give us a vivid picture about human error. This attempt will helps us to be cautious about future action.

Theoretical conceptions of error are not enough to understand error. We need to be concerned about human error in the context of practical field. In practical field human error is mainly referred as a factor in occurrence of severe adverse event. There are many underlying factors behind a successful action. It is also true that any system is operated by human being, so for any type of failure human beings will be ultimately responsible. Practically we blame agent on the ground that we believe only he/she is capable to correct an action before it results to an adverse event.

At this point we may explain that violation and error are not same things. We may punish the committer of a violation but not the committer of an error. If we analyze a list of severe accidents in different field we will observe there are many human errors behind an accident. It may happen that, some human errors were avoidable but it is not necessary that in every case operator was solely responsible for the unwanted incident. A system continues by teamwork. A backup procedure is always maintained there. So when we limit our thinking in blaming the operator of the sharp end, it is just the beginning of another error. Although this thinking does not imply that the operator is not responsible for this action. We want to say operator of the sharp end is

not the only person responsible for a blunder. There is also a blunt end of the failure. Persons who are indirectly responsible to a system failure are the blunt end of that incident. Supervisor, designer all are the example of the agent of the blunt end. So in explaining a system breakdown it is necessary to be concerned about the responsibility of all of them. If anyone among them ignores his/her error may lead to a more severe accident later. And then it would be consider as a crime. In this context following quote of Chinese philosopher and reformer Confucius (551 BC - 479 BC) is very significant, "Be not ashamed of mistakes and thus make them crimes."[3]

In this context another relevant quote of Albert Einstein is: "A person, who never made a mistake, never tried anything new."[4] That means error is a mean of venturing into something new. So error is not a mark of misfortune. Without error nobody can move on to his future. When someone attempts to do an action he may have a plan; but it is not necessary that situation will be always flawless. There are so many probabilities in the world; every time situation surprises us. Based on the current situation we may manipulate our execution; we can change our previous plan. So it is very natural that sometimes we become unable to perform exactly that which can lead us towards a successful action. As a result we fail to achieve the desired outcome. We refer to any type of failure error. Interesting point is that, according to unanimous possibility it is very clear that at least one error is almost obvious behind every success because flawless successful action is possible but very rare. That is an accidental event.

Echoing Winston Churchill's quote "All men make mistakes, but only wise men learn from their mistakes"[5] we may say that it is obvious that we can learn from our error. We may utilize error as a learning process. *Trial and error* is a renowned process of learning. There each trial act reinforces the agent if he gets success. Error will be an essential process of learning only when one can utilize it in a fruitful way. There are two significant quotes where the importance of learning is well mentioned. First quote is conveyed by Stephen R. Covey "Don't argue for other people's weaknesses. Don't argue for your own. When you make a mistake admit it, correct it, and learn from it

[3] Confucius . Retrieved on 12.9.2015 from http//quotationspage.com/quote/2725.html
[4] Einstein, A. (Retrieved on 12.9.2015) from http/quoteinvestigator.com/2014/12/16/no-mistakes/
[5] Charchil, W. (Retrieved on12.9.2015) from http//think.exist.com/quotation/all_men_ make_mistakes.../15788.html

immediately."[6] In this context another quotation may be relevant from Al Franken "Mistakes are a part of being human. Precious life lessons that can only be learned the hard way unless it's a fatal mistake, which, at least, others can learn from." [7]

In the literal meaning of 'learning' errors have an important efficacy. Errors represent the conception and misconception of students. Following learners' error the teacher prepares his lesson plan. Sometimes a specific pattern of error points to the un-effectiveness of the teaching process. If most of the students of a class commit similar type of error that may indicate loop holes in the teaching method. On the other hand specific error pattern of a single student may point to some kinds of learning disability of that particular student. So in both cases of effective learning and teaching procedure analyzing students' error is a very important matter.

In our everyday life we often criticize other's erroneous action and label them as careless person; but if one asks about our own error, we feel sorry; we are spontaneously getting ready to give innumerable excuses to prove that we are not liable for the incidents. Finding reason behind this type of attitude, Henry C. Link said "While one person hesitates because he feels inferior, the other is busy making mistakes and becoming superior."[8]

Finally we may say 'fallibility is intrinsic to human behavior"[9] which coincides with the meaning of our opening sentence. As I do, everybody does error though we know only our own. That may lead us to think that 'I am the only one who commits error and we should hide it'. But the fact is that, this type of common attitude towards error is established on the basis of some false myths on error. In this thesis we are going to explore some facts about error. We would address the following topics: what human error is; why they take place; what may be its probable consequences; what cognitive factors lie behind error; how human errors can be handled; and finally, finding some positive aspects of human error.

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6 Covey, S. R. (Retrieved on 1.06. 2016) from http://www.goodreads.com/quotes/355120-don-t-argue-for other-people-s-weakn

7 Franken, A. (Retrieved on 1. 06. 2016) from http://www.goodreads.com/quotes/12849-mistakes-are-a-part-of-being-human-precious-life-lessons

8 Link, H. C. (Retrieved on 11.05.2014) from http//www.quotationspage.com/quote/3139.html .

9 Huafei Liao, C. F. ,Trumbo, M. C. S. and Cardona-Revera, R. E. (2014). *Cognitive Neuroscience of Human System Work and Everyday Life* (Third Edition) U. S. A. CRS Press. p. 161.

1.1 Concept and Context of Human Error

Human error is an inescapable issue of our life. We commit error, face error, feel error, and even enjoy error from different points of view. We commit error without our own consent. We face error when an unwanted result makes us disgusted. We feel error when its adverse outcome makes us regretful. We enjoy error when we can identify others committing same errors as us. Error is related to many of our emotions. On the other hand emotion induces error too. Under the spell of emotion various type of error takes place. When one is extremely upset one misses many information, when one is elated one oversees information etc. Error in action or speech is usually related to the sense of humor. Many comedies have been composed on this theme like *The Comedy of Errors*; *A Midsummer Night's Dream* etc. Errors are also powerful enough to break any human bonding. So error is an unavoidable ingredient of our everyday life. Studying different literatures on error we will try to find its different uses. It will help us to know the preliminary concept and context of human error.

1.2 Origin and Meaning of 'Error'

The word "error" comes from the Latin word '*errare'* meaning wandering or straying. According to Oxford dictionary[10] 'error' as noun means the state or condition obeying wrong in conduct or judgment. 'Mistake', 'fault', 'blunder', 'slip', 'failure' all are synonyms of the word 'error'. Following the dictionary, we are explaining all these synonyms of 'error' with examples as follows:

Mistake

Here 'mistake' is an action or an opinion that is not correct, or that produces a result that is unwanted. As an example**: '**It would be a mistake to ignore his opinion.'

Fault

'Fault' is the responsibility for something wrong that has happened or been done. As an example: 'He believes that the product's poor image is partly fault of the press.'

[10] Hornby, A. S. (2010). *Oxford Advanced Learner's Dictionary of Current English* (Eighth edition), New Work, Oxford University Press.

Blunder

'Blunder' is used to denote stupid or careless mistake. An example of it is: 'I was not sure he understood what I was saying, but I blundered on my explanation.'

Slip

'Slip' is a small mistake, usually committed by being careless or not paying attention. We may give an Example of it as: 'He recited the whole poem without making a single mistake.'

Failure

'Failure' is an act of not doing something especially that we are expected to do. An example of it is: **'**His confession followed repeated failures to appear in court.'

1.3 Different Contexts of Using the Term 'Error'

Now after discussing literal meaning of error we are going to explain different uses of the term 'error'. It may be said that, the term 'error' is used in different senses; four among them are:

i) Error as a cause of an (unintended) action
ii) Error as an (unintended) action itself
iii) Error as a process (system procedure) leads to an unintended result
iv) Error as an unintended consequence (result) of an action

i) Error as the cause

In the context where we consider 'error' as a cause of an unintended observable outcome there we mean that a specific event was caused due to human error. Two examples of this type of uses are:

a) The oil spill was caused by human error.
b) Human error is an important contributing factor of Bhopal gas tragedy.

Here we may highlight human error as a causal factor of an unintended outcome like oil spilling. Further we may provide practical example of Bhopal gas tragedy. Analyzing this accident we may say that behind this incident there are several human errors are identified as cause. Some of them are:

- System error: Locating a high risk plant close to a densely populated area.
- Operators' errors: Repressurising the tank when it failed to get pressurized.

So when we discuss these contributory factors in Bhopal tragedy, we refer to these errors as cause. Thus, it is very clear that in a vast area human error is used as a cause of an unintended outcome.

ii) Error as action

In some contexts we consider operator's action as error. Decision error or skill error and perceptual errors (p.) are the examples of this type of concept. In decision error the operator's decision is an error (e.g. Helmreich, 2000). As an example: In Bhopal tragedy issuing orders by the authority for washing when MIC tank failed to be repressurised was a management error.

Here the term 'error' is treated as action. Here considered action is 'issuing order' by the management authority. This action is referred as error not because it caused an accident, but it was not appropriate for the actual situation (it is not able to produce intended outcome). If this action did not cause accident, even then it may have been treated as an error. In this study we take error in this sense. Thus error may be called action error too.

iii) Error as a system procedure

Error is also considered as a process (Sidney Dekker, 2003)[11].This concept is mainly used in a system procedure. In this sense in any system there are some kinds of specific operating procedures which lead to the intended outcome; but if any step of that procedure does not occur properly that will be titled as error. According to Shappell and Wiegmann (2001) violations are included in error only when we consider error as a process. Reason (1990) classifies error into active and latent following this conception. (Vide second chapter *Types of Error.)*

iv) Error as effect / consequence

When the result of an action is titled as error, "error" is used in this sense of consequence. Omission error, commission error are examples of this type. As an example: 'I made an error of putting milk in the black coffee.'

[11] Dekker, S. (2003). Illusions of explanation: A critical essay on error classification , *International Journal of Aviation Psychology,* 13(2) 95-106.

In this example error is used in the sense of consequence. The fact of coffee making is considered as error because this action produces one mug of milk coffee which is not intended. So, this result of operator's action may be considered as error.

It may be said thus though each synonym of error is used in deferent context, they have a similarity in pointing to an unintended outcome. There are many authors who have tried to define human error with different uses. It should be noted that each author has a distinct purpose in mind when they are formulating their definition; their definitions are mainly relevant to their context only. With the aim of finding some general features of human error, we are going to analyze error in different literature. There we will discuss some philosophers view on error and then we will analyze some popular definitions of human error in the next chapter.

Chapter2

VIEWS ON HUMAN ERROR:

SOME PERSPECTIVES

Chapter 2

VIEWS ON HUMAN ERROR: SOME PERSPECTIVES

Human error is a familiar topic in our everyday life. Error has been studied in heterogeneous disciplines. In exploring the concept of error we may venture some popular studies of error from different perspectives; but before any systemic discussion at first we need to know the literal meaning of error. In this chapter we are analyzing the different uses of the term "error" in relevant literatures. This chapter examines some significant contributions to the study of human error from different points of view. Descartes highlights human error as a resultant of disobedience to innate idea. In psychology discussion of human error has eminent scope. This study does not explain human error from hardcore psychological standpoint; but for conceptual understanding it cites Freud's view on error. Now a day's cognitive science has much interest to human error. This chapter also cites speech error from cognitive science tradition. In the last part of this chapter some definitions of human error has been analyzed.

2.1 Descartes' View on Error: From Philosophical Standpoint

Many philosophers discuss error from different perspective. In philosophy error is mainly used in two senses: invalid knowledge and incorrect means of knowledge. This study does not explain error from typical philosophical points of view; its aim is to find out origins of error and to change our attitude towards it. For a basic conception of error in philosophy this segment is going to discuss Descartes' view.

We begin this discussion with an interesting quotation from Rene Descartes, "There would be no doubt about this, except that it seems to follow that I can never be mistaken."[12] It means we cannot commit mistake but we do. It is clear that this quote

[12] Descartes, R. (2003). *Meditations and other metaphysical writings* (28th ed.) London, Penguin Classics.P. 44-45.

is represented in front of us as a paradox. Descartes gives an impressive explanation of this line in his attractive metaphysical discussion on error.

We all know about Descartes' *criterion of truth*: That which is clear and distinct to us is truth. On the other hand his *methods of doubt* implies that 'as a thinking thing I truly exist' *(First and Second Meditation*) is a certain knowledge. Following Deductive method from this truth in *The Fourth Meditation* he says that I am an incomplete and dependent thing so there is a complete and independent being and that is God. After that he says though we are dependent on God then everything of ours is coming from God. From this he concludes, "if everything I possess, comes from God and if he did not give me a faculty for making mistakes, it seems as if I could never be wrong about anything."[13] Thus according to him there is no cause of error or falsehood in 'myself'. Although he strongly admits that we commit error. "I find that I am subject to innumerable errors."[14]

In finding the cause of error he says, we have a positive idea of God as a Supreme Being; as well as we have certain negative ideas; but this nothingness cannot come from Supreme God. According to Descartes "I am like some kind of intermediate being between God and nothingness." [15].So, it may be implied that, "I was created by the supreme being, there is nothing in me by which I can be mistaken or led to error, but insofar as I also participate in some way in nothingness or non-being – that is, insofar as I myself am not the supreme being and I lack so many things- it is not surprising then if I make mistakes."[16] After that he says what kind of mistake we make depends on two causes acting simultaneously. They are:

- Faculty of knowing and
- Faculty of choosing or freedom of will

According to Descartes it is true that our power of understanding or power of willing comes from God; but that does not mean God is responsible for our error. According

[13] Ibid. P. 45.
[14] Ibid. P. 45.
[15] Ibid. P. 45.
[16] Ibid. P. 45.

to his explanation the main cause of error is that 'we do not use our freedom of choice correctly[17]'.

So Descartes admits that we have freedom to use our faculty of knowing. When we use this faculty properly then our knowledge will be certain and if we do not use the faculty correctly then we fall into error. Descartes in his *The Principles of Philosophy (part one)* cites four causes of error. They are:

i) The principle cause of error in our childhood is prejudices. According to him "During our childhood, our mind was so closely joined with the body that it had no time for any other thoughts apart from those by which it sensed things that affected the body."[18] He also cites that our childhood mind does not refer to anything outside itself. It cannot make difference between sensation of taste, sound, smell etc which do not represent anything located outside these thoughts and mind's perception of magnitude, shapes, movement etc which are certain kinds of modes of things that existed outside those thoughts. These all prejudices of childhood always result in error.

ii) Explaining the second cause of error Descartes cites that we cannot forget our childhood prejudices and that also leads us to error. Though our mind becomes mature day by day and we discover that many of our previous judgments are proved as false, many of our childhood memories are not erased. And such memories can be the causes of many errors. Descartes gives an example of it:

"We imagined from our childhood that the stars were very small; however even though astronomical reasons show as clearly that they are very large, our prejudice is still so strong that it is very difficult for us to imagine them other than as we formerly did."[19]

iii) Describing the third cause he cites, "the third cause of error is that we become fatigued by thinking of things that are not presented to our senses; as a result,

[17] Ibid. P.48.
[18] Ibid. P.140.
[19] Ibid. P. 142.

we are inclined to make judgments about them on the basis not of our current perception but of a preconceived opinion."[20]

iv) Finally, Descartes points out use of language as a cause of error. According to him we often link our concepts with words which do not correspond accurately to things that may also lead us to error.

So we may say that Descartes view on error is quite similar with the traditional concept of error. It considers error as false judgments or false conceptions of an object. In contemporary understanding, error refers to human action also. From that point of view human error is an intentional action which caused an unintended outcome. For a clear conception we will analyze some other established definitions on human error in the modern era in the end of this chapter. In the next section we will discuss error from psychological standpoint following Sigmund Freud.

2.2 Freud's View on Error: From Psychological Standpoint

It is interesting to note that error has been viewed completely differently in psychology. In this context we are going to glance at Freud's view. In any discussion of error Freudian slip is a well-known topic but here we are not discussing Freudian slip but error theory of Freud. We followed the three lectures delivered by him on error collected in the books *General Psychology of Psychoanalysis*. In these lectures Freud does not give any definition of error or he does not establish a general theory of error. He was investigating that, whether there is any significance or importance of error in process of psychoanalysis or not. Even after that we are discussing error following Freud because although he does not establish a theory of error but in these lectures he also gives a clear view of error. In these lectures he mainly discusses slip of tongue phenomenon. He emphasizes on this type of error not because he had special kind of interest on speech error, he choices this type of error just as an example of one type of error. He analyzed examples of this kind of error with this belief that basic characteristics of slip of tongue will be applicable to all types of error.

In the second lecture Freud starts his discussion about error in giving some examples of it. He gives examples of various kinds of error. In these examples he refers to the

[20] Ibid. P.142

errors which are committed by an individual not by a group or team. Speech error is an example of individual error. Explaining error in speech he says it is an error in which one wishes to say something but uses wrong word; he gives example of writing error which happens to a person in writing. He gives example of misreading, in which one reads something different from what is actually printed or written there. He discusses mishearing as a similar phenomenon of misreading. There without any disturbance of the auditory function one hears different than what was actually uttered. He also gives example of forgetfulness as error. According to him forgetfulness is one type of error and when one cannot recall a name which is well-known to him. Same as when one forgets to carry out a specific project at the proper time what he had set in his mind again and again all are examples of forgetfulness.

Here it is noticeable that according to Freud error is one kind of action, where according to rationalist philosopher error is one kind of irrationality. Freud by error means erroneous action. He points that in all types of error there is a similarity. And in language also this tradition was followed. In a footnote he indicates that, in German language all erroneous action is expressed by using prefix 'ver'. Such as-

- Slip of tongue: *verprechen*
- Slip of pen: *verschreiben*
- Misreading: *verlesen*
- Mishearing: *verhoren*
- Forgetting: *vergessen*
- Mistake at cooking: *verkoche*
- Laying in a wrong way (mislaying): *verlegen*

So this similarity in using the term 'error' in language also justifies that there is a correlation in all these types of action.

At first he analyzes some examples of slip of tongue occur in our everyday life. He points that there are some general conditions behind all these types of error. According to Freud generally it seems to us that these following conditions are related to the person who commits error. Someone may commit error in the following circumstances:

- When he is ill or
- When he feels fatigued or
- When he is getting excited or
- When he is distracted from his goal

That means error is an immediate effect of a distraction of the agent's attention. And according to Freud generally this type of distraction caused either by organic or psychic factors of the committer. In this context Freud quite clearly highlights that this theory is also applicable to all types of error not only sleep of tongue. ''… one mixes up words or objects during excitement, one picks up the wrong things; and the forgetting of projects, as well as the doing of any number of other unintentional acts, becomes conspicuous when one is distracted; in other words, when one's attention is concentrated on other things.''[21]

It is also noticeable that Freud explains error as *unintentional acts.* After that he cites that there is a differentiation in these conditions of error. Illness and disorders of circulation afford indicates a psychological basis of errors. On the other hand excitement, fatigue are different sort of conditions in committing error; all these conditions of errors are physical. So according to this discussion we may say that immediate cause of errors is insufficient attention to the action and behind this inattention there is a psycho-physical base.

Freud tries to find out another issue about roots or origins of error. Giving some examples of error he points that there are some errors which are not caused by any type of inattention or there is no prominent psycho-physical conditions are exist. Such as, we often forget a proper name or fail to present a project in a proper time. So Freud believes that inattention is not only one immediate cause of error. According to him some errors such as forgetting also may occur even when people are not fatigued, not distracted or not excited, it may take place in every way in their normal state.

He also gives example of many acts which one performs in a purely automatic way and with very little attention, but which are yet carried out quite successfully. Such as the pedestrian who scarcely knows where he is going, nevertheless keeps to the right road and stops at his destination without having gone off track. He also gives example

[21] Freud, S. (1920). *A General Introduction to Psychoanalysis* (pdf book), P. 20. Source: http://www.pdfbooksworld.com. (Retrieved on 19.04.2014)

of the practiced pianist who touches the right keys without thinking of them. They may, of course, also make an occasional mistake. In this context Freud says, there are some errors which are such types of action which are most successfully carried out when they are not the objects of particularly concentrated attention, and that the mistakes occur just at the point where one is most anxious to be accurate where a distraction of the necessary attention is therefore surely least permissible. This issue is very relevant with surgical/medical error (see examples of error).

Freud emphasizes on the issue that why a specific type of error takes place. In this context he says, "When it happens that I commit a slip of the tongue, I could obviously make any one of an infinite number of slips, and in place of the one right word say any one of a thousand others, make innumerable distortions of the right word. Now, is there anything which forces upon me in a specific instance just this one special slip out of all those which are possible, or does that remain accidental and arbitrary, and can nothing rational be found in answer to this question?"[22]

Freud analyzes lots of examples collected by Meringer and Meyar (1895). Meringer was a philologist and Meyar was a psychiatrist. They find that there is a resemblance in between the said word and the intended word. But Freud highlights that most conspicuous form of slips of tongue where saying word is just opposite of the word that means to say. There is not found any sound relation or resemblance effect between said word and intended word. So, in these types of error Freud tries to find a relation of psychological association.

In this context he asserts that in some of the examples it seems that, the product of the slip also makes sense." In explaining "it makes sense" he says, "I think, that the product of the slip has itself a right to be considered as a valid psychic act which also has its purpose, as a manifestation having content and meaning."[23] This statement is quite revolutionary to our traditional concept of error. It cites that, " sometimes the error itself were quite a normal act, except that it has thrust itself into the place of some other expected or intended act."[24] Where we think error is an unusual act. Freud takes the following example when a president once said in his opening address, "I declare the meeting closed." According to Freud "When the president with his

[22] Ibid. P. 24.
[23] Ibid. P. 26.
[24] Ibid. P. 26 .

opening words closes the session of the House of Representatives, instead of opening it, we are inclined to consider this error meaningful by reason of our knowledge of the circumstances under which the slip occurred. We may say he (the president) expects no good of the assembly, and would be glad if he could terminate it immediately."[25] Thus Freud says that slip of tongue is nothing but an unmistakable expression of an intended purpose. Freud clearly declares that although he concentrates his investigations on slip of tongue but he tries to establish a general theory of error which will be applicable to all types of error. But here he just wants to say that some error may have a meaning and this meaning may have a great importance in human life and personality. "if it should turn out that not only a few cases of slips of the tongue and of errors in general, but the larger part of them, have a meaning, then this meaning of errors of which we have hitherto made no mention, will unavoidably become of the greatest interest to us and will, with justice, force all other points of view into the background."[26]

In his third lecture on error Freud says that by saying 'error has meaning' he actually means that error has a purpose or it follows an intention. In the context of inaugural address of the president he says that there it may happen that the president committed the mistake with a particular intention of terminating the session. Although Freud repeatedly says that he does not mean that the president actually wants to terminate the session but there is a possibility that this error committed by him purposefully. Thus finally Freud concludes that, errors are not accidents but valid psychic acts. Here it is very necessary to clear that in these lectures Freud was not interested to establish a theory of error he was findings the importance of error in psychoanalysis in order to do that he had to explain what is error or what is the basics of error. And exploring what is error we just pick his conception of error. And from this lectures we find that according to Freud "They are not accidents, but valid psychic acts. They have their meaning; they arise through the collaboration—or better, the mutual interference—of two different intentions."[27]

[25] Ibid. p.26
[26] Ibid. P.28
[27] Ibid. P.34

2.3 Speech Error: From Cognitive Science Standpoint

A speech error is commonly referred to as a slip of the tongue. It is a deviation from the apparently intended form of an utterance. Sturtevant (1947) explains a speech error as an unintentional linguistic innovation. Echoing Sturtevant Boomer and Laver (1968) definition is "A slip of the tongue… is an involuntary deviation in performance from the speaker's current phonological, grammatical or lexical intention." [28] Most speech errors go completely unnoticed by both speaker and hearer unless someone points them out. A typical listener hears just the content of the sound. He fails to notice that something has gone away with its original form. Many speech errors are quite subtle, and it requires a high degree of understanding to language or behavior to notice them. But most psychologists admit that slip of tongue can provide enlightening glimpses into the mechanisms of cognition. By studying speech errors one can get clear feature about mind without doing any formal psychological experiment (H, Douglus. and M, David., 1989). According to them the production of speech has often been explained in terms of a speech chain akin to a military chain of command. At the top there are high level processes basically semantic and grammatical. High level precedes and sets in motion of various lower level processes. Lower level processes concerned with phonetic articulation and intonation. The lowest level consists with actual motor activity to the speech organs. Basically speech errors can be committed at any level high or low.

Malapropisms

The word 'malaprop' comes from the French term *mal a propos,* which means "inappropriate". Malapropism is an inadvertent substitution of one word for another. Usually this type of error is engendered by a strong phonetic similarity. According to Oxford Dictionary[29] malapropism is a mistake committed by the speakers when they use a word sounds similar to the word they wanted to use, but means something different. According to linguist Aitchison, J. (2012)[30] malapropisms tend to maintain the part of speech of the originally intended word. An example of Malapropisms is:

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[28] Boomer, D. and Laver, J. (1968) Slip of Tongue. *British Journal of Disorders of Communication (*3) p.4

[29] Hornby, A.S. (2010). *Oxford Advanced Learner's Dictionary of Current English* (8th ed.), New Work, Oxford University Press.

[30] Aitchison, J. (2012). *Words in the Mind: An Introduction to the Mental Lexicon.* (4th ed.) Oxford , Wiley.

*"*My father came from Scotland into the U.S *vis-a-vis* Canada." (*'via'* was intended)[31].

Following cognitive scientists we may say that our mind is full of conceptual associations. If concepts are visualized as regions in the mind, then a conceptual association would be an overlap of two such regions. Malapropisms show that one type of overlap can be phonetic. But it is not necessary that in malapropism, the erroneously retrieved word has a close semantic relationship to the desired word. By contrast, in many of this type of errors considered semantic overlap is of essence.

Spoonerisms

Oxford Dictionary defines spoonerism as an accidental transposition of the initial sounds or other parts, of two or more words. According to this explanation spoonerism refers a mistake in which you change around the first sounds of two words by mistake when saying them, often with humorous result.[32] So in simple words the term "spoonerisms" designates a swap of the initial sound of two proximate words. An example of spoonerisms is-

"*well-boiled icicle*" for "well-oiled bicycle**."**

"*Foon and spork*" (spoon and fork)

In this example we saw that spoonerisms almost always stay within the bounds of phonetics. According to Douglas,H and David,M. (1989) "spoon and fork" would never be spoonarised as "fpoon and sork". They explain "This indicates that an autonomous process in charge of phonetic alone is at work in the mind during speech production."[33] Another characteristic of this type of error is this type of error is unintentional.

Mixed metaphors and infelicitous metaphors

Mixed metaphor is a combination of two or more incompatible metaphors or idioms that produce a ridiculous effect. It is an utterance containing two metaphors in quick succession. It evoked imagery that in some way is incompatible. An example of it is:

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[31] Hofstadter, Douglas, R. and David, M. (1989). To Err is Human; to Study Error-Making is Cognitive Science. *Michigan Quarterly Review* 28 (2), p.187

[32] Hornby,A.S.(2010). *Oxford Advanced Learner's Dictionary of Current English* (8th ed.), New Work, Oxford University Press, p.1491.

[33] Hofstadter, Douglas, R. and David, M. (1989) To Err is Human; to Study Error-Making is Cognitive Science. *Michigan Quarterly Review* 28 (2), P.189.

"The child wanted to sleep on the sofa, but his father *put his foot down with a firm hand* and made him go to bed." (Here in this sentence there is a combination of two metaphors 'put ones foot down' and 'with a firm hand' which is produce in an unintended manner.)

An infelicitous metaphor is an utterance containing just a single metaphor that evoked descriptions that interacts with the context in an unintended manner. Douglus explains this mistake with following example where a British radio announcer utters, "Welcome to Israel, a *mecca* for tourist!" (Here for the announcer the term *mecca* had lost its connection with the Islamic religion and thus it becomes an inappropriate mixture of imagery).

In most contexts the specific imagery metaphor is so feebly activated that neither the speaker nor the listener "hears" the connotations of the imagery. In some special cases, the imagery may be strongly brought to mind and conveyed to the conscious level. In that case the significance of the understanding with certain concepts or images explicitly mentioned in the surrounding context. It is noticeable that any time any metaphor is used; its meaning is always at least to some degree activated in the unconscious minds of speaker and listener. Otherwise there would be no way for cognitive mechanism to recognize potential clashes.

Errors involving spreading activation

In explaining the notion of spreading activation cognitive science agrees that at any given moment in a particular person's mind, different concepts are activated to varying degrees. Like liquid a concept flows from a highly activated one to its associative neighbors. This type of errors provides strong evidence for such spreading activation. Here is a typical example of it is: If it is wanted the answer of the question as fast as you can: "What do cows drink?" Almost everyone finds that the answer "*milk*" comes to mind instantaneously. And it is clearly wrong. It is not tough to make out why this occurs. For anyone in our culture, the concepts "cow" and "drink" are both near neighbors of the concept "milk". And each of them has been activated by the question itself. So some activation from each concept ("cow" and "drink") spreads to the concept "milk". As a consequence milk is highly activated and the tongue, eager to answer rapidly. Thus our sense organ activated unquestioningly what the

mind hold out. Thus spreading activation provides a simple and elegant explanation of this error.

Malaphors

Malaphors are extremely common form of speech error. We may say malaphor is a blend of malapprosim and metaphor. Missouri and Rolla (1975) called it "syntactic blends". Malaphor designates a seamless blending of two or more stock phrases into a single phrase. In this error there are often two or more phrases that can bubble up in the mind and interact with each other in unexpected ways. In metaphors spreading activation plays the key role. Speakers have at their disposal an enormous repertory of stock phrases, linguistic chunks, metaphors, idioms, proverbs and colorful images from which they draw malaphor. An example is: "That was a *breath of relief."* (Here a "breath of fresh air" and "a sigh of relief" in advertently spliced together by the speaker). This type of error may be divided into two types:

i) Malaphors involving stock phrases and
ii) Malaphor involving single words

An example of *Malaphors involving stock phrases* is: *You hit the nail right on the nose*. In this example the erroneous sentence is a combination of two sentences: "you hit the nail right on the head" and "that is right on the nose".

An example of *Malaphors involving single words* is**:** *He is an easy go lucky fellow.* **(**Here the error is a blend at the word level "happy" and "easy". And the sentences are "happy go lucky" and "easy going*".)*

Mixed modality error

A Mixed modality error occurs when an action appropriate to a specific type of activity but mechanically applies to another type of activity. Almost always there is an understandable cause for the interchange that is the intended and performed actions are conceptually similar on abstract level. An example of it is: A post office clerk to the customer next in line: *'main street post office.'* (According to the example the clerk having just answered a phone call, she was still in telephone answering mode.) *[page 54]*

Capture error

A capture error occurs when one action sequence smoothly switches over into another more habitual action sequence. According to H,Douglas and M,David (1989) 'What triggers the switching over is the sharing up to particular action by the two sequences and this allows the second to "capture" controlled from the first.'[34] They give an example of it as: A writer (author) frequently adds a final 't' to two words that end in 'ough' , as in "*enought"* or "*throught*" , presumably having been captured by the high -frequency word "thought". We will explain this error in details in the Third chapter *Types of Error [page 55]*.

Cannibalism

Cannibalism is the eating of a word by an identical or similar word just before or after it. An example of it is: 'Hey look –an *MIT* shirt*'*. In this example the phonetic identity of two distinct units caused the two to be collapsed into one. Here the 'tee' of tee shirt was swallowed by that T of MIT.

Cannibalism is often produced in writing. Some theorist maintains that high-level thoughts involve writing in a rather straightforward descending hierarchy. They say, "A thought is translated into specific words, each of which is then translated into a sequence of abstract letter categories, which in turn are converted into sets of instructions for specific letterforms, which finally are realized on paper by familiar muscle actions."[35] Thus according to them cannibalisms reveal that an accurate account of the process of writing is much more involved. All these levels of representation in writing coexist simultaneously in the mind. And our mind is able- at least it has potentiality-to interfere with each other. Thus it is causing the suppression and inappropriate reasons. And for these finally spoken or written units as small as an individual stroke inside a letter, and as large as an entire phrase inside a sentence.

2.4 Some Definitions of Human Error

There are many definitions of human error given by the researchers in different fields. It may be said that each of these has a different perspective. Here we are discussing some popular definitions with the aim to get a basic conception of human error. In this

[34] Ibid. p.203
[35] Ibid, p. 205.

context we are going through with Maister (1966), Swain and Guttman (1983), Reason (1990), Hollnagel (1993), Whittingham (2004), and a research group of International Civil Aviation Organization (2012). All these definitions are discussed in brief below:

Meister's view on error

Defining human error Meister (1966) says "An error is a discrepancy between the operator's actual performance and the performance desired of him"[36] Maister gives this definition in the context of ergonomics. Ergonomics is a synonym for human factor. in general sense it is also used for engineering psychology (O'Brien and Meister, 2002) According to International Ergonomics Association "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Practitioners of ergonomics and ergonomists contributing to design and evolution of tasks, job, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people. Ergonomics helps harmonize things that interact with people in terms of people's needs, ability and limitations." [37] Ergonomics is a system-oriented discipline but now extends across all aspects of human activity. Meister (2002) explains at the beginning human performance was tested only comparing with machines. It was one type of trial and error process. The human either could or could not function with the machine. If the human could not match up with the machine, second one was selected until the right match was made. But now it is admitted that human factors may be of several types. We may include all of them in at least under three heads: physical, psychological/cognitive and organizational. Following cognitive ergonomics Meister (1966) explains failure as a broken chain of psychological functions. According to him any human behavior has a common sequence of psychological functions and there are three basic elements of it. They are: stimulus, organism and response. He explains these three basic psychological functions as below:

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[36] Meister, D. (1986). *Human factors and Evaluation,* NewYork, Elevester science publishing company, P. 249.

[37] International Ergonomics Association. *What is Ergonomics*. Source: http://www.iea.cc/. (Retrieved on 11.03. 2016)

Stimulus: In this context stimulus means perception by the senses of external cues which carry the information that an action should be carried out.

Organism: Organism is the way these stimuli are interpreted. It is the formulation of an appropriate action and the planning of how that action should be carried out.

Response: Response is nothing but the execution of the planned actions.

According to Meister (1986) when any element of this chain is broken, a perfect execution cannot be achieved. In explaining how the chain of execution may break, he points out following causes:

- A perfect execution cannot be achieved when the agent fails to possess stimulus.
- When operator is unable to discriminate among various stimuli it leads him/her to erroneous action.
- When the operator misinterprets the meaning of stimuli, it also may cause this failure.
- When the agent does not know what response will be made to a particular stimulus that may effect in error.
- When the operator has any physical inability to respond as required to the stimuli that may also result in error

Analyzing this definition it may be said that Meister (1986) emphasizes that:

i) No single human action can stand alone

ii) Every action is a part of a sequential process.

iii) He explained human error in the light of its consequences.

So this definition of Maister (1966) is based mainly on accident case study. And another point is that here human error is referred only as a human dependent failure; but in the recent study it is very clear that though human action is a part of sequential process human error cannot be explained only by human action. Human error is not synonyms of failure or the only one cause of it but it is better to consider error as a component of a system failure, the effect of an action or a symptom of deeper trouble (Sidney Dekker, 2001).

Another noticeable point is that, this definition does not provide any hints about possibility of error recovery. Many errors are recoverable. When the underlying mechanism of any error is identified then it would be recoverable while according to Meister error is nothing but a chance factor so indirectly he admits that there is no chance of recovering. It is inescapable that there always is a chance where in necessary the plan may be spontaneously changed or execution may be manipulated for achieving intending outcome.

Swain and Guttman's view on error

Swain and Guttman (1983) gave an interesting definition of human error. They define human error as any member of set of human action that exceeds some limit of acceptability. Thus an error is merely an out-of-tolerance action, where the limits of tolerable performance are defined by system.[38]

Following this definition it may be said that:

- This definition allows the system response to determine whether an error has occurred or not.
- According to this definition a human error is a deviation from normal or expected performance where the deviation defined by the consequence.
- In this context consequence denotes some measurable characteristics of a system whose tolerable limits have been exceeded.
- This definition admits that human error can be examined to determine the cause of the deviation after it has been committed.
- It explains that in an objective assessment of human error there is no connotation of blame or fault with it. (Guttman and Swain, 1983).
- In this definition it is also indicate that if the underlying causes of the error are identified then there are chances to reduce or eliminate them in future (Swain and Guttman, 1983).

[38] Swain, A. D. and Guttman, H. E. (1983). *Handbook of Human Rliability with Emphasis on Nuclear Power Plant application. Final Report*. NUREG/ CR-1278.Wasington DC: U. S Nuclear Regulatory Commission.

The interesting point of this definition is that, it provides the concept of an "out of tolerance". This definition highlights that there are limitations in human performance. Although it is very clear that this definition of human error admits that an out of tolerance situation is caused only by human action but it does not declare that out of tolerance situations are resulted of only human error. It makes clear that human error is a member of the set of actions which results in unacceptable outcome. So it admits there are other factors responsible for such outcome. On the other hand it is also noticeable that this definition is applicable only for system error. According to the definition here system sets the limit of acceptability or fixes the limit of tolerance. So this definition does not cover individual action error at all.

Reason's definition of human error

In 1990 Reason, J. gives a very popular definition of human error, "Error will be taken as a generic term to encompass all those occasions in which a planned sequence of mental or physical activities fail to achieve its intended outcome, and when these failures cannot be attributed to the intervention to some chance agency."[39]

Following this definition we may highlight some points about human error:

- Errors take place in a series of action.
- In these series of action the operator always follows a plan to achieve a desired outcome.
- Here the series of planned action do not lead the agent to achieve their intended outcome.
- This failure may occur due to improper execution of plan or it may be for the improper plan.
- It also admits that human error and intention are inseparable. According to Reason (1990) the notion of intention comprises of two elements:
- An expression of the end state to be attained and
- An indication of means by which it is to be achieved

And both the elements take part in human error. In simple word according to Reason (1990) in doing an action there are two intentions: intention of achieving a specific goal and intention of following a plan containing specific series of actions. So if

[39] Reason, J. (1990). *Human Error*. U. K ,Cambridge University Press, p. .9.

someone reaches to the intended outcome following planned way it will be successful action otherwise it will consider as error.

Some researchers point out that, this definition focuses on the outcome or consequence of the action rather than on the action itself (Whittingham, R. B., 2004). The most important thing is that this definition excludes random or chance factors from the category of human error. This definition also covers both individual action error and system error. It accepts a pattern behind errors. This gives us a general conception of error. It consoles us that identifying the pattern of error we may predict future error and can attempt to recover it.

Hollnagel's definition of human error

Hollnagel (1993) gives a definition of human error as: "An erroneous action can be defined as an action which fails to produce the expected result and/or which produces an unwanted consequence."[40] According to this definition noticeable points are:

- Hollnagel prefers to use the term "erroneous action" rather than "human error".
- He refers to human error as the cause of *unwanted consequences.*

In the comparison of other given definitions this one provides some new conceptions but basically this represents the old view of human error. This definition considers only individual action as error. It defines error on the basis of the effect of an action. It does not indicate what may be the causes of human error.

Whittingham's definition of human error

Whittingham (2004) provides a definition of human error as: "A human error is an unintended failure of a purposeful action, either singly or as part of a planned sequence of actions, to achieve an intended outcome within set limits of tolerability pertaining to either the action or the outcome."[41]According to this definition, the defining characters of a human error are:

[40] Hollnagel, E. (1993). *Human Reliability Analysis: Context and Control*, London, Academic Pres, p. 29.
[41] Whittingham, R. B. (2004). *The Blame Machine Why Human Error Causes Accidents* , Burlington ,Elsevier, p. 6.

- The action was purposeful
- There is not any prior intention to experience failure when the agent carries out the action.
- The intended outcome of the action was not achieved within set limits of tolerability.

Analyzing this definition it may be said that this definition has many acceptable points. It covers both individual action error and system error. It considers both an action and result as error. It admits that there may be other factors than error responsible for failure. But point to be noted that it refer only to the execution of an action as error. But it does not indicate improper plan as error. That is why decision error is not included in this definition. And according to Whittingham (2004) error is only unintentional, however we have considered intentional error also (vide third chapter *Types of Error*).

Definition of human error according to International Civil Aviation Organization

International Civil Aviation Organization (2012) defines human error as: "An action or inaction by an operational person that leads to deviations from organizational or the operational person's intentions or expectations."[42]

Following the definition we may highlights some points:

- This definition refers to error as inaction by an operational person
- It covers both organizational error/ system error and individual error
- It explains error in the context of expected or intended outcome
- It considers the operator's error or inaction as the only cause of unexpected outcome
- It does not declare that error always result in adverse event

The important point is that, according to this definition same action may be treated as both error and successful action. On the other hand it may be an example where an action may be treated as violation but not an error. Here it is said that in human error the intention may be of person's as well the as that of organizations'. So it may

[42] *Safety Management Manual* (2012). (3rd ed.) by International Civil Aviation Organization, p. 20.

happen that an action has occurred as person's intention but not as the organizations' intention; so in the organizational point of view it will be treated as error but from the person's point of view it is a successful action. In that situation it may also be an example of violation which is not an error. Similarly when any person is compelled to does an unintended action following the organization demand, according to the operator's point of view it will be an error; but according to the organizational point of view it is a successful action.

Discussing these views on error, we may say that these definitions are given from different perspectives and so they cover different characteristics of human error. Moreover there are some common elements of human error which are reflected in all these above definitions. Based on these common characteristics it may be said that human errors take place as an action which always results in an unintended outcome. And though the result of an action is referred to as unintended it implies that there is a prior intention of the agent and the actual outcome does not match with his/her intention. So in very simple words it may be said that error is an intentional action with unintended outcome. These characteristics are not enough for understanding human error distinctly and so we are going to discuss different types of human error in different contexts and from different points of view in the next chapter entitled *Types of Human Error.*

Chapter 3

TYPES OF HUMAN ERROR

Chapter 3

TYPES OF HUMAN ERROR

In understanding human error it is very important to identify its origin or roots. Due to different underlying factors, errors are different. So, it is very significant to classify human error according to their causes. In this chapter we are going to classify human error from different contexts. Much works have been done on the taxonomy of human error. On the basis of the literature survey we are providing a new taxonomy of error .We classify human error from two broad perspectives: genotype and phenotype. Then we further organize genotype and phenotype error from different stand points. We also categorize human error considering it as a contributory factor of system disaster. In this context we will classify human error into two types: active and latent error. Following is the hierarchical taxonomy of error as the first kind (Fig.1):

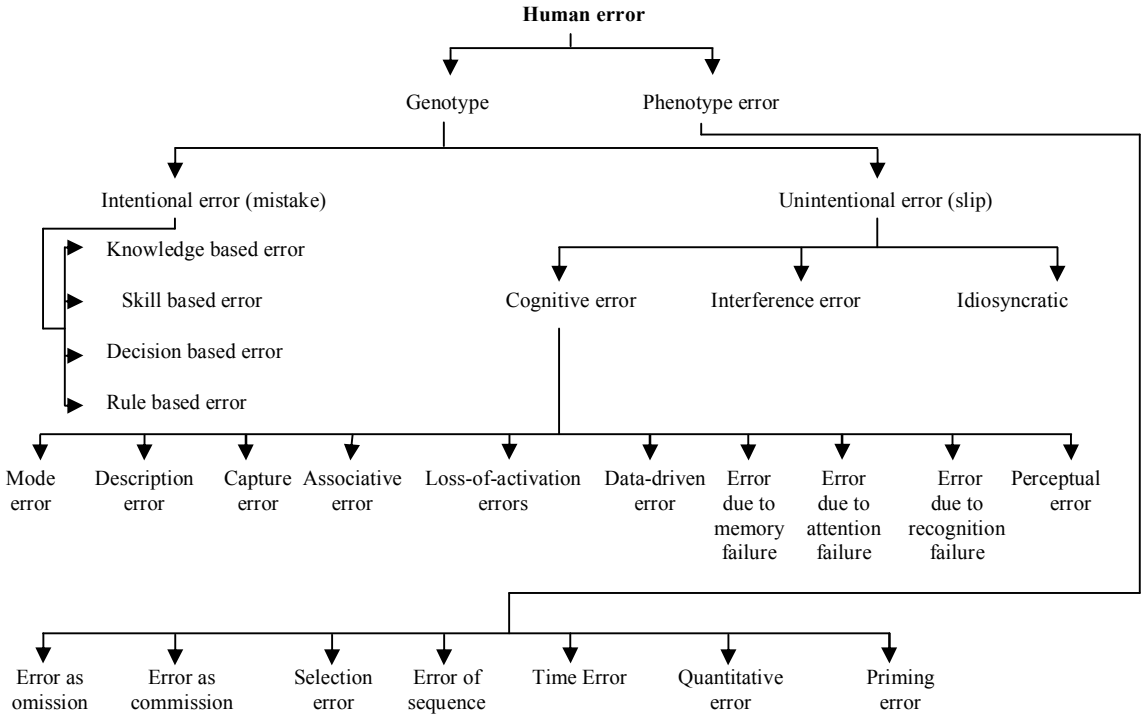

Figure -1

When we consider human error as contributory factor of system disaster it is called system error. Following is the taxonomy of system error (Fig.2).

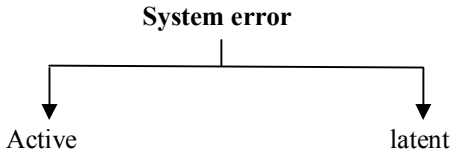

Figure -2

For avoiding confusion we will divide our chapter into five subsections: "Genotype and Phenotype Classification of Error", "Types of Genotype Error", "Types of Intentional Error", "Types of Unintentional Error", "Types of Phenotype Error", and "Types of System Error".

3.1 Genotype and Phenotype Classification of Error

When human error may take place in a system then it is treated as a human factor for a system; but each human error is an individual action. Many human beings work as a team in a system; each team member does his job according to his own capacity, so at first we need to know when an error takes place within a human action**.** Considering human error as an individual action we may make two types of classifications: genotype and phenotype. The words 'phenotype' and 'genotype' are taken from the biological sciences. Genotype is a type that is created on the basis of the 'internally coded, inheritable information' carried by all living organisms (Blamire, 2000). This stored information is used as a 'blueprint' or set of instructions for building and maintaining a living creature. A phenotype is defined as the 'outward, physical manifestation' of an organism. These are the physical parts of the organism, anything that is part of the observable structure, function or behavior of a living organism.

In the field of human error, the genotype classification of an error relates to its origin. When we classify error according to their cognitive or internal factors it is called genotype error. If an error takes place during the decision formation process or interpretation of situation will be categorized under genotype classification. Even though if a task is carried out from a proper plan and may lead to an undesirable outcome due to sudden interruption of external factor, that action also will be

considered under genotype classification. In simple words this genotype classification of error has been made on the basis of the underlying mechanism of human action process.

Another interesting point is that the factors of genotype errors may also be underlying factors of phenotype error which will be clear after discussing different types of genotype and phenotype error. So it may say that classification is little bit superficial. When a classifier categorizes error analyzing the origins of different actions it is genotype classification. On the other hand when someone classifies error observing the different unintended outcomes of different erroneous actions it is phenotype classification. Thus it can be said that the differences between these two types of error classifications reflect the distinction between cause and effect. Phenotype classification describes the outcome or result of an action and the genotype explains its causal factors in details.

3.2 Types of Genotype Error

In the second stage of the classification of human error we are categorizing genotype human errors. As we have said before that it is a classification of human error in the context of their internal mechanism. Here we classify genotype human error into two types:

- Intentional error and
- Unintentional error

Primarily we may say that when an operator intentionally does an action it is called intentional action. Similarly when an agent commits an error intentionally, it is intentional error; but interesting point is that describing unintentional error we cannot say that unintentional error is that which is done by the agent unintentionally. In unintentional error also the agent has an intention (which the agent fails to achieve in an erroneous action); so before describing unintentional error we need to clarify some confusion.

Firstly: Nobody wants to commit error; so causing error can never be the objective of one's intention, then how can we say that some human errors are intentional?

Secondly: In unintentional error there is an intention that means unintentional error is not unintentional (non-intentional) action but an intentional one (though it has a prior intention). How is it possible?

All these confusions are superficial. Preliminarily we may say 'unintentional' is not the antonym of intentional. 'Non-intentional' is the antonym of intentional. We begin with the concept 'intention'. According to Reason "The notion intention and error are inseparable"[43]. According to Oxford Advanced Learner Dictionary [44] 'aim', 'plan', 'purpose', 'intend', 'objective', 'goal', 'targets' all are synonyms for intention. According to Reason (1990) "The notion of intention comprises two elements: a) an expression of the end-state to be attained, and b) an indication of the means by which it is to be achieved."[45] So following Reason's explanation of intention we may say that in all intentional action there is an expression of the *end state to be attained*. In simple word an expression of the *end state to be attained* means expression of intended outcome. And the means by which the end state to be achieved indicates planning of the action sequences following which the intended outcome is to be attained. So intention is a mental state it comprises of two elements: the intending plan for the action and the intending outcome. In this context Searle's view on intention is very relevant. He says "Action and perception on my account are is a causal and intentional transaction between mind and the world".[46] According to him every action is composed of two parts: an intention, and a movement. The intentional component is mental and it is the causal component of the movement. That means all action must be caused and sustained by a form of intentionality. In this context he introduces two types of intention: prior intention and intention-in-action. Following Searle (1983) the Dictionary of Philosophy of Mind explains *prior intention* as an intention to act formed in advance of the action itself. It is the planning or mental projection of an action. According to Searle only premeditated or delivered action is caused by prior intention. On the other hand according to him all action must contain intention in actions as one of its constituent component. Intention in action is not formed in advance of the action is concerned; it is the cause of the any type of agent's

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43 Reason, J. (1990). *Human Error*, New York, Cambridge University Press, p. 5.

44 Hornby, A. S. (2010). *Oxford Advanced Learner's Dictionary of Current English* (8th Edition), New Work, Oxford University Press.

45 Reason, J. (1990). *Human Error*, New York, Cambridge University Press, p. 5.

46 Searle, J. (1983) *Intentionality: An Essay in the Philosophy of Mind* U. K , Cambridge University Press, p. 130.

bodily movement. But he highlights that the causal domain of the intention in action extends only as far as the bodily movement of an action; (Searle 1983.p.95) it does not cover the overall goals or conditions that such movements are supposed to bring about. According to him spontaneous action like gesturing while talking or pacing while thinking deeply is performed without formulating a prior intention but it necessarily contains intention in action. He says "The intentional content of the intention in action and experience of acting are identical."[47] Thus following Searle we get two types of actions:

a) Premeditated or delivered action is caused by prior intention.

b) Action which is not premeditated is caused by intention-in-action.

Spontaneous actions are included in this type.

Distinguishing the varieties of intentional behavior Reason (1990) provides an algorithm. There he explains five types of behavior: involuntary or non-intentional, spontaneous or subsidiary action, unintentional action (slip or lapse), intentional but mistaken action, and successful action. According to him an action where there is no prior intention or intention in action it is involuntary action. An action where there is no prior intention but there is an intention in action it is spontaneous or subsidiary action. If an action with prior intention proceeds as planned and it achieves the desired end it is successful action. When the action with prior intention does not proceed as planned it is unintentional action. And if the action with prior intention proceeds as planned but does not achieve the desired end it is intentional but mistaken action.

So according to Reason (1990) error is an action with prior plan. It does not achieve desired end or does not proceed as planned. There is two types of error: intention and unintentional. Intentional error is also called mistake. According to him, "Mistakes involve a mismatch between the prior intention and the intended consequences"[48]. It may be described as planning failure. On the other hand unintentional error includes slips and error which may be described as the discrepancy between the intended

[47] Ibid. p. 91.
[48] Ibid. p. 8.

actions and those that actually execute. Thus unintended error is nothing but execution failure.

Following Searle (1983) and Reason (1990) we may explain different types of action as following:

The action which occurs without any intention (prior or intention in action) is an *involuntary/non-intentional action.* 'Crying of pain' is an example of involuntary action. On the other hand when an agent does an action for achieving something mental or physical states of affair it is *voluntary action.* Voluntary actions are two types: action with intention in action or spontaneous action and action with prior intention. When an action is caused by intention in action it is considered as *subsidiary or spontaneous action*. According to Reason (1990) 'starting the engine of a car by the driver' is an example of spontaneous action.

Action with prior intention may be divided into two types: action which proceeds as planned and action which does not proceed as planned. Action which does not proceed as planned is described as execution failure. It is called unintentional error (*slip or lapse*). 'Putting salt instead of sugar in the coffee mug' is an example of *unintentional error.* Action which proceeds as planned is intentional action. It may be farther divided farther into two types: successful action and mistake. Successful action achieves their desired end and mistake fails to achieve desired end and proved as planning failure. 'Captain reduces the speed of the ship to avoid collision but he failed to avoid collision' is an example of mistake or intentional error. And when someone satisfactorily delivered his lecture according to his paper in is a successful action.

So neither spontaneous action nor non-intentional action is included in error. Only intentional action with prior plan can be included in error. And error and success are defined by the outcome (end state) of the action. Primarily if an agent achieves his intended outcome following the prior plan it is a *successful action.* On the other hand according to the established definitions of human error (vide second chapter) it is an action where operator fails to achieve his unintended outcome. So it may be said that the action which can be titled as error has at least four basic elements. These are:

i) There is an intending goal or desire states of the agent. In other word in this error there is a conception of the mental or physical states of affair which the agent wants to achieve by doing the specific action.

ii) Here the agent has an intending action process or prior plan following that the agent wants to achieve the intended outcome.

iii) There is an execution of the prior plan by the agent in other words there is a bodily movement of the agent caused by the prior intention of the agent.

iv) A comprehensible outcome must be resultant of the executed action.

Thus human error cannot be an action which has no intention (non- intentional or involuntary action) or which has no prior plan (spontaneous action).Now we are going to compare human error with successful action. As we have said that in a successful action an agent achieves his intended outcome by doing a specific action. But it may be said that successful action may be of three types: intentional, spontaneous and unintentional. When an agent achieved his intended outcome following a prior plan it is *successful intentional action;* when he achieves the desired outcome doing a random/unplanned action it may be called *successful spontaneous action*, and when the agent has a prior intention and he fails to follow it but achieves intended goal it is called *successful unintentional action*. In this context we will discuss *successful unintentional action*.

Successful but unintended action

When a plan is improper and the agent fails to execute the plan but the outcome is intended it is called successful but unintended action or unintentional successful action. It means here the agent achieves the intended outcome but fails to make a proper plan and also fails to follow the intended prior plan. It is clear that this type of action does not cover error's criteria (human error caused unintended outcome). More even it may not be included in the same type of successful intentional action we have discussed before. It may be said an erroneous action results in unintended outcome but this type of action's consequence is intended; on the other hand in successful intentional action the agent executes a proper plan successfully but here agent executes the action unintentionally and fails to follow the prior plan. Reason and

Searle called it 'successful yet unintended action'[49] .We are providing an example of this action given by Searle (1980) cited by Reason (1990):

'A man intends to murder someone by shooting him. He missed, but the sot stampedes a herd of wild pigs, which tramples the intended victim to death'[50]

We have explained different types of action and compared human error with them. A point of confusion may be stated at this junction: whether errors, mistakes and slips are synonyms or not. According to the established literature of human error these three terms are not synonyms. Many researchers included mistakes in intentional error and slips and lapses in unintentional error. In the next section we will discuss this issue in brief.

So, when the agent performs an action as his prior plan but cannot achieve the intended outcome it is called human error. So, a human error may be called unsuccessful voluntary action. Human error is always voluntary because it has a prior plan and no plan can be designed involuntarily by the planner. Another common characteristic of human error is, it is an unsuccessful action because its outcome/end is always unintended. This conception will be much clear with the explanation of 'intentionality' and 'intending'.

Intentionality and intending

Before explaining intentional and unintentional error following Searle (1991) we are providing a short discussion on intentionality and intending. According to Searle (1991) "Intentionality is that property of many mental states and events by which they are directed at or about or of objects and states of affairs in the world"[51].So intentionality means the quality of directedness or aboutness of a mental state. It is not a common feature of every mental state. Beliefs, hopes, fears and desires are intentional mental sates but some forms of nervousness, undirected anxiety are not intentional. For example if someone has a belief, it must be a belief about some facts. If someone has fear it must be fear of something. But undirected anxiety or depression does not have any specific object to which the mental state is directed to. So depression or elations are also unintentional. Any action which is led by such

[49] Reason, J. (1990). *Human Error.* New York, Cambridge University Press, p. 8.
[50] Ibid p. 8.
[51] Searle, J. R. (1991). *Intentionality an Essay In The Philosophy of Mind.* Cambridge, Cambridge University Press, p. 1.

unintentional mental state or executed unintentionally is unintentional error. Reflex action is an example of unintentional action because it does not follow any prior intention.

On the other hand intending is just one form of intentionality (Searle, 1991). It means "to have a plan, result or purpose in your mind when you we do something"[52] . Intending is a mental action, it is intentional because it has an intention to achieve intending outcome. So, human error as we have said in the context of intentional error is always intentional action. After these details discussion on different type of action defining intentional error and unintentional error as following:

Intentional error

When an error refers to an action which is executed following a prior plan, it may be called intentional error. So in an intentional action agent makes an improper plan and executes it as his plan; as a result he fails to achieve intended result. This error is intentional because both planning and execution part of the action takes place as the agent had intended. Nothing forced him in chalking out an improper plan and following that. Decision error is an example of this type.

Unintentional error

On the other hand when the error is not executed following the prior plan it may be included in unintentional error. Because the execution part of this action is unintentional. In the context of unintentional error there may be two alternatives:

i) Agent fails to follow the improper plan to produce intended outcome

ii) The agent fails to follow an improper plan

In both cases, if the action results in unintended outcome it is called unintentional error. But in this context confusion as *'Are mistakes included in intentional error?'* may be raised. Here we will follow the definition of mistake given by Reason. Reason (1990) defines mistakes as:"Mistakes may be defined as deficiencies or failures in the judgmental and/ or inferential processes involved in the selection of an objective or in the specification of the means to achieve it, irrespective of whether or not the actions

[52] Hornby, A. S. (2010). *Oxford Advanced Learner's Dictionary* (8th ed.). New York, Oxford University Press.

directed by this decision-scheme run according to plan." [53]Here according to Reason's (1990) definition there are three ends of the concept of mistake. These are:

i) If the agent fails to select the proper objective/goal to achieve the intended outcome will be included in mistakes.

ii) If agent fails to specify the proper means to achieve intended outcome it will be mistake

iii) If the action does not run according to the prior plan it will also be included in mistake.

Following the previous discussions on error we may say that considering these first and second characteristics, mistake covers the criterions of intentional error; but in the context of the third characteristic, mistake is included in unintentional error. More interesting point is that successful yet unintentional actions are also included in mistakes. So comparing the definitions of error and mistake it is not justified that mistakes may be included in the heading of unintentional error, intentional error or even of error in general sense; but it is better to say that mistake shows agent's incapability in doing an action in an unintended manner.

In this junction another question is *'Are slips, lapses unintentional error?'*According to Reason (1990) "Slips and lapses are errors which result from some failure in the execution and or storage stage of an action sequence, regardless of whether or not the plan which guided them was adequate to achieve its objective."[54]

In this perspective unintentional error and slip are identical. Following Norman we define slip as an action resultant of automatic behavior. Norman also gives an elaborate definition of slip. According to him, "Slips result from a lack of attention. On the whole, people can consciously attend to only one primary thing at a time. But we often do many things at once. We walk while we talk; we drive cars while we talk, sing, listen to the radio, use a telephone, take notes, or read a map. We can do more than one thing at a time only if most of the actions are done automatically, subconsciously, with little or no need for conscious attention. Doing several things at once is essential even in carrying out a single task. To play the piano, we must move

[53] Ibid. p. 9.
[54] Ibid. p. 9.

the fingers properly over the keyboard while reading the music, manipulating the pedals, and listening to the resulting sounds. But to play the piano well, we should do these things automatically. Our conscious attention should be focused on the higher levels of the music, on style, and on phrasing. So it is with every skill. The low-level, physical movements should be controlled subconsciously." [55]

Following these two established definitions of slip we may say that if we go with definition of slip given by Reason, slips are identical with unintentional error as we have explained it. On the other hand Norman (2002) provides huge information about the underlying mechanism of slip and there is no conflict if we regard slip as unintentional error.

So finally we may say that every human error is a failure/unsuccessful action because their intended outcome is always unachieved. But if for an action the planning and execution both happens as agent's intention and the agent fails to achieve desire goal that will be titled as intentional error. On the other hand when agent does not achieve intended outcome because he fails to execute the prior plan it is unintentional action. In the next section we will discuss different types of intentional error in details:

3.3 Types of Intentional Error

As we have discussed before that when an error refers to an execution of improper prior plan, it may be called intentional error .We may categorize intentional error into four types:

- Knowledge based error
- Skill based error
- Decision based error and
- Rule based error

Knowledge based error

When errors occur due to lack of sufficient knowledge it is called knowledge based error. In this situation a problem solving process fails to proceed due to inadequate or incorrect knowledge. We consider knowledge based error as intentional because this type of error takes place when without achieving sufficient knowledge one attempts to

[55] Norman, D. (2002). *The Design of Everyday Things*, New York MIT Press, p. 106.

perform an action. It may be said that in this context it is presupposed that this type of error is avoidable when the agent has sufficient knowledge. We may explain this error with following three kinds of configurations of problem situation. These are:

- Static
- Reactive-dynamic and
- Multiple-dynamic

When the configuration of a problem remains fixed in spite of the activities of the problem solver it is called *static configuration* of knowledge based level. In this level the agent can predict which knowledge would be required to do the specific action successfully. Where the configuration of a problem situation changes as a direct consequence of the problem solving action it is *reactive dynamic configuration*. In this level the operator has to know both about the action process and its probable result. It will help him to make proper plan to achieve intended outcome. When configuration of problem is changed from two directions, with the problem solvers activity and also independent system factors, it is *multiple-dynamic* configuration. In this stage agent has requirement of a wide knowledge about the whole system. Thus he can predict consequences of his activity in the background of whole system. It can help him to take spontaneous decision or manipulate execution in necessary. After this discussion we are highlighting some issues generally associate with knowledge based error:

- People cannot get sufficient knowledge because they have limited capability of knowledge storage, where knowledge is endless.
- Most of the time people do not have tenacity to accrue sufficient knowledge.
- People are not always able to use the accrued knowledge properly.

Observing underlying mechanism of knowledge-based error and following Reason (1990) we may consider some factors mainly responsible for knowledge based error:

Selectivity of attention

In every instance, there are some special key points, logically important to solve a specific problem. If the agent can identify these points, his reasoning will be considered as accurate according to that problem. So accurate reasoning in solving a problem critically depends upon the selectiveness of operator's attention. Reversely, if

the agent gives attention to less important or unimportant features and omits which are important for the success, mistakes may take place. It may happen when the operator is distracted from the real situation and commits error. In that case the operator does not perform the action following his/her knowledge or reasoning. He or she attempts to solve the problem by using "trial and error" process; but if she or he has used his/her knowledge or reasoning he /she will be able to solve the actual problem.

It may be observed that human mind always want to do an action in their comfort zone. As an example if someone has an option to do his or her job in that format which has already been successfully used by him/her, then he/she would never want to do his/her job with a new configuration. In that case the problem solver just tries to find out the similarity between the two situations: the present situation and the previous one. He/she may search different mental models of action plan applicable for the given situation. Usually a specific kind of mental model is integrated in the mind of the agent to solve similar kinds of problem. Sometimes this activity may remove burden in a regular workplace; but in this level the operator may have a tendency to solve the problem only with the integrated mental model [56](Johnson-laird, 1983) that is not appropriate for the given situation. Cognitive strain may result in such tendency of the agent in a monotonous work schedule. Thus we may say that selectivity of the agent's attention is an important factor behind knowledge based error.

Conformation bias

In a problem solving process if the cognitive model rapidly favors specific one among all the available interpretations it may result in error. It may happen if the

[56] According to C.S. Peirce (1896) reasoning is a process by which a human examines the state of things asserted in the premises, forms a diagram of that state of things, perceives in the parts of the diagram relations not explicitly mentioned in the premises, satisfies itself by mental experiments upon the diagram that these relations would always subsist, or at least would do so in a certain proportion of cases, and concludes their necessary, or probable, truth. In 1943 describing mental model Craik says if the organism carries a 'small-scale model' of external reality and of its own possible actions within its head, it is able to try out varies alternatives, conclude which is the best of them, react to future situations before they arise, utilize the knowledge of past events in dealing with the present and the future, and in every way to react in a much fuller, safer, and more competent manner to the emergencies which face it. He explained mental model as a programmatic basis for thinking. More recently, the theory was developed to account for verbal comprehension. Thus when individuals understand discourse, they can use its meaning to construct a mental model of the situation to which it refers (Granham , 1999 and Johnson-Laird, 1983).

agent forms a general hypothesis depending on his early knowledge and missed better interpretation and improvised data which come later (Greenwald, 1986).

Over confidence

Over-confidence may be a cause of error in knowledge based level. When the problem solvers becomes over-confident in evaluating his acquired knowledge he often justify his chosen course of action only by focusing on favorable evidences and avoid contradictory signs regarding the chosen plan (Reason,1990). This tendency may lead him to overlook fresh information and as a result he makes improper plan for achieving the goal.

Reviewing the "check-off illusion"

Usually a problem solver verifies his/her action plan at some time prior to its execution. The agent checks whether he has collected all the factors relevant to the problem solving process or not. In this stage if the agent fails to consider any factor or information important for the solution it may lead to knowledge based error. In this context Shepard (1964) says "all though we remember that at some time or another we have attend to each of the different factors, we fail to notice that it is seldom more than one or two that we consider at any one time."[57] According to Reason we may fail to check relevant information due to our limited capacity of reasoning. Reason named this situation 'check of illusion'. In this context Reason (1990) cites: "In respect, we fail to observe that the conscious workspace was, at any one moment severely limited in its capacity and that its content was rapidly changing fragments rather than systematic reviews of the relevant material. We can term this the 'check-off illusion"[58].

Illusory correlation

When a problem solver is poor at detecting different types of co-variation of the situation and he has little understanding of the logic, he/she may make an illusory correlation between various situations. Many times illusory correlation leads the operator to knowledge based error.

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[57] Shepard, R. N. (1964). On subjectively optimum selections among multiattribute alternatives. In M. Shelley & G. Brayan (eds.), *Human Judgements and Optimality*.New York, Wiley, p. 266.

[58] Reason, J. (1990). *Human error*. New York, Cambridge university press, p. 80.

Halo effects

The term `halo effect' was first used by the psychologist Edward Thorndike in 1920. A halo effect is a judgment based on a single striking characteristic. According to De Soto (1961) problem solvers may be the subject of halo effect. According to him if the agent is guided by his predilection or aversion it may cause error .It may be noted here that the halo effect may be an error at the selective attention stage. It may take place when we do not pay full attention in collecting all relevant information regarding problem situation but select only most available ones.

Problem with causality

Some problem solvers often have tendency to oversimplify the causality regarding the solution of a problem. It happens because primarily operators are guided by the stored recurrences of the past. In that case they may incline to underestimate the irregularities of the future. As a consequence, they plan for fewer contingencies, than for which it may actually occur. It finally leads the performer to commit error. Improper hindsight can lead people to overestimate their ability. Hindsight means knowledge of the outcome of a previous event. Sometimes they think that they can influence the future event. This overconfidence or illusion may be resultant of errors.

Problem with complexity

According to Brehmer (1987) and his research group, strength and weakness of human cognition have relation with complexity of the problem situation and mistake. In this context following Doerner (1987) we may categorize mistake into two groups:

i) Primary mistake

ii) Mistakes made by only poor performer

Common mistakes by human beings are *primary mistake.* Primary mistakes refer to those errors which occur due to the situation. In this context Descartes' theory of error is relevant (vide second chapter p.). According to him our childhood prejudice is the principal cause of error. In that case if a problem situation is different from our prejudice then anybody may fall into error in that situation. Some causes of primary mistakes are described below:

- Insufficient consideration of process in time

It is an important cause of primary mistake. In solving a problem of a real situation it is essential to understand how the action is going to occur. It can be possible if the agent acquires knowledge from his past experiences. This type of error may take place when the problem solver has concept about present situation but he does not consider how same type of problem evolved. J, Reason (1990) gives an example of it as: "They concentrated on the amount of money currently in the city treasure without regard for the ups and downs of its previous financial fortunes."[59]

- Thinking of immediate causal series instead of causal nets

If a decision is based on immediate causal series instead of causal relation it may cause of error. In a complex system people have a tendency to think about the main effect of their action upon the path to an immediate goal rather than the side effects of it. But it may result in to a very adverse event.

On the other hand when mistakes are committed because the performer has poor ability it may be called *secondary mistake*. These errors depend mainly on operator's ability or skill. Poor self assessment is a major cause of the mistake formed by performers. There is a tendency of operator's mind to be bounded by rationality. For lack of self assessment he/she cannot apprehend the present situation and becomes unable to use his knowledge to achieve his desired goal. As a result he/she just tries to escape from the problem.

In the context of learning mathematics Dorner (1987) says, "Whenever subjects have difficulties dealing with a topic, they leave it alone, so that they don't have to face their own helplessness more than necessary."[60] In learning mathematics it is very common that whenever learner faces difficulties they leave the problem away from him. Practically hiding their helpless condition they just escape from the situation. So this error may occur when the agent does not intend to solve the problem really. As a result the action provides a random conclusion which is not accurate as per actual problem. It is called *Thematic Vagabonding* (Dorner, 1987).

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[59] Ibid. p.92.

[60] Dorner, D. (1987) On the difficulties people have in dealing with complexity. In J. Rasmussen, K. Duncan & J. Leplat (eds.), *New Technology and Human Errors*. London, Willy, p. 101.

Skill based error

Errors which take place due to lack of proper skill may be called skill based error. It is expected that the operator would have proper skill for performing an action properly. That is why before executing an action in a real situation proper training of operators is needed. In the training session if the operator is frequently able to perform an action successfully, only then he should take a chance to do that action in a real situation. So when the operator commits error due to his lack of skill it is included in skill based error.

This error is mainly intentional because the agent intentionally attempts to do this action even though he knows that he is not completely efficient to do the action. In medical field in the initial stage of his /her profession, a physician or a surgeon may commit this type of error, although in any learning period this type of error is expected; but in any case if the agent is forced to do an action without proper skill then it will be considered as unintentional error. It may also happen that the agent cannot assess his/her skill; then his/her lack of skill may cause unintentional error.

Poor technique in controlling the aircrafts is an example of this type of error (Shappell, 2001). Operators' training, experience, and educational background, pilots vary greatly in the way in which they control their aircraft.

Decision error

In Decision error agent executes his/her plan properly but the plan itself proved as inappropriate for the given situation. Generally these errors are resultant of poor choice of the agent. It may also take place where relevant information is misinterpreted or collected information is inadequate to solve the problem. Decision errors may be classified into three categories:

i) Procedural errors
ii) Poor choices of goal and
iii) Problem solving errors

i) Procedural error

When the process of an action is planned improperly it may be called procedural error. Here the selected process is not appropriate to achieve the intended outcome.

Design errors also may be included in the heading of this type of error. Here design means a prior planning of process or a system for achieving the intended goal. So where the design does not enable to achieve the intended goal it is procedural error.

ii) Poor choice of goal

When in solving a problem the operator selects an inappropriate goal it may be included in this type of error. Here it may happen that an action is executed as planned but the plan is not appropriate to solve the problem. As an example in medical field when a surgeon takes decision to operate but later it found unsuitable remedy for the patient is a poor choice of goal.

iii) Problem solving error

When the agent commits an error because he does not understand the configuration it may be called solving error. It may also be titled as understanding error or interpretation error because here the operator cannot understand the situation or cannot interpret the problem of real situation. When a physician fails to diagnose the disease may be included in this type of error. It may also take place when he/she is under time pressure, or under any type of external pressures. In that situation he cannot understand the problem situation and fails to take proper decision (Orasanu, 1993).

Finally, when a problem is not well understood by the agent to respond in the usual way, then this situation needs a conceptual decision to solve the hazard. But if in that situation operator fails to take proper decision to handle the problem, then it is included in problem solving decision error.

Rule-based error

We have said in the previous section that in performing any action there is a specific mental model of the operator. This model consists of some existing rules. These rules are parallel with many other rules which are competing with the selected rules for the right path to represent the current states of the world. When rules represent the given situation accurately to generate a successful action they will be appropriate for that situation. That is why in performing an action, selection of proper rules and applying them accurately both are very important for success. So it may be said that in rule

based error someone fails to select appropriate rules or apply them accurately. It is intentional because here rules are selected intentionally but they are not appropriate for the given situation. These errors may be divided into two types (Reason1990):

a) Error due to misapplication of good rules and
b) Error due to application of bad rules

a) Error due to misapplication of good rules

In explaining this type of error here at first we need to define what is meant by 'good rule'. According to J. Reason "a 'good rule' is one with proven utility in a particular situation."[61] Following Reason, it may be said that a good rule has the following characteristics:

- It should match with the salient feature of the environment.
- It should prove that the rule has strength to perform that action successfully. That means there are some past incidents where this rule has been used successfully to perform an action.
- The rule has special ability to describe a situation more perfectly than any other rule.

It is to be noted that selection of good rules is not enough for success. Success depends on the proper application of good rules. So where errors are resultant of misapplication of good rule are included in this type. There are some conditions where good rules are often applied wrongly:

In the case of the first exception: It may happen that some rules were repeatedly shown reliable in the past; but in the given situation there is a significant exception. In such case if the rule is applied ignoring the exceptionality of the situation application of the rule may be proved as wrong. In this context we are going to quote an example from Reason (1990). There he describes an error committed by his friend Beveridge (Reason, J. 1990): "He was about to pull out into the traffic flow after having been parked at the side of the road. He checked his wing mirror and saw a small red car approaching. He then made a cursory check on his rear-view mirror and noted a small red car still some distance away. He then pulled out from the kerb and nearly hit by a

[61] Reason, J. (1990) . *Human error.* New York, Cambridge University Press p. 75.

small red car. There were two of them, one behind other. He had assumed they were one and the same. The first car had been positioned so that it was only visible in the wing mirror."[62]

So, here Beveridge followed the rule generally which is completely appropriate for that kind of situation but here the given situation was little bit exceptional and that is why the rule failed.

In the context of using signs, countersign and non-sign: In a situation where a general rule is not applicable because there is an exception there may be at least three kinds of information indicators in interpreting the real situation: sign, countersign and non-sign. *Signs* indicate the conditional aspects of an appropriate rule; *countersigns* indicate that more general rule is inapplicable and *non-signs* indicate that the existing rules do not relate to the system. So it is clear that these three indicators help the operator to decide whether a rule is compatible with the system or not. And here it is important to notice that if any of this information giving system is not operated properly or fails to indicate the actual situation then a good rule may be unable to lead to a successful action.

When Information is overloaded: In most of the real life situations the difficulty of detecting countersigns is very common. They arise because of the abundance of information, which confront the problem solver. As a result cognitive system fails to apply a good rule properly.

When rule strength is getting low: The strength of a rule depends on the number of times it has achieved a successful outcome in the past. More victory makes a rule stronger. According to Anderson (1983) and Holland (1986) the strength of the rules depends on whether it matches with the real situation or not. A rule matches with the situation means that rule enable to solve the problem. But it may happen that there is more than one rule is applicable to solve a problem then success rate of each rule will be an indicator of the strength of the rule. "it allows for a trade-off between the degree of matching and the strength of the rule"[63]. Generally our cognitive system selects the strongest one for the system but whenever it fails then error may occur.

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[62] Ibid, p. 72.
[63] Ibid, P. 77.

When rules are redundant: As we said in the previous section that, the strength of a rule depends on the degree of matching of it with the given situation. If the matching is considered within the particular elements of a rule and the conditional parts of the given situation, they will carry more weight in the rule selecting process. In that case when a problem occurs very frequently then the cognitive system of the agent becomes habituated to identifying the sign of that certain sequence basing on their co-occurrence; but this deployment may create bias if the cognitive system has a tendency to favor only frequent sign rather than the rarer countersign.

When rules are rigid: If a rule has been employed successfully in the past then usually there is a strong and remarkably stubborn tendency to apply it again; even though when according to the given situation, a simpler and more elegant applicable solution is readily available.

When a conflict arises between general versus specific rules: It may happen that the operator is confused in applying general or specific rules. In this context Holland (1986) says "people have a preference for using rules at the lowest, most specific hierarchical level; they customarily use rules at higher, more general levels only when no more specific rule provides an answer at a satisfactory level of confidence."[64] Explaining this concept it may be said that rules are of two types: specific and general. Specific rules are applied in the lower level in the case of individual incident. On the other hand general rule is applicable in the higher level, in the context of a group of some similar phenomenon. According to Holland (1986) where the individuating information is detected and if there the action consequences do not conflict with much stronger rules at a higher level only there people should operate specific rules at the more specific level.

b) Error due to the application of bad rules

When selected rules are not appropriate for the solution of the given problem in that context those rules are referred as 'bad rules'. And when an error or system deficit generates due to the application of bad rules they are included in the heading of rule based error due to application of bad rules. In explaining the underlying mechanism of

[64] Holland, J. H., Holyoak, K. J., Nisbett, R. E., and Thagard, P. R. (1986*). Induction: Processes of Inference, Learning and Discovery.* Cambridge, MA: MIT Press, P. 205.

this type of error following Reason (1990) we may consider that a rule may be "bad" for the following factors:

- Inefficient observation of the learners in their developmental phase
- Deficiencies of the operator in encoding a rule
- Action deficiency of him/her in applying a rule in a specific situation

Inefficient observation of the learners in their developmental phase: Problem solving action may takes place in various developmental stages. According to these developmental stages the observation power of the learner are improved. In this context following Karmiloff -Smith (1984) Reason (1990) provides three main phases of developmental stages. Each phase has some specific pattern of cognitive mechanism. The phases are: procedural phase, meta-procedural phase, and Conceptual phase.

Procedural phase is the early developmental stage for a problem solving action. In this stage the behavioral output of the operator is feedback-driven or success-oriented. They arbitrarily specify a rule for a new problem. As a result they gather a largely unorganized problem solving routines and fail to choose the right one. Comparing the children's cognitive mechanism with adult's Karmiloff-Smith cites, "The adult observer may interpret the child's behavior as if it was generated from a single representation, but for the child the behavioral unit consists of a sequence of isolated, yet well-functioning procedures which are recomputed afresh for each part of the problem." [65]

In the *meta-procedural phase* children are engaged in organizing the procedural rules which are used by them in the first phase in a meaningful category. According to Reason (1990) "One consequence of this inner-directed sorting of specific rules into general categories is that these more global rules are applied overenthusiastically and rigidly, with too little regard for local cues signaling possible exceptions."[66]

In this stage of *conceptual phase* performance is guided by delicate control mechanism. In this phase there is a struck between environmental feedback and rule structures. This phase is relatively error-free; but this success is arbitrated by quite different knowledge than which gathered in previous two phases. It modulates the

[65] Karmiloff -Smith, A. (1984). *Children's Problem solving.* In J. Lamb & A. Brown, (eds.) Advances in Developmental Phychology. Hillsdale, N. J. Erlbaum, p. 6.

[66] Reason , J. (1990). *Human Error.* New York, Cambridge university Press, P. 80.

interaction between data-driven and top-down processing. So a balance is struck between environmental feedback and rule structures. These new cognitive mechanisms can provide environmental feedback without making a mess for a rule based system.

Deficiencies in encoding a rule: Encoding appropriate rules is very important in solving a problem properly. If agent fails to choose appropriate rules on account of the given situation it will be an error. We observed much error of this type in learning process. In this perspective a rule is labeled as 'bad' under following three conditions:

1. If certain properties of the problem situation are not encoded at all then the applied ruled will be labeled as bad. When the operator is unable to encode the rules this type of error occurs. In this context there is an example cited by Reason (1990): 5 years old children cannot cope with manipulating two relationships at the same time so for them two relationships based rules will be bad.
2. If certain properties of the problem situation are encoded inaccurately then the rule is entitled as bad. Accurate encoding of all process is very necessary in problem solving case. Accurate encoding means interpreting the problem situation correctly. If any section of a problem is wrongly understood it may results in error. As example in learning if any concept or a term is misunderstood by the students it makes whole sentence or theory incomprehensible to them.
3. If a domain-specific exceptional rule is applicable then application of a general rule may cause error. In this situation the general rule will be labeled as bad. When the problem solver overlooks exceptions in applying a general rule it may generate such errors. In solving problems before applying established rules it is necessary to encounter all the exceptions of the given situation. Application of a general rule in an exceptional situation may make a problem more complicated to the agent.

Action deficiency in applying a rule: It may happen that a rule enables to achieve the desired goal but there is another rule to solve the problem better. Then comparing degree of effectiveness first rule is considered as bad. From this view clumsy or inadvisable rules are examples of this type of error.

- Clumsy rules

It is possible that a specific problem has multiple routes to a solution. To resolve these problems some rules are efficient, elegant and direct; others are circuitous and occasionally bizarre. So among them the rules which are able to achieve success but bring more acute problem further are nothing but clumsy rules.

- Inadvisable rules

In a problem solving action there are some rules which are perfectly adequate to achieve its immediate goal most time but some time unexpectedly they lead to accident could have been avoided. They are not wrong or clumsy. The source of these undesired outcomes is completely unidentified. To avoid unwanted consequences in long term these rules are inadvisable.

3.4 Types of Unintentional Error

We have explained that when an action does not executed following the prior plan and leads to an unintended outcome is unintentional error. We may explain unintentional human error under three heads:

- Cognitive error
- Interference error and
- Idiosyncratic error

All these errors are un-intentional because they do not follow the agent's intending plan; they just happen due to some cognitive or external or unusual circumstances. All these types of error are discussed in details below:

Cognitive error

Human errors whose underlying factors are only cognitive are called cognitive error. We are including those errors in this type which take place in cognitive level and cannot be judged by its observable features. We may include following ten categories of error under the heading of unintentional cognitive error:

a) Mode errors
b) Description errors
c) Capture errors

d) Associative activation errors
e) Loss-of-activation errors
f) Data-driven errors
g) Error due to memory failure
h) Error due to attention failure
i) Error due to recognition failure and
j) Perceptual error

a) Mode errors

Usually mode errors occur when devices have different modes of operation and the intended action is appropriate only for one mode. In this situation if the action slips into any other mode then the appropriate one is called mode error. The root causes of this type of error underlie in the forming of intention process. When the real situation is falsely interpreted by the agent this type of error may occur. Especially mode errors take place where the device does not make the mode visible; so the user tries to remember the correct mode and when he fails to identify the correct mode of a situation this type of error occurs. Mode errors are very common with digital watches and computer systems (especially text editors). Commercial aviation accidents are often caused by mode errors. It may happen especially in the use of the automatic pilots (which have a large number of complex modes). In aviation similar pilot inputs in different modes can produce drastically different results. In this context we may cite the a320 airbus incident[67]. Following Norman we may cite an example of mode error: "I had just completed a long run from my university to my home in what I was convinced would be record time. It was dark when I got home, so I could not read the time on my stopwatch. As I walked up and down the street in front of my home, cooling off, I got more and more anxious to see how fast I had run. I then remembered that my watch had a built-in light, operated by the upper right-hand button. Elated, I depressed the button to illuminate the reading, only to read a time of zero seconds. I had forgotten that in stopwatch mode, the same button [that in the normal, time-

[67] Described in details as an example of aviation accident due to force landing in the fourth chapter. *[Page – 50]*

reading mode would have turned on a light] cleared the time and reset the stopwatch."[68]

b) Description errors

Description error is proper execution of action plan for achieving wrong object. This type of error may occur when all the relevant information needed to specify the appropriate goal is not available. It may also happen when an appropriate goal has been set, but the description of situation is insufficient for doing the intended act. So the underlying mechanism of this type of errors may be described as an ambiguity in the selection of information from memory or perception. Replacing of the lid of the sugar container on the coffee cup is a prominent example of this type of slip.

Description errors may take place when we feel bored. It may also happen when we are not inclined to pay full attention to the task at hand. Usually this type of error occurs when the wrong and right objects are physically near to each other or looks similar. It may also happen when the agent is careless about his/her action situation. A defining example of it is: "A former student reported that one day he came home from jogging, took off his sweaty shirt, and rolled it up in a ball, intending to throw it in the laundry basket. Instead he threw it in the toilet. (It wasn't poor aim: the laundry basket and toilet were in different rooms)."[69]

c) Capture errors

Capture error is a very common type of slip. When a frequently done activity suddenly takes charge instead of (captures) the intended one it is called the capture error. The basic cognitive mechanism behind this type of error is that it appears whenever two different action sequences is common in their initial stages and the alternative action is well practiced than the intended one. In that case after doing the similar part of these actions, the more familiar or more recent activity continues; as a result the intended action does not take place at all (Norman, 2002).Capture error closely related to the errors caused by external activation. In this case a familiar works takes place as a substitute for the intended action sequence. A classical example of a capture error is given by James (1890) as: "Very absent-minded persons in going to

[68] Norman, D. (2002). *The Design Of Everyday Things*. New York , MIT Press, p.110.
[69] Norman, D. (2002). *The Design of Everyday Things.* New York, MIT Press, P. 107-108.

their bedroom to dress for dinner have been known to take off one garment after another and finally to get into bed, merely because that was the habitual issue of the first few movements when performed at a later hour." [70] Another example from my own experience is: I was finding a specific date counting numbers of days from two consecutive months. It took much time, to come to a solution because after 31st of the previous month, I assumed 32 as the first date of the second month instead of 1.

d) Associative activation errors

When an intention is going to activate a relevant set of action sequences are organized in the memory, it is called schemes. Although there may be other irrelevant schemes organized in memory too .When instead of the intended (relevant) action sequences associated irrelevant schemes are activated and it leads the action to unintended outcome it is called associative activation error. This type of error is quite similar with capture error. The only difference is that, in capture error there is no formal similarity between the activated schemes and relevant schemes but in this error there is a strong association between them. This type of error often occurs in speech. A prominent example of it is "My office phone rang. I picked up the receiver and bellowed 'Come in' at it." [71]

e) Loss-of-activation errors

Where the goal or intended plan is forgotten, but the action continues it may be called lack-of-activation error. It occurs because the presumed mechanism—the "activation" of the goals—has decayed. The less technical but more common term of it would be "forgetting." According to the cognitive mechanism it may explained into three types:

- Lack of desired intention
- Disordering of schema
- Leave out steps in sequence
- Repetition of a step
- Restarting of a sequence. of some earlier stage

[70] James, W. (1950). *The principles of Psychology* (vol-1). New York, Dover publications, p.115.
[71] Ibid, p.109.

Loosing of desired intention

This type of error happens when the operator starts an action with a prominent intention but in a junction he loses/forget that intention. As a result he/she fails to achieve desire outcome. An example of it is: "I have to go to the bedroom before I start working in the dining room. I start going there and realize as I am walking that I have no idea why I go there. Knowing myself, I keep going, hoping that something in the bedroom would remind me……. I get there but still cannot recall what I wanted…. So I go back to the dining room. There I realize that my glasses are dirty. With great relief I go back to the bedroom, get my handkerchief and wipe my glasses clean."[72]

Disordering of schema

Sometimes losing activations are take place when schemas are getting disordered. Verbal disordering in sentence construction is included in this type. An example of it: "Once while jogging with a colleague early in the morning, I reported my academic history as 'I got my degree at Harvard and was a post-doc and faculty member at Penn' (exactly the reverse of the facts)"[73]

A similar incident is cited about Iswar Chandra Vidyasagar as: Once Vidyasagar intended before returning to his bed, to put his stick in the corner of his room and lie down on the bed, instead he placed the stick on the bed and stood on the corner of the room.

Another interesting example cited by Norman is: "I was at the end of a salad bar line, sprinkling raisins on my heaping salad, and reached into my left pocket to get a five-dollar bill. The raisins knocked a couple of croutons from the salad to the tray. I reached and picked them up, intending to pop them into my mouth. My hands came up with their respective loads simultaneously, and I rested the hand with the croutons on the tray and put the bill in my mouth, actually tasting it before I stopped myself."[74]

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[72] Ibid, p. 109.
[73] Norman, D. (1981). Categorization of Action Slip .*Psychological Review* , 88 (1), P. 10.
[74] Ibid, p. 10.

Leaving out steps in sequence

Leaving out step in an action sequence is another type of loss of activation. A very common example of it is in a coffee making process we may forget to put water in the coffee mug.

Repetition of step

Losses of activation of schemas also result in unnecessary repetition of step in an action sequences. An example of this type from our everyday experience is: Someone is engaging in the starter of an automobile after the engine had already been started.

Restarting of a sequence

Sometime losing activation of schemas in an action sequence may cause restarting of action sequence. An example is: "I put cigarette into my mouth, got my matches out, then intended for my lighting the cigarette I took another one out of the packet."[75]

f) Data-driven errors

If human behavior is triggered by the arrival of the sensory data as an automatic action it may intrude the ongoing action sequence; when this data-driven activity causes intended outcome it is called data-driven error. Norman gives an example of it as: "I was assigning a visitor a room to use. I decided to call the department secretary to tell her the room number. I used the telephone in the alcove outside the room, with the room number in sight. Instead of dialing the secretary's phone number—which I use frequently and know very well—I dialed the room number."[76] Another example from our own experience: After dialing number of Y, X asks to the receiver 'I'm Y may I talk with X please'?

g) Errors due to memory failure

In psychology, memory is a process in which information is encoded, stored, and retrieved. *Encoding* allows information from outside world through five sense organs. Receiving, processing and combining of received information are also included in this stage. In this context as we explain memory failure is failure of remembering learnt information so input error means improper learning in the sequences of memory

[75] Ibid, p. 10.
[76] Norman, D. (2002). *The Design Of Everyday Things*. New York, MIT Press, p. 109.

processing. *Storage* is the second stage or process of memory. Storage means creation of a permanent record of the encoded information. Finally the third process is the retrieval. *Retrieval/ recall or recollection* refers calling back the stored information in response to some cue for use in a process or activity. Memory failure means one's failure to remember something. Many researchers explain that slips and lapses may occur due to memory failure. When memory failure causes an error that may be titled as cognitive error. In this type of error there is a deviation between intended and real outcome. Main processes of storage of memory are: information processing stage, storage of the learned information, and repossession of the storage materials, and execute the retrieval data in proper time and proper place. In any of these stages memory failures may cause human error. We may explain memory based error explaining different types of memory. There are three basic types of memories. They are:

- Sensory memory
- Short-term or working memory, and
- Long-term memory

Sensory memory

Sensory memory holds sensory information for less than one second after an item is received by sensory organ. The ability to look at an item and remember what it looked like with just a split second of observation is an example of sensory memory. It is an automatic response and is out of cognitive control.

Short-term or working memory

Short-term memory allows recall for a period of several seconds to a minute without rehearsal. Its capacity is also very limited.

Long-term memory

Long- term memory can store much larger quantities of information for potentially unlimited duration (sometimes a whole life span). Its capacity is immeasurably large.

On the basis of these three types of memory it may be said that most of the information that gets into sensory memory is forgotten, but information that we turn our attention to, with the goal of remembering it, may pass into short-term memory.

Short-term memory is the place where small amounts of information can be temporarily kept for more than a few seconds but usually for less than one minute. Information in short-term memory is not stored permanently. The storage in sensory memory and short-term memory generally has a strictly limited capacity and duration, which means that information, is not retained indefinitely. Only long term memory has potentiality to storage information for unlimited duration. According to Reason (2008) in this context the commonest error is forgetting intentions. Memory for intentions is called prospective memory .Usually it has to be held in memory until the right time and place for its execution. If someone forgets his/her intention the action can never be carried out as intended. Thus memory based errors may take place in different levels. Reason gives an example of this type of error as "…in trying to introduce a person whose name you know well, but at the moment of saying it, your mind is a blank."[77] Experience of *tip-off the-tongue* is also an example of this type of error. Generally that lost word or name appears as a deliberate search usually when we are doing some routine job like washing up or vacuuming; watching TV program; reading newspaper. It could be that when we are doing some other external source the word or name is mentioned somehow and we recognize it as the item we have been searching. Some common incidents of memory failure are: forgetting the plan, forgetting action status and forgetting items in a plan.

- Forgetting the plan

Usually this type of memory failure seems to us as a vague feeling of 'should-be-doing-something'. Here we have an uneasy sense that we should be carrying some action, but can't remember what or where or when it should be done. It occurs very often with me when I start walking for my class. Then I am waiting for a while with this feeling that "I have forgot to take something."

- Forgetting action status

This type of situation may be explained as the sequence where the intention has been lost for some while. Here we feel like 'what-am-I-doing-here?'. In this experience initially we can remember the intention and start to carry it out, but somewhere along the line (usually because you are preoccupied with something else or are distracted)

[77] Reason, J. (2008). *The Human Contribution.* UK, Ashgate publishers, p. 41.

we forget our intention for what we have come at a specific place to do something. Reason gives an example from our everyday things as we sometimes find our-self looking into an open drawer or refrigerator, or standing at a shop counter, and our mind is blank. At least one example of it also exists in my experience of cooking when I forget if I put salt or it is to be served to do in the cooking dish.

- Forgetting items in a plan

When we set out to perform a plan of action, think that we have completed it, but later discover we have left something refers this type of memory failure. A common experience of it is in returning home find a letter one had meant to post still on the table of the hall. (Reason,J. 2008). Another example from our everyday experiences: we often forget to take some listed items from the grocery.

h) Errors due to attention failures

According to James (1890) attention "is the taking possession by the mind, in clear and vivid form of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness is of its essence."[78] So in error due to attention failure attention is 'captured' by something unrelated to the task in hand and it leads the action to unintended outcome. Comparing capture error (see capture error) it may be said that in capture error intended action is captured another unintended action but here intended object of attention is captured by another object. It is possible that someone's attention is diverted from the focus automatically according to the nature of his cognitive mechanism. According to James (1908) novel and exciting objects capture one's attention involuntarily, although an effort or willpower can bring attention to some less interesting subject. "When we are studying an uninteresting subject, if our mind tends to wander, we have to bring back our attention to bear on them."[79]

From the experiences of everyday activity it can be said that absent-minded slips often occur in highly familiar and relatively unchanging surroundings like kitchens, bathrooms, bedrooms, offices. According to Reason (1990) limited attention is the resources of some inappropriate operation. According to him most part of attention is

[78] James, W. (1890). *The principals of Psychology*. New York.Holt, p. 403-404.
[79] James, W. (1908). *Talks to Teachers on Psychology: and to Students on Some of Life's Ideals*. (3rd ed.) London. Longmans,green & Co, p101.

captured by external distraction or internal preoccupation; but interesting point is that when too much attention is directed at some largely automatic action sequence then also error may take place (medical error p.). So it can be said that attention is the gatekeeper of consciousness and when our attention switches off from the current action this type of error occurs. There are some situations mentioned by Reason (1990) where this type of error frequently takes place:

- When intended goal demands a departure from some well-established routine.
- When changing problem situation requires a modification of some familiar or oft-performed action sequence.
- When a familiar environment associated with a particular set of behavioral
- When features of the present environment contain elements are similar or identical to highly familiar circumstances. (For example: 'As I approached the turnstile on my way out of the library, I pulled out my wallet as if to pay - although I knew no money was required.'[80]

i) Errors due to recognition failures

When someone commits error because he fails to recognize the object he/she perceived or knew before it is error due to recognition failure. This type of error is a combination of perceptual error and memory failure. We may explain these errors into three main categories: misidentification, non-detections, and wrong detections.

Misidentification

Misidentification may takes place due to wrong identification of objects, message, signals, etc. Such errors have had catastrophic consequences in the Harrow train disaster in 1952. In that incident the train driver occasionally identify a red signal as green. Some causes of this type of error are similarity - in appearances, locations, and functions. Indistinctness, poor illumination and ambiguous sensory data are also responsible for this error.

[80] Reason, J. T. (2008). *The Human Contribution: Unsafe Acts, Accidents and Heroic Recoveries*, Farnham, Ashgates publishing, p. 43.

Non-detections

This type of error may be defined as the failure to detect a signal or problem. They may result from lack of training or inexperience. These errors generally occur under the following conditions:

a) The inspection is interrupted before detecting the defect;
b) The inspection has completed but the agent is preoccupied, tired or in a hurry;
c) A problem is not expected for the agent in that location (actual problem situation);
d) One defect has spotted but there was another one close to it, has missed;
e) Attempt to perform the task unwillingly.

Wrong detection

When the actual situation is not detected properly, this type of error may occur. We have cited it as cause of the rule based error before (p). In this type of defecting detection interprets such a situation which is not actually present. In a military defense system this type of error like false alarm may result in catastrophic outcome.

j) Perceptual error

When one's perception of the world differs from matter of fact called perceptual error. (Shapell, 2000). They may take place when the recognition accepts something another that the accurate as a match for the proper object. An example of it is: Someone intended to pick up the milk bottle, but actually reached out for the squash bottle. (Here the slip originates in accepting similar looking object for the intended object.)

Visual illusion is one type of perceptual error. They may occur when the brain tries to "fill in the gaps" with what it feels belongs to a visually impoverished environment, like that seen at night or when flying in adverse weather. Visual illusion is common in flying at night, or in other visually impoverished environments. When an aircrew misjudges the aircraft's altitude, attitude, or airspeed it is included in this type of error.

Spatial disorientations are another type of perceptual error. It may occur when the vestibular system cannot resolve one's orientation in space and therefore makes a

“best guess” — typically when visual (horizon) cues are absent at night or when flying in adverse weather. So generally this type of error occurs when the chosen thing looks like the proper object or is located in the expected situation or does the similar job. Usually these errors take place in a highly routine action. There are different types of perceptual error. Some of them are:

- No detection (visual)
- Expectation bias
- Late detection (visual)
- Spatial confusion
- Misread Perceptual confusion
- Visual misperception
- Perceptual discrimination failure
- Misidentification of perceptual tunneling
- No identification due to stimulus overload
- Late identification visual failure
- No detection (auditory)
- Mishear

Interference Error

Underlying factors of human error are not all cognitive but some external factors are also responsible for it. Errors which are mainly caused by some external factors it is called interference error. It is noticeable that interference errors are not different type of error than cognitive error but it is a different explanation of error. In the previous section we observed that there are different cognitive factors are under lied behind error; and according to these cognitive factors we have classified error in different types. We called errors under that taxonomy cognitive error. In this section we are explain different external factors responsible for error. According to the external interference error may be different types. We include this classification under genotype because this classification is also based on the origin of errors. This type of errors results from 'crosstalk' between two currently active tasks or between elements of the same task (Reason, 1990). In this context we will discuss blending, spoonerism, anticipation error, and external activation.

Blending

These errors occur when two or more active plans are triggered simultaneously but the person is unsure which one of them he has to perform. As a result the two actions are being mixed with each other. As an example one in the way to choice a word between "close" and "shut" responses "*clut*" (Norman, 1981). Behind blending cognitive factors are underlie behind activation of two plan simultaneously. And external factor is the relation of two words. Here 'close' and 'shut' are direct opposite with each other so speaker thinks about both in a spur of moment. As a result plan of utterance the words activated at the same time and bled with each other.

Spoonerism

In spoonerism a swap of the initial sounds of two proximate words. 'She is wearing a *wed rig*' is an example of spoonerism. Here the speaker utters *wed wig* instead of *red wig*. (Hofster and Moser, 1989). We discussed it in details in speech error (p.).

This type of errors may occur in both speech and writing; spoonerism shows that word being planned are not spelled out as phonem sequences one at a time. According to Ellis (1979) short time memory is involved in spoonerism. According to her here prior plan exits before the action take place. According to (Reason, 2008) here intended action sequences are exits prematurely and closely similar second act triggered unintentionally in the first act speech and as same as fast action sequence takes place in second act.

So in spoonerism both cognitive factor like short time memory and external factor like similar word pattern both are responsible and that is why we explained it as interference error.

Anticipation error

In anticipation error a phonem takes place in advance of its proper position in the sequence. In context of action error it may be said that when an action takes place in prior than its actual place is called anticipation error. Norrman (2002) gives an example from his own experience: One day running on morning trek, he saw a woman ahead. He was counting steps, but as he neared the woman he decided to say 'Good morning'. When I got to the woman, she smiled and said 'good morning'. And he responded 'thirty three'.

Here the speaker intended to utter two words. First one is “good morning” and second is telling his number of steps “Thirty three”. But for some cognitive factor instead of saying ‘good morning’ he answered to the second question before asking. Behind this error both cognitive mechanism of the speaker and specific action sequence both are responsible.

External activation

This type of errors results from the analysis of external events. This type of error is a resultant of a specific situation. The situation or ambiance of the action interferes in the indented action. A very prominent example of a psychological experiment is given by Norman, D. (1981) in this context. In this demonstration the names of colors (e.g., blue) are printed in colors that differ from the name; so that the word ‘blue’ might be printed with red ink. The task is that one looks at the word as rapidly as possible and says aloud the name of the ink color in which it is printed. There is extreme difficulty caused by the intrusion of printed name.

Idiosyncratic errors

The term "idiosyncrasy" originates from Greek term *idiosynkrasía.* It refers a peculiar temperament or a habit of body. Thus *Idiosyncrasy* is an unusual feature of a person. It also means odd habit. The term is often used to express peculiarity or unconventional behavior. Idiosyncratic errors refer to these errors which are resultant of a combination of operator’s personal factors and vulnerable organizational factors. When social variables and the current emotional state of the operator’s individual performance work together and both are responsible for a task failure then it may be included in idiosyncratic error. For example we may refer to commercial aviation maintenance error and error in communication.

Communication error

When an authorized pilot refuses to listen to more experienced younger crew members’ opinions on safety related issues then it is an example of communicative error. Here the error is resulted by the lack of communication between two crew members. They occur due to the operator’s emotional states but the ambiance of their workplace is also responsible for it.

Maintenance error

Maintenance errors are also included in this type. They may cause by the internal state of operator, proper supervision of the authority, lack of resources, other crew members' responsibility and for many other factors (Kirwan, 1998).

We explain idiosyncratic error in a different category because there is not any specific cognitive pattern or external factors behind this type of error. All factors are randomly take place and results in error.

3.5 Types of Phenotype Error

When we classify an action on the basis of its observable factors is called phenotype classification of error. According to this classification we may include following errors under the heading of phenotype.

a) Error as omission

When any step of the intended action is omitted it is called error as omission. Every successful action constitutes with some operator's inputs. But if the operator does not able to perform all necessary steps and as a result the intended result is not achieved it is called omission we may provide two types of omission:

- **Omitting entire task**: To perform an action a person may omit the entire task which was essential to organize a successful action. It may happen due to lapses of memory or attention. It may also happen due to other underlying cognitive mechanism of the operator.
- **Omits one step of the task:** If someone omits one important part of an action sequence and fails to achieve intended result it will also included in omission. As the previous category of omission this type of error also includes lapses and slips but the difference is that not it may also occur due to lack of knowledge and other intentional actions. Some types of violation are included in this error. As an example when one fails to follow any authorized rule or regulation that violation will be included in this type of error.

b) Error as commission

When someone does an action which is unnecessary or which creates interferences for a successful action is called commission error. It may occur due to slips, lapses or improper knowledge. Repetition is an example of this type of error. We may categorize these errors into at least two types:

- Error which occurs due to an extra action which does not interfere to produce the action, such error but interferes to produce the action in expected condition. There errors may be responsible for time error or quality error.
- Error of commission may become an obstacle to produce a successful action. When a desired action cannot provide desired outcome because an unnecessary extra step takes place, it will be included in this type of error.

c) Selection error

When performer selects wrong step it is called selection error. A.D.Guttman and Swain (1983) include wrong control, reversal errors and improperly made connections in this type. They also include issues with wrong command or information in this type. Lexical misselection is an example of this type of error (p.)

d) Error of sequences

This type of error refers to an action which is done in a wrong sequence. It may happen that the agent does an action without omitting any step adequate for a successful action or he does not do any unnecessary step even then error may take place if the agent fails to follow the action sequence in proper way. As an example in cooking, action sequence is very important. Proceeding in a wrong sequence can ruin a dish badly. Likewise in logic or math following of a wrong sequence may lead a procedure to wrong answer.

e) Time error

When an action does not take place at the desired time it is called time error. Sometimes we desire not only the success but we intend that it is to be completed in proper time. In medical field or other accident prone field proper time means a lot. In that case if an action occurs too early or too late it may results in severe adverse outcome. (Vide medical error. *[page 81-82]*)

f) Quantitative error

When an action occurs then its quantity is also very important. If any output is undesired because of its quantity they may included in this type of error. If the produced output is insufficient; too little or too much for the adequacy it will be included in this type of error. This classification is very important in many critical fields. Wrong dose error is an example of this type of error.

g) Priming

This type of errors is developed from the repetition of prior sounds or actions. Many children's games are based on leading people into error through recurrent sound primes; one of them is mentioned by Reason (1990) as an example of priming error:

From what tree does an acorn come? *(Oak.)*

What noise does a frog make? *(Croak.)*

What do you call a funny story? *(Joke.)*

What is another name for a cape? *(Cloak.)*

What rises up from a bonfire? *(Smoke.)*

What do you call the white of an egg?

Here, the vast majority of people will respond with *'yolk'* - it is almost irresistible. Three contextual factors combine to make the error highly likely: the prior phonological priming; the fact that a correct answer to the question (the white) was in the question itself - and that is most unusual one; lastly, another correct answer (albumin) is a seldom used word in our 'yolk'; on the other hand, it is very strongly associated with 'egg'.

3.6 Types of Error in a System

In the next chapter of this dissertation we are going to depict different features of human errors in four practical fields as medical, aviation, marine and mining. So it is very relevant to classify human error from system perspective approach because all these fields run as a system. In this context we consider error as a system failure. Here

human error is a resultant of a combination of some external conditions like as inadequate equipments, poor designs, inadequate supervision, maintenance failure, inadequate training of operators etc and some operator's performance. From this point of view we may classify human error into two types:

i) Active and

ii) Latent

i) Active errors

In the context of human contribution to system disasters active error is that whose effects are felt almost immediately (Reason, 1990). Generally these errors are associated with the performance of the operators in a complex system. Active failures are also referred to errors at the sharp end of a system disaster. These errors at the sharp end are noticed first because they are immediate consequent on the actions of the worker. Pilots, air traffic controllers, control room crews etc are the sharp end of aviation accident (Reason, 1990). In medical domain the physicians, surgeons, nurses are directly liable for the patient's safety. In marine accident active errors are committed by the captain, first master, watch keeper etc. For mining disaster errors of the sharp end are committed by the managers and workers or vehicle operators. Thus it may be said that, active errors occur at the point of contact between a human and some aspect of a larger system (e.g., a human-machine interface). They are generally readily apparent (e.g., pushing an incorrect button, ignoring a warning light) and almost always involve someone at the frontline.

ii) Latent errors

On the other hand latent errors are those whose adverse consequences may lie dormant within the system for long time, only becoming evident when they combine with other factors to breach the system defense. At the comparison with active error, there are many layers of the safety management system that affect the person involved in the front line activity they are the "blunt end" of a system failure. Latent errors are caused by the *blunt end operator* of a system. These are most likely to be spawned by those whose activities may be recoverable as management of future adverse event. These errors are committed by designers, high level decision makers, construction

workers, and manager and maintenance personnel (Reason, 1990). Naturally these errors lie unnoticed from the immediate task.

Thus in this chapter we have reviewed a wide variety of human error. We also have classified them from two basic points of view. We have categorized human errors analyzing their underlying mechanism and similarly we classify them following their different dimensions of outcome. Not only that but also human error is very relevant as a factor of system error and so we have categorized human error from that point of view. And in the next chapter we are going to discuss further human error in different system generated domains with some real examples.

Chapter 4

EXAMPLES OF HUMAN ERROR:

A QUEST FOR RECTIFYING MEASURES

Chapter 4

EXAMPLES OF HUMAN ERROR: A QUEST FOR RECTIFYING MEASURES

In the preceding chapter we have discussed different types of human error following different existing taxonomies. Until now we have analyzed errors from general point of view. We have tried to find the roots of different types of human error. The aim of any investigation of human error is preventing adverse event, so it is very important for us to highlight some human errors take place in practical field and cause various unpleasant events. Here we are highlighting errors in four different sectors: aviation, medical, maritime and mining. In all these domains human errors very frequently result in severe adverse incident even death. In *safety culture*[81] also human errors of those fields are treated very sensitively. In this context we are analyzing some errors of the four said fields with the aim of finding measures to handle them. Before enter into the main discussion it is noticeable that our chosen fields are different from each other in the context of system procedure. Error has important efficacy in each sector but according to contributing factor they take place differently in different sector. Thus our analyzing procedures also are different in different background. We will explain human error in medical sector on the basis of our everyday experience; we will explain aviation sector and marine sector on the basis of existing literatures on them. We have analyzed human error in these two sectors following accident reports. In aviation sector we could identify active and latent error but in marine sector incidents are so interrelated to each other that in a fraction of moment situations change; so there we could identify human errors behind accident but have not able to

[81] The term "Safety Culture" was first introduced after the Chernobyl disaster in 1986. It is used to describe the corporate atmosphere or culture in which safety is accepted as the number one priority. Safety culture alludes to individual, job, and organizational features that affect and influence health and safety. The safety culture of an organization is the product of the individual and group values, attitudes, competencies and patterns of behavior that determine the style and proficiency of an organization's health and safety programs. In safety culture all levels of an organization shares perceptions and experiences of the importance of safety and provides confidence to prevent unsafe incidences.

categorize them into active and latent as aviation sector. In mining sector we have followed annual report of Indian mining authority. There we got an official annual accident list of the Indian mining accidents but details of individual incidents are not available. So explaining different types of mining accident we will provide a list of some typical human errors that are responsible for all types of mining accidents take place in India.

4.1 Human Error in the Medical Sector

Our discussion on human error in practical field starts with errors in medical sector. Almost every people requires to encounter the medical setup for his/her own or others treatment many times. On the other hand, in this sector a simple error may cause a fatal outcome. Generally human error in medical sector is known as *medical error*. We will provide some precautions to reduce adverse outcome due to medical error in the context of each type of medical error.

Basic medical procedures

Medical system is a combination of some health care procedures. Explaining basic steps of medical procedure we may say: Generally patients come at health care institute with some complaints about their health. At first they communicate with attendants of the institute or with physician's own assistants. Then a general physician takes preliminary case history of the patient's complication and she/ he refers the patient to the relevant doctor. Following general case history the specialist physician interrogates the patient and finds the origin to his/her complications. After that if the physician can diagnose the disease without any investigation, he/ she prescribes medicine after knowing the details about patient's weight and proneness to allergy. If the physician decides that some detailed investigations are necessary further for diagnosing the disease then he suggests investigation for the patient. After investigations if the disease is diagnosed the specific physician decides which type of treatment is needed for the patient. If the disease is curable with medication then specialist physician prescribes medicines or if the patient needs surgical treatment then it follows operative procedure as treatment.

Some definitions of medical error

"Medical error" is referred as error in any procedure of medical treatment. Medical profession defines medical error in different ways. Not only medical sector but many fields have much interest in studying human error. They explain medical error influenced by differing contexts and purposes, such as research, quality control, ethics, insurance, legislation, legal action and statutory regulation. So to get a clear conception of medical error we may analyze multiple definitions of medical error in different contexts.

Schimmel (1964) defines medical error as "Noxious episode" in medical process. According to him all complications and mishaps that result from acceptable diagnostic or therapeutic measures deliberately instituted in the hospital are included in medical error. In a report of The California Medical Insurance Feasibility Study (1977) the term medical error is adopted as potentially compensatable event. According to this report medical error is treated as potentially compensatable event due to medical management that results in any kind of disability of the patient or leads the patient to prolong hospitalization. In this report it is also described that medical error may lead to malpractice claims in medical sector.

In 1990s, many definitions described medical as an adverse event. According to medical dictionaries, adverse event is referred as malpractice. It defines adverse event as "An injury caused by medical management rather than by the underlying disease which prolongs hospitalization, produces a disability at the time of discharge, or both Etiology Drug effects, wound infections, technical complications, negligence, diagnostic mishaps, therapeutic mishap, and event occurring in the emergency."[82]

Here it is very clear that all of these given definitions of medical error are outcome-dependant definitions; but for a safer health care system designing proper procedure is also necessary. A safe health care design ensures that patients are protected from the threat of injury. So a definition of medical error should be covered health care process or system failures also. From this point of view medical error may be explained as error that leads adverse outcomes for the patient, as well as it exposes patients to risk. Unintended medical procedures that do not result in injury are also very serious issue

[82] Segen, J. C. (eds.) (2003). *Concise Dictionary of Modern Medicine.* (6th ed.) New York, McGraw-Hill Companies, Inc.

in this domain. They are often familiar as near misses, close calls, potential adverse event or warning events.

Institute of Medical Report (IOM) explains medical error as preventable adverse event. They highlight two important points in this context:

- Medical error is error in healthcare system and
- It is preventable adverse event

According to this report explaining preventable adverse event it may be said, most patients admitted to hospital has high risk; but some adverse incidents are preventable. Medical error is mainly responsible for those adverse events which are preventable. [83]

In 2001 Reason defined the term medical error as deviation from the process of care, which may or may not cause harm to the patient. It is noticeable that Reason's definition is not only process-dependant but it also covers the outcomes of an error. It also distinguishes between errors of execution and errors in planning, acknowledging that mental/judgmental and physical / technical failures both contribute to errors (Reason, 1990).

Human error is a complex incident; it has multiple components; so improving a system blaming health care personnel is not the only remedy. It needs to find out all probable real factors behind them and keep fighting for handling them.

Examples of different types of medical error and measures to handle them

In this section we will explain different types of medical error with proper example. We will explain medical error basing on our common experiences and finding measures to reduce them. Following the basic concepts of medical procedure it may be said that there are three basic different steps in medical procedure: medication, diagnosis, and surgery. Moreover, process of anesthesia is also very significant with medical treatment mainly surgery. So, we may categorize medical errors in four basic types:

[83] Clement, J. Mc Donald. , Michal ,W., Siu, L, H. (2000). Deaths due to Medical Errors are exaggerated in Institute of Medicine Report, *The Journal of The American* Medical *Association* , 284(1), 93-94.

i) Medication error

ii) Diagnosis error and

iii) Operative/ surgical error

iv) Anesthesia error

According to the basic principles of nursing practice *medication error* is 'Mistakes associated with drugs and intravenous solutions that are made during the prescription, transcription, dispensing, and administration phases of drug preparation and distribution'[84]. We may say that, there are three basic steps in medication process: prescribing, dispensing and administrating. Following these steps we may categorize medication error into three types: prescribing error, dispensing error, and medication administration error. Thus we get following types of error in medical sector:

- Prescribing error
- Dispensing error
- Medication administration error
- Diagnosis error
- Surgical error and
- Anesthesia error

This section explains all these types of medical error and underlying factors behind them. It will also provide some effective measures to reduce these errors.

Prescribing error

Prescribing error is the most common type of medication errors (Patanwala, A. E., Hays, D. P., Sanders, A. B., Erstad, B. L., 2011). Prescribing is a process whereby a doctor or other registered professional authorities provide instructions about how and when specific treatments should be applied to a patient.[85] Prescriptions may be handwritten or computerized. It contains patient's name and address, the date, details of the patient's present condition and description of his/her complains. Physician prescribes specific treatments basing on these patient's details with an authorizing signature. There are various types of prescribers in different countries. But always

[84] Wolf, Z. (1989). Medication Errors and Nursing Responsibility. *Holistic Nursing Practice*. p. 8.

[85] Haas, R., Maloney, S., Pausenberger, E., Keating, J. L., Sims, J., Molloy, E. et al. Clinical decision making in exercise prescription for falls prevention. *Physical Therapy Journal.* (Published online January, 2012).

prescription is a means for prescribers to communicate with pharmacists. Prescription is very useful for people to stay healthy following doctors remedy. It is essential to manage long-term medical procedures. Physician also provides some suggestions to handling emergency situation in the prescription. But when prescriptions becomes subject to error it may leads to a hazardous outcome. According to medical science when an improper prescribing process leads the patient to unintended outcome it is called prescribing error. Incorrect drug selections, improper doses, illegible prescriptions all are included in prescribing error. We may classify prescribing error into some basic types:

Error in processing: Prescription always should be processed by the relevant practitioner. His prescription should be based on indications and contraindications of the disease. He considers allergies and weight of the patient, existing drug therapy, and other factors. But if the physician fails to follow any of these steps in prescribing medicine, it will consider as his/ her prescription error. Some common incidents related to this type of error are:

a) Wrong drug(s) are prescribed

b) Wrong dose (too much / too little / no dose) is mentioned on the prescription

c) Wrong time for taking drug is instructed on the prescription

Error in communicating: Prescription is a communicating process in between doctor and the patient. It also guides pharmacists in following the doctor's direction. But if a prescription is not sufficient to communicate treatment procedure then it will be a subject of communicating error. A very common incident is: the case where physician prescribes correctly but he fails/forgets to instruct the treatment procedure either orally or written form.

Error in patient identification: Prescription should be always written on behalf the appropriate patient. Many times the prescription of one patient is handed over to another patient suffering from different illness it is error in patient identification. In that case although instruction is correct for the patient but prescribed medicines are inappropriate. This type of error may take place when prescriber writes another name instead of the name of the attended patient.

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It is important to note that lack of proper knowledge of the physician about the prescribed drug, dose or patient details may result in prescribing errors. Other contributing factors are: inaccurate case history, confusion with the drug name, inappropriate indication of drug dosage and using abbreviations in verbal orders. Following these factors behind prescription error we may consider some approaches for reducing this type of error**.** For this purpose we take a cue from *Guide to Good Prescribing:* A practical manual[86] published by W.H.O.

- Physician should prescribe drugs or treatment only when he has adequate knowledge of the patient's health, and he is confident that the drugs or treatment he is going to serve to the patient that is compatible with the patient's needs. For example, medicine for a psychiatric disorder must not be prescribed by a general physician.
- He/ she should provide effective treatments based on the best available evidence.
- He/she must check that the care or treatment he/she is going to provide for each patient is compatible with patient's case history and any other treatment the patient is receiving, including (where possible) self-prescribed over-the-counter medications.
- Prescriber must make good use of the resources available to him/her.
- He/ she must maintain a clinical record of his patient. It provides him experience for the future.
- It is sometimes difficult, because of time pressures, to give patients as much information as the prescriber or the patient would like. To help with this other members of the healthcare team may consider that role. Such as pharmacists can undertake medicines reviews, explain how to take medicines and offer advice on interactions and side effects.
- Electronic prescribing procedure may be helpful in reducing prescribing errors resulting from illegible handwriting.

[86] Vries de, T. P. G., Henning, R.H., Hogerzeil, H.V., Fresle, D. A. Guide to Good Prescribing: Apractical manual published by World HealthOrganization Action Programme on Essential drugs geneva. from http/ apps.who.int/medicinedocs/whozip 23 pdf (Retrieved on 12.03.2016)

Dispensing errors

"Dispensing refers to the process of preparing and giving medicine to a named person on the basis of a prescription. It involves the correct interpretation of the wishes of the prescriber and accurate preparation and labeling of medicine for use by the patient"[87]. This process may take place in the private clinic, hospital, health care centre or a medicine shop; so such types of errors are generally committed by pharmacists or by nurses to provide correct medicine according to the prescription to the patient. Dispensing errors include wrong dose, wrong drug, and the use of computerized labeling leading to transposition and typing errors which are among the most common causes of dispensing errors. Some examples of dispensing errors are given below:

Dispensing wrong drugs: It may be caused by the pharmacist or nurse for similar name of drugs or illegible handwriting of the practitioner.

Dispensing wrong patient: When nurse or attendant dispenses medicine as prescription on wrong patient is included in this type. It may happen when it is dispensing for more than one patient at a time.

Dispense unauthorized drug: It refers to dispensing expired drugs. It may happen when checking of medicine is not carried out properly before it is taken by the patient.

Poor hygiene: It should always be necessary to maintain proper hygiene during medicine dispensing process. If it is not carried out properly, dispensing error occurs.

Error in maintaining proper record of the treatment: Dispensing process includes proper recording of the treatment procedure. If reliable person fails to do it properly it will be admitted as error.

In the context of reducing dispensing errors it should be needed to maintain proper dispensing environment. According to the pharmacy guideline the dispensing environment includes staff, physical surroundings and storage area, surfaces used during work, equipment and packaging material. In this context following precaution should be obviously taken for reducing dispensing errors:

[87] Spivey, P. (2012). Ensuring Good Dispensing Practice . In Embrey ,M.(Eds) *Managing Access To Medicines And Health* ,U.S.A, Management Science for Health, Inc. p..30. 2.

- Any stuff involved in dispensing process must maintain good personal hygiene and should wear uniform or other clean clothing.
- The physical surroundings must be kept free from dust and dirt as much as possible.
- The dispensary accessible to patients should be taken in a protected place.
- It is also very important to separate drugs with a similar name or appearance.
- Keeping interruptions in the dispensing procedure to a minimum and maintaining the workload of the pharmacist at a safe and manageable level are necessary.
- Finally it may be said that awareness of high risk drugs such as potassium chloride may reduce dispensing error. Introducing safe systematic procedures for dispensing medicines in the pharmacy is also a useful initiative in reducing dispensing errors.

Medication Administration error

"Medication administration is defined as preparing, giving and evaluating the effectiveness of prescription and non-prescription drugs"[88]According to Headford (2001) medication administration error refers to any deviation from the physician's medication order as written on the patient's chart.[89]. Medication administration will be proper if it is done for right patient, with right drug, with right dose, in right time and if it follows right route. Generally medication is administered by nurses or attendants of the patients and so they are the sharp end of the medication administration error. There are different types of medication administration error. Some of these are mentioned below.

Administration processing error: In medical care, administration should be processed in proper way. If it is not processed properly we may call it processing error. Following incidents are examples of this type of error.

a) Administration does not process at all when it is required
b) Administration carries out when not required / carried out when already been done

[88] Mosby . (2009) *Mosby's Medical Dictionary*, Elsevier.
[89] Headford, C., Mc Gowan, S., and Clifford, R. (2001). Analysis of Medication Incidents and Development of a Medication Incident Rate Clinical Indicator. *Collegian.* 8 (3) 26-31.

c) Administration carries out without prescription or professional's advice
d) Administration processes are too late in respect of patient's condition

Communication error: This type of error occurs when administration does not communicate the patient adequately. Usually it takes place when the drug is given by another person than the professional one or the patient takes by himself. One common contributory factor of these errors is lack of proper direction of the dispenser (who dispenses medicine). Some conditions where this type of error takes place are:

a) There is no written chart of drug administration
b) Liable person makes a wrong chart and so the patient is given drug wrongly
c) Administration not carried out but recorded drug is given in the chart

Wrong patient Error: If drug administered to one patient but recorded in another patient's chart called wrong patient error. It may be result in repeated drug therapy or wrong diagnosis. Wrong-patient medication errors can be thought of as both an unordered-drug error for the patient who received the dose and an omission error for the patient for whom the dose was intended.[90]

Wrong administration-technique error: If medical error is caused due to the applications of wrong technique called wrong administration technique error. If the wrong infusion rate is used but patient receive correct dose it will be error due to wrong technique.

Some common incidents of medical administration error are:

a) Omission error: It refers to the failure of administrator as missing a scheduled dose for the patient. That means when attendant or patient misses a prescribed dose that will be included in this type. Generally this type of errors is committed by the attendants of the patients.
b) Wrong time error: Administration of medication not following the prescribed schedule of time is called wrong time error. The time for intake of medicine should be symptomatic nature than haphazard.
c) Unauthorized drug error: Administration of drug to the patient which is never authorized by a legitimate prescriber for the patient is always tagged as error.

[90] Flynn, E. A., Barker, K. N. (2007) Research on errors in dispensing and medication administration. Chapter 2. In: Cohen MR, ed. *Medication errors*. (2nd ed.). Washington (DC): American Pharmacists Association; 15-42.

Self medication is very common example of it. Generally it takes place due to negligence of the patient party.

d) Improper dose error: Administration of a dose to the patient that is greater than or less than the amount ordered by the prescriber or administration of duplicate doses to the patient, i.e., one or more dosage units in addition to those that were ordered is called improper dose error. It may occur due to attendant's slip or lack of attention.
e) Wrong drug-preparation error: If drug product is prepared incorrectly or manipulated before administration, it is called wrong drug-preparation error. When a patient is treated with multiple drugs or a combination of different drugs, this type of error has high change to take place.
f) Deteriorated drug error: If a patient is administrated by a drug which is already expired or for which the physical or chemical dosage-form integrity has been compromised. Attendants' lack of attention and negligence may be responsible for these errors.

Following approaches may be taken for reducing drug administration errors:

- Checking the patient's identity carefully.
- Ensuring that dosage calculations are checked independently by another health care professional before the drug is administered.
- Ensuring that the prescription, drug, and patients are in the same place in order that they may be checked against one another.
- Ensuring the medication is given at correct time and minimizing interruptions during drug rounds.
- Talk with the individual patient and explain what you are doing before you are providing medications.
- Answer each questions asked by individual patient providing privacy for the individual.
- Help the individual to be involved as possible as in the process. Never leave medications unattended, even for a moment.
- Give medication administration with complete attention. For that it is necessary to choose a quiet area for giving medications.

Diagnosis error

Diagnosis error is defined as "Any mistake or failure in the diagnostic process leading to a wrong-diagnosis, a missed-diagnosis, or a delayed-diagnosis. This definition could include any failure in timely access to care; elicitation or interpretation of symptoms, signs, or laboratory results; formulation and weighing of differential diagnosis; and timely follow-up and specialty referral or evaluation."[91]

Usually diagnosis process includes some steps. Such as after appearance of the patient, the attendant or physician collects history of the patient's complication and records his/her medical reports and then the physician examines the physical conditions of the patient. After that if necessary she/ he suggests necessary pathological testing for the patient, evaluates the findings patient's conditions and the doctor makes his/her assessment. Then he/ she pass on the patient to the specialist and finally the specialist diagnoses the disease by his/her own knowledge. In any of these stages a medical error may take place. Some examples of diagnosis errors are given below:

Error in presentation: When the attendants or nurse or physician does not take proper care of the patient or delays to take care of the patient it is called error in presentation. It may take place due to lack of communication, lack of human resources or lack of proper management.

Error in history taking: This type of error may occur when the physician or administrator fails or makes delay in eliciting critical piece of history data of the patient. It also may happen due to inaccuracy/misinterpretation in taking information about the patient's complication.

Error in taking weight of the patient: A patient's weight is important information because on basis of it appropriate medication dose is calculated. When medication errors arise due to inaccuracy of unknown patient's weights, the dose of a prescribed medication may be significantly different from the appropriate.

Error in physical examination: This type of error happens due to the same causes which have discussed in the context of error in history taking. Failure or delaying in eliciting

[91] Schiff, G. D., Hassan, O., Kim, S., Abrams, R., Cosby, K.., Lambert, B. L. (2009). Diagnostic Error in Medicine. *American Medical Association's journal of internal medicine.* 169 (20), p.1881.

critical physical exam finding, inaccurate or misinterpretation of patient complaining, failure or delay to follow up are some example of this type of error.

Error in pathological test: This type of errors occur mainly by the lab related medical personnel or their assistants. Radiologist, pathologists, and laboratory assistants may commit this type of error. Two common examples of this type of errors are: error in referring and error in performance. Error in referring may happen when the practitioner fails or delays in referring needed test(s). When the doctor suggests a wrong test(s) or unnecessary test, it is also included in this type. On the other hand generally error in performance is committed by the person who are the sharp end of the medical investigation and that means who directly operates the investigation such as radiologist, pathologist and their assistants. Some examples of this type of errors are:

a) Mislabeling: It refers labeling specimen to wrong patient, or sample mix-up among different patients.

b) Technical errors: poor processing of specimen/test is an example of this type

c) Erroneous lab: Failed or delayed transmission of result to clinician is an example of error in lab performance.

Error in Assessment: This type of errors occurs in the final stage of the diagnosis. It refers to error committed by the physician in drawing decision to diagnose the disease. Some examples of this type of errors are:

a) Error in hypothesis generation: When a physician fails to do the correct diagnosis in proper time that is called error in hypothesis generation.

b) Recognizing urgency/complications: When the physician fails to appreciate the urgency or acuteness of the patient condition it is included in this type of error.

The limitation of human knowledge and unique complexity of each human body makes proper diagnosis almost impossible. Basically human error in this context can never be eliminated completely however improving the cognitive factors related to diagnosis process it is possible to manage and reduce diagnosis error. Adopting following precautions it may reduce error takes place in this stage of medication:

- Proper diagnosis is only possible when the physician gets proper history of the patient's complications. Thus medical consultation of the physician with the patient is a special occasion in the diagnosis process. In this process physician must ask relevant questions to the patient to determine the cause of the complaint.
- For proper diagnosis clinical examination is necessary. Following of proper technique and strategy of clinical examination always helps the physician to make proper diagnosis.
- In any confusion physician must take second opinions from the expert of relevant department. For taking better decision consultation with different specialists is very useful in taking better decision in this context
- Updated knowledge in this field is important for making proper diagnosis. Training for improving cognitive awareness is also very effective in reducing Designing error.

Surgical Error

Surgical error is a very sensitive issue in medical world. We have said in describing medical process that after investigation the physician decides which treatment is needed for the patient. This treatment may follow medication or it may be operative or surgical. We are discussing basic errors in surgical treatment. We may categorize surgical errors into following three types:

i) Preoperative surgical error
ii) Intra-operative surgical error
iii) Postoperative

i) Pre-operative surgical error

In the preparatory steps of surgery routine investigation of the patient is done. Depending on the investigations of patient's general condition surgeon takes decision whether the patient is fit for the operation or not. In this stage different specialist doctors give consent that the patient is fit for the specific surgery. After the confirmation the surgeon, nurse and operation theater assistants get ready for surgery. In this stage if the surgeon or any operation assistants fails to follow the necessary

action it will be included in this type of error. Two common examples in this context are:

a. Improper sterilization of the operative instruments or operation setup
b. Insufficient investigation of the patient before operation.

ii) Intra-operative surgical error

When an error takes place during operation it is called intra-operative surgical error. This type of errors may be committed by the surgeon or any other person assisting during the operation. Lack of skill error is very common factor behind this type of error. Some examples are:

a. Hand-off error is a very common incident of surgical error. It means surgeon's failure to continue his operation after a sudden time. It may occur due to unexpected physical complication of the patient or lack of experience of the surgeon.
b. Incision of the wrong site is an example of this type of error. It may occur if depending on memory the surgeon does not mark operation site before giving the incision.
c. Forgetting foreign body (instrument or any other operative accessories) inside the patient body is also included in this type. It may take place when surgeon or attendant does not follow the proper protocol.

iii) Post-operative error

This type of errors takes place after operation. It happens mainly due to lack of proper caring or follow-up of patient. Surgeon, physician, nurse or other attendants may be responsible for this type of error. Ignoring patient's condition and lack of understanding in following the proper instruction of the physician are of common factors behind this type of error. Though any type of medication errors may take place in this stage. Some examples of postoperative errors are:

a. Error in referral: Error in referral is an important diagnosis error. Failure to execute proper or necessary referral procedure leads to diagnosis error. Failure or delay in ordering needed referral and inappropriate or unneeded referral are included in this type.

b. Error in follow up: Follow up is an important step in post-operative procedure. Although medical science has reached almost the zenith but human body is so complex that there is no certain conclusion here. Medical science basically follows the "trial and error process" in treatment procedure. So follow up is very important step to the physician to judge his decision in treatment if his administration leads to predict feedback then he may be confident otherwise he cannot adopt next step of treatment. So error in follow up may occur by the physician but an important cause of it is patients' ignorance. Two common incidents of this type of error are:

    1. Failure to refer for close monitoring
    2. Failure/delay in timely follow-up/rechecking of patient

Reducing surgical errors is the main objective in national patient safety issue. In this context it is necessary that surgeons and other responsible authority should obey the proper rule and process related to patient safety. Following international protocol of risk management we are providing some approaches and precautions for reducing surgical errors below:

- Avoiding unusual objects in surgical set-up: Proper operation setup is a very important issue in reducing adverse event in surgery. This is a management part of the surgery. But any complication related to surgery is announced as surgical error. In a surgical process the operation may be successful but without proper set up it may result post operative complication.
- Be aware about any type of distractions: Any type of distractions from goal may increase chance of surgical error. It is very important that all operation staff should be very cautious; they need to verify and mark the incision site, verify instruments, proper sterilization etc. There was reported an incident where nurse could not follow the instruction during sterilization. She sterilized the instruments following the scheduled duration but failed to estimate the gap due to power cut for sometimes. As a result due to improper sterilization it caused a major surgical error.
- Avoid Error in judgment: Error in judgment is the most contributing factor for surgical error. It may occur due to lack of knowledge or lack of experience of the surgeon. It may also take place due to unexpected

complication. These factors may lead to choosing wrong technique or process in an operation procedure.

- Reducing reliance on memory: Failure of vigilance/memory is the second probable contributing factor for surgical error. It may occur due to workload, fatigue, professional pressure etc of the surgeon. These errors may be also committed by the junior doctor or preliminary level of the profession due to lack of experience. In simple words surgery is a very sensitive process. On the other hand memory may betray any time. So surgeon should always follow the protocol than relying on his memory. As example a surgeon may forget any operative instrument lying inside the patient body if he does rely on his memory only.
- Standardizing surgical processes: Medical science is progressing every day; so imitativeness in improving professional is very important for good surgery. Due to lack of basic and advance knowledge, a surgeon may commit error. If a surgeon improves his knowledge and turn to use new technology he/she can provide better remedy for the patients.
- Improving communication among team members: Communication failure is an important factor of surgical error. Usually surgery is not a one operator's job. For a successful operation cooperation of all persons participated in the surgery is necessary. Misunderstanding among operation assistants and surgeons may be result in harmful operation error any time.

In a review of surgical errors it has been identified that when a patient has multiple complications, he has need of multiple surgical procedures. Naturally multiple surgeons will be included in that surgery. Then a conflict may take place among those surgeons. And that may lead to a major surgical error. So, for a successful operation healthy communication is very important.

Anesthesia errors

Generally when a patient undergoes a surgical procedure, anesthesiologists often use a general anesthetic, which allows the patient to enter an unconscious or semi-conscious state in the absence of pain. An anesthesiologist has the responsibility to correctly regulate a patient's consciousness during a surgical procedure. If the medical provider administers insufficient dose of anesthesia, a patient may wake up in the middle of the

procedure. This can be a horrifying experience, since the person is often paralyzed and unable to speak yet he is aware of what is happening and may even experience the extreme pain of surgery. On the other hand overdose of anesthesia may cause death.

Anesthesia errors may occur as a result of professional negligence or lack of current medical knowledge. It may be responsible for the patient's injuries and suffering. Tracheal damage or injury to surrounding areas may be caused by intubation errors. Lack of adequate oxygen supply, cardiovascular injury during anesthesia process may result in heart attack or stroke or birth defects, brain damage, traumatic brain injury or spinal cord injury. These factors often lead to paralysis or loss of feeling and function in the body, coma, even death of the patient. Anesthesia errors may occur at various points during or before a patient's operation in the hospital or doctor's office. Some common anesthesia mistakes related to medical negligence or wrongful action are mentioned below:

Anesthesia dosage error: When anesthetist administrates incorrect dose it is called anesthesia dose error. If an anesthesiologist gives the patient too much or too little anesthesia both are included in this type. Usually it happens when the anesthetic products are labeled improperly.

Delayed anesthesia delivery: Delaying in aesthesis procedure may cause severe adverse event during operation. This type of anesthesia error may take place due to vaporizer leakage, syringe-swapping troubles, and other complications at the outset of surgery.

Injury caused during intubation: During surgery, an anesthesiologist will often intubate a patient to help him/her breathe safely during the procedure. If this medical provider makes an error during intubation, serious injury can result.

Failure in monitoring of a patient properly: An anesthesiologist is responsible for regulating a patient's level of consciousness during the procedure, ensuring that a patient is not experiencing any complications or distress. Failure to fulfill these essential duties constitutes medical malpractice.

Failure in recognizing complications: If there is violation of step in antithesis process it may lead to complications. In that case if the anesthetist fails to detect complications it may result in harm for the patient.

In order to reduce human induced anesthesia error we may provide following suggestions as necessary for proper anesthesia process:

- The operating room can be a hectic busy environment, with many items for distraction. However, as previously stated, an anesthesiologist and other medical providers have the primary duty of monitoring the patient and preventing harm.

- Most of machine errors can be eliminated by checking anesthetic machines. Proper inspection should be the first thing before doing any anesthesia process. This should include pressure checking of the machine as well as visual inspection of all the machine's parts. By following this guideline many unforeseen complication may be avoided.

- Normal healthy patients may face an unexpected crisis due to mistakes in handling anesthetic machines and equipments. These can be traced as an incorrectly set up of the breathing circuit or a disconnected circuit, oxygen flow meter in the off position or no source of oxygen, ventilator failure, under filled or overfilled vaporizers, exhausted absorbent granules, stuck or missing one way valve, a closed pop off valve and lack of adequate monitoring.

It is very clear that there are innumerable varieties of medical errors and we are just not able to catalogue all of these. But analyzing human error we have tried to give a view that there are lots human error scattered in medical sector and if we can identify them it is possible to manage them. If we develop this attitude to reducing medical error it will be very fruitful in advancing safety in medical domain. We discussed about cognitive errors in the previous chapter. Cognitive error is also related to medical error whenever this is beyond the scope of our research.

4.2 Human Errors in the Aviation Sector

It is accepted by almost every one that human error is the leading cause of commercial airline accidents. Transport Minister of South Africa Dipuo Peters said "human factor accounts for more than 70% of all aviation accidents globally"[92]. In this field, errors

[92] Source: SABC News Monday 9 June 2014 15:02.

may occur in different stages and for different cognitive factors. This section provides a brief discussion of basic flying operations and common human error related to them. We are analyzing error from two points of view. We discuss different types of error that take place in basic operational procedure and after that we will highlight different cognitive factors of aviation error; and finally we will provide some approaches for reducing human error in aviation domain.

Basic concepts of flying process and common errors related to them

Aviation sector is a very relevant topic in the context of human error. In this field human error may results in various severe accidents. In this sector human error may takes place in any necessary steps of flying operation. Aviation sector is not very familiar to common people so understanding human error of this domain it is necessary to give a brief discussion about basic aviation procedure. Following *Airplane Flying Handbook* [93]we may explain basic flying maneuver into three modes:

i) Before flight activity

ii) During flight activity

iii) Post flight activity

i) Before flight activity

Before an air plane takes off there are two basic actions: cockpit management and ground operations. According to that there are some common errors related to such actions. We are discussing them in brief below:

Cockpit management: After entering the airplane, the pilot should first ensure that all necessary equipments, documents, checklists, and navigation charts appropriate for the flight are on board. The pilot must adjust his seat to be able to see inside and outside. He should interact before starting the engine, with passengers briefing on the proper use of safety equipment and exit information.

Though cockpit management is the initiative task for flying but if the flying personnel fails to do this action it may result in error at any time during flying operation. Three

[93] *Airplane Flying Handbook*. (2004). Published by U.S. Department Of Transportation Federal Aviation Administration Flight Standards Service.

types of cockpit management errors are explained in aviation psychology. They are - task initiation error, task prioritization error, and task termination error.

- Task initiation error

  It may be described as misleading to do an action. Late configuration, ad failure to tune navigation and failure to communicate radios are included in this type.

- Task prioritization error

  The failure to start a task on time (or at all) or the discussion to start a task too early may often be explained as task prioritization error. It may take place due to complication like weather, improper traffic watches etc.

- Task termination error

  These include early autopilot disengagements, altitude, altitudes overshot and improperly continued landing under unsafe conditions.

Ground operations: It is important that a pilot operates an airplane safely on the ground. This includes being familiar with standard hand signals that are used by ramp personnel. Errors occur in this section are discussed below:

- Error in Engine starting

  Before the engine of an aircraft starts, a checking procedure is always necessary. If pilot fails to do so it results in error to start the engine, which is included in the heading of error in engine starting.

- Error in Taxiing

  Taxiing is the controlled movement of the airplane under its own power on the ground. Since an airplane is moved under its own power between the parking area and the runway, the pilot must thoroughly understand and be proficient in taxi procedures. An awareness of other aircraft that are taking off, landing, or taxiing and consideration for the right-of way of others is essential to safety. When taxiing, the pilot's eyes should be looking outside the airplane, to the sides, as well as the front. The pilot must be aware of the entire area around the airplane to ensure that the airplane will clear all obstructions and other aircrafts. If at any time there is doubt about the

clearance from an object, the pilot should stop the airplane and have someone to check the clearance. It may be necessary to have the airplane towed or physically moved by a ground crew. Incidents as collision of the airplane with vehicle on the ground, boundary wall or animals on the ground are included in this type.

- Failure in before takeoff check

  The early takeoff check is the systematic procedure for making a check of the engine, controls, systems, instruments, and avionics prior to flight. Any type of inattention may result in error in this stage.

ii) Operations during flight

There are four fundamentals of basic flight maneuvers. They are: straight-and level flight, turns, climbs, and descents. Based upon these maneuvers all flying tasks take place. All controlled flight consists of either one, or a combination or more than one, of these basic maneuvers.

Error in Straight flight (laterally level flight): Straight-and level flight is accomplished by visually checking the relationship of the airplane's wingtips with the horizon. For this both wingtips should be equidistant above or below the horizon and any necessary adjustments should be made with the ailerons, noting the relationship of control pressure and the airplane's attitude. With the wings approximate level, it is possible to maintain straight flight by simply exerting the necessary forces on the rudder in the desired direction. However sometimes the practice of using rudder alone is not correct and may make precise control of the airplane difficult. Straight–and-level flight requires almost no application of control pressures if the airplane is properly trimmed and the air is smooth.

Common errors in the performance of straight-and level flight are:

- Attempting to use improper reference points on the airplane to establish attitude.
- Forgetting the location of preselected reference points on subsequent flights.
- Attempting to establish or correct airplane attitude using flight instruments rather than outside visual reference.
- Attempting to maintain direction using only rudder control.

- Habitually flying with one wing low.
- Pushing or pulling on the flight controls rather than exerting pressure against the airstream.
- Improper scanning and/or devoting insufficient time to outside visual reference.
- Fixation on the nose (pitch attitude) reference point.
- Unnecessary or inappropriate control inputs.
- Failure to make timely and measured control inputs when deviations from straight-and-level flight are detected.
- Inadequate attention to sensory inputs in developing feel for the airplane.

Error in trim control: If the airplane is flying out of that basic balanced condition, the use of trim tabs relieves the pilot of this requirement. Sometimes proper trim technique is more important than basic flying skill. A properly trimmed airplane is an indication of good piloting skill. Trim control errors are common pilot error. Some of these are:

- A common trim control error is the tendency to over control the airplane with trim adjustments.
- Attempting to "fly the airplane with the trim tabs" is also a very common fault in basic flying technique even among experienced pilots.

Errors to perform level turns: A turn is made by banking the wings in the direction of the desired turn. Banking is to travel with one side higher than the other when turning. Some common errors in the performance of level turns are:

- Failure to adequately clear the area before beginning the turn.
- Attempting to execute the turn solely by instrument reference.
- Attempting to sit up straight, in relation to the ground, during a turn, rather than riding with the airplane.
- Insufficient feel for the airplane as evidenced by the inability to detect slips/skids without reference to flight instruments.
- Gaining proficiency in turns in only one direction (usually the left).
- Failure to coordinate the use of throttle with other controls.
- Altitude gain/loss during the turn.

Climbs error: When an airplane enters a climb, it changes its flight path from level flight to an inclined plane or climb attitude. Like other maneuvers, climbs should be performed using outside visual references and flight instruments. It is important that the pilot know the engine power settings and pitch attitudes that will produce the following conditions of climb. Common errors in the performance of climbs and climbing turns are:

- Attempting to establish climb pitch attitude by referencing the airspeed indicator, resulting in "chasing" the airspeed.
- Applying elevator pressure too aggressively, resulting in an excessive climb angle.
- Applying elevator pressure too aggressively during level-off resulting in negative "G" forces.
- Inadequate or inappropriate rudder pressure during climbing turns.
- Allowing the airplane to yaw in straight climbs, usually due to inadequate right rudder pressure.
- Fixation on the nose during straight climbs, resulting in climbing with one wing low.
- Failure to initiate a climbing turns properly with use of rudder and elevators, resulting in little turn, but rather a climb with one wing low.
- Improper coordination resulting in a slip which counteracts the effect of the climb, resulting in little or no altitude gain.
- Inability to keep pitch and bank attitude constant during climbing turns.
- Attempting to exceed the airplane's climb capability.

Descent error: Decent is the action of the plane in coming or going down. When an airplane enters a descent, it changes its flight path from level to an inclined plane. It is important that the pilot know the power settings and pitch attitudes that will produce the following conditions of descent. Common errors in the performance of descents and descending turns are:

- Failure to adequately clear the area
- Inadequate back-elevator control during glide entry resulting in too steep a glide

- Failure to slow the airplane to approximate glide speed prior to lowering pitch attitude
- Attempting to establish/maintain a normal glide solely by reference to flight instruments
- Inability to sense changes in airspeed through sound and feel
- Inability to stabilize the glide (chasing the airspeed indicator)

Error after landing: After landing, the airplane should be gradually slowed to normal taxi speed before turning off the landing runway. During this period the pilot should give full attention to controlling the airplane and after-landing checking. After-landing check should be performed only after the airplane is brought to a complete stop clear of the active runway. There have been many cases of the pilot mistakenly grasping the wrong handle and retracting the landing gear, instead of the flaps, due to improper division of attention while the airplane was moving.

Error during shutting down the engine: Finally, parking in a designated, supervised area, the pilot is going to shut down the engine. In this process he/she should always use the procedures in the manufacturer's checklist for shutting down the engine and ensuring the security of the airplane. Failure to operate any of the following stages may generate error in engine shut down:

- Set the parking brakes on
- Set throttle to idle or 1,000 r. p.m. In the context of aviation "idle" is when the engine generates enough power to run, but not enough to perform useful work
- If turbocharged observe the manufacturer's spool down procedure
- Turn ignition switch off and on at idle to check for proper operation of switch in the off position
- Set propeller control (if equipped) to full increase
- Turn electrical units and radios off
- Set mixture control to idle cutoff
- Turn ignition switch to off when engine stops
- Turn master electrical switch to off
- Install control lock

When the engine shuts down, a flight of an airplane is completed.

iii) Post flight operations

After shutting down of the engine and deplaning passengers, for securing and servicing the airplane, the pilot should accomplish a post flight inspection. If any of the following steps will be missed, errors may take place at that stage:

- Checking the general conditions of the aircraft.
- For a departure, the oil should be checked and fuel added if required.
- If the aircraft is going to be inactive, it is a good operating practice to fill the tanks to the top to prevent water condensation from forming.
- When the flight is completed for the day, the aircraft should be hangared or tied down and the flight controls secured.

Some examples of aviation accident and finding human error behind them

Air accidents may occur any time anyplace. Accident reports show that a majority of air accidents occur either during take-off or landing. And mainly it takes place near major airports where flight paths get congested. In addition, air accidents also occur frequently at remote inaccessible places like forests, hilly and mountainous regions, high seas, etc. Causes of air accidents are either human failure of pilots, air traffic controllers or technical on-board failures landing instruments. In rare cases, it may also be the result of terrorist activities. Air accidents are by and large of four types:

i) Mid-air collisions

ii) Forced landings

iii) Air-crash in mountainous terrain and

iv) Crash due to technical snags

We are going to analyze all these types of incidents. We will follow one real incident on behalf of each type of accident. Our aim is to find out human errors behind these types of accident and finding the precautions to handle them in future.

i) Aviation accident due to mid air collision

We may define mid-air collision is an aviation accident in which two or more aircraft come into contact during flight. In this context we take the incident of *Charkhi Dadri mid-air collision*[94] for analysis.

Brief discussion of the incident

On 12th November 1996 an aviation accident or mid-air collision occurred over the village of Charkhi Dadri, near west of New Delhi, India. It occurred in between Saudi Arabian airlines Boeing 747-168B and Kazakhstan airlines Ilyushin Il-76. On that very day the Saudi Arabian Airlines *Boeing 747-168B*, was scheduled for international Delhi–Dhahran–Jeddah passenger service as flight *763 (SVA763)*. On the other hand the Kazakhstan Airlines Ilyushin Il-76TD was on a charter service from Chimkent to Delhi as *KZA1907*.Air Kazakhstan flight *KZA1907* departed Kazakhastan for Delhi at the scheduled time. As per aviation protocol while the aircraft was descending on airway G452, the crew contacted the Delhi Airport to give their status report and asking for clearance. Delhi Airport gave permission to *KZA1907* for descending to 15,000 feet (4,600 m). Then *KZA1907* was 74 nautical miles (137 km) from the beacon of the destination airport Delhi. At the same time on the same airway as *KZA1907* the Saudi Airways flight *SVA763* was travelling. It was cleared to climb to 14,000 feet (4,300 m). Apparently there was not any contradictory decision; because *SVA763* was flying to the opposite direction of *KZA1907*. About eight minutes later, around 18:40, *KZA1907* reported having reached its assigned altitude of 15,000 feet (4,600 m) but in reality it was lower, at 14,500 feet (4,400 m), and still descending. So the controller advised the flight, to identify the traffic receiving. But the aircraft did not reply. The controller called *KZA1907* again, but there was no reply again. Then he warned the other flight to keep distance, but it was too late. The two aircrafts had collided, the tail of *KZA1907* cut through *SVA763*'s left wing and horizontal stabilizer. The crippled Boeing quickly lost control and went into a rapidly descending spiral motion toward the ground with fire trailing from the wing. The Boeing broke up in the air under the stresses before the wreckage hit the ground at almost 1,135 km/h (705 mph).

[94] Sources: http://aviation-safety.net/ (Retrieved on 13.08 2015)
And .http://www.airsafe.com/ (Retrieved on 13.08.15)

As a result of this accident, rescuers discovered four critically injured passengers from the *KZA1907*. They all died soon afterwards. Two passengers from the Saudia flight survived the crash, still strapped to their seats, only to die of internal injuries soon after. In the end, all 312 people on board *SVA763* and all 37 people on *KZA1907* were killed. We may identified some human errors are identified as probable causes behind this accident. These are:

Active error

The root and approximate cause of the collision was the unauthorized descending by the pilots of Kazak aircraft. The commission determined that the accident had been the fault of the *KZA1907*commander. According to *Flight Data Recorder* (FDR) evidence he had descended from the assigned altitude of 15,000 to 14,500 feet (4,600 to 4,400 m) and subsequently 14,000 feet (4,300 m) and even lower.

Latent error

According to the reports, it may be ascribed that, some important contributory factors behind this accident were:

- Lack of English language skills on the part of the Kazakh aircraft pilot; they were entirely relying on their radio operator for communications with the *air traffic control* (ATC)[95].
- The radio operator did not have his own flight instrumentation but had to look over the pilots' shoulders for a reading.
- Kazakh officials stated that the aircraft had descended while their pilots were fighting turbulence inside a bank of cumulus clouds.
- Radio operator of *KZA1907*failed to identify the actual altitude of the flight and as a result he provided wrong information to the pilot.
- Indian air controllers also complained that the Kazakh pilots sometimes confused their calculations because they were accustomed to using *meter altitudes and kilometer distances, while most other countries use nautical miles and feet.*
- Furthermore the Indira Gandhi International Airport did not have secondary surveillance radar, which provides extra information, such as the aircraft's

[95] Air traffic control (ATC) is a service provided by ground-based controllers who direct aircraft on the ground and through controlled airspace.

identity and altitude, by reading transponder signals; instead the airport had primary radar, which produces readings of distance and bearing, but not altitude.

ii) Aviation accident due to forced landings

A forced landing is a landing by an aircraft made under factors outside the pilot's control, such as the failure of engines, systems, components or bad weather which makes continued flight impossible. Explaining this type of accident we are analyzing the incident of Indian Airlines flight 605, Airbus A320-231 [96] below:

Brief description of the accident

This accident took place in Banglore on 14th February 1990. The aircraft was totally destroyed due to this accident[97]. A-320 was listed for a daily round trip between Mangalore and Dubai. That very day the flight landed at Dubai uneventfully. After that the airplane was serviced and refueled. The airplane taxied out for departure on scheduled time. The take-off, climb and cruise were uneventful. But there was no conversation between the two pilots for about 1 hour and 40 minutes because the Captain was asleep. The first officer was operating all the radio calls. At about 130 miles from Mangalore, the first officer requested descent clearance. But at that time this was denied by the ATC. Then he was using standard procedural control, to ensure safe separation with other air traffic. While the aircraft had commenced descent, there was no recorded conversation regarding the preparation for descent landing briefing. But it was mandatory according to the *standard operating procedure* (SOP)[98]. After the aircraft was at about 50 miles and descending out of *flight level* (FL)[99] 295, the conversation between the two pilots indicated that an incomplete approach briefing had been carried throughout the descent profile and DME[100] (*Distance Measuring*

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[96] Report on The Accident to Indian Airlines Airbus A320 Aircraft VT-EPN on 14th February, 1990 at Bangalore By The Court of Inquiry Hon'ble Mr. Justice K. Shivashankar Bhat, Judge, High Court of Karnataka Government of India, Ministry of Civil Aviation.
source: http://lessonslearned.faa.gov/IndianAir605 . (Retrieved on 2.5.2010)

[97] www.flightsafety,org(aviation-safety.net). (Retrieved on 2.5.2010)

[98] A Standard Operating Procedure (SOP) provides a flight crew with a step by step guidance to carry out operations effectively and safely.

[99] In aviation and aviation meteorology, a flight level (FL) is defined as a vertical profile of airspace at standard pressure, expressed as a nominal altitude in hundreds of feet.

[100] By the aircraft's DME equipment an aircraft can compute its distance to the beacon (radio transmitter) from the delay of the signal.

Equipment) approached for *instrument landing system* (ILS)[101] 24. The aircraft was much higher than normally expected altitudes. The Tower controller, thereafter, asked the aircraft to report having established on 10 DME for ILS runway 24. But the captain was operating the flight in *window of circadian low* (WOCL)[102]. In particularly between two and six in the morning – in which the urge to sleep is especially strong. And the restorative effects are also much better if one sleeps during this period. This time period at night is referred to as the WOCL. So, in order to increase the rate of descent the aircraft continued to be high and did not follow the standard procedure of intercepting the ILS glide path at the correct intercept altitude. This incorrect procedure led to the aircraft being at almost twice the altitude as compared to a standard ILS approach. During approach, the Cockpit Voice Recorder (CVR) indicated that the captain had selected flaps 40 degrees and completed the landing check list. The radio altimeter had alerted the pilot about the altitude of 2500 ft. This was immediately followed by the first officer saying "It is too high" and "Runway straight down". In reply, the captain had disconnected the auto pilot and simultaneously increased the rate of descent considerably to establish on the desired approach path. After that the captain had forcefully prompted the first officer to give a call of "Affirmative" about landing. The tower controller gave landing clearance thereafter and also indicated slower wind. The aircraft was high on approach and touched down on the runway, much farther than normal. The aircraft had crossed the threshold at about 200 ft altitude with indicated speed in excess of 160 ft, as compared to 50 ft with target speed of 144 ft for the landing weight. Despite the *enhanced ground proximity warning system* (EGPWS) [103] warnings and calls from the first officer to go around, the captain had persisted with the approach in unsterilized conditions. Short of touchdown, there was yet another (Third) call from the first officer, reporting that they didn't have runway left. But the Captain had continued with the landing and the final touchdown was about 5200 ft from the threshold of runway 24, leaving approximately 2800 ft of remaining paved surface. The Captain had selected thrust reversers soon after touchdown. Within 6 seconds of applying

[101] An instrument landing system (ILS) enables aircraft to land if the pilots are unable to establish visual contact with the runway

[102] Window of circadian low (WOCL) is adapted usual day-wake/night sleep schedule by the individual who working in the aviation sector. This schedule is calculated from scientific data of the performance of the aircrew.

[103] A ground proximity warning system (GPWS) is a system designed to alert pilots if their aircraft is in immediate danger.

brakes, the aircraft overshot the runway including the strip of 60 meters. After overshooting the runway and strip, the aircraft continued into the *Runway End Safety Area* (RESA)[104] of 90 meters. Thereafter, the aircraft hit the boundary fence and fell into a gorge. We have identified some human errors as causes of the accident. These are:

Active error

It is identified that the direct cause of this accident was the pilot of the victim aircraft failed to realize the gravity of the situation and to respond immediately towards proper action of moving the throttles.

Latent error

Behind the active error of incident there are some latent causes. These are:

- In spite of availability of adequate rest period prior to the flight, the Captain was in prolonged sleep during flight, which could have led to sleep inertia. As a result of relatively short period of time between his awakening and the approach, it possibly led to impaired judgment. This aspect might have got accentuated while flying in the WOCL.
- Mangalore Area Control Radar (MSSR) was inactive; it had happened due to problem in serviceability. The aircraft was given descent at a shorter distance on DME as compared to the normal. However, the flight crew did not plan the descent profile properly and results in remaining high on approach.
- Probably for ambiguity in various instructions empower the 'copilot' to initiate a 'go around ' mode. Although the first officer gave repeated calls to warn him about its effect, but did not take over the controls to actually discontinue the ill-fated approach.
- It may also be said that the pilot has lack of knowledge about RESA; it is also a contributory cause of the accident.

iii) Aviation accident due to air-crash in mountainous terrain

This is an aviation accident in which under pilot control, an aircraft is unintentionally flown into the ground, a mountain, a body of water or an obstacle. Explaining this

[104] Runway end safety area (RESA) is defined as the surface surrounding the runway prepared or suitable for reducing the risk of damage to airplanes.

type of accident we are analyzing the incident of the accident of a Indian Airlines *Boeing 737* flight IC257.

Brief description of the incident

This accident took place on 16th August1991. On that very day Indian Airlines flight IC257 departed Calcutta at 11:54 on a scheduled 60-minute flight to Imphal, India. The crew contacted Imphal at 12:34. The flight was cleared to descent from FL290 to 10,000 feet and asked to report overhead the VHF **(***Very High Frequency)* Omni Directional Radio Range ILS runway 04. In short form VHF Omni Directional Radio Range is called (VOR) for. In this context describing VOR we may say that it is a type of short-range radio navigation system for aircraft, enabling aircraft with a receiving unit. It determines the position and stay of the flight on course by receiving radio signals transmitted by a network of fixed ground radio beacons. At 12:39 the crew reported that the flight was12 miles inbound at 10,000 feet. The pilot then asked the air traffic controller as to whether they could set course directly outbound for letdown or not. This was approved. Two minutes later the flight reported overhead the VOR about that it was still 14 miles out. The controller then queried: "understand you are proceeding on a radial 217 for ILS". At 12:42 Imphal ATC cleared the flight to proceed outbound for an ILS approach to runway 04 descending to 5,000 feet. Accepting the approach at 12:44 the flight reported commencing the procedure turn. It was its last reporting of the victim flight. Around 12.46 the aircraft crashed at Thanjing hill about 300 ft below hill peak at a distance of 2.19 nautical miles from lmphal airport. The flight had 6 crew and 63 passengers on board. All the 69 persons died in the accident. The aircraft was completely destroyed. We have identified some human errors as cause of this accident. These are:

Active error

The accident occurred by reason of a grave error on the part of the Pilot-in-Command. He could not realize that his early descent to 10,000 feet and turning right for outbound leg without reporting overhead VOR would result in loss of time reference and as such misplace him in the hilly terrain.

Latent error

Some contributory factors behind this adverse event were:

- Crew did not follow operational flight plan. He did not go overhead Agartala but flew directly to Imphal. The Pilot-in-Command's action may have been influenced by his extreme familiarity with the terrain.[105]
- *Distance Measuring Equipment* (DME), which is co-located with *Very High Frequency Omni Range* (VOR) was not installed.
- The pilot also commenced descent nearly 10 minutes before the top of descent prescribed in operational flight plan. The reason for crash was given as pilot not adhering to operate the flight path.
- The weather was above minimal for ILS approach. On the other hand status indicator lights of ILS were not functioning in the Control Tower.
- No equipment for *runway visual range* (RVR)[106] was provided. This equipment is very vital to pilots for instrument approach.
- ATC multi channel tape recorder did not install. As a result proper monitoring by the ATC officer was difficult.
- Neither refresher courses nor proper licensing effected for the ATC officers.
- The aerodrome was also not licensed. There were no maintenance schedules for ground navigation and landing aids.
- GPWS *(Ground Proximity Warning System)* came on about 6 seconds prior to crash but it was not possible to clear the hill.

From this accident it is very clear that there were many interlinked factors that led an aviation accident. It indicates that so many loopholes were responsible for the single accident and by reducing human error it is possible to control aviation accident. In the last section of this topic we are discussing some approaches about it.

[105] Gopal, P. (2000) Analysis of factors leading to pilot error accidents in civil aviation .*IJASM* , 44 (l) 34 - 38.

[106] In aviation meteorology, runway visual range (RVR) is the distance over which a pilot of an aircraft on the centerline of the runway can see the runway surface markings delineating the runway or identifying its centre line. RVR is normally expressed in feet or meters.

iv) Aviation accident due to technical snags

In India many aviation accidents took place due to technical snag. We are discussing here the Incident of B747-400 aircraft in the context of finding human error behind this type of accident.

Brief description of the accident

The accident of the B747-400 took place on 4th September, 2009 at the Mumbai Airport. This Indian aircraft was listed for a scheduled flight from Mumbai to Riyadh as AI-829. There were 213 passengers and 16 cabin crew members onboard. While the aircraft was taxing on G, the engineer who was allocated on the other company aircraft also saw the fuel leak from No 1 engine of the aircraft. Instantly he took off his ramp jacket and started signaling to the aircraft. The *cabin crew in-charge* (CCIC)[107] did see the person signaling but could not figure out the reason and hence ignored the scene. The "Follow me" jeep in the vicinity noticed the fuel leak. ATC informed the authority to switch off the engine immediately because it was a heavy fuel leak from the left engine. The commander announced for CCIC in the cockpit and started the emergency checklist. By the time, the engine no: 1 already caught fire and started moving towards no. 2 engine. The CCIC saw the fire while getting up from her located position and immediately gave evacuation commands. The passengers by now had also noticed fire from the cabin windows and rushed towards the door. The crew managed the passengers and deployed the side escape slides. All the passengers and the crew evacuated the aircraft safely. After ensuring nobody was left behind inside the aircraft, CCIC evacuated the aircraft. Since the cockpit is on the upper deck, both the pilots evacuated from the upper deck and did not come down to the lower deck during evacuation. They also came out before evacuation was completed. In the process of emergency evacuation, there was minor injury to 21 passengers of the aircraft and were given first aid and then shifted to hospital. By the time the fire vehicles had reached the aircraft and sprayed foam to put off the fire.[108]We have identified following human errors as cause behind this accident:

[107] An operator is nominated as CCIC whenever more than one cabin crew is assigned. CCIC is entrusted with the responsibility of leading the team of cabin crew on board the aircraft.

[108] http//dgca.gov.in/accident/reports/VT-ESM.pdf

Active error

Direct cause of this accident was engine on fire. It occurred due to dislodging of tie wire. It was caused by the failed tie wire hole. Heavy fuel leak and leaked fuel falling on hot engine resulted into fire. And finally the accident took place because of the pilot's lapses during walk around inspection.

Latent errors

Some contributory factors behind this near miss adverse event were:

- It was not tightening the coupling to the proper specification and procedure during maintenance resulting to ductile failure of coupling material which is the main contributory causative factor:
- Installation and maintenance were not done following proper protocol.
- ATC personnel failed to handle emergency situation effectively.
- There was lack of situational awareness and poor coordination among the crews.
- The crew had not followed the correct approach procedure, which resulted in the aircraft being high on approach.
- They had kept the engine at idle thrust and allowed to reduce the air speed than normally permissible value on approach.
- They then maneuvered the aircraft with high pitch attitude and executed rapid roll reversals.

This resulted in actuation of the stick shaker stall warning indicating an approaching stall. At this stage, the crew initiated a 'Go Around' procedure instead of 'Approach to Stall Recovery' procedure resulting in an actual stall of the aircraft, loss of control and subsequent impact on the ground.

Some common cognitive errors behind aviation accident

After discussing basic flight maneuvers and common accidents, it may be said that human error is an important cause behind aviation accident. Here we find out a basic cognitive pattern behind flight operation. And based on it we provide some typical cognitive error as a factor of aviation accident:

From cognitive point of view we may conclude that there are three basic mechanisms in a flight operation: receiving the concerning data or information, comprehension of the received data and using the data where necessary. So basing on this basic mechanism we may categorize aviation error in the following three categories:

i) Error due to non availability of the data
ii) Error due to lack of comprehension of the current situation
iii) Error in projection of future status.

i) Error due to non availability of the data

For the first step in flying operation, it is necessary for the pilot that to have sufficient information of the status attributes, and dynamics of relevant elements in the environment. The pilot needs to accurately perceive information about his/her aircraft and its systems (airspeed, position, altitude, route, direction of flight, etc.), as well as weather, air traffic control (ATC) clearances, emergency information, and other pertinent elements. If any of this information is unavailable to him it may result in adverse event. This type of error takes place in following situations:

Data not available: When sufficient Data about any system is not available, system operator may fail to get necessary information, and so this is a vital problem in any system which may take place due to failure of the system design to present it or failure in the communication process.

Data hard to discriminate or detect: When operator cannot identify necessary data, there may be undesired outcome. It may happen due to unexpected environments or lack of proper managements. Examples are poor runway markings or inadequate lighting, noise in the cockpit, or obstructions blocking view.

Failure to monitor or observe data: Data is available, but is not scanned due to simple omission, attention narrowing, and distractions due to multi-tasking or high workload.

Misperception of data: Sometimes data may be misperceived due to prior expectations or is misunderstood due to task distraction. An example of it may be wrong signal reading following (forward car movement) others movement.

Memory loss: Forgetting information is due to disruptions in normal routine or high workload also leads to the failure of the operators.

ii) Error due to lack of comprehension of the current situation

Understanding of the real situation is necessary for any system operation. If the operator does not comprehend the given information, it may cause error. Comprehension of the situation is based on a synthesis process of the received information. In this stage the operator becomes aware of the elements he has already received and then he/she tries to understand the significance of these information and finally he/she uses these to achieve the goals. So knowledge of current situation is very important to take proper decision. But comprehension of the receiving data and its significance is also very important. In modern times a novice operator may be more efficient to gather information than an experienced one by using new gadget but he needs more experience to use it properly in a critical situation. Not only in aviation sector this hold good for any other sector. Some factors behind this type of error are mentioned below:

Poor mental model: Poor mental model means operator with lack of decision taking skill. This type of operator fails to combine the information needed to achieve goals. But for any system it is very necessary that the operator has ability to comprehend the information which is primarily associated with automated systems. So when he is not able to associate information with the system, it causes system failure.

Use of incorrect mental model: When received information is interpreted wrongly it is called use of incorrect mental model. It may happen due to misconception of the system or misunderstanding of the collected information by the operator.

Over-reliance on default values: Sometimes operator keeps all his faith on the collected data without analyzing them. But then it may happen that he collects incorrect data. Generally in this situation a conflict may arrive but the operator is not aware of the chance factor and so the system will be out of control. Mainly in a regular work or in monotony work this type of incident take place.

iii) Error in projection of the knowledge for the future status

The ability to take the appropriate future actions against the current environment is very important in aviation. It reflects the situation awareness of the operator. The quality of situation awareness is achieved through knowledge of the status, a comprehension of the real situation and dynamic quality of decision making. For example, the pilot must not only comprehend that a weather cell—given its position, movement and intensity—is likely to create a hazardous situation within a certain period of time, but she/he must also determine what airspace will be available for route diversions, and ascertain where other potential conflicts may develop. This ability enables the pilot to decide the most favorable course of action. If the pilot fails to do so it will be called error in projection of knowledge in the future situation. Some contributory factors behind this type of error:

Improper projection of that state: It is not enough that information of current state is correctly understood, for a successful presentation it is also necessary that this information is used perfectly for the exact situation. So when the operator fails to project his knowledge, it may cause a system failure. It may happen due to poor understanding or lack of experience.

Over-projection of current trends: It may happen that, the operator knows how he projects his current knowledge to manage the future situation but it is not sufficient. He has to update his knowledge every time. Without this quality he may make mistakes at any time.

Some Approaches for reducing human error in aviation sector

Analyzing different causes behind aviation error it is very much clear that there are anonymous contributory factors behind aviation error. Here we include some of them and finding measures to handle them:

Improving communication among crews

In aviation sector, communication means mutual understanding between the AMT and many people such as management, pilots, parts suppliers, aircraft servicers. Lack of communication between technicians can lead to a maintenance error and result in an aircraft accident. This is especially more meaningful where more than one

technician performs the work on the aircraft. It is critical that accurate, complete information be exchanged to ensure that entire work is completed without any step being omitted. Knowledge and speculation about a task must be clarified and not confused. Each step of the maintenance procedure must be performed according to approved instructions as though only a single technician did the work.

A common scenario where communication is critical is during shift changing time. When a worker finishes his or her workday and the partially completed job is transferred from one technician to another technician then there is communication gap. Many steps in a maintenance procedure cannot be seen or verified once completed due to the installation of components hiding the work. No steps are in the procedure can be omitted and some steps remain to be performed.

So, in reducing human error in this sector the technician in charge should explain thoroughly what has occurred. It will help the next technician to operate their job correctly. Repetition or escaping of a critical step both may result in severe outcome in this sector. So lack of communication at this juncture could result system failure in future.

Some steps to improve communication between crews are:

- It must be signed off by the technician doing the work as it is performed. In a continuing process a shift should be changed after a face-to-face meeting of technicians. If necessary, a phone call may be made to obtain an oral turnover when technicians cannot meet face-to-face at the work area. In general, the technician must see his or her role as part of a greater system focused on safe aircraft operation and must communicate well with all in that system to be effective.
- The applicable paperwork should be reviewed, the completed work discussed, and attention for the next step should be drawn. Absence of written or oral turnover serves a warning for a system.
- Work should always be done in accordance with the approved written procedure and all performed steps should bear the signature of the technician who accomplishes the work.

Recovering lack of knowledge

The technology always differs from aircraft to aircraft. So updating of technology and procedures on a single aircraft is very necessary for operating of an aircraft properly. Lack of knowledge about relevant aircraft may cause a great danger for the flight. To reduce errors due to insufficient knowledge of the crews following precautions may be adopted:

- Technicians must be able to use the latest relevant data. For proper knowledge technician must consult with the experienced one. If one is not available, or the consulted technician is not familiar with the procedure, a manufacturer's technical representative should be contacted.
- They must also be aware that design and maintenance procedures are varied on different aircrafts. So it is important for technicians to go through in training on different types of aircraft.

Avoiding any type of distraction

If crew is distracted from any running flight procedure it may cause severe accident. When work is resumed, it is possible that the technician skips over a detail that needs attention. Distractions can be mental or physical in nature. They can occur when the work is located on the aircraft or in the hangar. They can also occur in the psyche of the technician independent of the work environment. Something as simple as a cell phone call or a new aircraft being pushed into the hangar can disrupt the technician's concentration on a job. Less visible is a difficult family or financial matter or other personal issues that may occupy the technicians thought process as work is performed. This can make performance of the required maintenance less effective. Regardless of their nature, numerous distractions may occur during the course of maintaining an aircraft. To avoid these problems, technicians should follow the following steps:

- Use of a detailed step-by-step written procedure and signing off each step only after it is completed also helps.
- Incomplete work can be marked or tagged, especially when the technician is pulled from the work by a distraction, and it is unknown when work will be resumed and by whom.

- Disconnect any connector and leave it plainly visible if an installation is not complete. There is a tendency to think that a job is finished when a component is "hooked up." Similarly, when a step in the maintenance procedure is complete, be sure to immediately lock wire or torque the fasteners if required. This can be used as an indication that all is well up to that point in the procedure.

Take precaution about becoming fatigue of the air crews

Fatigue is a major human factor that has contributed to many aviation errors resulting in a severe accidents. A person is said to be fatigued when a reduction or impairment in any of the following occurs: cognitive ability, decision-making, reaction time, coordination, speed, strength, and balance. Fatigue reduces alertness and often reduces a person's ability to focus and hold attention on the task being performed. Symptoms of fatigue may also include short-term memory problems, channeled concentration on unimportant issues while neglecting other factors that may be more important, and failure to maintain a situational overview. A fatigued person may be easily distracted or may be nearly impossible to distract. He or she may experience abnormal mood swings. Fatigue results in an increase in mistakes, poor judgment, and poor decisions or perhaps no decisions at all. A fatigued person may also lower his or her standards. Tiredness is a symptom of fatigue. However, sometimes a fatigued person may feel wide awake and engaged in a task. To prevent fatigue the following steps may be useful:

- The primary cause of fatigue is a lack of sleep .So good restful enough sleep on a regular basis is the best remedy for fatigue. The technician must be aware of the amount and quality of sleep obtained. Caution or time off is justified when too little sleep has occurred and errors are probable during maintenance. Sleep and exercise daily. Eight to nine hours of daily sleep are recommended to avoid fatigue.
- Fatigue can also be caused by stress and overworking. A person's mental and physical state also naturally cycles through various levels of performance each day. Variables such as body temperature, blood pressure, heart rate, blood chemistry, alertness, and attention rise and fall in a pattern daily. This is known as one's circadian rhythm. A person's ability to work (and rest)

rises and falls during this cycle. Performance counter to circadian rhythm can be difficult. Until it becomes extreme, a person may be unaware that he or she is fatigued. It is easier recognized by another person or in the results of tasks being performed. This is particularly dangerous in aviation maintenance since the lives of people depend on maintenance procedures performed at a high level of proficiency.

- Working alone when fatigued is particularly dangerous. Constant monitoring by some means is important.
- Usually aviation maintenance technicians (AMT) [109]are performed at night.. Therefore, shift work is required to maintain the fleet. It is already known that turning work over to other technicians during shift change is a problem that can lead to errors due to lack of communication. But shift work alone is a cause of fatigue that can degrade performance and also lead to errors. Shift work requires technicians to work during low cycles of their natural circadian rhythm. It also makes sleep more difficult when not on the job. Furthermore, regular night shift work makes one's body more sensitive to environmental disturbances. It can degrade performance, morale, and safety. It can also affect one's physical health. All of these can be reflected in degraded maintenance performance—a dangerous situation. The technician must be aware that shift work is the norm in aviation. Avoidance of fatigue is part of the job. Title 14 of the Code of Federal Regulations (14 CFR) part 121, section377, only requires 24 hours time off during a week of work. Since this is obviously not enough, it is up to companies and technicians to regulate shift work and time off to reduce the potential for errors. Most importantly, each technician must monitor and control his or her sleep habits to avoid fatigue.

Recovering lack of resources

A lack of resources can interfere with one's ability to complete a task because there is a lack of supply and support. Low quality products also affect one's ability to complete a task. Aviation maintenance demands proper tools and parts to maintain a fleet of aircraft. Any lack of resources to safely carry out a maintenance task can

[109] Aviation Maintenance Technicians (AMT) inspect, service, maintain, troubleshoot and repair aircraft engines.

cause both non-fatal and fatal accidents. Some approaches to recovering lack of resources are:

- Within an organization, making sure that concerned person has the correct tools for the job is as important as having the proper parts when they are needed. Having the correct tools means having no power to improvise. For example, an aircraft that had received a new interior needed to be weighed prior to its flight. Two days before the planned release, the aircraft was weighed without the proper electronic load cells placed between the aircraft jack and the aircraft. Because the correct equipment was not used and consequently, the aircraft slipped off of one of the load cells and the jack point creased the spar. The cost of improvising can be very steep. The right tools to do the job must be used at all times, and if they are broken, out of calibration, or missing, they need to be repaired, calibrated, or returned as soon as possible.
- Technical documentation is another critical resource that can lead to problems in aviation maintenance. When trying to find out more about the task at hand or how to troubleshoot and repair a system, often the information needed cannot be found because the manuals or diagrams are not available. If the information is not available, personnel should ask a supervisor or speak to a technical representative or technical publications department at the appropriate aircraft manufacturer. Most manuals are in a constant state of revision and, if organizations do not identify missing information in the manuals, nothing is done to correct the documentation. Resources, such as publication departments and manufacturer's technical support, are available and should be used rather than ignoring the problem. Another valuable resource is that the maintenance department should rely on the flight crew.
- Organizations should encourage open communication between the flight crews and the maintenance crews. The flight crew can provide valuable information when dealing with a defective part or problem. When the proper resources are available for the task at hand, there is a much higher probability that maintenance will be better. Organizations must learn to use all the resources that are available and, if the correct resources are not available,

they make the necessary arrangements to get them in a timely manner. The end result saves time, money, and enables organizations to complete the task knowing the aircraft is airworthy.

4.3 Human Error in the Marine Sector

Human error refers to an individual behavior performed for a specific system. So it is very important to analyze human error occurred in the practical field. An important approach for handling errors and reducing marine accident is finding the causal factors of human errors. In this context at first it is needed to find out what types of marine accidents occur in marine transport. This section analyzes some real incidents we will try to identify human error behind these accidents and suggest some measures to rectify.

Basic concepts of marine job

We are starting this section with basic maritime job. Without it we will not be able to understand the maritime incident at all; and then it will be impossible to search causal factors of accidents. In describing what kinds of work are actually performed on board ships according to the report on the European project BERTRANC (2000) [110]it is possible to define basic maritime work with five tasks. They are:

- Navigation
- Propulsion
- Cargo handling
- Ship management

Navigation: Navigation is the art or science of determining the ship's or aircraft's position and of conducting a ship or aircraft from one position to another. The problems of navigation are identifying position, direction and distance. So in navigation responsibility of route planning, track keeping and collision avoidance are to be considered.

Propulsion: Marine propulsion is the mechanism or system used to generate force to move a ship or boat across water. The person, who operates the propulsion system of

[110] Grech, M., Horberr, T. J., Koester, T. (2008). *Human Factors in the Maritime Domain* Boca Raton, Florida CRS Press, p.12

a ship, has the responsibility for the integrity of the ships propulsion system and associated auxiliaries.

Cargo handling: The word 'cargo' refers in particular to goods or produce being conveyed; generally for commercial gain by ship, boat, or aircraft, although the term is now often extended to cover all types of freight, including that carried by train, van, truck, or intermodal container. In the context of maritime industry cargo handling process refers to loading, unloading and keeping the goods of passengers in good condition and safety.

Ship management: Ship management is an important part of maritime traffic supervision and management. It includes the registration and management of ships, visa of ships entering and leaving the port, management of foreign vessels, ship maintenance management and technical ship management. So in simple words it refers to the allocation of tasks and responsibilities, control and supervision and communication of the crew members and the authority.

Some examples of aviation accident and human errors behind them

Different types of accident take place in maritime industry. We select four among them. We select these incidents because details reports on these accidents are available which may help us to find out the human errors behind these accidents. Moreover in marine sector there are some typical human errors responsible for all types of accidents. So if we can find the human errors in this sector we can provide remedy to recover them. We will discuss following four types of marine incident in this section:

i) Collision or contact

ii) Capsize or foundering

iii) Grounding

iv) Fire or explosion

i) Collision or contact

Ship collision is a very common marine accident. It is the structural impact between two ships or one ship and a floating or a still object such as an iceberg. The collision between the Hong Kong flagged bulk carrier *Spring Glory* and Danish flagged container ship *Josephine Maersk* be noted here as an example of this type of accident.

Brief discussion of the collision accident

This accident took place on 5 June 2012 at 22:34:40 hours in the eastern approaches to the Singapore Strait. That very day Hong Kong flagged bulk carrier *Spring Glory*, loaded with 80,400 mt iron ore. Denmark flagged container ship *Josephine Maersk*, loaded with general cargo in containers many of which were refrigerated containers. It navigated westbound and was about to enter the Traffic Separation Scheme (TSS)[111] of the Singapore Strait. According to the international regulations for preventing collisions at sea, *Spring Glory* was the ship to give way, and *Josephine Maersk* was the ship to stand on. The officer who was keeping watch on *Spring Glory* noticed on its radar only about 10 minutes prior to the collision that, *Josephine Maersk* was approaching on a crossing course. Due to the lack of understanding of the traffic situation, the officer of the watch hesitated and waited for actions to be taken by *Josephine Maersk* to avoid a collision. During the last minutes prior to the collision, he attempted to communicate with *Josephine Maersk*, but it was too late to avoid a collision. On the other side the officer of the watch on *Josephine Maersk* observed visually *Spring Glory* approaching at a distance about five minutes prior to the collision. During the time until the collision, he confirmed his observation by the use of binoculars, answered briefly calls from *Spring Glory* ascertaining the identity of that ship, found the distance between the ships on the radar, checked his own position on the GPS and plotted it into the chart. He misunderstood a message on the VHF (Very High Frequency) radiotelephone to increase the speed that was actually meant for another ship and that motivated him not to conduct any effective maneuver in due time. He called the master for assistance and took an evasive action by giving helm hard to starboard; however, too late to avoid a collision. The collision caused damage

[111] A Traffic Separation Scheme or TSS is a traffic-management route-system ruled by the International Maritime Organization or IMO.

to both ships and to the cargo of *Josephine Maersk*. In *Josephine Maersk* a fire in the electrical installations of some refrigerated containers was caused by the collision.[112]

Identified human errors behind this accident

According to the hindsight report of this accident we may explain following incidents as contributory factors of the accident:

- *Spring Glory* was navigating in a Traffic Separation Schemes (TSS). According to this scheme traffic transiting is regulated in both directions. There were bright background lights from many ships at anchor in the vicinity of the TSS, which impeded the visual detection of other ships.
- When *Josephine Maersk* was first time visible on the radar of *Spring Glory* thereafter for the next 18 minutes and until the collision at 22:34:40 hours, *Josephine Maersk* remained visible on the radar with a clear trail. Instead of that the watch officer of the *Spring Glory* failed to realize the collision risk until when the ship was at a distance of approx. 5 nm.
- Bridge team of both ships failed to play any active role prior to the collision.
- The navigation of *Spring Glory* failed to maintain its course and speed and thus the last minute attept by *Spring Glory* to avoid a collision came too late.

ii) Capsizing

When a boat or ship is turned on its side or it is upside down it is called capsizing. It is a very serious marine accident. In a very recent instance of capsizing, 68 died in a Bangladesh ferry capsizing. In February 2015 around midday, this accident took place. Overcrowding of ferries and poor monitoring systems are persistent problems for this accident. Here we are analyzing the incident of capsizing *Questar* in detecting human error behind this type of marine accident.

Description of the accident

This accident took place on August 21, 1994, when *Questar* was a disabled 18-foot motorboat. It capsized while being towed by the Coast Guard Auxiliary vessel *Puppet* immediately south of Shelter Island, Lynn Canal, near Juneau, Alaska. That very day during taking part in fishing competition (Golden North Salmon Derby) the outboard engines of *Questar* were stopped. The operator of *Questar* did not have a radio and

[112] *Marine Accident Report* issued on May 2013 The Danish Maritime Accident Investigation Board.

flagged down a nearby recreational boat, to ask for help. He asked the idle hours' operator in emergency to call the Coast Guard for assistance. Chief Radioman of the coast-guard informed the *Puppet's* operator to help *Quester*. *Puppet* was the nearest vessel of the *Quester* at that point of time. The vessel *Puppet* got under way shortly thereafter and prepared to take the *Questar* in tow. But the *Puppet'*s operator did not get any information about the *Questar* or it's the operator and passengers. Even he did not discuss any alternatives before towing it. *Puppet*'s operator took the *Questar* in tow heading for Auke Bay. He determined what speed he was able to make; but he did not provide any situation report to Station Juneau, his patrol commander. In fact then operator of *Puppet* also missed that there was a passenger on the *Quester*'s deck. Unknowingly he locked the oassenger in the cabin. Sea conditions in this area were confused with chop and breaking waves. After a few times *Puppet*'s auxiliary crewmember noticed that the *Questar* was down by the bow and alerted the operator to slow down. After a wave suddenly broke over the *Questar*'s bow, the vessel assumed a bow-down attitude and it was flooding the foredeck of the motorboat. In a few minutes water swept at the back, collapsing the deckhouse front accordion door and flooding the cabin of *Questar*. The operator of the *Quester* was trapped in the vessel's cabin. When the *Puppet*'s operator, who was steering from the flying bridge, realized what had happened, it was too late, and as a result the *Questar* capsized. The master of the *Kamilar*, the nearest ship from that accident place launched one of his small boats to try to set the *Questar* and extract its operator. When the master realized that efforts to set the vessel would not be successful, he weighed anchor and maneuvered the *Kamilar* alongside the *Questar* so that he could use the *Kamilar*'s seine winch to lift the *Questar*'s bow out of the water. He was able to raise the *Questar* far enough out of the water. He allowed crewmembers from the *Kamilar* to remove the operator from the Questar's cabin. About 25 minutes after the initial capsizing of the *Questar*, the unconscious operator was carried to the deck of the *Kamilar*, where one of the crewmen who were a certified emergency medical technician (EMT) immediately initiated Cardiopulmonary resuscitation (CPR)[113].CPR was administered to the operator continuously during the trip to the hospital but the

[113] Cardiopulmonary resuscitation (CPR) is a procedure to support and maintain breathing and circulation for an infant, child, or adolescent who has stopped breathing (respiratory arrest) and/or whose heart has stopped.

operator he pronounced was dead at that evening. An autopsy indicated drowning as the cause of death.

Some human errors are identified as cause behind this incident

Following the hindsight reports of this accident we may include following factors as its probable causes:

- Coast Guard personnel accepted and passed on inaccurate information about the vessels and its operator's condition without question or verification.
- Coast Guard did not have proper training to assist cases involving hazardous weather and sea conditions.
- The Coast Guard Auxiliary operator of the Puppet used improper towing procedures.
- Puppet's operator failed to assess properly the risk before deciding to tow the vessel in hazardous sea conditions.
- The Puppet's operator failed to remove the Questar's operator and passenger before towing the vessel.

iii) Fire and explosion

Shipping accident which may lead to serious financial losses or large scale environmental damages is fire aboard ship at sea. It is one of a seafarer's worst fears. It is also another potential threat that all seafarers and passengers are faced with. It sometimes results in total loss of the ship and / or her cargo. In spite of high safety standards, it is an immediate danger for life, cargo and the environment. Shipboard fires which may either be a cargo fire, accommodation fire or engine room fire may occur suddenly and on some occasions their effects are not localized. The hazards ranging from such incidents are up to several cables, or even miles, and there may be some potential for them to impact on shipping routes, particularly in narrow waters[114].

The most disastrous ship fire / explosion took place in December 30, 1917 in Port of Halifax, Canada. The French freighter "Mont Blanc" was loaded with high explosives. Estimated 3,000 people died and more than 7,500 were injured. Similarly, in December 20th 1987, the ferry "Dona Paz" (designed to carry 1,400 passengers and a

[114] Faturachmana, D. , Mustafa, S. S. (2011) . Transportation Accident Analysis in Indonesia , *Procedia - Social and Behavioral Sciences* 00 (2011) 000–000, p.1-6

crew of 50) crowded with approximately 3,000 passengers collided head-on with the tanker "Victor" loaded with 8,300 barrels of oil; in the subsequent explosion and fire at least 3,000 people died; only 24 passengers survived in Tablas Strait, off Mindoro Island, Philippines. For lack of proper data in analyzing these accidents, we cannot identify human error as its factors so we take another example of fire at *Deepwater Horizon* rig.

Brief description of the accident

The incident of explosion on *Deepwater Horizon* rig[115] took place on the evening of April 20, 2010. At approximately 9:50 p.m. while the crews of the *Deepwater Horizon* rig were finishing work after drilling the Macondo exploratory well, an undetected influx of hydrocarbons escalated to a blowout and consequently this accident happened. Shortly after the blowout, hydrocarbons had flowed onto the rig floor catch fire in two separate explosions. Flowing hydrocarbons fuelled a fire on the rig that continued to burn until the rig sank on April 22. Eleven men died on the *Deepwater Horizon* that evening. Over the next 87 days, almost five million barrels of oil were discharged from the Macondo well into the Gulf of Mexico[116]

Deepwater Horizon was not an extractive oil rig, but an exploratory rig. When it exploded on April 20 it was in the process of completing its exploration by capping the well it had bored some three miles below the ocean floor. Before moving on to another exploration site this required the rig to plug the oil well and separate its riser piping from the wellhead to the rig. A separate rig would later have come to access the sealed wellhead. *Deepwater Horizon*'s exploratory drilling had been troubled by unusually frequent and forceful contact with explosive natural gas deposits. According to one worker's account, submitted to Bea in the previous several weeks of the accident, so much [gas] came belching up to the surface. On the day of the explosion, engineers reportedly argued over whether or not to remove dense drilling mud from the well bore, replacing it with much lighter sea water. The decision was taken to replace the mud before plugging the well, even though this would increase

[115] Analysis of past accidents in offshore oil and gas operations (2012) European Commission Joint Research Centre Institute for Energy and Transport.

[116] This estimate is based upon pressure readings, data, and analysis conducted by U.S. scientific teams commissioned by the National Incident Commander.
Source:
http://www.doi.gov/news/pressreleases/US-Scientific-Teams-Refine-Estimates-of-Oil-Flow-from-BP-Well-Prior-to-Capping.cfm. (Retrieved on 12.5.2013)

the chances of an explosion. This was a clearly reckless decision to press forward to protect BP's profit interests, because it paid rig owner Transocean an estimated $500,000 per day for use of Deepwater. It made anxious both Horizon and its crew to bring the new well into active production. On the evening of April 20, a geyser of seawater erupted onto the rig, shooting 240 feet into the air. This was soon followed by the eruption of a slushy combination of mud, gas and water. At this point workers knew they were in danger because the mud could only have come from 10,000 feet down, Bea said. On the rig, the gas component of the slushy material quickly transitioned into a fully gaseous state and then ignited into a series of explosions followed by a firestorm. Workers immediately attempted to activate the blowout preventer, but they failed to do it.[117]

Identified human errors behind this accident

Analyzing the accident reports, we may explain following factors as the causes of the accident:

- The operator failed to identify the probable hazard rising from the frontier conditions and from changes to well design.
- Responsible personnel could not recognize early warning signals and failed to react.
- Failure in reacting to emergency situations due to lack of appropriate training of personnel.

iv) Grounding

Ship grounding is the impact of a ship on seabed or waterway side. It may be intentional, as in beaching to land crew or cargo careening for maintenance or repair. Unintentional grounding, as in a marine accident may result simply in stranding, with or without damage to the submerged part of the ship's hull. Breach of the hull may lead to significant flooding, which in the absence of containment in watertight bulkheads may substantially compromise the ship's structural integrity, stability, and safety. Here in this context we are discussing the grounding of *Dart*.

[117] Eley, T. (2010). What Caused The Explosion on The Deep Water Horizon? International Committee of The Fourth International (ICFI) . Source : wsws.org retrieved on 08.08.2014

Brief description of grounding *Dart*

Dart was a waste disposal vessel and was reported to have carried mud. On 31st July 2013 at 0440, the Tanker *Dart* departed Dusavik, Norway, after having been loaded with drilling mud towards Floroe. It was to be further loaded in Norway. On its way towards Floroe, the ship called at Kopervik for maintenance of the electronic chart and display information system (ECDIS). *Dart* resumed its voyage towards Floroe at 1625. When the ship's ECDIS had been serviced, it was observed that the sound alarm inherent in the system did not work. Except for lacking sound alarm, the voyage proceeded as planned. Ten minutes before the grounding, the ship deviated from the planned route because the mate had fallen asleep immediately before a waypoint.[118] As a result the ship touched the ground under a rock in the Aafjorden. As consequence there were damages to the ship's bulb stern as well as leakage between the forepeak and the bow thruster room.

Identified human errors behind this accident

The underlying causes of the accident are described below:

- Watch keeper failed to keep watch because he had fallen asleep immediately before a waypoint. He was probably not been able to realize or react to this tiredness.
- The on-board crew did not realize that the bridge watch alarm did not function as intended. Bridge watch alarm did not work in the time of grounding. It was a software problem of *bridge navigational watch alarm system.* The purpose of a *bridge navigational watch alarm system* is to monitor bridge activity and detect operator disability which could lead to marine accidents. The system monitors awareness of the Officer of the Watch (OOW) and automatically alerts the Master or another qualified person if for any reason OOW becomes incapable of performing OOW's duties. This purpose is achieved by series of indications and alarm to alert first the OOW and, if he is not responding, then to alert Master or another qualified person.

[118] The Marine Accident Report January 2014 issued on 18 December 2013. The Danish Maritime Accident Investigation Board.

- In addition, this incident may include in ship maintenance error but it is true that alarm was a passive measure that did not require intentional action to be de-activated. Moreover the design of the bridge watch alarm meant that it was possible to test it only while the ship was at speed and in case of lacking movements on the bridge. Therefore, the routine test of the bridge watch alarm before departure did not reveal the inappropriate location of the sensor in the specific case.

Some common human errors behind marine accident

Following these examples given it may be cited that there are some typical human errors behind maritime accidents. Some of these are:

Navigational errors

Navigation is an increasingly exact science (Koester, 2007)[119]. Electronic positioning systems give the navigator a greater certainty than ever; regarding his position within a few meters. But some approximations are used there. For example, when the navigator uses his latitude graduations as a mile scale to compute a great-circle course and distance, he neglects the flattening of the earth at the poles. When the navigator plots a visual bearing on a Mercator chart, he uses a thumb line to represent a great circle. When he plots a celestial line of position, he substitutes a thumb line for a small circle. When he interpolates in sight reduction tables, he assumes a linear (constant-rate) change between tabulated values. All of these assumptions may indicate errors. There are so many approximations in navigation. There is a natural tendency for some of them to cancel others. However, if various small errors in a particular fix all have the same sign, the error might be significant. The navigator must recognize the limitations of his positioning systems and understand the sources of position error. One of the major causes of the collision between *Spring Glory* and *Josephine Maersk* (discussed on page no..) is the navigation error of *Spring Glory*.

[119] Koester, T . (2007). *Terminilogy Work in Maritime Humah Factors* (First e-book edition), Denmark, Frydenlund publishers.

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Error in watch keeping

Lack of proper watch keeping is a central issue of marine accident. Watch keeping is the responsibility of a deck officer, who comprise the master and first and second mate and perhaps a third mate who typically operates a three-watch system. Ships' officers have two 4-hours watches per 24 hours period. The first mate takes responsibility for the 4-8 watch; second mate the 12-4 watch and the third mate or the master the 8-12 watch. Lower quality and fragmented sleep are major factors for accident due to this error. It is one of the common factors behind all the examples given here.

Error in bridge discipline

In accordance with the company's procedures, the vessel was required to maintain a master's order book which contained the master's standing orders and daily orders. But if there is any doubt the bridge team should ask the master questions for clarification.[120] Lack of communication between bridge team may results accident like the collision of *Spring Glory* and *Josephine Maersk.*

Some approaches for reducing marine accident due to human error

People involved in the maritime system are ship's crew, pilots, dock workers, Vessel Traffic Service operators, and others. They operate a ship as a team and their performances depend on many traits such as their skill, knowledge and ability. As human beings, marine operators have certain abilities and limitations. For example, human beings are great at pattern discrimination and recognition. There is no such a machine in the world that can interpret a radar screen as perfectly as a trained human being can. On the other hand, they are fairly limited in their memory capacity. They can never calculate numbers quickly and accurately as a machine. With these inborn characteristics human performance is also influenced by their acquired knowledge and skills and by internal regulators such as motivation and alertness. Likewise any other field knowledge, skills, abilities, memory, motivation, alertness may be cited as the main human related factors in marine industry. Here we are discussing some human

[120] Report on the investigation of the grounding of Maersk Kendal (2009). Source:http://www.emsa.europa.eu/Documents/medias/51-462.pdf (Retrieved on 1.10.2015)

factors related to the marine safety and we will provide some remedies for reducing human error in these factor:

Taking decisions based on adequate/sufficient information

Mariners often have a tendency to rely on either a favored piece of equipment or their memory. In avoiding error they have to make navigation decisions based on all available information. According to reports many accidents was a resultant of the failure to consult available information (such as that from radar or an echo-sounder). In the other hand lack of critical information and due to incorrect information many navigation errors may take place.

Giving importance on adequate general technical knowledge

The main contributor to error in this sector is the lack of knowledge of the proper use of technology like radar or other equipments. Mariner often fails to understand how the automation works or under what set of operating conditions it is designed to work effectively. The unfortunate result is that mariners sometimes make errors in using single equipment or depend on only one piece of equipment where alternative sources was available.

Improving communications

In reducing marine accident another area is improvement of communications between shipmates, between masters and pilots, ship-to-ship, and ship-to-VTS (Vessel Traffic Service). According to NTSB (National Transportation Safety Board) reports 70% of major marine collisions occurred while a state or federal pilot was directing one or both vessels. Providing better procedures and training may improve communications and coordination between vessels. Bridge Resource Management (BRM) is a first step towards this improvement.

Taking proper management of fatigue

The NTSB has identified that fatigue is an important cross-modal issue in this context. Managing fatigue is very pertinent in the maritime industry and any other automotive industries like aviation and rail. Fatigue has been cited as the “number one” concern of mariners in relevant studies. It was also the most frequently mentioned problem in

a recent Coast Guard survey. So for maintaining fatigue problem authority has to take proper principles in introducing work schedule.

Acquiring adequate knowledge of own ship systems

A frequent contributing factor to marine casualties is inadequate knowledge of the relevant ship design, its operations, and its equipment. Several studies and casualty reports that difficulties in marine industry encountered mainly by the crews and pilots who are constantly working on ships of different sizes, with different equipments, and carrying different cargoes. A combination of better training, standardized equipment design, and proper method and following effective principles in assigning crew to ships can help to solve this problem.

Advancing design of automation

In reducing marine error one challenge is to improve the design of shipboard automation. Poor design for shipboard automation often result in collisions and other marine accident. It may also cause misinterpretation in radar displays, oil spills and overfill of the devices .for improving this problem equipment designers have to consider how a given piece of equipment will support the mariner's task and how that piece of equipment will fit into the entire equipment "suite" used by the mariner. Routine uses of human factors engineering methods and principles may help in improving equipment design and evaluation.

Well maintenance of the ship

Poor maintenance of the ship may result in a dangerous work environment. It may produce problem like lack of working backup systems, crew fatigue, and any type of emergency repairs. Poor maintenance is highlighted as a leading cause of fires and explosions in many relevant literatures.

Taking precaution for management in hazardous natural environment

The marine environment is always full of risk. Currents, winds, and fog often create treacherous working conditions for the mariners. It is very necessary that the design of a ships and equipments are incorporate with these factors. It helps the mariners to adjust their operations in handling the hazardous environmental conditions. If it does not work mariners may fall in great risk.

Maintaining standard of policies

Usually in a system there are some policies introduced for avoiding hazard. And introducing this rules the authority must follow the available reports, written, and comprehensible operational procedures aboard ship. If something goes wrong, and if a well-written manual is not immediately available, a correct and timely response is much less likely to lead to future problem. Thus maintaining proper standard in introducing policies may reduce marine error in many stages.

4.4 Human Error in Mining Sector

From prehistoric time to the present, mining has played an important role in human existence (Madigan, 1981). On the other hand the mining industry has been viewed as a high-risk environment from earliest period. Now a day's safety is one of the main concerns, but it still remains as one of the most high-risk professions in India. According to agenda papers for 37th and 38th meeting of the standing committee on safety in coal mines[121] we may provide an accident list (Fig. 3) of last four years in the field of Indian mining as following:

Sl no	Parameters	2011	2012	2013	2014
1	Number of fatal accidents	65	83	96	100
2	Number of Fatalities	67	87	114	105
3	Number of Serious Accidents	534	515	436	338
4	Number of Serious Injuries	557	526	458	348

Figure -3

The above table shows that though the numbers of accidents and injuries have decreased over past four years but the numbers of fatal accidents and death have increased.

[121] Agenda papers for 38th and 39thmeeting of The standing committee on safety in coal mines On 28th January, 2014 and 13thMarch, 2015 held At New Delhi (Government of India Ministry of coal)

So in India mining accident is a sensitive issue in the context of industrial safety. Many of the accidents in this field take place due to human error. These errors are not committed only by the mining labors. Management authority may also be responsible for mining accidents. Lack of proper scientific precaution is also a major cause behind mining accidents. In India details of mining accident reports are not available but even after analyzing the background of some accidents we are trying to find out some common human errors behind mining accident in India.

Basic concept of mining

The term 'Mine' means excavations, made in the earth to extract minerals. So, mining is the activity, occupation, and industry concerned with the extraction of minerals. In simple words mining is used as encompassing the extraction of any naturally occurring mineral substances—solid, liquid, and gaseous—from the earth for utilitarian purposes. In India mining is mainly related with coal. It is one type of fossil fuels for humankind**.** Organic mineral substances that can be utilized as fuels are called fossil fuel. Coal, petroleum, natural gas, coal bed methane, gilsonite, tar sands etc are included in this type. These minerals are also known as mineral fuels. Mainly two methods are used in mining:

i) Surface mining and
ii) Underground mining

We will touch upon mining procedure in brief. For better understanding we are providing some pictures of different mining processes and some mining equipments for the sake of better understanding.

i) Surface mine

If the excavation used for mining is entirely open or operated from the surface it is termed as surface mine. Surface mining is a method of mining used to extract minerals and metals which are near the surface of the Earth. There are three basic types of surface mining:

- Open pit mining
- Strip mining and
- Quarry mining

Open pit mining

Open pit mining involves excavation which looks like a terrace (Fig. 4). Cuts are made into the ground, and the area at that depth is readied around the circumference of the mine. Once the minerals and waste have been removed from the ledge, called a bench, the excavation moves down a level and work begins afresh. This type of surface mining, also known as hard rock mining, is typically employed to extract metal ores, like copper, gold, iron, aluminum, and other minerals.

Image of open pit mining in India (Srinivas Karuganti Coal India[122])

Figure -4

Neyveli Lignite (Fig. 5) is the largest open cast mines in India. This mine is operated by Lignite Corporation Limited (NLC). It is a government owned mining operator and power generating company in India. In addition lignite, often referred to as brown coal, is a soft brown combustible organically formed sedimentary rock that does so from naturally compressed peat. It is considered the lowest rank of coal due to its relatively low heat content.

[122] http://srinivaskuruganti.photoshelter.com (Retrieved on: 13.08.2015)

Neyveli Lignite mining[123]

Figure -5

Strip mining

Strip mining is a form of surface mining that is primarily used for coal excavation. The rock and dirt covering the ore is removed one strip at a time. Once the ore has been taken from the first strip, a second strip is cut next to it, and the waste from the second strip is used to back fill the first. This goes on until the ore is exhausted, and then the waste from the first strip is used to fill in the last (Fig. 6).

Image of strip mining in India a coal mine at Dhanbad India

Figure -6

[123] www.thehindu.com (Retrieved on: 13.08.2015)

Quarry mining

Sand, gravel, clay, granite, and other materials used in building are mined in *quarries*. This type of mining begins by blasting into rock in a manner so as to create the greatest fracturing. Rocks are further reduced by crushing machines and separated according to size (Fig.7). Mining ornamental stone does not blast the rock, but employs a method called *broaching*, which uses wedges placed into holes rather than explosives. The wedges are hammered into the holes until the stone breaks off.

Image of a quarry mining[124] (The green marble quarry located at Keshariyaji, Udaypur)

Figure -7

ii) Underground mine

In this country most mining procedures are underground. Defining underground mining it may be said that, it is a technique used to access ores and valuable minerals in the ground by digging into the ground to extract them. Here excavation consists of openings for human entry below the earth's surface. Interesting part is that when people think of mining, they often visualize underground mining. There are three types of underground mining: unsupported, supported, and caving.

[124] Source: www.mumalmarble.com. (Retrieved on 15.08.2015)

Wide areas unsupported roof are present in certain partsof the galleries of Western Winspit[125]

Figure-8

Unsupported method

The unsupported methods of mining are associated with strong ore and surrounding rock. These methods are termed unsupported because they do not use any artificial pillars to assist in the support of the openings (Fig.8). Room-and-pillar mining is the most common unsupported method, used primarily for flat-lying seams or bedded deposits like coal, trona, limestone, and salt. Support of the roof is provided by natural pillars of the mineral that are left standing in a systematic pattern. Stope-and-pillar mining (a stope is a production opening in a metal mine) is the similar method used in non-coal mines where thicker, more irregular ore bodies occur; the pillars are spaced randomly and located in low-grade ore so that the high-grade ore can be extracted.

Supported mining methods

Supported mining methods are often used in mines with weak rock structure(Fig.9). Cut-and-fill stoping is the most common of these methods and is used primarily in steeply dipping metal deposits. The cut-and-fill method is practiced both in the overhand (upward) and in the underhand (downward) directions. As each horizontal slice is taken, the voids are filled with a variety of fill types to support the walls. The fill can be rock waste, tailings, cemented tailings, or other suitable materials. Cut-and-

[125] www.southampton.ac.uk. (Retrieved on 13.8.15)

fill mining is one of the more popular methods used for vein deposits and has recently grown in use. Square-set stoping also involves backfilling mine voids. It relies mainly on timber sets to support the walls during mining. This mining method is rapidly disappearing in North America because of the high cost of labor. However, it still finds occasional use in mining high-grade ores or in countries where labor costs are low. Stull stoping is a supported mining method using timber or rock bolts in tabular, pitching ore bodies. It is one of the methods that can be applied to ore bodies that have dips between 10° and 45°. It often utilizes artificial pillars of waste to support the roof.

Supported mining[126]

Figure-9

Caving methods

Caving methods are involved in caving the ore and/or the overlying rock. Subsidence of the surface normally occurs afterward. Long-wall mining is a caving method particularly well adapted to horizontal seams, usually coal, at some depth (Fig.10). In this method, a face of considerable length (a long face or wall) is maintained, and as the mining progresses, the overlying strata are caved, thus promoting the breakage of the coal itself. A different method, sublevel caving, is employed for a dipping tabular or massive deposit. As mining progresses downward, each new level is caved into the mine openings, with the ore materials being recovered while the rock remains behind.

[126] www.mininghistoryassociation.org. Retrievrd on 1.2.2015

Block caving is a large-scale or bulk mining method that is highly productive, low in cost, and used primarily on massive deposits that must be mined underground. It is most applicable to weak or moderately strong ore bodies that readily break up when caved. Both block caving and long-wall mining are widely used because of their high productivity.

Image of a caving mining method at the southern slopes of Meghalaya [127]

Figure-10

In addition to these conventional methods, innovative methods of mining are also evolving. These are applicable to unusual deposits or may employ unusual techniques or equipment. Examples include automation, rapid excavation, underground gasification or liquefaction, and deep-sea mining.

In India mining is mainly related with coal. And methods used here are opencast surface and underground caving.

Some examples of mining accident and human error behind them

There are various types of mining accident take place in India. Most of them result in serious adverse event. For finding human error behind them we would discuss them in details. For this reason we have provide an accident list of the major accidents in the Indian Coal Mines

[127] www.kipeoeo.in retrieved on 13.08.2015

of the post Independence period (1952-2014).[128] To make this table (Fig.11) we have followed some half yearly agenda papers of standing committee on safety of Indian mining. From this table we would select some accidents to analyze.

S.N.	Dates of Accident	Name of Mines	Fatalities	Cause
1	12/07/1952	Dhemomain	12	Roof fall
2	05/08/1953	Majri	11	Inundation
5	05/02/1955	Amlabad	52	Explosion of fire damp.
6	26/09/1956	Burra Dhemo	28	Inundation
7	19/02/1958	Chinakuri	175	Explosion of fire damp.
8	20/02/1958	Central Bhowra	23	Inundation
9	05/01/1960	Damua	16	Inundation
10	28/05/1965	Dhori	268	Coal dust explosion
11	11/04/1968	West Chirmiri	14	Premature collapse of workings
12	18/03/1973	Jitpur	48	Explosion of fire damp.
13	08/08/1975	Kessurgarh	11	Roof fall
14	18/11/1975	Silewara	10	Inundation
15	27/12/1975	Chasnala	375	Inundation
16	16/09/1976	Central Saunda	10	Inundation
17	04/10/1976	Sudamdih	43	Explosion of fire damp.
18	22/01/1979	Baragolai	16	Ignition of fire damp
19	24/08/1981	Jagannath	10	Water gas explosion
20	16/07/1982	Topa	16	Roof fall
21	14/09/1983	Hurriladih	19	Inundation
22	13/11/1989	Mahabir	6	Inundation
23	25/01/1994	New Kenda	55	Fire/suffocation by gases
24	26/09/1995	Gaslitand	64	Inundation
25	06/07/1999	Prascole	6	Fall of roof/collapse of workings
26	24/06/2000	Kawadi	10	Failure of OC bench
27	02/02/2001	Bagdigi	29	Inundation
28	05/03/2001	Durgapur Rayatwari	6	Collapse of partings/workings
29	16/06/2003	Godavari Khani-7LEP	17	Inundation
31	15/6/2005	Central Saunda	14	Inundation
32	11.11.2013	Basantimata- Dahibari Colliery	04	Roof fall
33	17.07.2014	Makardhoda OCP	02	Mining accident with mining vehicle

Figure -11

[128] Source: http://www.coal.nic.in retrieved on 05.07.2015

Following the above accident list, it can be said that in India major coal mining accidents are of following types:

1) Roof/side fall Mining
2) Accident with mining vehicle
3) Mining accident with mining machine
4) Accident for dust/gas and
5) Fire
6) Inundation

Now we are discussing all these mining accidents in brief. Then we are trying to find the human error behind these accidents. We are also discussing some remedy as approaches to reduce mining accidents.

Roof/side fall

Fall of roof and sides is a common phenomenon in underground coal mines. In India most of the serious accidents are caused due to roof or side fall. According to the agenda paper for standing committee on safety in Indian mining (2014), 12% accident occurred due to roof or side fall. A list of Major disasters about roof/side fall occurred in the past are given below (Fig.12). We make this list following agenda papers (half yearly) for meeting of the Standing Committee on Safety in Coal Mines published by government of India Ministry of Coal:

No Name of mine	Date of occurrence	Fatalities
Sitalpur colliery	15.10.1910	12
Kessurgarh Colliery	09.08.1975	11
Prascole	06.07.1999	06
Topa Colliery	16.07.1982	16
GDK-8A	16. 10.2003	10
Basantimata	11.11.2013	04

Figure-12

A description of a roof fall accident

This accident occurred in The Basantimata Colliery [129] located in the western part of Raniganj Coal field and about 2 km, south from Mugma railway station of Eastern Railways and about 8 km. south west Chirkunda town in Dhanbad District, Jharkhand. The accident took place on 11.11.2013 at about 11.30 hrs. Number of persons injured: Fatal – 4 (four), Serious Injury – 1 (one) Method of Working: Bored and pillar depillaring with caving by low height. Probable causes behind this accident are:

a) Diagonal line of extraction of the panel was not followed properly
b) The method and manner of extraction of pillars as per condition No. 2 of permission granted by DGMS was not being followed.
c) It has come to notice that generally roof bolting was being done only in 1st shift.

After examination and analysis of evidences, the standing committee on Safety in coal mines declares the following persons are prima facie responsible for the accident.

- The Agent failed to take necessary steps for safe mining operation.
- Manager failed to effectively ensure compliance with the provisions of SSR in depillaring panel, and also failed to maintain diagonal line of extraction in the depillaring panel and manner of extraction as per DGMS permission.
- The Assistant Manager did not ensure compliance with the provisions of SSR in the depillaring panel, also failed to maintained diagonal line of extraction in the depillaring panel and manner of extraction.
- Pit Manager did not ensure compliance with the provisions of SSR in the depillaring panel, also failed to maintain diagonal line of extraction in the depillaring panel and manner of extraction.

[129] Agenda papers for 36th meeting of The standing committee on safety in coal mines On 23th May, 2012 held At New Delhi (Government of India Ministry of coal)

Mining accident with mining vehicle

In India the main mining vehicles are dumpers and conveyers, trucks, wagons and haulage. Dumpers carry coal with tipper mechanism. Haulage is mechanism of lowering coal by tubs. Other transport machineries are non-transport machinery like loading machinery, crusher etc. According to the agenda paper for 38th meeting of the Standing Committee on Safety in Coal Mines[130]it is shown that 12% accident among all accident in CIL (Coal India Limited) is due to mining vehicles. In this paper it is reported that in Makardhoha OCP (17.07.2014) two labors died in accident with mining vehicles. Mining accident related to mining machinery is caused by following reason:

1) Vehicles are used in open cast mines or underground, always huge and heavy, and as a result any accidents which occur are usually serious. In addition there is an extra complication with the driver's sitting position. In the mining vehicles, the driver sits in a very elevated position. This elevated position makes the driver not always able to see what is happening directly in front, to the side or to the rear of his vehicle. Not having a clear view of what is happening around him may result in sometimes deadly accidents. A mining truck, for example, is such a huge vehicle that if the driver cannot see a normal LDV parked in front or behind him, he may accidentally drive right over it. As the vehicle is so large and the terrain often rough, he may not even be aware that he has driven over an obstacle and will simply continue to travel. Accidents of this nature are a regular occurrence since people do not always realize the danger of being close to one of these vehicles.
2) Many people assigned such tasks of loading and unloading equipment and supplies have not been trained in safe rigging practices or proper communications between equipment operators and ground personnel.
3) Most mine operators instruct equipment operators to use seatbelts, but many do not have program which reinforces their use and ensures that equipment operators are using them consistently. Also, there is a misconception among equipment operators that it is usually better to jump out of control a piece of equipment than to ride it out. Fatalities have occurred when equipment

[130] 38th meeting of the Standing Committee on Safety in Coal Mines (Published by government of India Ministry of Coal,2014),

operators apparently jumped from the vehicle. In nearly every instance the condition of the equipment operator's compartment indicates that drivers would have been protected if they had worn their seatbelts.

4) Sudden movement of vehicles under repair may cause fatalities. For instance, unchecked trucks roll over mechanics working beneath them; Most of these accidents could have been prevented if the mechanics and maintenance personnel were thoroughly trained in the hazards associated with the sudden or unexpected movement of equipment.
5) Lack of adequate communication between the drivers of vehicles also may results in accidents and/or a central despatching operation.
6) Mine operators construct mine roads according to geographic location, traffic type, expected weather conditions and frequency of use. But they are not always built with adequate consideration for potential adverse weather. Poor drainage and failure to properly surface the roads often create very slick road conditions during inclement weather conditions. Additionally, mine operators sometimes attempt to maintain daily production goals when conditions have deteriorate, which exposes miners to serious haulage hazards.

For avoiding such accidents, the following remedy may be accepted:

- In order to avoid these types of accidents, Eddie Smith recommends the supplies of a wide range of cameras and other products that are currently being installed on mining vehicles. Some of the vehicles are equipped with an 8m radar system which warns the driver when something is in his path. In addition to the radar system we can also install GPS Traffic Alert systems which warn the driver to right time of any possible accidents.
- The truck may also be equipped with cameras. These can be mounted on the front, the side and the rear of the vehicle. Before starting his vehicle the driver should check all sides of the vehicle to ensure that the road is clear.
- Though cameras can only be used for short range observations and furthermore, vehicles utilized for open cast mining often need to operate in foggy or poor weather conditions which are often complicated by dust in this situation "Path FindIR" thermal imaging cameras with the technology that

can help drivers of mining vehicles to suggest their safe way for driving and avoid accidents.

- Many literatures on safety of Indian mining recommend that Coal companies should think about creating separate corridors for coal transportation in the opencast projects and take all proper measures with any additional investment as there is no dearth of resources with coal companies for taking measures for avoiding such accidents.

Explosion under mine

An explosion is an intensely rapid combustion of a substance or a mixture of substances (gas, liquid or solid) forming largely or entirely gaseous substances with the development of high pressure and heat. The main explosive substances are methane and coal dust in coal mines and sulphide dust in metal mines. Two factors viz. the presence of an explosive mixture and a suitable source of ignition are essential to cause an explosion. The explosions are caused due to the following reasons in the mines:

- Firedamp alone
- Coal dust alone
- Both firedamp and coal dust

Following is a list (Fig.13) of fatal mining accidents due to explosion:[131]

Name Of Mine	Date Of Occurrence	Number Of fatalities
Dhori Colliery	28.05.1965	268
Poidih Colliery	18.12.1936	200
Chinakuri Colliery	19.02.1958	176
Jeetpur Colliery	18.03.1973	48
Sudamdih Colliery	04.10.1976	43
Baragolai Colliery	22.01.1979	16

Figure -13

[131] Source: http://www.coal.nic.in; Retrieved on 08.05.2015

Dust/gas

Accidents take place due to explosions of noxious gases, due to absence of oxygen, due to explosion of coal dust etc. Mining accidents due to explosion of poisonous gas are common in Jharkhand, which has India's largest coal deposits. In this accident the rescue work is also hampered because of poisonous gases. Following is a list of mining accident due to dust/gas (Fig. 14).

Name of the mine	Date of the accident	Number of fatalities
Darma coliary (Raniganj Coalfield)	14.3.1954	10
Chinkuri Colliery (Raniganj Coalfield)	19.2.1958	176
Dhori Colliery (East Boaro Coalfield)	8.5.1965	268
Jeetpur colliery (Jharia Coalfield)	18.3.1973	48
Baragolai Colliery (Dibrugarh District, Assam)	22.1.1997	16
New Moghla Colliery (Rajouri District (J&K State)	3.3.1997	10

Figure-14

In this context we are going to describe the incident of Bhatdih colliery of Jharia Coalfield[132]. This accident took place at 6th September 2006. On that very day the 460m-deep (1,500 foot) mine in the western region of Jharia was rocked by an explosion. Only five miners who were working at the upper levels of the mine managed to escape. It causes several injured. Fifty persons were killed in this accident. Rescuers retrieved the bodies of 19 miners who died after the blast. This incident also affected the other nearby places of the city. Finding causes behind this accident it is reported that an explosion like the Bhatdih blast requires a highly inflammable substance that, on combustion, produces large volumes of hot gases almost instantly. Bhatdih is a highly "gassy" mine, with a methane gas production of over 10 cubic metres a tonne of coal mined. It was classified as a "third degree gassy mine" by the DGMS. It requires special precautions to control the production and accumulation of methane. According to D.K. Srivastav, Deputy Chief Personnel, BCCL Methane build-up is prevented by a number of precautions: The first step is

[132] Source: *Frontline* Volume 23 – Issue 19 (Sep. 23-Oct. 06, 2006)

ensuring that the mine is ventilated well using a powerful fan and a system of partitions to direct the blast. This ensures that gas is pushed out of the mine even as it is produced. The second step is the use of safety lamps and methano-meters to check methane levels in workspaces so that workers can be evacuated in case of methane emergencies. The third step is the blocking of used mining channels. It is called "stowing". Passages in gassy mines must be blocked with a mixture of sand and water and gas forms in areas must leave vacant. According to the workers interviewed by Frontline it is revealed that they haven't stowed a bunker for almost three months prior than the accident. One worker spoke on the mining condition as the mine has been getting hotter and hotter by the day, but no one seems concerned. According to the workers, the management simply engineers a roof fall at the entry of the passages and seals it with sand. The rest of the tunnel is left empty to accumulate methane. This accumulation caused by incomplete stowing could be a primary cause for methane accumulation and the said explosion. In this state's the incident of the worst mine collapse occurred in 1975, in that accident nearly 400 miners were killed.

Inundation in mine

Accidents are caused by inundation of a surface or underground mine by a liquid (or semi-solid) or a gas. Accidents due to sudden rushing in of water are also indeed in it. Underground coal mines are associated with the problem of water inflow which may fill up the workings places. The inflow may be gradual or sudden, either from surface sources or from underground sources. Gradual inundations do not cause any casualty to men but make the working districts inoperative and drown the machines. However, sudden in-rush of water into the mines has resulted in heavy loss of life in addition to causing stoppage of work and drowning of equipment.

Sources of surface water: River and nallahs, tanks and reservoirs and accumulated water in old opencast workings or low lying areas.

Sources of underground water: Old water-logged workings, a sump either in the same seam or another seam, water-logged workings in the adjoining mine and highly water-bearing strata overlying the working seam. Water from the above sources may inundate the active workings because of the following reason:

- Accidental connection
- Development of cracks, fissures and fractures
- Failure of barrier or parting

Following is a list (Fig.15) of mining accidents due to inundation/ failure of dam[133].

Name Of Mine	Date Of Occurrence	Number Of fatalities
Newton Chikli Colliery	10.12.1954	63
Burra Dhemo Colliery	26.09.1956	28
Central Bhowrah Colliery	20.02.1958	23
Damua Colliery	05.01.1960	16
Silwara Colliery	18.11.1975	10
Chasnalla Colliery	27.12.1975	375
Central Saunda Colliery	16.09.1976	10
Hurriladih Colliery	14.09.1983	19
Mahabir Colliery	13.11.1989	06
Gaslitand Colliery	26.09.1995	55
Bagdighi Colliery	02.02.2001	31

Figure -15

Fire in the mine

Fire is one of the most serious hazards in underground mines because an underground fire can fill a mine with deadly carbon monoxide gas, smoke and heat in minutes. Mine fire may classify into two categories: Accidental fire and Spontaneous heating.

i) Accidental Fire: Accidental fire in mines is caused due to any of the following reasons:

- Fire on conveyor belt
- Spiracle on cutting machines
- Electricity problem
- Explosive and blasting

[133] http://www.coal.nic.in . Retrieved on 08.05.2015

ii) Spontaneous Heating: Coal undergoes slow oxidation on exposure to air at ambient temperatures with the evolution of heat, gases and moisture. The heat generated, if not dissipated, increase the temperature of the coal which in turn increases the rate of oxidation. This oxidation process is known as spontaneous combustion / self heating. Spontaneous heating is considered as a main cause of mine fires. Two basic factors are to be kept in mine while preventing spontaneous combustion of coal are: Elimination of coal from the area, and control of ventilation so as to exclude oxygen entirely from the area or to maintain air flow rate such as it can dissipate the heat efficiently as it is generated and before a significant temperature reached. Following is an accident list (Fig. 16) of fire in mining (India).

S.N	Dates of accident	Name of mines	fatalities	Cause
1	14/03/1054	Damra	10	Explosion of fire damp
2	5/2/1955	Chinakuri	175	Explosion of fire damp
3	18/3/1973	Jitpur	48	Explosion of fire damp
4	4/10/1976	Sudamdih	43	Explosion of fire damp
5	22/1/1979	Baragolai	16	Ignition of fire damp
6	24/8/1981	Jagannath	10	Water gas explosion
7	25/01/1994	New kenda	55	Fire/ suffocation by gases

Figure -16

Some approaches for controlling fire are discussed below:

1. Use of Inert gases

Use of inert gases may be useful in controlling fire under mine:

- Inert gases can be used in fighting mine fires in the following ways:
- Reducing the oxygen concentration in the air around the seat of fire to such a percentage that fire dies down.
- The prevention of gas explosions when they are fought directly or when seals are constructed or closed.
- Reducing the intensity and spread of secondary combustion and cool the area surrounding the fire zone.
- Sealing fire zones with pressure chambers.

- But the main drawbacks of inert gas methods have been the limited availability of large quantities of gas at site at short notice. Moreover, the methods are costly.

2. Use of foam

For successful using of foam is an important method for controlling fire. But this is useful only in fighting mine fires in roadways where direct attack with water is not possible. The foam helps in controlling the spontaneous heating in following manner:

- It reduces air leakage.
- It reduces temperature.
- It reduces the rate of oxygen by the coal as the foam forms a thin protective film over the coal.

3. Dynamic Balancing of Pressure

When an area is isolated/ sealed by two or more stoppings, the pressure on the outer faces of each stopping should, as far as is practicable, be balanced to prevent circulation of air through the sealed area to prevent initiation or existence of heating. It utilizes available mine ventilation pressure to neutralize the pressure differential across stoppings.

4. Software Development

Safety in Mines Testing and Research Station (SIMTARS), Queensland, Australia has developed many software packages to improve mine environment monitoring system to identify and track incipient heating and mine fires.

Following precautions can reduce fire in mining:

- Installation of a number of doors in a mine at strategic locations which can even be closed remotely for isolation of any segment of the mine that gets affected by fire.
- As precaution in mining it should be maintained that there are of two totally independent working zones. If any one of them gets polluted by toxic gases of fire the other remains safe for withdrawal of personnel. For this purpose multi-zonal ventilation system may provide advantage.

- Thorough training of every personnel working underground regarding the use of safety wares viz., self rescuer and other breathing apparatus, alternate escape route, ventilation circuits, effect of fire on ventilation etc. is necessary, rather it should be made compulsory.
- For the purpose of early warning throughout the mine, recently developed ultra low frequency radio signaling system may be adopted after giving it a trial.
- Suitably designed safety chambers to accommodate all personnel of an active working for about a week may be constructed close to a working.

Some common human errors behind mining accidents

After discussing mining accident and contributory causes of it following Jessica Patterson, and M.S.Scott Shappell, (2008) we may provide a list of cognitive errors responsible for mining accidents. :

Decision errors

Decision errors are the actions that proceed as intended, but the plan proved as inadequate or inappropriate for the situation. Decision errors are divided into three types: rule based errors, knowledge based errors, and problem solving errors. Rule based errors occur when a situation is either not recognized or is misdiagnosed and the wrong procedure is applied. Knowledge based errors occur when an operator chooses between various action plans but selects the incorrect procedure for the situation. This error may take place due to time pressure, inexperience, stress, etc. Problem solving errors committed by the agent he is put in a situation where the problem is not well understood by him. If may also happen when no formal procedure appropriate for the situation is exist. A novel solution is required for these situations. During these situations individuals must resort to reasoning and thought processing which is often time consuming and mentally taxing.

Routine disruption errors

Routine disruption errors occur with little conscious effort during highly automated tasks. The routine disruption error would arise when the person simply repeats a past experience without noticing the present situation. Routine disruption errors are susceptible to failures of memory or attention. Failures of attention have been linked

to breakdowns in visual scanning, task fixation, and inadvertent activation of controls. So these errors may occur when an operator checks the status of the ground support and activates the control of any mining machine very mechanically just as he/she usually does. These errors may occur in the similar backgrounds in training and experience the way an individual operates equipment can cause an increased likelihood of committing an error. Memory failures often appear as missed steps in checklists, forgetting intentions, or place losing. Most people can relate to others that get somewhere only to realize that they have no idea what they came to get. In everyday situations, these failures have minimal consequences. Consider the pedestrian on a mine site who forgets to wait for radio confirmation before proceeding into an area with heavy vehicles. The consequence of this action could quite literally lead to death. These errors increase during emergency situations when stress levels increase. Routine disruption errors are also caused by the technique employed to carry out a task.

Perception errors

Usually when in an impoverished environment sensory input is degraded then perceptual error occurs. These errors occur due to the misinterpretation of the input itself. In the mining industry operators, especially those who are working underground with limited lighting and constantly changing ground and rib conditions are trapped by these errors.

Some approaches for reducing mining accident

Human error is one of the important causes behind mining accidents. Our aim is to point out how handling that factors, we can reduce mining accident. In this context we mention some approaches below:

Maintaining professionalism in handling negative personality of mining labors

Operator's personality is an important factor behind human errors in mining sector. In mining field many accidents occur due to the negative affectivity, risk-taking tendency and depression of the employee. *Negative affectivity* refers to the chronic experience of negative emotional states and lack of emotional stability. Researchers suggest that individuals with high negative affectivity suffer from attention lapses on the job, which make them more susceptible to accidents/injuries. *Rebelliousness*

represents the degree of frustration of an individual when they are exposed to regulation. It increases the possibility of experiencing injuries at work. *Impulsivity* represents the extent to which individuals behave spontaneously with little anticipation of the consequence of their behaviors. Therefore, impulsive employees may rush to complete a task without adequate consideration of following safe operating procedures, resulting in an increased risk of injuries. *Risk-taking tendency* is an undesired behavior which may lead to work injuries but the workers seldom repeat this behavior to complete the work fast. *Depression* represents the frequencies with which individuals have symptoms such as depression mood, feeling of worthlessness, poor concentration, and loss of appetite and sleep disturbance.

Analyzing these entire issues about operators' psychology if organizers prepare working schedule then mining accidents may be reduced at a large rate.

Providing proper training

Lack of employee's skill also is a major factor for mining accident. Skill of an operator depends on his education, job training, experience on the job, experience on a related job, prior injury history, visual perception, overwork, load and blast in a hurry, and work-stress among others. However, education, job training, and experience play vital roles. In India 20% of the persons involved the mine accidents are found to be contractual workers of which about 40% were in the age group of 18 to 25 and 45% in the age group of 26 to 35 that means a major reason of mining accident is perhaps lack of training of these workers.[134]Proving proper training for the employees and managing novice's duty under experienced one may be very useful steps in reducing mining accident due to human error.

Maintaining safety in task factors

Rock blasting is very risk task. In this job an excellent coordination of a series of tasks is very necessary. The list of tasks includes examination of the driller's log, inspection of the side wall, roof and review of laser profiling data, if any. The boreholes are examined for spacing, burden, inclination, and general layout. The blaster should coordinate loading and firing activities with the mine foreman to ensure safety and efficiency. Failure to properly coordinate the tasks can result in serious injury or

[134] Source: Agenda Paper (2014) For 38th Mining of The Standing Committee On Safety Of Indian Mining

death. But in mining very few of these tasks are performed by the blaster while others are performed by the blasting crew under the supervision of the blaster. Several tasks are also performed by crews who do not have any proper training on blasting. So for following proper safety and supervision many mining accidents can be reduced definitely. [135]

Improving Job involvement

Job involvement indicates the degree to which the workers are concerned about their work for improving safety and productivity. Researchers show that job involvement has direct impact on the accident and injury in mines.

Removing Job hazards

The job hazards include physical hazards, production pressure, job boredom, job dissatisfaction, and job stress. Physical hazards represent the extent to which individuals are exposed to dangerous equipment, unsafe working conditions and poor environmental conditions (Dawson et al. 1983). Job boredom represents the degree to which individuals find their job boring and uninteresting (Frone and McFarlin 1989). Job dissatisfaction represents individuals' overall thoughts towards their job. The job overload, job ambiguity, and job conflict are the major job stressors in mining industry.

Serving professional education

Education programs are considered effective by many professionals. With initial training of basic mining task training of safety issues related to storage, transportation, and use of explosive products are also very necessary. A quality training program should address aspects of modern blasting technology and explosive safety issues.

Providing social supports

Social supports in mining include the variables like management-worker interaction, coworker supports, and supervisory supports. Management–worker interaction includes the variables such as overall labor- management relations ambience and labor supports for safety disciplinary actions. Some literatures suggest that there is a

[135] Bajpayee, S., Rehak,T. R., Mowrey, G. L., Ingram, D. K .(2004). Blasting Injuries in Surface Mining with Emphasis on Flyrock and Blast Area Security, 35(1), 47-57.

significant positive relationship between poor management–worker interaction and work injuries (Gaertner, 1987; De Michiei 1982; Pfeifer; 1976).

In this chapter we have seen that human error is a very common and important factor of system error. Human error caused severe types of accidents. Though human error is not only one cause behind those accidents but controlling human errors, it is possible to reduce adversity of accidents in different domain. Following some established protocol, increasing responsibility of the relevant operators, organization authority and improving communication process of the operative team, it is possible to handle human error and upgrading safety issues in any systematic working zone.

Chapter 5

ERROR IN LEARNING AND PEDAGOGICAL REASONING

Chapter 5

ERROR IN LEARNING AND PEDAGOGICAL REASONING

In the previous chapters of our dissertation we observed that human error was not considered to be desirable for human being though naturally ingrained in almost every person. On the other hand it is true that perfect knowledge and proper behavior makes us more confident; it helps us in appraising our skill and finally it inspires us to be innovative. So by handling errors how we can acquire knowledge is a relevant issue of our study. This discussion is related to learning through the formal education system. Learning is a key process in human behavior. Learning is change in behavior that is the resultant of practice and experience. Skills, knowledge, habits, attitudes, interests and other personality characteristics are all the result of learning. There are different types of learning. Such as *Motor learning* refers to the learning of our everyday activities which depended on muscular coordination. Walking, running, skating, driving, climbing all these activities are related to motor learning. *Verbal learning* involves the language we speak, and the communication devices we use. Learning related to signs, pictures, symbols, words, figures, sounds, etc which we use for communication are verbal learning *Concept learning* is the form of learning which requires higher order mental processes like thinking, reasoning, intelligence, etc. *Learning of principles* refers to Individual's learning of certain principles related to science, mathematics, grammar, etc. in order to manage their work effectively. *Problem solving* learning requires the use of cognitive abilities-such as thinking, reasoning, observation, imagination, generalization, etc. *Attitude learning* refers to learning of proper behavior in a certain situation. Learning proper attitudes of nurse towards her profession, patients are an example of it. In formal education system we follow each type of learning mentioned above.

The theories which explain how people learn and why they learn are called theories of learning. We all know that Trial and Error is a popular learning theory. This theory

was developed by an American psychologist E.L. Thorndike (1874-1949). He argues that learning takes place through trial and error method. According to him learning is a gradual process where the individual will make many attempts to learn. The essence of this theory is 'as the trials increase, the errors decrease'. Learning by Insight is another theory of learning. It presupposes that many times learning proceeds by the more efficient process of trying those methods which seem to have a relation to solution. This theory was developed by a psychologist known as Wolfgang Kohler, who belonged to Gestalt school of psychology. Both theories are relevant to any type of learning. In this chapter we are going to discuss the efficacy of errors in learning. This chapter will highlight that errors may provide very positive result in learning. The relation between error and learning is not a new study. Many theories of learning consider error as a learning process. Emilie, N. A. (2004)[136] clearly admits learning is a process of trial and error. In this chapter we will analyze different types of learners' error showing that it helps us in evaluating the level of understanding of the learner.

In this context we will discuss pedagogical reasoning as teacher's reasoning skill or practical knowledge for effective teaching. Only in such effective teaching teacher may handle learners' error in a positive way. In this chapter we will point out using his knowledge and skill how a teacher can develop his teaching as an art and make learning meaningful for the learners.

Different types of error in learning

We have observed that learning is an ongoing process where a learner acquires knowledge and overcomes his problem. In learning process we concentrate on learners' error when they fail to follow the subject content properly. It happens due to lack of proper understanding of the course taught. In this context to evaluate the understanding level of the students analyzing their errors is the only one way. Thus in other words the teacher starts his teaching process following the errors of the learner. Every learner is unique. Each has distinct personality and ability. Errors will be different according to individual learner. That is why in learning errors are innumerable in types and variety for each learner. Among them we are going to consider some common errors on behalf of the learners in this chapter. Our purpose is

[136] Emilie, N. A. (2004). Teaching fractions: Strategies used for teaching fractions to middle grade students. *Journal of Research in Childhood Education*, 18(3), 193-199.

to provide a general feature of error in learning. We will discuss learners' errors in the context of three different subjects. These subjects are basic for any discipline. These fields are:

i) Error in the scientific experiment
ii) Error in language learning
iii) Error in learning mathematics

5.1 Human Errors in the Scientific Experiments

It is very interesting to note that errors are unwanted for the learners but for a laboratory researcher error is the only process of experiment. We are starting this section with errors in experimental action. In this context it has to be noted that experimental error and human error in experimental process are not similar. We are going to describe a comparative discussion on *experimental error, random error, systematic error, and human error in experiment*.

Experimental error and human error in experiment

Experimental error is a very common term in the context of error. In common sense error which takes place during experiment is experimental error; but in technical sense experimental error has different meaning. Usually in discipline of chemistry "experimental error" is a common kind of error. In a laboratory, no measurement is exact and this fact always affects the experiment it is called experimental error. It is also called measurement error. It is to be noted that experimental error is not human error because experimental errors are non-voluntary while human error is always voluntary. Basically human are not responsible for experimental error they take place due to the nature of chemicals. In this context it is also very important to highlight that this discussion *does not imply that* 'No incident of human error takes place in laboratory'. We will discuss three types of errors that take place during experiment: random error, systematic error, and experimenter's error. We are explaining these concepts in brief below:

Random Error

Random errors in experimental measurements are caused by unknown and unpredictable changes in the experiment. These changes may occur in the measuring instruments or in the environmental conditions. Random errors most often result from

limitations in the equipment or techniques used to make a measurement. Two examples of causes of random errors are:

- Electronic noise in the circuit of an electrical instrument.
- Irregular changes in the heat loss rate from a solar collector due to changes in the wind.[137]

Systematic Error

Systematic error can be caused by an imperfection in the equipment being used. It may also cause from mistakes the individual makes while taking the measurement. Systematic errors in experimental observations usually come from the measuring instruments. They may occur because:

- There is something wrong with the instrument or its data handling system.
- The instrument is wrongly used by the experimenter.

Human error in conducting experiment

Following concept of random error and systematic error we may say that human errors in scientific experiment refer to mistake, blunder, or screw-up which is committed by the experimenter during experiment. In addition in context of experiment random errors are not human error but some systematic errors are human error. Some examples of this type of human error are:

- Misreading an instrument
- Using the wrong chemical(s)
- Fails to follow directions
- Spilling or general sloppiness
- Wrong calculations
- Using the wrong formula

5.2 Errors Committed By the Students in Learning Mathematics

Mathematics is about pattern and structure. Logical analysis, deductions, calculations take place within these patterns and structures. Patterns are often found in different

[137] Source : http://www.physics.umd.edu/courses/Phys276/Hill/Information/Notes/ErrorAnalysis.html (Retrieved on 3.5.2012)

areas of science and technology. The mathematics of these patterns can be used to explain and control natural happenings and situations. Mathematics has a pervasive influence on our everyday live so explaining errors in learning mathematics is quite relevant. We will discuss different types of error in mathematic learning.

Different types of error in learning mathematical

Hendrik Radatz (1979) claims that an "analysis of individual differences in the absence of a consideration of the content of mathematics instruction can seldom give the teacher practical help for individualizing instruction or providing therapy for difficulties in learning a specific task".[138] According to him learning mathematics is a complex process. It depends on many factors like curriculum, teacher, learning environment etc. Analyzing errors, he said "The learning of mathematics is the result of very complex processes. A sharp separation of the possible causes of a given error is often quite difficult because there is such a close interaction among causes"[139]. There are various factors related to mathematic learning so, naturally mathematical error will be of different types according to these factors. On the basis of existing taxonomies we may say that there are mainly two types of errors are related to mathematic learning: slips and bugs. We are discussing these errors in details below:

1) Slips

"Slips" are the mistakes that take place due to lapse of memory or due to impulsivity of the learner (Ginsburg 1987). Usually this type of error does not refer to the errors due to misunderstanding of the learner. It occurs when the student fails to follow a particular method because he was destructed from the problem (intended focus) for a moment. Memory deficits, impulsivity, visual/motor integration problems may also be responsible for this type of error. So it may take place even though the student knows the procedure well. These are often termed as careless errors and usually included in calculation or sign (doing the wrong operation) errors. Researchers explain that these errors may also be considered as errors in strategy implementation (Cumming & Elkins, 1994). When multiplication is to be confused with addition or division, or

[138] Radatz, H. (1979). Error Analysis in Mathematics Education. *Journal for Research in Mathematics Education,* 10 (3), p. 164).
[139] Ibid, p, 164.

division tending to be confused with subtraction or multiplication are also included in this error (Campbell, 1997).

2) Bugs

Bugs are well known as procedural errors in mathematics. It may also be named as pattern error. Radatz (1979) analyzes error pattern of algebra. These errors are considered as most serious issue because this type of error indicates non-understanding or incomplete understanding of the student. When a student uses an inaccurate/inefficient procedure or strategy repeatedly it is included in pattern error. Usually incorrect application of a rule or strategy is also an example of this type of error. If students have deficit in understanding the concepts of mathematics they will commit different type of pattern error. We may classify pattern errors or bugs into five heads (Radatz, 1979). These are:

- language errors
- difficulty with spatial information
- deficient mastery of prerequisite skills, facts, and concepts
- incorrect associations and rigidity of thinking
- incorrect application of rules and strategies

a) Errors due to language problem

Mathematics is like 'foreign language' to many students. In learning mathematics, students need to understand some basic mathematical concepts; they have to learn some basic symbols; and need to be enriched with some basic vocabulary. At the beginning it is necessary for the students to know the language well in which the problem is described. If student has not sufficient knowledge about the language to understand the problem he may commit errors and that will be included in this type. Usually when learner attempts to solve problem describing his second language this type of error occurs. It may occur due to gap in basic knowledge about using language. We will discuss language learning process in the next section.

b) Spatial information errors

Errors caused by difficulties in obtaining spatial information are called spatial information Error. A strong correlation is found between spatial concepts and algebraic concepts (Poon & Leung, 2009). When problems are represented by using

icons, shape, sign, or visuals symbol, it is required that the students have proper concept of space. For example, students may make errors in the context of Venn diagrams due to difficulties in understanding that lines represent boundaries and if any student has deficiency in understanding spatial concept he may commit this type of error repeatedly.

c) Procedural errors

When students fail to apply mathematical rules and strategies correctly it is called procedural error. Rushed solutions and carelessness attitude of the student result in this type of errors. It may take place when student knows which rule will be applicable but they apply wrong rules unintentionally. This type of error may also occur when learner's knowledge is inadequate to apply the appropriate rules. (Vide rule based error *[page 47]*)

d) Structural errors

Structural errors are the one that arises from the failure in understanding the relationships involved in the different components of a problem. Here student fails to grasp the essential principle of the problem. When a learner does not use his/her mathematical visualization to check the problem solving process this type of error may occur. It may also take place if he/she misses an important visual interpretation of the integral assigned areas underneath the curve **(**Donaldson, 1963 and Orton, 1983).

e) Arbitrary errors

Arbitrary errors take place when learner behaves arbitrarily and fails to follow proper method to solve the given problem. These errors are characterized by the failure of the learner to adhere with the problem. They often result in guessing, quitting or giving an answer without justification. These are harder to reduce unless the student is willing to presume their problems by themselves.

f) Executive errors

Executive error refers error where student fails to manipulate mathematical principles. In these cases student knows the principles but fails to understand how he use these in the given situation. (Orton 1983). It is also called "loss of hold" error.

5.3 Errors Committed By the Students in Learning Language

We have seen in the previous section that language difficulty is a strong factor behind error in learning. Language is the only way to express knowledge; it is the main media of learning. Language learning error is a common scenario almost in every discipline. In the context we are discussing errors in English as a second language. We do so because this issue is common for worldwide general educational system. Through error analysis we may determine the incidents, nature, causes and consequences of ineffective language learning process. In language learning process learners learn from their mistakes by observing feedback from their new attempts. In this context Corder (1967) said, "Learners error can also provide to the researcher evidence of how language is learned or acquired, what strategies or procedures the learner is employing in the discovery of the language"[140] . He identifies the significance of errors in three ways:

Firstly: Undertaking a systematic analysis, teacher can understand the linguistic progress and difficulties of the students.

Secondly: For the researcher, errors provide evidence about how the learners learn the language and what strategies or procedures they employ to achieve the learning goal.

Thirdly: Errors are vital to the learners themselves since they are an essential device for them to test their hypotheses during the process of language learning.

Corder (1967) suggests three steps of error analysis including data collection, description, and explanation. Ellis (1997) proposes a more detailed model of error analysis including selection of corpus of language, identification of errors, classification of errors, and explanation. Richards and Sampson (1974) support that error analysis is an important tool for teachers to evaluate learners' learning ability in order to set the priority to solve learners' problems from the most frequent errors made by them. Therefore, error analysis is regarded as a diagnosis and prediction of the problems and difficulties of learners.

[140] Corder, S. P. (1967). The significance of learners' errors. *Applied Linguistics in Language Teaching,* l 5 (4), P. 167.

Different types of error in learning language

It is established that errors of learner provide significant evidence for teachers to give their students proper instructions and materials to support their learning. In this section we are going to focus on error in learning language. We are trying to categorize learner's errors into following types:

1) Performance errors and competence errors

Researchers of the field of applied linguistics distinguish two types of errors: performance errors and competence errors. *Performance errors* are committed by learners when they are tired or hurried. Normally, this type of error is not serious and can be overcome giving little effort by the learner.

Competence errors, on the other hand, are more serious than performance errors since they reflect inadequate learning. In this connection, it is important to note that researchers of error in learning (Gefen, 1979) distinguish between *mistakes* and *error*. According to them, mistakes are lapses in performance and errors reflect inadequate competence.

2) Global error and Local error

In the context of written error correction of language, Burt and Kiparsky (1975) distinguish two types of error: Global and Local. Based on their doctrine, Chens (1979) makes major distinction between them. Researcher defines global error as: "global errors—those that interfere with the overall message of the text—and local errors, which do not inhibit a readers' comprehension"[141].

According to this definition *global error* interferes with the entire message of the written text. It may also create problem with communication and may disrupt the meaning of utterances. Global error includes the errors with conjunctions, error with subjects, objects, and complements, run-on sentences, misplacement, relative clauses, sentences fragments, inversion and errors with other constructions. Following is an example of global error where 'coma' is used wrongly and that changes the intentional meaning of the sentence:

[141] Ferris, D. R. (2002). *Treatment of Error in Second Language Student Writing*. Ann Arbor, MI: The University of Michigan Press, P. 57-58.

If one writes "My $10 million estate is to be split among my husband, daughter, son and nephew." [142]instead of **"**My $10 million estate is to be split among my husband, daughter, son, and nephew." it will be an example of global error. Omitting the comma after son would indicate that the son and nephew would have to split one-third of the estate whereas the intended expression in each one will get one- fourth of the estate.

On the other hand *local errors* are caused by minor violations of linguistic rules that have no effect on the intended meaning of the written text. Local errors do not obstruct communication and understanding the meaning of an utterance. Errors involved in determinations of noun and verb inflections, and the use of articles, prepositions, or auxiliaries are included in local error. An example of local error is:

Error: Never have a nap *in* noon.

Correction: Never have a nap at noon.

It is an error, because according to the rule of English grammar before noon preposition at always takes place. Another point is that it is a local error also because in the erroneous sentence the intentional meaning of the writer is undisturbed.

3) Encoding or decoding error

When the learners are operating the phonological or the graphological substance systems, they may produce an encoding or decoding error. Misspelling or wrong pronunciation are included in both of these type. According to this taxonomy we may divide these errors into at least four types (Wenfen Yang, 2010): punctuation errors, typographic errors, dyslexic errors, and confusables errors.

- Punctuation errors

An error in using punctuation is called punctuation error. Some common examples of them are overuse of the exclamation; disordering of closing inverted comas; under or over use of capitals; over inclusion of a comma between an antecedent and a restrictive relative clause; and wrong selection of comma instead of the semi-colon or reversely wrong selection of semi-colon instead of comma. Generally these errors

[142] Straus, J. (2008). *The Blue Book of Grammar and Punctuation* (10th ed.), New Jersey John Wiley & Sons, Inc, p. 54

happen due to lack of proper knowledge of the rules. An example of misusing comma instead of semicolon is given below**:**

Error: Call me *tomorrow,* I will give you my answer then.

Correction: Call me tomorrow; I will give you my answer then.

Here the violated rule is **"**Use a semicolon in place of a period to separate two sentences where the conjunction has been left out."[143]

- Typographic errors

Error in type writing is typographic errors. People who are quite good spellers might be a poor typists. Typist with poor skill often commits this type of error. Usually, typing in a mechanical process. It follows temporal and spatial mechanisms. Skilled fingering on the typewriter, or keystrokes on the word-processor is necessary for it. Error in letter space, mixing front, and mixing capital letter with small letter are also included in this heading.

- Dyslexic errors

Reading disorder (Dyslexia) is generally characterized by difficulties with the alphabet, word recognition, decoding, spelling, and comprehension. So error due to dyslexia may be called dyslexic errors. We will discuss the issues in this chapter in the context of factors behind error in learning. (p…..).An example of this type of error is**:**

'deb' instead of 'bed'.

- Confusables errors

When learner has confusion between similar sounding morphemes or similar meaning of words it is called confusable error. Some examples of this type of error are:

a) **Error**: We walked *till* the river and back.
Correction: We walked to the river and back.

b) **Error**: I'll stay here to next month.
Correction: I'll stay here till next month.

[143] Ibid , P.59

Here both the 'to' and 'till' (preposition) obtain similar meaning but according to rules "Use *to* with distance, and *till (until)* with time".[144]

4) Composing errors

When a language learner commits error in composing a text, it is called composing error. We may refer to composing error as understanding error because it mainly happens due to lack of understanding of the learner. In this context Chomsky (1980) draws a distinction between lexis and grammar. According to him lexis consists of open systems, to be irregular and unsystematic. By contrast grammar is said to be organized in closed systems, to be systematic and regular. Following Chomsky we may divide composing errors into two types: lexical errors and grammatical errors.

A. Lexical errors

Lexical errors are errors relating to the words or vocabulary of a language. As an example words of different classes can be derived from the same root: bright→ brightness→ brightly. If learner fails to use the proper form of the word due to inadequate vocabulary it will be included in this type. For some learner groups lexical errors take place very frequently. We may classify lexical errors from two perspectives: syntactic and semantic. Syntactic error includes errors in sentence structure, coordination/ subordination, and ordering), and semantic errors include miscommunication or ambiguous communication among words. James (1998) classifies lexical errors into two main categories:

a) Formal error and

b) Semantic error

a) Formal errors: Formal errors are classified into three types: misselection, misformation and distortion.

- Misselection

Misselection denotes error which takes place due to lexical forms (visual and sound similarity) of words. Two examples of misselection are given below where learner selects incorrect suffix:

[144] Fitikides ,T.J., (2002). *Common Mistakes in English* Sixth edition Malaysia , Pearson Education , p.83

i) **Error:** Damage to the building was considerate.
Correction: Damage to the building was considerable.

ii) **Error:** It was very considerable of him to wait.
Correction: It was very considerate of him to wait.

Here two words have the same root but with different suffix containing different meaning.

- Misformations

If learner uses such word that do not exist in the target language and the source of these errors are influence by learner's mother tongue it is misformation. It is also called 'interlingual misformation errors'. An example of it is:

Error: We have to find a car to bring us go to the hospital.
Correction: We have to find a car to bring us to the hospital.

- Distortion

Likewise misformation in this type of error learner uses which do not exist in the second language. However, these errors are not influenced by the native language but it is resultant of the misapplication of the target language. It may take place due to insufficient knowledge about the lexis of the target language. Some examples of this type of errors are:

i) Omission : *intresting* instead of interesting
ii) Over inclusion : *dinning* instead of dining
iii) Misselection : *delitouse* instead of delicious
iv) Misordering : *littel* instead of little
v) Blending : *travell* instead of travel or travelled

b) Semantic errors: James classifies semantic errors in lexis into two main types: Error due to confusion of sense relations and collocation errors.

- Error due to confusion of sense relations

Psycholinguistic evidence suggests that learner stores words in terms of sense relations in their mental lexicon (Deese,1966 and Aitchison,1987). Vocabulary

meaning normally involves concepts of words and their relations in lexical fields. When one uses more general term (superonym) where a specific one (hyponym) is needed it may be a resultant of confusion of sense relations. An example is:

Error: We have modern equipment in our house.

Correction: We have modern appliances in our house.

- Collocation errors

Collocation is a word or phrase that is frequently used together with another word or phrase and sounds natural and correct for native speakers. Inappropriate collocation may not be absolutely wrong, but rather infelicitous. An example is:

Error: The city is grown.

Correction: The city is developed.

B. Grammatical errors

Following James (1998) and N. Kittiporn, (2013) we may create a revised taxonomy of grammatical errors. Grammatical errors may be divided into four types: omission, malformation, disordering, and overgeneralization.

- Omission

Omission is the lack of specific grammatical form that is supposed to have in the sentence. If the learner omits necessary article it will be included in omission. Where the learner omits necessary main verb/ helping verb/ preposition/ punctuation/ etc these are also included in this type. An example of this type of error is:

Error: She came and asked my book.

Correction: She came and asked for my book.

- Malformation

Malformation is using wrong forms of words or structures in a sentence. It includes incorrect word selection, wrong form of verbs, wrong from of adverbs, wrong form of adjectives, and wrong form of nouns. An example is:

Error: I will go tomorrow if it's fine.

Correction: I shall go tomorrow if it's fine.

It breaks the rule as "To express simple futurity in the first person say *I shall* don't say *I will*."

- Disordering

Disordering refers to putting words or sentences in a wrong order or sequence. Incorrect placement of adjectives, nouns, or verbs is included in this type. An example is:

Error: It's hot too in Rome in the summer

Correction: It's too hot in Rome in the summer.

(Here the adjective too is placed incorrectly)

- Overgeneralization

Overgeneralization is using over grammatical forms in sentence. Putting a preposition when it is not needed, applying 'ed' as past tense signal with irregular verbs, putting 's' to signal plural for exceptional nouns etc. Such are examples of this type of error. An example is:

Error: He goed to farm.

Correction: He went to farm.

(Here it is applied 'ed' as past tense form with an irregular verb 'go')

5) Pragmatic errors

Usually this type of error is committed by the young learners. Pragmatic errors take place due to using limited linguistic knowledge into practice. They may arise when the speaker misquotes a message or when learners do not understand the meaning of any message but try to identify its meaning by pragmatic force. On the other hand, in discourse when interactional gap is found, this type of error may take place. Pragmatic failure was firstly coined by Jenny Thomas (1983) in her article Cross-cultural Pragmatic Failure. She defines pragmatic failure as the inability to understand what is meant by what is said [145]As an example if a young learner does not know how to use language for different purposes, he/ she may commit this type of error. A list of sentences expressing different purposes is given below:

[145] Thomas, J. (1983). Cross-cultural Pragmatic Failure. *Applied Linguistics*, 4 (2), 91-112

- greeting (e.g., hello/ goodbye)
- informing (e.g., I'm going to get a book)
- demanding (e.g., Give me a book)
- promising (e.g., I'm going to get you a book)
- requesting (e.g., I would like a book, please)

So if the learner fails to use proper sentence in expressing exact intention will be included in pragmatic error.

6) Inter-lingual errors and Intra-lingual errors

Errors due to the influence of the native language are called *inter-lingual* errors. These errors are also called transfer or interference errors. Inter-lingual errors are caused by mainly mother tongue interference. Inter-lingual error is found as one of the most important factors affecting learning target language. According to Bhela (1999) it is obvious that these errors result from the word for word translation strategy or thinking in mother tongue language. An example of inter-lingual error is:

Error: we must guard ourselves from bad habit.
Correction: we must guard ourselves against bad habit.

(It may occur when learner's mother tongue is Bengali.)

Intralingual errors when the learners have insufficient knowledge of target language.. Intra-lingual errors reflect the improper application of rules of the target language like faulty generalization, ignoring the exception in applying rules and failure to learn conditions under which rules apply. An example of this kind of error is:

Error: The child is learning word by word.
Correction: The child is learning word for word.

5.4 Some Factors Behind Learner's Errors

After discussion of different types of error in learning it may be said that learning error is the reflection of false concept of the learner (Richard, 1971 and Stenson, 1974). Many cognitive and external factors are responsible for learners' errors

Misconception: Misconception of the learner is the main cause of learner's error. According to Oxford Advanced Learner Dictionary (8th edition) a misconception happens when a person believes in a concept that is objectively false. Due to the subjective nature of being human, it can be assumed that everyone has some kind of misconception. Misrepresentation of a concept is not a misconception but it maybe resultant of misconception. Explaining important characteristics of it Hammer (1996) indicated the following point about students' misconceptions:

a) They are strongly held in stable cognitive structures.
b) They differ from expert understanding.
c) They affect in a fundamental sense how students understand natural phenomena and scientific explanations.
d) This type of condition must be overcome, avoided, or eliminated for students to achieve expert understanding (p. 99).

Following Hammer (1996) and Li (2006) provided a developed view of student's misconceptions. According to him student's errors are the symptoms of their misconception. There are different types of misconception. Some of these are:

a) Misconception of the meaning of the problem.
b) Misconception of the background upon which the problem is based.
c) Misconception of the procedural knowledge relevant to the problem.

Interesting point is that blunder, miscalculation or misjudging is also the resultant of misconception. The challenging issue concerning misconceptions is that many people face difficulty to overcome misconceptions because the false concept is deeply ingrained in their mental map as prejudice.

In the context of analyzing computation error, Ashlock (2009) categorizes misconception into two types:

a) Overgeneralization and
b) Overspecialization

Ashlock (2009) explains overgeneralization as jumping to conclusion before having adequate data at hand. Overspecializations generate when a student overspecializes

concepts during learning process. It happens when students make their concept rigidly. We will explain generalization as a factor of learner's error differently.

Generalization: Learners often choose general method or rule in solving problems. As an example in language learning process students have a tendency of using one common form of verb in constructing sentence it is called simplification; but it may often lead to an error. As an example of this type of error is:

Error:	Since he come, we are happy.
Correction:	Since he comes, we are been happy.

In this example simplification is involve in using simple present tense instead of the present perfect continuous tense.

Avoiding tendency: In learning it may happen that some syntactic structures are difficult to understand for learners. In this case it is observed that these learners have a tendency to avoid these complex structures and using cooperatively simple structures. But it makes their learning incomplete that may result in error. (see thematic vagabonding *[page 45]*)

Lack of prerequisite skills: When a student fails to adopt the necessary prerequisite skills, facts, and concepts relevant to solve a problem, he or she may commit error in his learning procedure. For example, if a student does not know how to combine like-terms, he or she may face difficulty solving multistep equations involving combining like-terms.

Incorrect associations or flexibility: Difficulties due to incorrect associations or rigidity of thinking are also common aspect of error. According to Radatz (1979) "Inadequate flexibility in decoding and encoding new information often means that experience with similar problems will lead to habitual rigidity of thinking".[146]

Language problem: Any learning procedure is dependent on the communication between the teacher and the students. So in learning it is very important that students have proper skill of using language for communicating with the teacher. If the teacher maintains an environment where learners can improve their communicative skills and

[146] Radatz (1979) Error Analysis in Mathematics Education . *Journal for Research in. Mathematics Education.* , 10, p. 164

express their understanding it will be helpful for a meaningful learning. Lack of such learning environment learners will not be able to follow the subject content and it leads them to commit error. Some causes behind language problems are:

- Language transfer

When one language interferes in learning of another language it is called language transfer. Language transfers are of two types: positive transfer and negative transfer. Usually positive transfer occurs when both the native language and the language which has the similar form of linguistic feature. It makes learning easier and does not result in errors. Both languages may share aspects of grammar such as some patterns of word order. Negative transfer or interference is the use of a native-language pattern to another language incorrectly. It leads to an error like using inappropriate form of native language in the target language. (see inter-lingual error *[page 167]*)

- Sociolinguistic situation

Sociolinguistic situation shows the connection between language and society. It reflects the way in which people uses language in different social background. According to different social structure language may be different. So situation may influence learner to commit error.

- Fossilization

Some errors, specifically errors in pronunciation, persist for long periods and become quite difficult for the learner to get rid of it is called fossilization. Describing uncontroversial features of fossilization Han (2004) says "fossilization involves premature cessation of development in defiance of optimal learning conditions; and that fossilizable structures are persistent over time, against any environmental influences, including consistent natural exposure to the target language and pedagogic interventions."[147] According to him fossilization occurs locally. It takes place only in parts of the inter-language system. Moreover, it is an observable process rather than a product. Han believes for adult learners, the major cause of fossilization is influence of the learner's native language.

[147] Han, Zhao Hong. (2004). *Fossilization in Adult Second Language Acquisition.* Clevedon, Multilingual Matters Ltd, p.23

Lack of proper teaching materials: Only the text book does not provide all the needed information for a meaningful learning. So in text book-oriented teaching method where teacher-students oral communication is being neglected, there is a high chance that learner may commit error. Faulty presentation of subject content or misinterpretation of textbook may also lead to error in learning.

Inadequate learning and false concepts hypothesized: This is mainly caused by ignorance of rules or restrictions of the target solution. Inadequate knowledge of differentiation between two patterns or rules may also cause this type of error. It may also happen that many learners' at a time make wrong hypotheses in solving a problem. It may be caused by faulty teaching.

Ineffective teaching method or Faulty teaching: Sometimes it happens that origin of learners' error is underlies as faulty teaching. It may happen that the teacher fails to provide proper teaching materials or he presents the subject content improperly. It may happen due to his inadequate knowledge or lack of teaching skill. Many times these factors are closely related to hypercorrection where teacher gives enthusiastic effort to correct the learner error. In teaching real life conversation is very effective. If teachers fell timid in real-life interaction with learners and go on with text book knowledge their students will not acquire proper knowledge. So for meaningful learning a teacher should always adopt a communicative approach in his teaching method.

Teachers' competence: For effective teaching a teacher needs proper ability of teaching. There are various literatures in which the characteristics of ideal teacher are discussed. Following Edward Sheffield (1969) it is mentioned some important characteristics of teacher below:

- He/she will be master of his/her subject, competent.
- His/her delivered lectures will be well prepared and orderly.
- He/she teaches in an ambience of subject- related life and in a practical environment.
- Students' questions and opinions are always encouraged by him/her.
- He/she will be enthusiastic about his/her subject.
- He/she will be approachable, friendly, and available to the students.
- He/she will be concerned for students' progress, etc.

- He/she has a sense of humor and is amusing.
- He/she will be warm, kind, empathetic.
- He/she will be able to use teaching aids effectively.

Lack of any of these qualities in a teacher may be a factor of learners' error.

Learning disability of the students: In the context of learner's error Wenfen Yang (2010) describes dyslexic error which indicates that dyslexia is one type of source of spelling error. But not only dyslexia but there is many types of learning disability which lead to error in learning. Though students with learning disability needs proper care in learning so in any discussion on learning process learning disability is important issue. Here we are discussing some types of learning disability in brief:

Attention deficit hyperactivity disorder: Some students with learning disabilities have difficulties in focusing, sustaining and shifting attention. These difficulties might result from physical discomfort, emotional issues, interest and motivational factors or from challenges with self-regulation. Persistent patterns of difficulties such as inattention, hyperactivity, or impulsivity, or any combination of these, might be the result of a biologically based condition known as Attention Deficit Hyperactivity Disorder.

Memory difficulty: Students with learning disabilities might demonstrate problems with one or more types of memory. There are three types of memory: working memory, short term memory, and long-term memory.

- Problem with working memory

  The component of memory, in which information is stored and/or manipulated for brief periods of time in order to perform another activity, is called Working memory. A student with working memory difficulties faces problem to hold on to pieces of information until the pieces blend into a full thought or concept. They might have forgotten the first part of an instruction by the time the full instruction has been given. They might be unable to recall the beginning of a sentence by the time he/she has read to the end. Some students will be unable to hold material in working memory in order to complete a task or understand a concept. Working

memory is important for a range of activities, such as controlling attention, problem-solving, and listening and reading comprehension.

- Problem with short term memory

  In this component of memory information is stored briefly until it is either forgotten or integrated into long term memory. A student with short term memory challenges might not be able to remember information long enough to copy it down from one place to another.

- problem with long-term memory

  It refers to information that has been stored and is available over a long period of time. Effective short-term memory is critical to move information into long-term memory. A student with long-term memory difficulties might find it necessary to review and study information over a longer period of time in order for it to become part of his or her general body of knowledge. Rehearsal, repetition and association are well-known paths to improve long-term memory.

Arithmetic disorder (Dyscalculia): Arithmetic disorder is generally characterized by difficulty in learning or comprehending mathematics. It affects a person's ability to understand and manipulate numbers or understand numbers themselves.

Writing disorder (Dysgraphia): Writing disorder is generally characterized by distorted writing in spite of thorough instruction.

Spelling disorder (Dysorthographia): Spelling disorder refer to the difficulties of the learner with spelling. They stem from weak awareness or memory of language structures and letters in words.

Auditory processing disorder: Auditory processing disorder describes a variety of disorders that affect the way the brain processes or interprets what it hears even though the student might have adequate hearing.

Visual processing disorder: A visual perception disorder involves difficulty in making sense of what is seen, even though vision is intact.

Sensory integration (or Processing) disorder: Sensory integration disorder is associated with the ability to integrate information from the body's sensory systems such as visual input, auditory input, olfactory input, taste, tactile input, vestibular input (balance/movement) etc.

Organizational learning disorder: An organizational learning disorder is a type of learning disability related to challenges with executive functions. This type of difficulties accompanies other learning disabilities frequently. Organizational learning disorder might include difficulties in handling too much stimuli or information at one time, thinking in an orderly and logical way, distinguishing direction, or organizing materials and time.

Social cue disorder: Individuals with social cue disorder have difficulty in behaving an automatic way. Picking up spoken and unspoken cues is a complex process. Information must be detected, processed, and meaning be extracted; then a response must be formulated.

After this discussion we may say that each learner is different in nature. Each of them has different cognitive factors. On the other hand in formal education system there is a one general teaching method provided for all students of a class. So it is very natural that some students fail to achieve proper knowledge. According to their different personality they need individual attention. If a teacher fails to maintain this issue in his teaching method it may result in learners' error. Following incorrect teaching material students may fall into error. In all cases teacher has a huge responsibility to understand the specialty of the child and to provide them the proper content knowledge in effective way. In this context in the next section we are going to discuss pedagogical reasoning as a concept of effective teaching method.

5.5 Handling Errors in Learning by Pedagogical Reasoning

In the previous section we observed that there are various types of error take place in learning. These errors have important significance in learning. They are the indicator of learners understanding as same as they are the basis of teachers' teaching strategy. Learners' errors may be the key component of meaningful learning or effective teaching only when these are handled very sensitively by an efficient teacher. In this

section we are going to provide an effective cognitive model of teaching. It is reasoning based teaching method. This method presupposes that:

- Teaching is a knowledge base profession , and
- When teacher knowledge will be effective for meaningful learning it will be pedagogical reasoning.

Concept of pedagogical reasoning

The concept of pedagogical reasoning is a well-known concept. Pedagogical Reasoning was first suggested by Shulman (1987) in his article "Knowledge and Teaching: Foundation of the New Reform". In this article he gives a vivid description of this concept. Providing a new framework of effective teaching he analyzes pedagogical reasoning. According to him pedagogical reasoning is a combination of some basic teaching components such as knowledge of subject matter, observation power to maintain the classroom, skill of using the teacher knowledge as compatible with classroom ambiance etc. Following Shulman (1987) many educationists provide different features of teacher knowledge later. Here we emphasize on how pedagogical reasoning can be a useful in teaching method.

Pedagogy is often used as the practice (or the art, the science or the craft) of teaching. In modern educational perspective the term 'Pedagogy' is applied to refer to the instructional techniques and strategies which makes learning effective. It considers interactive process between teacher and learner (Creemers, 1994). Thus pedagogy may be explained as the act of teaching with its attendant discourse. (Alexander, 2003).

In describing the view of teaching we may cite that in the preliminary level of teaching, a teacher knows something which is the target knowledge for the students. If the teacher can transform his understanding to the learner correctly and it may make learning meaningful it is called effective pedagogy. In effective pedagogy teacher modified his knowledge comprehensible for the students. There are various ways of teaching: talking, showing, enchanting, etc. Any method of teaching necessarily begins with a teacher's reasoning about what he has to teach and how he will teach. It proceeds through a series of activities. So the goal of teaching is to achieve new comprehensions by both of teacher and the students. In this process teacher promotes

comprehensions among students so it is necessary the teacher has a strong base of different types of knowledge (Fenstermacher, 1978 and Shulman,1987). In the next section we will discuss what types of teacher knowledge is necessary for an effective teaching.

Teacher knowledge: The base of pedagogical reasoning

'Teacher understanding' or 'teacher knowledge' is a complex idea. Teacher knowledge is the combination of knowledge which is necessary to comprehend by a teacher for development of his pedagogical reasoning. To explain teacher knowledge, Shulman (1987) defines seven categories of it. They are:

a) Content knowledge
b) General pedagogical knowledge
c) Pedagogical content knowledge
d) Curriculum knowledge
e) Knowledge of learners and their characteristics
f) Knowledge of educational contexts
g) Knowledge of educational ends, purposes and values

Among these first four are highlighted by many educationists. Basically the remaining three are included in the first four points. So, we are discussing the first four components of teacher knowledge below:

Content knowledge

Content knowledge is the knowledge of the subject matter which a teacher is going to teach. In simple word it refers to subject knowledge of the teacher (Shulman 1987). There are many literatures on content knowledge. Schwab (1967) in his article 'Making Distinction between Substantive and Syntactic Structures of Knowledge', give us the basic conception about teacher knowledge.

According to Joseph Schwab, according to different subject teaching method will be different. For describing a specific fact concepts of its background is necessary likewise for effective teaching it is not sufficient for the teacher to understand that *what something is*; the teacher must have to know *why that is so*. He must has efficiency to give justification of each sentences delivered by him. Moreover, it is expected that, the teacher has knowledge about why a specific topic is included in a

particular discipline/course. So finally it may be said that teacher's vast knowledge is crucially important to the improvement of teaching and learning.

General Pedagogical Knowledge

According to Shulman (1987) general pedagogical knowledge is concept of the broad principles and strategy of classroom management. Brown and McIntyre (1993) mention some general aspects which are necessary for effective teaching. These are:

- Creation of a relaxed and enjoyable atmosphere in the classroom
- Retention of control over the whole class
- Transfer comprehension in an interesting way thus it motivates the learner
- Helping pupils in their difficulties
- Encouraging pupils and raise expectations in them
- Development a personal mature relationships with pupils
- Teacher will be able to use his personal talents in teaching
- Know about the curriculum and its context well
- Understanding the learning ambiance

Pedagogical content knowledge (PCK)

According to Shulman (1987) pedagogical content knowledge refers to the knowledge about how to teach. Later he explains PCK as a *knowledge growth in teaching* (Shulman and Grossman, 1987). He did a project work on knowledge growth during teaching. The project involved an investigation which highlighted how novice teachers gained new understanding of the subject matter during their teaching. Shulman (1987) further explained PCK as: 'a way of knowing unique to teachers whereby they take an aspect of the subject matter and transform their understanding of it into instruction that their students can comprehend.'[148] So in this regard, PCK can be described as a unique type of teacher knowledge (Geddis, 1993). PCK includes powerful analogies, and proper illustrations, appropriate examples, and adequate explanations, accurate demonstrations comprehensible and alternative representations for conveying ideas to the students. It also includes assessment techniques, the mastery of skills and the development of a meaningful teaching strategy of the content

[148] Shulman, L. S. (1987). Knowledge and Teaching: Foundations of the New Reform. *Harvard Educational Review,* 57 (1), p.8

knowledge for the students. In addition PCK also includes a teacher's personal ability in guiding a learner in proper way. Using PCK teacher makes learning easier for the learner. He can understand students' misconceptions about the topic.

Grossman (1990) also linked PCK with the knowledge of the subject matter. In his model of Teacher Knowledge, he included some issues relating to the development of PCK such as the purpose of teaching, curriculum materials, students' comprehension of the subject matter, instruments to assess students' understanding, effective teaching practices to teach certain subject matter and certain principles for the teachers to create the positive atmosphere for learning. The term PCK is also used to explain how the new knowledge gained by the teachers is related to teaching (Fenstermacher, 1994) So in describing PCK echoing Shulman (1986) we may say "It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction"[149]

After discussing all the categories of teacher knowledge it can be said that among these pedagogical content knowledge is the most important because it identifies the distinctive components of knowledge for teaching. It represents the blending of content and pedagogy into an understanding that how a particular topic, problem or issues are organized and how it can be delivered in a class for a meaningful learning. It is suggested that pedagogical content knowledge is a special kind of teacher thinking which develops new types of knowledge through some process. And Sulman (1987) introduces 'Pedagogical Reasoning' as a term for this new kind of knowledge . In the next section we will discuss how teacher knowledge is developed as pedagogical reasoning.

Developmental stages of teacher knowledge to pedagogical reasoning

In the discussion of pedagogical reasoning we observed that development of pedagogical reasoning is a continuing process. It is obtained by the teacher during teaching. So it may be said that teaching and learning processes are correlated. Through a teaching teacher learn how to teach. Thus in a teaching process both

[149] Ibid. p.8

teacher and learner learns. And in the end when teacher realizes the knowledge of teaching then he becomes able to provide a meaningful learning for the learner.

We may illustrate the development of pedagogical reasoning in six steps. These are: comprehension, transformation, instruction, evaluation, reflection, and new comprehension. In each stage pedagogical reasoning is developed gradually and finally it will be considered as a measure of meaningful learning. Then it will also be useful in rectifying learner's error. The process of pedagogical reasoning is described below:

Comprehension

This is the preliminary stage of teacher's understanding. Here the teacher comprehends what he/she is going to teach. It is very clear that pedagogical aim is not to teach students some specific text but helps the learner to fulfill their educational purpose. Teacher engages himself firstly to teach the students what they will do with their literacy; how do they use and enjoy their freedom; how they take care of their responsibility. He/she encourages the learners in developing their understandings, skills, and values needed to function for a free society. In simple words a teacher must comprehend both the content and purpose of his teaching; then he/she finds the strategy to convey his comprehend knowledge to the students in a specific background. Thus it can be said that in this step teacher prepares his knowledge base for teaching.

Transformation

Transformation is the way of transforming comprehended idea of teachers to the students. In this stage teacher motivates the learners and transfer to them the knowledge of subject matter. Transformation is not a single process. We may suggest the following orders of transformation:

- Preparation

  Preparation involves examining and critically interpreting the materials of the given text in terms of teachers' own understanding. In this stage teacher scrutinizes his teaching materials, educational purpose or goal in the light of his own comprehension and assess whether those materials are prepared for delivering the students or not.

- Representation

  Representation is the process by which a teacher can deliver his knowledge to the student. Representation involves thinking through the key ideas of the text or lesson. In this step teacher identifies alternative ways of representation for the students. For presentation teacher may find appropriate analogies, metaphors, examples, demonstrations. These may help him to convey his comprehension to the students through proper presentation. There are multiple forms of representations. Cognitive psychologists argue that processes of internal representation are key elements in any type of representation.

- Selections

  In this stage teachers use their knowledge about learners. Teacher influenced by the ideas, beliefs and values of the learners to select effective teaching strategies. Teaching strategy includes lecture, demonstration, recitation, or seatwork. It also includes cooperative learning, reciprocal teaching, Socratic dialogue, discovery learning, project methods, and learning outside the classroom setting (Shulman, 1987).

- Adaptation

  Adaption means modifying the content suitable for the students according to their ability, age, gender, language, culture, prior knowledge, motivation and skill. Shulman(1987) finds similarity between adaption and tailoring. According to him adaptation is like preparing a suit of a particular style, color and it is prepared for purchase by a particular customer, however, it must be tailored to fit perfectly.

  So in this stage teacher must know about the relevant aspects of students' ability such as language, culture, motivation, or prior knowledge skills which may affect their response to different forms of representation. He/she also acquire knowledge about students' conceptions, misconceptions, expectations, motives, difficulties etc. Teacher must select strategies by which he/she may assess students approach, understandings and misunderstanding of the subject materials.

- Instruction

  Instruction is the activity which involves to the observable performance of the variety of teaching acts. It includes many of the most crucial aspects of pedagogy, such as:

  i) Organizing and managing the classroom
  ii) Presenting clear explanation and vivid descriptions
  iii) Assigning and checking work
  iv) Interacting effectively with students through questions and probes, answers and reaction
  v) Praise and criticism

Thus instruction includes management, explanation, discussion, and representation of all the observable features for an effective teaching. There is a powerful relationship between the comprehension of a new teacher and the styles of his teaching technique (Shulman, 1987). In this context Grossman (1990) explains that teaching behavior is bound up with comprehension and transformation of understanding. In a flexible and interactive teaching technique teacher uses available learning equipments to the learner for a meaningful learning.

Evaluation

In this process teacher evaluates students understanding and misunderstandings. In analyzing the learner's comprehension a teacher requires a clear conception about the aim of teaching and the process of learning details. Evaluation may differ according to the teacher and teaching method.

Reflection

Reflection is a set of process through which a teacher learns from his experience of teaching and depending on it he/she reconstructs or recaptures the events, the emotions, and the accomplishments. Reflections are not merely a disposition or a set of strategies, but also the use of particular kind of analytic knowledge brought to bear on work. Central to this process, review of the teaching in comparison to the ends is sought.

New comprehension

New comprehension represents what the teacher has learnt from all the previous processes. In this stage through act of teaching, a teacher achieves new comprehension of both the purposes and of the subjects they taught. New comprehension does not occur automatically, after evaluation and reflection for new comprehension it is needed to follow some specific strategies as documentation, analysis and discussions. Thus new comprehension gives the teacher a nit conception of his own established knowledge, students' standards, and the concept of teaching environment. And using his conception if a teacher can perform his teaching it will be pedagogy or art of teaching.

In this chapter we have discussed various types of learners' error. We observed that, errors are very natural with students when they attempt to integrate new learning materials. Error shows the gap in between their target knowledge and their base knowledge. So, erroneous phenomenon in learning is unavoidable but very fruitful for taking proper attempt in teaching students. On the other hand pedagogical reasoning is a key component of meaningful learning. We observed in the discussion of pedagogical reasoning that for an effective teaching it is needed for the teacher to evaluate student's understanding. In this context educators are much interested in using errors as useful diagnostic tools to determine the nature of learners' understanding of a specific subject. Analyzing errors, teacher can also predict the possible source of errors and he can select proper strategy to transfer his comprehend knowledge to the learners. Thus learners' error is a key source in gaining new comprehension for the teacher. The new comprehension is the final form of pedagogical reasoning. It is the classroom knowledge of the teacher. With this skill teacher can handle learner's error properly. In other words this reasoning may be a rectifying measurer learners' error. Thus pedagogical reasoning is a process during which teaching ability of the teacher and attempt knowledge of the learner both are developing toward their desired end.

Chapter 6

BREAKING SOME MYTHS AND EXPLORING UTILITIES OF HUMAN ERROR

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Until now we have discussed human error in different ways. We have classified human error into different types. We have identified some probable underlying factors of common human errors. We have also analyzed that human error takes place in four different practical fields. Thus we have obtained wide vision of human error. This chapter is going to unfold another aspect of human error. In popular parlance usually human error is taken in negative senses. Almost often it is considered as a cause of unwanted consequences; but there is also some popular sayings like 'failure is the pillar of successes'. In everyday life we all take lesson from the erroneous actions committed in the past. In this chapter we will unveil some more positive dimensions of error from different perspectives. In this context we will start with a analytical discussion about popular myths about error.

6.1 Breaking Some Myths about Human Error

In finding utility of human error it is necessary to know what common people think about error. There are many similar thinking about error popular among common people. Most of these are no way related to truth. We would call them myths on human error. In this section we are going to analyze some of these myths. It will help us to wiping out irrelevant views on error and it will also motivate us to change our attitude towards error.

i) To err is human

In this context we start with the most common myth about human error 'To err is human'. It means committing error is a common nature of human beings. Everybody commits error. No man is beyond error. We may analyze this myth from two points of view:

Firstly: In the second chapter *Types of Human Error* we have found that there are several cognitive and external factors responsible for an error. These factors are always changing during an action. If these factors influence the action to be successful it will be positive factor of the action; on the other hand if these factors obstruct the success of an action it will be considered as negative factor for the action. Now though it is very clear to us that, man's life is full of actions and each action depends on innumerous factors and any factor among them can ruin the action. So, it is not a false claim at all that each man commits mistake.

Secondly: We may criticize this myth according to the following statement of Reason (1990).

"There is usually only one way of performing a task correctly, or at best very few, but each step in planned sequence of action or thought provides an opportunity to stray along a multitude of unintended or inappropriate pathway." [150]

Following Reason it can be said that though there are very few way to achieve success. From that perspective we may say that *Probability of error is greater than probability of success.* In explaining this myth it is relevant to analyze a popular working definition of human error which we discussed in the first chapter (second chapter). For analyzing further we repeat this definition below:

"Error will be taken as a generic term to encompass all those occasion in which a planned sequence of mental or physical activities fail to achieve its intended outcome, and when these failure cannot be attributed to the intervention of some chance agency."[151]

According to this definition human error is an action, which has a planning background; it must be executed by at least an operator and which results in an unintended outcome. Analyzing this definition we need a clarification that what do we mean by planning?

- It may mean achieving desired outcome any how or
- It may mean some pre-decided specific steps, following which we may be able to achieve our goal.

[150] Reason, J. (1990). *Human error*. New York, Cambridge university press p.2
[151] Ibid p. 9

If we take planning according to the first alternative then there are no differences between removing pain from a finger by medicine and removing pain by amputation of that finger. And there is no doubt that this explanation is not acceptable.

If we go with the second alternative then there is only one option for a successful action. And that is: if and only if every step of an action takes place just as it was planned then an action must be successful. But if we admit this view then there is little chance for an action to be successful; because for success according to the changing circumstance we often manipulate plan or execution.

ii) Errors are outcome of abnormal performance

Analyzing this myth at first we need to clarify what we mean by 'normal performance' and 'abnormal performance'. Generally by *normal performance* we mean natural or usual performance and by *abnormal performance* we mean rare or exceptional performance. So this myth denies that human errors are resultant of our everyday performances; which is not acceptable. Error takes place in our life very frequently. We observed in the previous chapters that origins of error are grounded in our natural mental model. So error is not abnormal performance. In the second chapter we highlighted lots of examples of error; each of them justifies that errors are very common phenomena to us. Taking an example of capture error from my own experience we may explain it.

Once I was counting dates from end of a month to the next month. Then naturally I was counting as "29, 30, 1, 2, 3, 4 . . ." after that I shifted to a new task of correcting examination papers. Then too while calculating total marks of answer scripts I shifted to 1, 2, 3, etc after 30.

Here the error is not a consequence of any abnormal activity; not only has it taken place in a habitual performance. So it may be said that, failures are outcome of normal performance but not a consequence of abnormal performance**.**

iii) More protection results a higher safety

This myth is not directly associated to the discussion of human error but indirectly it is relevant to this topic. Usually safety issue is related to success of an action. Usually safety is our first preference. If we complete a work safely it is called successful

work. In this context this myth presupposes that, more protection can resist human error and can makes an action safe.

From one perspective this statement is quite true. If errors are predictable and causes of them are revealed then they may be handled or corrected before their occurrence. As an example, error due to inattention can be reduced by better attentive.

There is another perspective according to which more awareness is a factor of failure. In our observation of medical error it is revealed that doctors do more error when they become more conscious. That is one cause why doctors rarely treat their family. According to them more protection induces anxiety about the probable unwanted outcome than the proper treatment. Simply they become diverted from their concentration. In this discussion we may conclude that in the mechanical or habitual action more protection results in lesser safety. In previous chapter we observe that more enthusiasm of a teacher may cause learner's error. But overall proper protection reduces error and results in higher safety.

iv) Errors are intrinsically bad

It is a very popular impression about error among common people that errors are intrinsically bad. 'Bad' is the opposite concept of 'good'. *Good* and *bad* both are ethical concepts. "A thing is generally said to be good when it is valuable for some end. Thus particular kinds of medicine are said to be good for this or that complaint. Similarly, when we speak of conduct as good, we may mean that it is serviceable for the end or ideal that we have in view. It should be carefully observed, however, that the term good is also used to signify not something which is means to an end, but something which is itself taken as an end. Thus the *summum bonum,* or supreme good, means the supreme end at which we aim."[152]

After this ethical explanation apparently it may seem that error is an unintended action; that means due to error we fail to achieve our intending outcome. It may also be said that intending outcome is our aim or end of our action. So, if we take good or bad in narrow sense then error is intrinsically bad because it is not valuable for the end. But in ethics this narrow sense of good and bad is rarely used. If we accept end as *summum bonum* then previous ethical explanation of error will be meaningless. In

[152] Mackenzie, J. S. (1929) *Manual of Ethics* (6th ed.) London, The University Tutorial Press, Ltd. p.2

ethics object of moral judgment is agent's intention. Here 'intention' consists of three components: agent's desired goal, his prior plan of action, and the consequences of the action. If all three components are considered as valuable according to ethical sense then the action will be good. But in the context of human error it is considered that whether that action is able to produce intended outcome or not. So error is not the synonym of bad. 'good' or 'bad' that is completely another issue. So, we cannot say that error is intrinsically bad.

If we take 'bad' in common sense then also we cannot agree with the myth 'Errors are not intrinsically bad'. It is established in many theory of educational psychology that error is essential for learning process (trial-and-error theory of Thorndike); in that context we may say error is valuable for learning. So, errors cannot be titled as intrinsically bad.

v) Error always results in adverse outcome

To understand human error with positive perspective it is very important to explain the difference between error and its consequence. In popular speech the term 'error' often refers to the action and its negative consequences. Sometimes error means the consequence of an action (I put salt in coffee mug) but it is only one aspect of human error. Human error does not refer to its consequence only, if the prior plan of an action does not enable to produce intended outcome that is also called error (decision error). Basically the point is that when the outcome of an error is unintended that means not successful. It may result in adverse outcome or near miss. It may also be just indicator of the system status.

There is another explanation that can falsify the myth. According to that theory errors may be understood as deviation from intended outcome. According to this concept there are at least three basic characteristics of human error which indicates the differences of error and its consequences:

- Human error occurs only in a goal oriented action. Because only goal oriented action can be intentional.
- Consequences of human error are unintended, and

- Errors have potentiality to be avoided and it was not chance based. (Ferse and Peters, 1988; Rasmussen, 1987; Reason 1990). That means, error and its consequences are not connected in a necessary causal relation.

So, we may analyze human error in at least three steps: intention of the action, the execution of the action and the consequences of the action. So the consequence is a part of erroneous action not the whole. And human error is not the only causes behind an adverse outcome. In the examples of error in practical field we observed human error is only one factor of adverse event; there are many other causes like system failure, changing situation, unpredictable atmosphere, limitation of human ability all are responsible for an unwanted accident. So we can never say that error always leads to adverse event.

vi) Bad people make bad errors

It is also a very common belief in human beings. They believe, it is a universal law that bad things happen to bad people, and good things happen to the worthy. But this is not an established truth. Following causal relation it cannot be said that any unrelated factors or bad luck can ruin the best organized plan in achieving intended outcome. One basic rule of error management is that the best people can make the worst errors. There are many reasons for this. The best people have a tendency to expand the limit of his experience. They always try to induce new techniques. They are often in a supervisory capacity and generally their works are multi-tasking. So they always have chance to take risk and break the formal rules. All this facts increase chance of errors among extra-qualified people than a common one. For an example in a system management, sometimes a manager may elect to carry out 'hands on' tasks ill-advisedly in order to avoid being de-skilled (Reason, 1990).

The other perspective is that, “bad man” is an invalid term; because ‘good’ or ‘bad’ are ethical concepts. According to ethics intentional action may be right -wrong or good-bad, it is not applicable to human beings. We have already discussed this issue in details in the previous myth. So we do not agree with this myth.

vii) Errors are random and highly variable

This is another widespread myth about human error. We may discuss this point in two perspectives. In etiological context we may state that each error is different from each

other but errors are not random and they have specific origin. Following specific type of causes we can classify errors into different types and we can also predict them in future. Justifying our view we can cite Reason (1990) in this context."Human error is neither as abundant nor as varied as its vast potential might suggest. Not only are error much rare than correct actions, they also tend to take a surprisingly limited number of forms, surprising, that is when set against their possible variety. Moreover, errors appear in very similar guises across a wide range of mental activities. Thus, it is possible to identify comparable error forms in action, speech, perception, recall, recognition, judgment, problem solving, decision making concept formation and the like."[153]

viii) Human errors are one type of violation

This thinking is also very common in human beings. Behind this view we may point one factor that is: there are some similar qualities which are attributed both to error and violation. Explaining this context, we may provide definitions of both error and violation.

In defining error flowing Reason (1990) it may be said that "An error is an action, omission or decision resulting in an unintentional departure from procedures and regulations."[154]

And explaining violation it may be said "A violation is an unauthorized action, omission or decision involving an intentional departure from known procedures and regulations."[155]

In reviewing these definitions, we have noticed that both errors and violations are different only on the basis of individual's intention. There are two levels of a intention;

a) One is to follow the authorized rules and procedures and
b) Another one to get the intended outcome.

[153] Reason, J. *(*1990). *Human Error.* New York, Cambridge University Press, p. 2.
[154] Sellers, R. (2011). Understanding human error and violation and its role in the development of culture *Understanding Human Error and Violation* .Convergent Safety Pty Ltd, p.2.
[155] Ibid, p.2.

It seems that, an individual who commits an error and a person who violates rules in both cases they may has a similar intention. And the intention is achieving the intended outcome safely. One may say that in most cases of violation the agent fails to predict that it will result in a negative consequence. But there is also a difference that the error committer makes plan to follow authorized rules; but in the context of violation the agent may intentionally disobey the authorized rules. It is to be noted that if one violates rules unintentionally while performing an action then this type of violation is also included in error.

Thus in determining the difference between error and violation, we need to identify the individual's intentions. If the individual intends to follow the prior plan but fails to achieve desired outcome, this would be described as an error. And if the agent intentionally disobeys the authorized rules and procedures, this would be described as a violation. In other words if making a plan the agent follows the approved rule it will not be violation but if he does not follow allowed rules it will be violation,

In explaining this myth we are citing another useable definition of human error given by International Civil Aviation Organization. They define human error as "An action or inaction by an operational person that leads to deviations from organizational or the operational person's intentions or expectations."[156]

The important point is that, according to this definition same action may be treated as both error and successful action. On the other side it may be an example where an action may be treated as violation but not as an error.

It may happen that an action may occur according to agent's intention but not as rule following of the organizations' then from the organizational point of view it will be treated as error but from the person's point of view it is a successful action. In that situation it may be also an example of violation which is not an error. Similarly a person is compelled to do an action not intended to him but by the organizational demand. In this situation the same action is considered as successful action according to the organizational point of view but for the operator it is referred to as unsuccessful action.

[156] International Civil Aviation Organization. (2012). *Safety Management Manual* (SMM) (3rd ed.), p. 20

Therefore, it may be said that in the context of management system, errors and violations are needed to be treated differently. These errors are resultant of breakdowns of human limitations (knowledge, information processing, memory, motor skills etc.) it may be unintentional; whereas violations are fully intentional behaviors (intend to proof more efficiency, saving time, inventing some new rules etc.).

ix) Systems will be safe if people comply with procedures

This myth is invalid due to over generalization. It is true that sometimes system may be safe if people comply with the procedure but it is not true that non compliance with procedures mean safety is lost. When errors are predictable compliance of compatible procedures may increase the possibility rates of safety but in every system there are some unpredictable situation and then the myth is not applicable. As an example:

DC-10 united airlines 232 crashed in south cities in July 1989 due to rear engine disintegration and hydraulic loss of all control surfaces. In that situation the existing two pilots improvise with a third pilot among the passengers. As a result decision 50% of lives onboard were saved. Here though the operators (pilots) did not compliance with authorized procedures but it result in more safety.[157]

Here we may also give example of medical science. According to it each body is different from each other, so in treatment practically there is no chance where doctor can comply with exact given procedures. He/she often take some new decision in the context of unexpected situation.

x) Human error is the largest single cause of an accident or an unwanted incident

We are use to declare that failures are caused by humans but it is also undeniable that human effort is the root of success. So the concerned myth is not acceptable. On the other hand like any voluntary action human error is committed by humans. In a system operator of the sharp end is only one factor behind an adverse event. Behind operators' error there are several external conditions which are responsible to an error. As an example

[157] source : http://www.ntsb.gov/investigations/AccidentReports/Pages/AAR9006.aspx (Retrieved on 10.10.2014).

In Jan 1992 A320 was crashed at Mont Sainte Odile[158]. Here the active error of this accident is the selection of wrong descent mode by the operator during the flight; but there are several causes behind this sharp end like:

- Time pressure
- No alert from flight systems
- It was Night time

These are blunt end of the accident. Therefore the fact is that human error is not only one cause for an accident.

In the previous section we have observed that there are many misconceptions engraved in the sense of common people and because of these, human errors are looked upon in the society as a taboo. People fear to admit error. They curse others for their error. But error is not to be hushed up; it can be corrected or handled. It will be possible only when we admit our error and take lesson from them. We would discuss some positive aspects of error in the next section. It may help us to change our attitude towards error.

6.2 Exploring Some Utilities of Error

The title of this section *Exploring Some Utilities of Error* sounds somewhat paradoxical. In common sense the use of 'error' and 'utility' in a same heading is bit contradictory. As we have said in the previous section in discussing myths on human error that error connects with our sense negatively; but here we are finding some positive importance of error in our everyday life. We all experienced efficacy of error in our life but very often realized. In the next section we will explore our everyday experience and will find some incidents where we unknowingly use to manage error better. In this context we will discuss error from three points of view:

i) In context of system procedure
ii) In context of training procedure
iii) In context of learning

[158] Official report into the accident on 20 January 1992 near Mont Sainte-Odile (Bas-Rhin) of the AIRBUS A320 registered F-GGED operated by Air Inter by France Ministry of Transport and Tourism
Source: http://lessonslearned.faa.gov/AirInter148/Accident_Report_Eng.pdf. (Retrieved on 09.10.2013)

6.2.1 Utilities of Error in the Context of System Procedure

Almost everywhere 'error' and 'failure' are used synonymously. When the operator fails to make proper plan or fails to execute a plan in producing intended outcome it is called error. We are going to say that every error may be a factor leading to a successful action. In this segment we will explore how we can use error as a positive factor for the success of a system. We are highlighting some important values of human error in a system procedure below:

Error can be highly informative

In a journal of business research Arnold, B. and Roe, E. (1987) assumed that an organization can profit from errors. According to them "When the user is able to find out what has caused the error and how to correct its errors it may be highly informative."[159] Analyzing some human errors that take place in aircraft ground damage incidents they provide a methodology that allows reports of human error. In this report it is proved that development of the mentioned sector is based on the analysis of the report on error (Caren, A. Wenner, Colin G. Drury, 2002).[160] We may highlight the following points to justifying that error gives us important information for the advancement of a system:

- By analyzing error we can find out the contributory factors of it. It may help us to take proper recovery steps to handle them. That will definitely decrease the rate of adversity in a system.
- When an unsuccessful action is labeled as error it gives the information that there is a loophole in the system. This imperfection may be placed in the plan or procedure; it may be due to lack of skill of the agent.

This discussion does not mean that error is a necessary factor of each successful action it implies that almost in every successful action error is ingrained as a factor. In other word it may be said that, each error has a potentiality to be a part of a successful action.

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[159] Arnold, B. and Roe, E. (1987). User errors in human-computer interaction. In: M. Frese, E. Ulich and W. Dzida (eds.) *Human Computer Interaction in the Work Place*. Elsevier, pp.205

[160] Wenner, C. A., C. Drury, C. G. (2000) *International Journal of Industrial Ergonomics* 26, 177-199.

We take lesson from severe outcome of errors

According to Argyris (1992) and Weiner (1985) people become motivated to learn when things go wrong. They take error as a challenge and try to overcome it. Thus error incidents challenge the status and promote learning (Cyert and March, 1963, Levitt and March, 1988). According to Sitkin (1992) learning through failure may be a strategy of small loss. It may also be said that incident of error with severe negative consequences tend to stimulate the learning behavior. (Reynolds 2005).

Industrial accidents often occur with severe negative outcomes and most often we fail to learn from these incidents because they do not take proper initiation to analyze these incidents. There is also another aspect where error with adverse event can be interpreted as a positive outcome. When a severe negative consequence takes place, people are compelled to investigate the whole system in finding where it had gone wrong. Analyzing the hindsight of an accident they obtain knowledge about the underlying factors of the incident. It helps the authority in improving or changing the system component using significant experience of the past incidents. Thus they can prevent the re-occurrence of that same incident in future.

On the other hand it may be said that, more severe negative consequences makes more people involved in learning (Zakay and Shevalski, 2004). More severe consequence imposes perturbation to more people and motivates them in learning to avoid the unwanted incident in future. From this anxiety and guilt of their past experience they engage themselves in improving system with all of their efforts. Ethical issues haunt them. So it may be said that severity of error consequences relates positively to the generation of new ideas and insights and the implementation of improvements.

Errors compel employee to communicate

Lack of communication is an important factor of accident. It is very relevant in any system. There are many people involved in a system. Learning from error will be possible if operators share their past experiences of error with others (Edmond, 1996 and Rochlin, 1999). Edmond (1996) emphasizes on creating environment where it is possible to encourage open reporting, active questioning and frequent sharing of insights supports for learning from error. Some researchers of applied psychology argue that communication in the context of error is essential for the promotion of

learning and innovation (Dyck, C.V., Frese, M., Baer, M., Sonnentag, S., 2005). [161]. It leads to sharing knowledge about error. Rochlin (1999) stresses the importance of communication when dealing with human error. He argues that dynamic and communication act facilitates organizational learning effectively. Communication about error gives employees the opportunity to generate new ideas and passing it to others.

On the other side the silence of the employees' about their error can lead a system or organization toward a more complex situation; it may result in much severe negative consequence. If operators share their experiences of error then at least there is a chance to avoid it; they can take precaution to manage negative consequences. So, proper communication among employees of an organization is very important for any success and system advancement. In contrary lack of communication is a major factor of error or unpleasant result.

It is very common phenomenon that employees hesitate to share their error with their colleagues. The probable causes of it may be:

- People are uncertain about the reaction of their colleagues and authority regarding feed back of their erroneous action.
- They are scared that their errors could damage their career.
- They try to cover up their error by any means before it becomes exposed to others.
- They try to avoid potential blame for his/her error. (Cannon and Edmondson, Husted and Michailova, 2002).

But it is also true that when human error results into major negative outcome then employees are forced to overcome their hesitation. There are two causes responsible for that:

Firstly: severity makes operator feel guilty and responsible for the incident. Such as severe outcome forces people to communicate with others and they engage themselves for system advancement.

[161] Dyck, C. V., Fres, M., Baer, M., Sonnentag, S. (2005). Organizational Error Management Culture and Its Impact on Performance: A Two-Study Replication, *Journal of Applied Psychology* , 90 (6) 1228 –1240

Secondly: when a major accident takes place usually more than one person is liable for that. It makes them easy to face the reality. Basically in such condition the visibility and impact of negative consequence of error makes it necessary for the employee to communicate, because there is no other opportunity for covering up.

In this context it is highlighted that people have a basic desire to believe that they have control over unsuccessful action. This illusory belief may set obstacle for learning. When people cannot asses their limitation of controlling power over the situation they overlook the causes of error. This type of fake confidence of the operators may lead them to ignore legitimate risk .as a result they fail to take measures in avoiding accident[162]. So it may be said that errors with serious consequence make people understood that they are not able to prevent all of their error; if they try to prevent them individually it may cause such negative consequences again with more adversity. So they should improve communication with others.

On the other hand a small failure generally does not lead people to communicate because people do not feel necessity to learn from it but catastrophic failure demands the necessity of learning due to its negative impact (Edmondson, 1996).

Error helps people in their self assessment

Generally any action under a system is preplanned and so it is done mechanically. Most people use to do such work as part of their routine work. They are not interested in brain work. But often doing such mechanical work people faces complication because there is no chance of self assessment. Error motivates employees in their self assessment which is quite useful for improvement of a system.

As an example when people perceive flaws in their actions, they try to identify the underlying causes of it (Weiner, 1985). And these error experiences guide them in future. In other words if people do a job without committing any error they become overconfident about their ability and they become unwilling to improve the system. 'Positive illusions (of)…control and efficacy may be incompatible with an honest

[162] Taylor, S. E., Brown, J. D. (1988). Illusion and Well-Being: A Social Psychological Perspective on Mental Health *Psychological Bulletin* , 103(2), 193-210 (204).

acknowledgement of failure, and thus, while promoting happiness, can inhibit learning.'[163]

So here identification of errors and acceptance of the errors both are important for system advancement. If people have illusion that the system is perfect it may result in a severe accident at any time because no system is so perfect that it is out of improvement. Modern technology is developing day by day so it is necessary for a system that it would be updated regularly. On the other hand human are very complex being; there are various physical and psychological factors for a person to perform a work properly. For that continuous attention and focused activity is very necessary.

Error may be a warning of an adverse outcome

In the context of utility of error we may take error as a warning of a serious adverse event. We saw that error is not an accident. There are always specific causes behind error. It means when an error takes place it indicates something is going wrong. Then if we can identify the causes of the error in its preliminary stage we may try to correct them. Even if it is shown that error is not recoverable then also error gives a chance to take pre-caution for future.

With an example of medical sector we may say that: as in medical sector if symptoms of disease are identified in the preliminary stage then with proper treatment we may avoid the severity of the disease but if we ignore the preliminary complication that may lead to a serious condition. Similarly if a machine gives simple trouble we should take it as a warning and if we find out the causes of trouble it may help us to avoid bigger trouble. Exactly in same way if somebody commits an error it should be taken as a sign of inconsistency of him/her physical or mental status. In this context following to Van Dyck (2005) we may cite that error consequences as small losses may be interpreted as warning of severe adverse events and such error can take part as a strong factor to the employee's better attention to the action. The evaluation of past behaviors and acting upon the awareness that errors hold useful information are indeed considered as important practices to learn from error.

[163] Mark, D., Cannon and Amy, C., Edmondson. (2005). Failing to Learn and Learning to Fail (Intelligently): How Great Organizations Put Failure to Work to Innovate and Improve Mark D. Cannon and Amy C. Edmondson. *Long Range Plan*, 38(3), p. 302.

6.2.2 Usefulness of Error in Training Session

Errors committed by the trainee during their training may provide lots of positive effects to their experience. Errors give opportunity to the trainee to practice further (Ferse, 1987). According to Reason, a group who are allowed to commit error in training period will be better performers for a future system than the group who did not get opportunity to make errors. (Reason,1990). Errors in training period provide following kind of useful functions:

Error is the criterion of one's acquired knowledge

At the level of abstract thinking, errors can help the trainee discriminate between those meta-cognition which works from those that they have not done yet. Reason gives an example on this aspect. Explaining this aspect he said, "If a novice thinks of a word processing system as a type writer model become apparent when he finds he cannot write a blank space in the insert mode."[164] That means the novice can understand mismatch in between expectation and interpretation of reality. So error may be the criterion of one's acquired knowledge.

Errors encourage trainee in new invention

When an error is committed by the operator it encourages him to engage in inventing another innovative way to do the same action more smoothly. Then he/ she may change his/ her plan or execute the plan more attentively. In training period error motivates the trainee to provide creative solution to the problem; it often leads him to explore new strategy. Following the example of a typewriter, Reason explains that when the type writer can discriminate the expectation mode and real mode of the type machine he may be inspired to find out the useful mode for the situation spontaneously.

Errors in training lead to the conscious reappraisal of action patterns

According to Reason (1990) an action pattern is normally controlled by low level processors. It becomes automatable with time and behavior. In the training period trainee exercises an action pattern slowly and so there is a chance of reappraisal of the action pattern before being converted in automatic mode. So learn to identify the

[164] Reason, J. (1990). *Human error.* New York, Cambridge university press, p.244

error. They also learn to predict whether an action leads to an unwanted adverse event or not.

6.2.3 Usefulness of Error in Learning

In the fourth chapter "Error Handling in Pedagogical Reasoning" we observed that errors have an important role in learning. Many educational theories refer error as a learning method. Though here we are not highlighting error in the context of traditional learning theory we are going to discuss the efficacy of error in learning. Some specific way to justify that error can be used in positive way in learning are as follows:

Error considered as a method of learning

In any sense when we say that error can be useful in our everyday life that will be true only when we learn from our errors. Usually we often overlook small deviation from the expected outcome. According to some these deviations have mere significance in learning process (Edmondson, 2005). But according to the modern learning theory, error makers have better understanding of the circumstances if they identify the causes of their errors and naturally they can use this knowledge in future. Arnold and Roe assumes that, "errors may have great functionality for the user, especially during learning." [165]

In different social contexts and situations people handle error or react to its occurrence error differently. So, it is very important to know in what social context specific type of error takes place. It helps people to learn from error. If a person has chance to rectify his error it may help him to gather experience; but if he does not get any chance to revise his work his error will be only a human factor of adverse outcome. In a *Journal of* Applied *Behavioral* Science explain the relation of error and learning as "a cyclical process involving the evaluation of past behavior, the discovery of error or opportunity, the invention of new behaviors, and their implementation."[166]

[165] Arnold, B. and Roe, E. (1987). User errors in human-computer interaction. In: M. Frese, E. Ulich and W. Dzida (eds.) *Human Computer Interaction in the Work Place*. Elsevier, p.205

[166] Lipshitz, R., Popper, M., Friedman, V. J. (2002). A multifacet model of organizational learning. *The Journal of Applied Behavioral* Science, 38(1), 81–82)

A memory of errors and prediction error may be fruitful in learning

The current view of sensory motor learning suggests that a memory of errors may become helpful in learning. Sensory motor learning refers to improvement, through practice, in the performance of sensory-guided motor behavior. According to this theory when we revisit a task, the brain recalls the previously learned motor commands. According to this view memory of motor commands is acquired through trial-and-error process. The important factor is reinforcement it refers how much the brain is willing to learn from the current error. It depends on the history of their previous occurrences of error. This suggests that the brain stores a memory of errors and provides insights into problem solution.

Explaining this concept it may be said that, according to standard model of motor learning theory trial to overcome the error imposes an anxiety on an agent that is called sensory consequence. Sensory consequence pushes the learner to update his or her belief about the environment. Based on their belief about the environment, the learner predicts the probable error on the basis of it he improves his/her performance. Thus memory error and prediction error may be helpful in learning. In addition, considering an environment perturbation continues trial to trial process; the brain should learn from error better because the perturbations are likely to keep learning continue from error. And each trial performance will be better than the previous one. So it may be said that, when we are better at a motor task, it is partly because the brain recognizes the errors as experienced before.[167]

Error can motivate learner because it gives them another opportunity to do better

Error always seems unpleasant to us, it makes us depressed. On the other hand when we succeed it makes us happy. Naturally we always try to avoid sorrow and desire for happiness. And though as we know achieving desired object we can be happy and keep away sorrow then automatically we try with more enthusiasm to perform an action perfectly. Thus, indirectly the past experience of errors motivates us with a positive attitude to do well.

[167] CONEUR-954; page no. 9 Human sensorimotor learning: adaptation, skill, and beyond. (2011). Source :www.sciencedirect.comp. (Retrieved on 12.11.2015)

As an example, in an examination hall we commit error; this may happen due to our lack of skill, lack of knowledge, lack of meaningful learning or because of any other external event; but every time there are some cognitive factors behind our errors. Apparently those errors result in low score in the report card; but it also identifies our flaws and we may overcome these making practice. Thus we may improve our future result in learning from the past experience of error.

In this chapter we have discussed error from different points of view. Mainly we have highlighted utility of error from two perspectives: as a factor of system advancement and as a process of learning. In a system error have much effective role. Error can help operators to obtain practical knowledge and sharing their experience of error. They can take precautions handling adverse events due to error. Analyzing learners' error, we have observed that learners' status of understanding and misunderstanding is only represented in their error. We have pointed usefulness of error for the trainee distinctively because it is relevant with both learning method and system procedure. In context of training scientists, laboratory researchers, apprentices all can use errors more positively. In experiment error is the only method; so errors have very important role for laboratory researcher. Thus error is not only a negative fact it is a natural incident and for that we say humans are error prone. Finding underlying factors, we can classify errors and recover them before it result in negative outcome for mankind. Thus it can be said that error would depend on our attitude towards error.

Chapter 7

CONCLUSION

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'Philosophy means the study of wisdom, and by wisdom we understand not only prudence in affairs but also a perfect knowledge of all things which man can know both for the conduct of his life and for the conservation of his health and the invention of all the arts."[168] Explaining this quotation of Descartes Coplestone says under the general heading of philosophy, Descartes included not only metaphysics but also physics or natural philosophy, other sciences, principals related to medicine, mechanics and morals etc. So it is very clear that Descartes insisted on the practical value of philosophy. Our study about human error is an effort to explain error in the background of the practical life. Research on error is not a new endeavor. In philosophy error is much discussed. Philosophers consider error mainly from two points of view: epistemological and metaphysical.

Descartes explains error from epistemological stand point. According to him the source of human error is sense perception. Inferences based on our five sense organs are misleading. We experience illusion of various types, thus inferences drawn upon the sense organs are not certain. Mathematics like certainty can never be obtained from the inferences based on sense experience.

In Indian philosophy error has been considered from both epistemological and metaphysical standpoint. In connection with *pratyaksa pramāna* the theory of erroneous perception is advocated by different schools of Indian philosophy. These discussions also explain the existence/reality of the object of erroneous perception. Theories of erroneous perception are called *khyātivāda*. In Indian philosophy '*khyāti*' means 'apprehention'. There are five different theories of *khyātivāda*. These are *Asatkhyātivāda, Atmakhāytivāda, Akhyātivada, Anyathkāhyātivāda, Satkhyātivāda* and *Anirvachaniyakhāytivāda.* We are going to discuss these theories in brief below:

[168] Descartes. cited by Frederick Copleston, S. J. (1994). In *A History of Philosophy* , vol-iv (Image edition) New York, The Newman Press and Burns & Oates, Ltd. p.67

The theory of *Asatkhyāti* is advanced by the *Mādhyamikas* or *Sunyavādins*. According to them error is erroneous cognition. And what is cognized in erroneous cognition is absolutely non-existent or unreal. Justifying this theory it is said that if the silver perceived in nacre were real, it could not be *sublated* afterwards on correct perception. Moreover as silver seen in erroneous perception is not seen in correct perception, it is clear that the silver of erroneous perception does not really exist. Due to the power of ignorance, cognition manifests a non-existent silver. The impression of the previous perception of silver is responsible for the perception of an appearance of silver in erroneous judgment. Thus according to this theory, *sunya* or the non-existent is the object of erroneous cognition.

Atmakhyātivāda is accepted by the *Vijnānavādins*, the *Vaibhāsikas* and the *Sautrnātikas*. According to this theory of error, the mental is mistaken for the material. They hold the silver perceived in nacre is not silver really existing somewhere outside. This silver is real as an object of internal cognition, but unreal as an object of external perception. It has subjective existence and objective non-existence. This silver is an object of the mind and not of the senses. It is ideal and not real, psychological and not physical; and error is the projecting outward, as a material object, of the internal mental concept which is non-material.

Anyathākhyātivāda is the view of the *Nyāya, Vaiseshika* and Kumarila Bhatta's school of *Purva-Mimāmsā.* This theory holds that error consists in the apprehension of a thing as what it is not. In an erroneous cognition, the attributes of one thing are super imposed on a different thing; and so the object appears as something other than what it is. Where nacre is perceived as silver, in this erroneous perception, ‘silverness’ is not perceived as it is. It is not the character of nacre; but the 'this-ness' of nacre with a character of glittering that is perceived in erroneous perception. A memory of silver arises in the mind of the perceiver when the character of glittering which is attributed to silver is perceived. Now, what is perceived erroneously is neither nacre fully, nor silver really; but the 'this-ness' of nacre with the quality of 'silverness' attributed to the fact of glittering. So, what is perceived is not merely a memory of silver, but the silver existing somewhere else brought into relation with the perceiving eye by the memory arisen in the mind. Thus according to this view the substratum and the percept of erroneous cognition are independently real.

Akhyātivāda is the theory of the *Sānkhya*, *Yoga* and the Prabhakara's school of *Purva-Mimāmsā*. According to this theory, in error there is non-distinction between a memory-image and a perception. The theory of *Akhyāti* holds that the inability to discriminate (*Aviveka*) between cognitions of different kinds and between their corresponding objects is error. Error is not the perception of something existent, but the non-perception of difference between different cognitions of different characteristics and contents. The two cognitions are real independently, without reference to each other. In the perception of silver in nacre, the perception of 'this-ness' is true perception, but the vision of the silver is only a memory of what was previously perceived. The object of perception and the object of memory are different from one another. But this difference is not perceived in erroneous perception. It may take place due to some defect in sense-perception.

The theory of *Satkhyāti* is held by Ramanuja and his followers. According to this theory, there is no error in fact. According to *Satkhyātivāda*, all objects exist independent of the knowledge which others have of them. The nonexistent cannot be perceived. Truth is the correspondence between knowledge and an object which has independent existence. The erroneous cognition of silver in nacre is not really the cognition of something unreal as such, for it refers to something which exists. According to them erroneous judgment may be due to defective sense-organs.

The *Anirvachaniyakhyātivāda* is the theory of the *Advaitin*. It is the logical conclusion arrived at through a criticism of the various other views on error. The silver seen in nacre is neither real, nor a memory, nor existent somewhere else, nor an internal idea, nor absolutely non-existent like a human horn. This silver is not different from the real alone, not different from the unreal alone, and not different from both the real and the unreal alone. One cannot definitely describe the nature of the silver perceived in nacre.

Thus preliminarily the discussions of error theory in Indian philosophy highlight error from both the epistemological and metaphysical standpoints. It also reveals the psychological background of erroneous perception.

Causes of error based on some perception of which we have made taxonomy, have occupied a substantial position in this dissertation. When we perceive, reason, speak or write the source of human error are our senses in content of perception. Ernst

March (1905) says "Knowledge and error flow from the same mental sources, only success can tell one from the other."[169] Thus sources of error lie in processing the information i.e., senses in the context of perception and absence of 'natural light' in reasoning.

Error is indistinguishable from the body of knowledge or from the process before it is identified. Thus though existent, error has no status before being identified. As an entity error is latent in knowledge. Only a subsequent knowledge helps us to identify the error. Error can be inferred from the effect (especially when there is devastation).

Arriving at error from both first person and third person point of view is different. From the first person view point when the expected result is not arrived at we look back into this steps and try to locate the wrong step. The process is reflexive. Sense of guilt, shame etc are associated with error. From the third person point of view error committed by someone else is identified much earlier than the person who commits error. Taunting, criticizing, blaming etc are associated with third person error.

Time and again error has significantly contributed to scientific inventions. Since it has been said that failure is the pillar of success, each failure in scientific experiment has been routed through some error and rectification of error led to success.

Error has an important efficacy in practical life. Successful action mostly depends on the ability of the agent to make the right decision in a complex world situation. Insensible decision may cause unintended goal of an action. When an action is ruined for lack of right decision of operators it may be called decision error. In this context discussion of the concept of 'rationality' or reasoning is very relevant. According to Nick and Mike (2004), most of the time we are remarkably rational. In daily life our reasoning breaks down and we fail to take proper decision. "But our failures of reasoning are only salient because they occur against the background of rational thought and behavior that is achieved with such little apparent effort that we are inclined to take it for granted."[170]

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[169] March, E. (1905). Cited by Reason, J. (1990). In *Human Error*, New York, Cambridge University Press, p.1

[170] Nick, C. and Mike, O. (2004). Rationality and Rational Analysis. In Manktelow, k. l. and Chung, Man Cheung (eds.) *Psychology of Reasoning : Theoretical and Historical Perspective*. Psychology Press Hove, New York, p.44

According to them there are two types of rationality: formal rationality and everyday rationality. Taking right decision in a complex real situation is called everyday rationality. Everyday rationality concerns people's ability to think and act in the real world. On the other hand formal rationality concerns formal principals of good reasoning. Good reasoning followed by the mathematical laws, logic, probabilistic theory etc. Depending on these two types of rationality there are two different viewpoints. The primacy of everyday rationality says that everyday rationality is fundamental in taking any decision. And when people explicitly use formal rationality their behavior becomes poor. (Goodman, 1954 and Cohen, 1981). In their words "Formal rationality is acceptable only in so far as it accords with everyday reasoning"[171]. So, according to this theory when one makes decision on the basis of the background of the problem situation then it may lead to success. On the other hand who stand for the primacy of formal reasoning starts from a different point of view. Thus they consider everyday reasoning is fallible, and it may be corrected by following the directions of formal theories of rationality.

Numbers of theorists acknowledge that formal rationality and everyday rationality are entirely separate enterprise. They give two different notions of rationality. In the sense of 'everyday rationality' 'rationality' means thinking, speaking, reasoning, making decision or acting in a way that is generally reliable and efficient for achieving one's goal. On the other hand 'rationality' in 'formal rationality' means thinking, speaking, reasoning, making decision or acting when one has a reason for what one does sanctioned by a normative theory.

In practical field error is considered as individual action. In this sense error is explained from two perspectives: end of an action and means of an action. This theory holds that every action has two main components, goal or end and the means, by which the desired goal is trying to be achieved. The end and its mean both are subject of agent's intention. If we refer to error as an action with unintended outcome then we may explain error from both of these stands points (end and mean). If the action does not provide intended goal it will be considered as error. On the other hand if the action is not executed following intended means that will also be included in error. Explaining means it is said that means of an action is comprised of two elements: plan

[171] Ibid, p. 48

of the action and execution of the action. So if the plan of an action is improper to provide intended result that is included in error same as if execution is not following from intended plan that will also be included in error. Plan failure is called mistake and execution failures are called slips/lapse (Reason, 1990).

Beside these theories, error has some folk uses in our everyday life. 'Everybody commits error' it is accepted by all and sundry but attention-grabbing point is that nobody admits that 'This error is carried out by me' though the second sentence is necessarily implied by the first. We often exclaim to ourselves "I did this error!" That means although we know that everybody commits error but we think that error highlights only our inability. Influenced by this complex we are always conscious to hide our errors rather than taking measures to reduce these. During our research we observed in different domains that nobody is ready to share their experience about error with others. It indicates that people cannot confess their own weakness to other. Due to this attitude it is almost impossible to analyze individual error whose result is not observable. In this situation the only way of finding human error is the analysis of observable outcomes of different actions. Sidney Dekker called it 'hindsight'. According to him "Hindsight means being able to look back, from the outside, on a sequence of events that led to an outcome you already know about."[172] According to him hindsight gives us almost unlimited access to the true nature of the situation that surrounded people at the time when an incident takes place. If people who were the part of the incident share their experience, it gives us information about where they actually were versus where they thought they were; they state the information about the actual background of the system versus what they thought it was in. Hindsight allows us to pinpoint what people missed and shouldn't have missed; what they didn't do but should have done. But hindsight also biases our investigation. Investigating hindsight we infer the past but we can never know the actual situation. As a result, we may assess people's decisions and actions mainly in the light of their failure as a critical piece of data. We have followed some established theories of error and literatures of different disciplines. Thus we have got a general concept of error.

As we have repeatedly cited that human error is engraved in every segment of our life same as many discipline highlight error from different points of view. Study of human

[172] Dekker, S. (2001). *The Field Guide to Human Error Investigation.* U.K, Ashgate, p.17

error is most popular in ergonomics. Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system. It finds the human error behind a system disaster. Safety culture is used to describe the corporate atmosphere or culture in which safety is accepted as the number one priority. In safety culture all levels of an organization shares perceptions and experiences about safety and provides confidence to prevent unsafe incidences. Safety culture identifies individual error or organizational features that affect the health and safety. In psychology human error has great significance. Different psychological factors behind human error can be studied in psychology. It discusses the influences of error to human behavior. Educational science also discusses error. Educationists explain the efficacy of learners' error in effective teaching. Researchers of some practical fields are also engaged in investigating human error. Aviation, marine, mining and medical field also highlight human error. These accident-prone fields are affected by human error directly. Most adverse events in these fields are the resultant of human error.

In the first chapter of our dissertation we discussed about the meaning of 'error'. We pointed the literal meaning of error following different relevant literatures. According to the literal meaning error means the state or condition obeying wrong in conduct or judgment. 'Mistake', 'fault', 'blunder', 'slip', 'failure' all are synonyms of the word 'error'. The term 'error' is also used in different senses. Four among these are: error used as a cause of an unintended action; error used as an unintended action itself; error used as a process or system procedure that leads to an unintended result; and error also used as an unintended consequence or result of an action.

In the second chapter we have analyzed some views on human error from different disciplines. We have analyzed the view of error following Descates (1956), Sigmund Freud (1890), Maister (1966), Swain and Guttman (1983), Hofstadter, Douglas, R. and David, M. (1989), Reason (1990), Hollnagel (1993), Whittingham (2004), and a research group of International Civil Aviation Organization (2012). Analyzing all these views on human error we may say that human errors take place as an action which always results in an unintended outcome. And it implies that there is a prior intention of the agent and the actual outcome does not match with his/her intention. So in very simple words it may be said that *error is an intentional action with unintended outcome*.

Human errors are of various in types. In the third chapter of the dissertation we categorized human error mainly from two aspects: according to their origins and according to their observable outcomes. We have drawn a genotype classification of error following the underlying factors of it and we categorized errors according to the outcomes under the phenotype classification. We have further classified genotype human error according to the plan and execution of the action error. We have included plan failure as intentional error and execution failure as unintentional error. Following James Reason (1990) we have farther analyzed error according to the nature of their origins. Error whose underlying factors are mainly cognitive we categorized them under cognitive error; error which is the resultant of the interference of some external factors we called them interference error; and errors which arbitrarily take place we called them idiosyncratic error.

We are most concerned about human error when it refers to a cause of an adverse event. In this context we discussed error in four accident-prone sectors: medical, aviation, marine, and mining. While studying medical sector we observed that it is very critical, sensitive and stressful domain. Every human being needs to interact with the medical domain. Professional health care authorities most of the time struggle with a huge work-load to the extent that in some govt. hospitals in India two hundred to four hundred patients are assigned to a single doctor in a day. More over human body is so complicated that doctors have limited ability to cure a patient. But side by side patients are depressed and their close relatives are also very worried. Thus the physician works in a very stressful ambiance. For all these reasons human errors randomly take place in medical domain. And most sorrowful fact is that in this sector adversity of human induced accident is very high. We have analyzed different medical error as per general medical procedure in our study. We observed that patient comes to the primary unit of a health institute with some complications. In this primary unit there may be some physicians, some junior doctors or may be other attendants to attend the patients. They take case history of the patient and direct him to the relevant department for treatment. If the physician does not need any farther investigation for diagnosis the root of the patient's complication, then he may prescribe medicine to the patient. If there is need of any investigation then the physician suggests investigation for the patient. And after that he prescribes medicine. Some examples of medical error, of this type are: prescribing error or laboratory error.

After that the patient's personal attendant or nurse takes medicine from the pharmacy and administers these to the patient. Medical errors in this stage are called drug administrative errors. If the complication is recoverable by surgery then physician suggests surgical treatment. Any wrong action during surgical procedure will be called surgical error. And errors related to anesthesia process called anesthesia error. Thus we classified medical error into six types: prescribing error, dispensing error, medication administration error, diagnosis error, surgical error, and anesthesia error.

Finding what types of human error are committed in aviation sector we have selected some incidents from the accidents list which took place in India. In that context we explained basic flight procedure before flight, during flight and after landing. We have analyzed four different types of air accidents: mid-air collisions, forced landings, air-crash in mountainous terrain, and crash due to technical snags. In explaining aviation error we followed the accident reports given on accounts of the individual incident. We observed that most of these reports pointed at the operator of the sharp end as a liable person for the accident. We have highlighted human errors which were responsible for these incidents. Following the underlying factors of those operators' errors it may be said there are some other factors which contributes to the accident directly we called them active error. There are also some contributory factors responsible for an aviation error we pointed them as latent error. Following all these factors of aviation accidents we mentioned some underlying factors of this error and simultaneously we proposed some remedy to reduce human error in the said field.

In this chapter we also went through the errors in the field of maritime. We analyzed different maritime accidents. We saw that there are mainly four types of marine accidents. They are: collision, capsizing, explosion, and grounding. We found out human error behind these accidents. But due to lack of proper accident investigation reports we could not analyze further underlying factors behind the human errors responsible for each accident distinctly. We have provided a list of typical and common human error responsible for marine accident. We also mentioned some remedy to handle them.

Occurrence rate of accidents in the field of coal mining is very high. And most of these accidents are related to human error. We analyzed different mining accidents and tried to find out human errors behind them. We have provided a brief description

of mining procedure because without professionals common people have naive idea about mining. We went through mining accident or mining error in the Indian subcontinent. But in our country mining accident reports are confidential so, we could proceed following only the annual reports of Indian mining. On the basis of these reports we described six types of mining accidents: roof/side fall mining, accident with mining vehicle, and mining accident with mining machine, accident for dust/gas and, fire, and inundation. Discussing these accidents we had put forward some precautions as measure of reducing mining error.

We discussed learning errors in the fifth chapter. We explained what types of error take place in different learning process. We took example from laboratory experiment, mathematics learning and language learning. We explained those errors as human induced experimental errors which are committed by the experimenters conducting experiment. In the laboratory no measurement is exact also measurement varies from laboratory to laboratory which always affects the results of experiments. These measurement errors are also one type of experimental error but they are not human error. Human errors in scientific experiment are not different from mistake, blunder, or screw-up.

In the context of learning error we discussed error in learning mathematics. We observed that mainly two types of mathematics error are performed there: conceptual error and lapse. Where learners do not have proper conception about the problem, they do not understand what they have to do then it is called conceptual error. It may happen due to lack of understanding of basic mathematical concepts. It is also called bugs. On the other hand when learner commits error due to inattention it is called slip. Other cognitive factors may be responsible for it. It is noticeable that both types of learner's error may influence each other.

In this chapter we discussed error in learning language. We highlighted mainly errors which take place in learning English as second language. We observed that there are two main types of error: composing error and encoding error. Errors which are committed by the learners during composing a text it is called composing errors. On the other hand encoding error is one type of slip in writings or speaking. Where the learner encodes grammar wrongly it is called encoding errors. Learners may commit these errors due to their lack of knowledge or lack of skill.

Analyzing learners' error we may say that errors are the executer of the learners learning status. So a teacher should have proper knowledge of the learners understanding. Not only that, he should have knowledge of general learning system, about the curriculum and also about the subject content. If he does not have proper content knowledge or he has lack of observing power then he would not identify the learners' errors. Without skill of effective teaching the teacher is not able to provide his knowledge to the students. In this context for meaningful learning of the students he should follow the curriculum and ambiance of the learning environment. If teacher is able to use this knowledge in the classroom his teaching will be effective. And only with effective teaching he may handle learners' error. We described pedagogical reasoning as an effective knowledge based on teaching method. Following Shulman (1987) we explained how teacher knowledge develops as pedagogical reasoning. We explained the basic steps of development of pedagogical reasoning. There are four steps following which teacher can handle learner errors by pedagogical reasoning. These are: transformation, evaluation, reflection and new comprehension. *Transformation* is the way of transforming comprehended idea of teachers to the students. In this stage teachers think how to motivate their learners and transfer them the subject matter so that they understand through act of teaching. In the *evaluation* process teacher evaluates students understanding and misunderstandings. The *reflection* process is a review process of teaching. In this stage teacher compares the learners' comprehension with the ends of the teaching. *New comprehension* represents what the teacher has learnt from all the previous processes. New comprehension helps the teacher in handing students error in future.

While analyzing human error we saw that many errors are avoidable if we can predict them from our past experience and take precaution to prevent them. If we would heartily try, we must be able to reduce the percentage of erroneous actions. At least we can recover our action during its processing stage before it results in any adverse event. This requires a positive attitude. It will be possible, only when our society accept us as an error prone human being rather than a perfect super human. We all commit error; sometimes it may be caused due to our carelessness; but if we become aware of these errors and be careful enough to perform an action then we could reduce the frequency of our errors. Many times error gives us opportunity to do better in the future. Thus in the end of this dissertation we highlight positive aspects of error.

In this dissertation we saw that human error has an expanded context. There are various issues related to error which can be the subject of further research. We can investigate whether error is the object of moral judgment or not. Which is other word, 'Do we judge error as good or bad'? We have considered this topic in brief in explaining the myths about human error. We clarified that error attributes in an action but moral judgment evaluates the intention. And the meaning of intention is also different in theory of error than ethics. Thus though explaining nature of error moral issue is not very relevant but error as a cause of adverse event may be explored more from the ethical stand point. There are some more issues that may be discussed in the future. To mention some as: how error can be reduced or which attitudes of ours are reasonable towards error. Before exploring any of these areas we should understand the basic concept of error. This dissertation is just an attempt to provide a basic understanding of error. We discussed many views on error any finally we may say about error in simple words as:

i) Error is a voluntary action with unintended outcome.

ii) Errors have different types of cognitive factors.

iii) Grossly it can be said that error mainly takes place in following conditions:

- When we do not know the actual problem situation
- When we disobey /violate the authorized rule
- When we take attempt to do a professional work without proper skill

iv) In the practical fields error is a important factor behind adverse event but it is not necessary that error always results in accidents. It is also possible that there may be multiple errors behind one accident. Error induced adverse event take place mainly in the following conditions:

- When we are unaware about our error
- When we do not admit our error
- When we fail to identify the underlying factors behind errors
- When we go through with the common peoples' view on error without justifying these.

v) Most of the time error can be avoided and rectified if we interact to it with proper reason. Not only that we can often use error with a positive attitude. There are some conditions following which we can use error as a factor for further success:

- If we accept error as a way of gathering experiences
- If we accept error as a small loss to rectify the future action
- If we take error as highly informative for the future system planning
- If we consider errors as the basis of our self assessment
- If we take error as a motivation to invent preferable new method for success

In this dissertation our goal was to break the myth of human error and wipe out some illogical negative aspect of it. We have highlighted how to reduce human error by taking into consideration cognitive factors in avoiding adverse events. Though, we did not deal with this aspect in detail which is beyond the scope of our dissertation. Finally we conclude that if we take lesson from error and motivate people in sharing their erroneous experience with other, we would be helping each other towards reducing error.

It thus can be concluded by saying that proper attitude towards error would lead to success at ease. Emotional discomfort and negativity can be overcome through attitude. For example, if in schools errors are not associated to punishment, errors are viewed as stepping stone to learning, it would then be easy to comfort and teach the children. This will also allow the teacher to restrain from engaging in humiliating punishment to make the student learn. In place of blaming for committing error it is more important to explore how the error can be rectified. Anxiety and stress would be much reduced if the attitude towards punishment changes. A correlation study may be considered between error and punishment in learning. In future research an empirical study to this effect can be conducted.

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ABBREVIATION

AMT	-	Aviation Maintenance Technicians
ATC	-	Air Traffic Controller
ATCO	-	Air Traffic Control Officer
CCIC	-	Cabin crew in-charge
CFR	-	Code of Federal Regulations
CVR	-	Cockpit Voice Recorder
DME	-	Distance Measuring Equipment
EGPWS	-	Enhanced Ground Proximity Warning System
FL	-	Flight Level
FDR	-	Flight Data Recorder
GPWS	-	Ground Proximity Warning System
ILS	-	Instrument Landing System
NTSB	-	National Transportation Safety Board
OOW	-	Officer of the Watch
PCK	-	Pedagogical content knowledge
MSSR	-	Mangalore Area Control Radar
SIMTARS	-	Mines Testing and Research Station
RESA	-	Runway End Safety Area
RVR	-	Runway Visual Range
SVA	-	Saudi Arabian Airlines
SMC	-	Surface Movement Control
SOP	-	Standard Operating Procedure
VOR	-	Very High Frequency Omni Range
VHF	-	Very High Frequency

WOCL	-	Window of Circadian Low
AMT	-	Aviation Maintenance Technicians
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