DISCUSSION
Chapter 5

Discussion

A hallmark of human cognition is its flexibility. We are able to pursue multiple goals or tasks simultaneously, but can also prioritize these in accord with both our internal states and the continually changing nature of the external environment. Moreover, we are able to switch rapidly from one primary task to another, which can have a dramatic effect on the way in which we interact with the environment, even when that environment remains constant (Norman and Shallice, 1986; Miller and Cohen, 2001). This ability suggests that task-related information must be actively represented in a way that can bias perception and action.

In our today's fast paced and competitive life we have to face various types of problems and in the solution of many such problems, our cognitive system plays a very important role. In fact, it is cognitive system that enables an individual to make independent and/or accurate decisions by planning, abstract thinking, initiating appropriate actions and inhibiting inappropriate ones. Set-switching is one such cognitive operation that requires an individual to switch between response sets by inhibiting earlier used rules and by applying new rules (Barcelo & Knight, 2002).

The ability to flexibly shift between task sets shows the most protracted development and continues to improve into adolescence (Chevalier and Blaye, 2009; Best and Miller, 2010; Diamond, 2013). Although children of 3 to 4 years of age are able to successfully shift between two simple rules (Zelazo, 2004), performance continues to improve at later ages for more complex task sets and higher numbers of rules. Several studies have consistently shown that two components of task shifting – the ability to switch from one rule to another rule (i.e., switching per se) and the ability to sustain & select two (or more) rules – follow different developmental time courses (Crone et al., 2004, 2006; Kray et al., 2004, 2008, 2012; Huizinga and van der Molen, 2007; Karbach and Kray, 2007). For instance, Huizinga & Van der Molen (2007) reported children’s set switching abilities reached adult levels by the age of 11 years, whereas set
maintenance continued to improve by the age of 15 years. Some persons engaged in task may shift easily and other may face difficulty (more time and more errors which are referred as switch cost). So, considering the significance of phenomenon and with an orientation towards the outcomes of previous studies, current study was an extension in the way of understanding the phenomenon of set switching in a broad manner through investigating the various facets of set switching; its relation to cognitive facilitation/interference, temperamental measures of mobility and lability and to other tasks of executive processes measuring set switching via numerical and anagram tasks; and an examination of the effectiveness of some selected intervention strategies among individuals with high switch costs or difficulty in set switching.

The present study was designed to investigate the phenomenon of set switching (mainly rule switching) by engaging individuals in such tasks that followed rule based learning. The first objective, “to study various facets of set switching” was achieved by administering tasks involving set-switching, i.e. Wisconsin Card Sorting Test (WCST), numerical and anagram solution task. WCST is a standardized test which involves rule switching as well as perceptual switching. Other tasks of interest, i.e. numerical and anagram solution were formulated in such a way that they necessitated rule based learning and switching. Both these tasks were standardized in the pilot phase of the study. So, the primary focus of attention in achieving the first objective of the study was accomplished by involving verbal tasks measuring set switching (rule switching), i.e. numerical task and anagram task; and non-verbal task measuring set switching, i.e. WCST. These tasks were administered to a large sample during the second phase of the study. After response recording and scoring, data were converted to T-scaling and then analyzed via factor analysis. Principal Component (PC) analysis extracted three factors having Eigen value greater than unity (i.e. 1.00) and explaining a total of 74% variance. First factor was a pure measure of set switch vs. switch cost. Cluster of variables representative of switch cost involved number of trials administered, errors committed, perseverative responses and errors, non-perseverative errors and no. of trials taken by S to complete first category. On the other hand, cluster of variables representative of set switching included no. of correct responses, conceptual level responses and no. of categories completed. It revealed WCST performance as a dimension of conceptual learning –errors. Second component was also a switch cost vs. set switch measure.
with mix variables from different tasks i.e. verbal and nonverbal tasks. Perseverative errors on these tasks were representative of switch cost, while numbers of categories completed represented set switching. Third component was a measure of set failure with the number of correct responses and total no. of trials taken by subject. Thus, with an increase in the number of trials, the number of correct responses with failure to maintain set also increased. In a way, the tasks tapped set formation and set switching. Our findings were in line with the outcomes of Miyake et al. (2000) study, which reported shifting ability as a vital constituent of perseverative errors in the WCST. In an another study by Luria (1966); and Stuss and Benson (1986), it was accounted that people with frontal lobe impairments executed same tasks or responses again and again even when the response is inappropriate (perseverative errors), interpreted as switch cost. Different explanations had been provided for perseverative errors in WCST. Miyake et al. (2000) supported the view that perseverative errors on the task resulted from a failure by the participants to switch the sorting criterion in response to negative feedback supported by structural equation model. Dunbar and Sussman (1995) argue for a related account of the origins of perseverative errors. They used a dual-task paradigm in which WCST was paired with a range of tasks varying in working memory requirements and found more frequent perseverative errors when the secondary task involved the phonological loop (e.g., when participants were required to repeat a nonsense syllable) than when it did not (e.g., when it involved addition or tone detection). Dunbar and Sussman interpreted their results as indicating that perseverative errors arise from a failure to maintain information in the phonological loop. However, it is unclear what information must be maintained in the phonological loop to avoid such errors, but presumably it involves verbalization of the sorting criterion hypothesized by the participant. In fact, more recent work suggests that verbal mediation may facilitate task switching (e.g., Baddeley, Chincotta, & Adlam, 2001; Cragg & Nation, 2010).

The present study also revealed that performance on switch task, e.g. WCST, was executed in the form of switch cost through a number of trials administered, errors committed, perseverative responses and errors, non-perseverative errors and no. of trials taken by S to complete first category, whereas the no. of correct responses, conceptual level responses and no. of categories completed were measures of set switching/shifting. The findings of the present study further reported failure to set maintenance, no. of correct responses with trials, as another component of
set switching. These results were also in accordance with the findings of Cooper et al. (2012) who reported that the decrement in performance was evidenced not only by an increase in classical perseverative errors in the critical condition, but also by an increase both in non-perseverative errors and the no. of trials needed to attain the first rule, and by a decrease both in cards correctly sorted and categories achieved. They had further suggested that one must internalize the negative feedback, reject the current hypothesis (e.g., that the sorting criterion is colour), and generate an alternative hypothesis (e.g., that the sorting criterion could be shape) in order to avoid a subsequent error (and so negative feedback). Perseverative errors are likely to arise if one were to ignore negative feedback (through failure to monitor the incoming information). In contrast, if one were to reject the current hypothesis, but select an alternative at random, then both perseverative and nonperseverative errors are likely to arise. Bull et al. (1999) had found two latent variables in their study. One was a set of general measure of performance related to set failure, non-perseverative error, no. of correct responses and total trials taken by subject. Another variable was incorporated with measures of perseveration. So, overall findings of the present study are consistent with findings of previous studies.

It was further investigated to find out the generality of factors, identifying set switching across a variety of tasks. For achieving this purpose, verbal, i.e. numerical and anagram solution task; and non-verbal, i.e. WCST were administered to a large sample (N=296) in the second phase of the study. After administration of task, responses were scored and the data were accounted for factor analysis.

The results clearly revealed various measures of WCST, e.g. errors, trials, % non-perseverative error, % perseverative error, % perseverative response and trials to complete first category took positive loadings while percent conceptual level responses, number of categories completed and correct responses took negative loading on this factor. The cluster of variables having positive loadings was a switch cost measure where as the cluster of variables with negative loadings was a set switch measure. These results were also supported by the previous finding of Miyake et al. (2000), Cooper et al. (2012) and Bull et al. (1999). Another component that emerged was a general measure of switch cost and set-switch with an intermix of other variables, including perseverative errors of varied tasks, i.e. numerical, anagram and WCST at one pole, whereas number of categories completed of varied tasks, i.e. numerical, anagram and WCST, cognitive
facilitation and flexibility of attention at another pole. Bull et al. (1999) had reported that individuals with lower mathematical ability had more perseverative as well as non-perseverative errors and had more no. of trials to complete the first category. Bull and Scerif (2001) had found that % perseverative responses correlated negatively with mathematical capability. A number of studies (Blair, Knipe, & Gamson, 2008; Agostino, Johnson, & Pascual-Leone, 2010; Clark, Pritchard, & Woodward, 2010;) exhibited that shifting ability is essential for execution on multifaceted academic tasks that require shift between different facets of arithmetic operations. These findings (perseverative errors) can be described with reference to SAS model of attention control by Norman and Shallice's (see Shallice, 1982) and Baddeley's (1996) central executive. Individuals with low mathematical ability exhibited high perseveration errors indicate that they have difficulty in switching form practiced reaction to a categorization method to a novel categorization method.

SAS model has explained these findings in the way that poor performance of the central executive would result to difficulties in attempting to override such practiced responding. Ginsburg, (1997) and VanLehn, (1990) have stated a way named procedural bugs (often accounted in complex addition and subtraction problems) through which this can be examined. It takes place when an individual uses processes that are appropriate for some problems, but are inappropriate for other problems. Deficits in cognitive flexibility and failure to utilize evaluations of response to switch from one aspect to another, as revealed by more perseverative responses, may affect the performance on arithmetic task because the individual may be incapable of applying ongoing schemes/strategies of identified processes to novel circumstances and may hesitate to withdraw useful plans/approaches of previous learning but now they have become incompetent processes. Lemaire and Siegler (1995) have reported that performance in arithmetic can be improved by alteration in strategy use, which involve the attainment of fresh strategies and rejection of previous ones.

Factor analysis also revealed another component which was a temperamental measure of both mobility and lability. These findings are in accordance with the findings of Mangan (1967c) which revealed that mobile subjects seem able to change set more efficiently because of strong inhibitory control. Strelau (1977) found that high flexibility and fluency go together with behavioural mobility and the reverse. The emergence of this factor can be explained in the way
that individuals who are more mobile and labile, will take less time in switching from one set to another and hence make quick shifting. However, there is a scarcity of studies/evidence to our knowledge related to set switching processes and nervous system properties that will lead to build some obvious decision or conclusion. So, there is a requirement of further research towards this area.

In current study, it was also found that the task demands, i.e. whether the task is multifaceted or simple, modulated set switching (through % perseverative errors). Results revealed that tasks involving higher demand or complexity, such as WCST (participants have to complete six different categories by sorting the cards, according to the demanded rule, maintaining the rule and then switching to a new rule/category after a specified criteria has been achieved), also had more percentage of perseverative errors in comparison to tasks involving fewer complexity or demands, such as numerical and anagram task (participants have to complete only two categories). These results can be interpreted in terms of cognitive load theory (Sweller, 1988). Extrinsic cognitive load define these outcomes as the presence of more than two possible ways of sorting the cards in a category, a large amount of cognitive processing takes place which necessitates more cognitive resources in form of mental efforts for the solution. This load on mental resources ultimately hinders the performance. On the other hand, numerical and anagram task which had only two categories required fewer cognitive processing as well as mental efforts as compared to WCST. So, due to more cognitive load in WCST task more perseverative errors were committed by subjects in comparison to tasks with low demand, i.e. numerical and anagram solution task and even more in numerical than verbal anagram task. There is a lack of studies to our knowledge that have recognized similar or diverse outcomes so more research is required to this area for insight. An interesting finding was that the context perse too matters irrespective of their number of category based complexity or mental load.

The findings of the correlation analysis exhibited significant association among set switching measures, cognitive facilitation and temperamental dimensions of personality, i.e. mobility and lability. It was found that Ss who were high on cognitive interference (low cognitive facilitation), low on mobility and lability had high switch costs in the form of more perseverative responses and lesser numbers of categories completed by them. With relation to cognitive interference and perseverative errors, current findings are identical with Bull and Scerif (2001) and Schiebener et
al. (2014) study. Bull and Scerif (2001) reported interference was correlated with perseverative errors. A number of studies (Allport et al. (1994); Monsell, Yeung, & Azuma, 2000; Koch, Prinz, & Allport, 2005; Arbuthnott, 2008a; Yeung & Monsell, 2003a, 2003b) explained this interference in terms of proactive interference (i.e. performance on a preceding task interferes with performance on a nearby competing task) and higher switch costs on switching to a stronger and dominant task. Schiebener et al. (2014) study revealed that perseverative and non-perseverative errors exhibited significant correlation with interference scores. Similar findings were also observed in an Indian study by Sinha, Sagar and Mehta (2008), in which ADHD group had more perseverative errors and interference than the control group. With relation to cognitive interference, mathematical performance and perseverative errors, present findings are in correspondence with Rourke (1993), Bull & Scerif (2001) study. In a study by Rourke (1993), it was found that children who exhibited difficulty in solving arithmetic problems with a pattern of neuropsychological weakness have difficulty in shifting psychological sets. Bull and Scerif (2001) have reported that higher mathematical ability was related with lower interference and interference was positively correlated with perseverative errors on WCST. Relation among WCST variables, cognitive interference and temperamental traits of mobility and lability can be explained through Mangan’s (1967c) study which revealed that mobile subjects seem able to change set more efficiently because of strong inhibitory control. Strelau (1977) found that high flexibility and fluency go together with behavioral mobility and the reverse. The relationship between various variables can be understood in the manner that Ss who exhibited high scores on mobility and lability, will take less time in switching and make quick shifts from one set of information or task to another and thus, execute less perseverative responses, perseverative errors and completed more categories. However, there is a lack of findings to our knowledge related to the relationship between these different variables. So, there is a necessity of supplementary research towards this area of neglect.

Studies that have emphasized on the teaching of executive control processes examined different age groups and areas, such as, adolescents (Jaeggi et al., 2008; Karbach and Kray, 2009); older adults (Buschkuehl et al., 2008; Dahlin et al., 2008; Li et al., 2008; Zinke et al., 2012), and clinical populations, e.g. ADHD (Klingberg et al., 2005) or with low executive function abilities (Holmes et al., 2009) with a little evidence for training and transfer effects among adolescents.
This information is quite notable because these control processes are very important and required in adolescents' day to day activities and educational activities of school, e.g. reading or mathematic (van der Sluis et al., 2007). In addition to their pervasive significance, executive control functions are among the few processes that reveal growth routes well into adolescence [in relation to comparatively delayed growth of the prefrontal cortex (Bunge et al., 2002; Luna et al., 2010)]. Several latest findings have proposed a progressive growth of various executive control processes not only to adolescents but also to young adults (Rubia et al., 2006; Huizinga et al., 2006). Considering the outcomes of these studies, it seems clear that particularly this age group has large potential for plasticity through cognitive control training and motivated us to examine the effectiveness of intervention strategies in a group of Ss having high switch costs.

Regarding the effectiveness of intervention strategies, current findings indicate a near transfer of training to the tasks that were identical in structure and learning method (rule based) to the task that was used in the intervention/training phase. In contrast to a number of studies (Shaffer, 1965, 1966, Meiran, 1996; Hoffmann, Kiesel, & Sebald, 2003; Koch, 2001; Dreisbach, Haider, & Kluwe, 2002; Meiran, Chorev & Sapir, 2000; Sudevan & Taylor, 1987) that revealed robust switch costs also in task cueing conditions, the current study's findings are in corresponds to other studies that exhibited significant intervention or transfer effects to a similar task. In Tornay and Milán's (2001) study it was found that with an increase in response stimulus interval (RSI), reaction time (RT) was decreased and in unpredictable blocks of trials switch costs were eliminated when a long RSI (1200 ms) was provided. With correspond to Cole et al., (2010), Cole and Braver's (submitted) and Karbach and Kray's (2009) findings, current findings revealed that task switching training (explicit instructions) results to more reduction in switch costs not only on non-verbal task, i.e. WCST, as well as on verbal tasks of numerical and anagram; and transfer effects were observed to a structurally similar task but with different rule based learning.

These findings can be explained by the influence of decision support on decision making through Finucane & Lees's (2005) "the person task fit" framework. Supportive information on advantageous choices is frequently used to help decision making by those with reduced cognitive abilities. For example, persons with declined neurocognitive functioning, particularly of the central executive system, which depends on the integrity of the prefrontal cortex, are put in a
position to make decisions about medical treatments with different probabilities for complications. However, the possible interaction between the explicit advice and the individual executive resources in predicting the decision-making outcome has not yet been systematically investigated. Finucane & Lees's (2005) model has been investigated in many studies. Some types of support include direct advice (making recommendations for the choice) [Chu and Spires (2000), Yates, Veinott, and Patalano (2003), Chua, Yates, and Shah (2006), Jonas and Frey (2003)]. Explicit and helpful support can reduce the cognitive effort needed to come to decisions and/or can improve the quality of decisions [Todd and Benbasat (1994), Engelmann et al. 2009]. Individuals with above average executive functions or above-average working memory functions, exhibited advantageous decision-making behavior independent of advice. Furthermore, the route of decision making behavior followed for the completion of the task indicates that participants shifted to an advantageous strategy after the first third of the task and that individual differences in executive functions and working memory affected this route. Brand, Labudda, Markowitsch's (2006) theory also revealed similar findings and suggested that persons with lower abilities in these domains may make a more disadvantageous decision because they have more problems with finding an appropriate strategy. Based on this it may be assumed that these persons performed better with advice because the help that they received facilitated categorizing the alternatives according to their probabilities, as well as finding a good decision strategy. The advice was clearly explicit and had large effect sizes when considering mean comparisons.

Current finding of the present study in relation to implicit intervention (in the form of diverse background colors) are unique one in its mode of administration and there is no such study, to our knowledge, that has followed this feature and procedure. With reference to previous studies [Sohn & Anderson (2003); Lau & Passingham (2007); Weibel et al (2013) and Manly et al. (2014)] that have accounted priming as a way of intervention, present study's findings for priming intervention revealed significant decrement in switch costs. Sohn and Anderson (2003) have reported that stimulus related priming is automatic; no direct control of executive functions exists. Arrington & Logan (2005) have found that participants took less time and made fewer errors to switch (smaller switch cost) when the task was signaled by explicit cue. In a recent study by Manly et al. (2014) it was found that priming by cues that were beyond the conscious
awareness was shifted not only to the trained task, but also to the new task that require similar processes. Although current findings are in contrast with Waszak, Hommel & Allport’s (2003) study, which reported that poor performance (more switch costs), was made to the stimuli which took place earlier in the competing task.

Most of the studies related to training in task switching conditions revealed decline in both types of costs, i.e. switching and mixing, as a result of practice (Cepeda et al., 2001; Kray et al., 2008). Many studies have reported more decline in mixing costs as compared to switch costs as a result of training (Berryhill and Hughes, 2009; Strobach et al. 2012). However, as current study was emphasizing on switch costs, so, no such comparison was made. But the findings of the current study have reported a firm evidence for a decrease in switch costs as a result of training/intervention and are in line with the findings of Karbach and Kray’s (2009) study which reported training gains for both types of costs.

Limitations

In spite of the positive outcome of the study, current findings did not claim these cognitive processes are the only executive functions that play significant role in the execution of these tasks (verbal as well as nonverbal), nor would these findings propose that they are the basic components of cognition. In current study, only WCST was a standardized test that compute set switching and switch cost, while the two other tasks (numerical and anagram solution) were not standardized like WCST. Both these tasks, i.e. numerical and anagram, involved only a smaller number of trials (20 and 30 respectively) as well as number of categories (only two) as compared to WCST which involve 124 trials/cards and six categories. Although, the findings revealed that all these three tasks accounted set switching and switch costs, yet, correspondence in tasks may reveal obvious contribution of each factor. The study is also limited in the aspect of assessing only the switch costs, and not mixing costs. Examination of far transfer of performance may also lead to fruitful outcomes.
Implications:

1. Cognitive control should be useful e.g. for calculating probabilities before making the decision or - if several decisions have to be made - for developing a strategy and control behavior accordingly when making the choices. For exerting such cognitive control over behavior, executive functions are thought to be responsible (Norman and Shallice, 1986; Shallice and Burgess, 1993; Brand et al., 2006)

2. Considering the importance of EF for numerous life outcomes, the identification of successful cognitive training interventions may not only be beneficial for the compensation of cognitive deficits in clinical samples, but also to promote cognitive performance and development in healthy children and adolescents.

3. Every individual has its own style of activity depending on his temperamental traits and every type of temperament has its own advantages and its own roads to success. Assessment of specific dynamic traits can help in placement and recruitment of right person in a specific profession for e.g. an acrobat must possess a mobile and strong nervous system.

4. A number of findings related to academic achievement and executive functions (EFs) have repeatedly confirmed EFs as important prerequisites for the general ability to attain knowledge and novel abilities. EFs are not only limited to higher level cognitive abilities that made significant contribution to educational achievement, but also to performance in the classroom (Titz and Karbach, 2014). Many studies (Swanson, 2004; Altemeier et al., 2008; Andersson, 2008; Alloway and Alloway, 2010; Lu et al., 2011), have reported as much variance in academic attainment as intelligence (believed to be the main potent predictor of academic success (Gustafsson and Undheim, 1996).

5. Obtained findings from the study may help us in understanding the unity and diversity of executive functions. These findings also revealed patterns of assets and deficits that may be predictive of later generalized academic performance in various areas such as in arithmetic, grammatical and other performance task/activities by early neuropsychological assessment. For example, Ss who exhibited high anxiety made more errors and took more time in task switching (Derakshan et al. 2009).
6. Findings may be productive in the industries where multitasking is a necessity and in automatization with prolonged serialization to control complacency also.

7. There may also be long term educative implications and even an enhancement in the feeling of self-efficacy.

8. Findings may be also helpful in understanding various executive processes in a better manner and may lead to formulation of significant intervention planning for those who have same or similar difficulties and help us to deal effectively according the the changing demands or requirements of environment.

**Future Directions**

Apart from clinical settings, recent studies have also focused on educational contexts. The few existing studies have provided mixed but encouraging findings, indicating that cognitive control training has the potential to improve academic abilities, particularly in the field of language and reading. The beneficiaries from these studies are not only normal individuals, but also individuals having some deficit in cognition or difficulties in learning. Further empirical work is needed to test these predictions and develop stronger theoretical models which accurately represent this complex area of study. Clearly, more research is required to have a better understanding of the processes mediating the transfer of cognitive training to academic abilities. These studies will be of major importance for tailoring interventions programs to the individuals with special needs. Moreover, future studies may want to assess the relation between social and emotional growth to improvements induced as a result of training and to which amount training related benefits may be determined by motivational components. Generality of rule switching across tasks (non verbal, numerical and verbal) suggests the use of the three tasks in task switching paradigm also with a seeming application of such processes in composite academic achievement test or unitary test after the training or a course. There is a case to form groups of persons (students) on the basis of their characteristics such as cognitive interference and mobility of nervous processes to tackle the problems of cognitive processes – set formation, set maintenance and set switching even multiple switching over rules or tasks or mixed settings (as executive processes).