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Research Paper

Measures of Set-Switching and Cognitive Flexibility among School Adolescents

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ABSTRACT

Our study mainly emphasized on the cognitive control processes that are essential when automatic behavior/processes are not enough to achieve targets. Present study aims to examine the relationship of executive processes through verbal and non-verbal tasks of set-switching with cognitive flexibility. For achieving the aim, Wisconsin Card Sorting Test (WCST) - a measure of cognitive set-switching (Non-verbal task), Numerical problem-solving task following rule switching (verbal task) and Color-Word Stroop test - a measure of cognitive flexibility was administered on 296 school adolescents with an age range between 12 to 15 years. Results revealed significant correlation among verbal and non-verbal measures of set switching and cognitive flexibility.

Keywords: *Executive processes, Cognitive, Non-verbal, Tasks, Switching, Significant*

It is a fundamental characteristic of human beings to behave according to changing environmental demands. This adaptability and flexibility in behavior are achieved with the help of cognitive processes. Due to this control and flexibility, we are capable of responding quickly and accurately in achieving our goals. Individual differences exist in this ability to switch between various types of tasks. Some may switch very quickly from one task to another and hence results in a faster shifting while others may take longer time, hence, results in a slower shifting. This ability of individuals which is associated with an ability to switch response sets on the basis of feedback is known as Set-switching. In psychology, "set switching may be defined as a cognitive operation that entails an ability to switch response sets, whereby one must inhibit previously learned rules and apply new ones" (Barcelo & Knight, 2002).

It is the most significant attribute of human behavior to become accustomed and flexible in accordance to the altering situational requirements. This plasticity in behavioral performance involves higher cognitive control processes, which allows human beings to respond quickly and to attain objectives and execute tasks in a well manner. Cognitive flexibility is such an ability that appropriately adjusts one's behavior according to a changing environment (Armbruster et al., 2012 & Scott, 1962). It enables an individual to work efficiently to disengage from a previous task, reconfigure a new response set, and implement this new

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response set to the task at hand. Greater cognitive flexibility is associated with favorable outcomes throughout the lifespan such as better reading abilities in childhood (de Abreu, et al., 2014), higher resilience to negative life events and stress in adulthood (Genet & Siemer, 2011), higher levels of creativity in adulthood (Chen Q, et al., 2014) and better quality of life in older individuals (Davis, et al., 2010).

REVIEW LITERATURE

Task switching is an increasingly popular method used in studies of cognitive control. Although the task-switching paradigm was originally developed by Jersild (1927), its use has only recently become widespread, due to a growing interest in executive function. According to Delis, Kaplan, & Kramer (2001), Wisconsin Card Sorting Test (WCST) has been considered the 'gold standard of executive function tests' from a long time. The successful execution on the WCST requires- "efficient switching to the new sorting rule on the basis of feedback, i.e., set-switching", and "retaining the current sorting rule in mind through varying stimulus conditions, while ignoring irrelevant aspects of the stimuli i.e., set-maintenance" (Barcelo & Knight, 2002 and Heaton et al. 1993). Miyake et al. (2000) in their study uses shifting task, updating task and inhibition task and found that all the three variables are not completely independent, rather, there exists a correlation (ranging from .42 to.63) which suggests some unity accounted by inhibitory function. Another study conducted by Bull & Scerif (2001) reported that interference correlated with perseverative errors. Results of the study conducted by Schiebener et al. (2014) also favour the outcomes of previous researches by revealing that perseverative and non-perseverative errors exhibited significant correlation with color word interference test. There is small, but a growing body of promising research (Allport et al. (1994); Monsell, Yeung, & Azuma, 2000; Koch, Prinz, Allport, 2005; Arbuthnott, 2008a; Yeung & Monsell, 2003a, 2003b) showing that higher switch costs occurred on switching to stronger, more dominant task.

A number of recent studies argued that the ability to shift between conceptual representations, selection and maintenance of appropriate strategies and disengagement from irrelevant ones is particularly important for performance on complex academic tasks requiring alternation between different aspects of problems or arithmetical strategies (Agostino, Johnson, & Pascual-Leone, 2010; Blair, Knipe, & Gamson, 2008; Van der Sluis, De Jong, & Van der Leij, 2007). This suggests that shifting ability (or cognitive flexibility) would be mainly related to performance in subjects like math, which has indeed been reported in several studies (Bull &Scerif, 2001; Clark, Pritchard, & Woodward, 2010; Mayes, Calhoun, Bixler, & Zimmerman, 2009), although others have failed to find this association (Espy, McDiarmid, Cwik, Stalets, Hamby, & Senn, 2004; Lee et al., 2010; Monette, Bigras, & Guay, 2011). To summarize, recent findings (Agostino, Johnson, & Pascual-Leone, 2010; Blair, Knipe, & Gamson, 2008; Clark et al., 2010 and Mayes et al., 2009) indicated that shifting ability is essential for execution on multifaceted academic tasks that require shift between different facets of problems or arithmetical approaches and shifting ability is mainly associated with performance on mathematical tasks.

A keen observation of above studies highlights the growing interest of researchers towards various task switching paradigms and its relation with other cognitive aspects. Therefore, with an aim to extend previous findings, present study was designed to study the relationship of executive processes by using verbal and non-verbal measures of set-switching and cognitive flexibility among adolescents in Indian context.

Objective

To examine the relationship between cognitive set-switching measures (verbal and non-verbal) and cognitive flexibility.

Hypotheses

- Subjects with high cognitive flexibility will have less switch costs (less perseverative responses and high number of categories completed) on non-verbal task of set-switching, i.e., WCST and vice-versa.
- Subjects with high cognitive flexibility will have less switch costs (less perseverative responses and high number of categories completed) on verbal task of set-switching, i.e., numerical problem-solving task and vice-versa.

METHODOLOGY

Sample

The final study followed a two-stage sampling. At first stage, Jalota's Group test of General Mental ability was administered to a large sample (N = 428) as inclusion criterion variable. At the second stage, subjects within the average range of General Ability scores and among those who were available as well as consented for participation in this research (N=296), were selected. This sample for final study consisted of subjects of both sex (M = 200, F = 96) between age range of 12 to 15 years (M = 14.07 & SD = 0.91). Remaining subjects who did not fall in inclusion criteria and were absent or did not consent were excluded. All the students were students of senior secondary classes.

Tools used

- **Wisconsin Card Sorting Test (WCST) – Revised and Expanded (Heaton et al., 1993)** The usual form (Heaton, 1981; Heaton et al., 1993) of WCST comprises of four stimulus cards and 128 response cards with geometric figures that differ in three ways of perceptual measurements (i.e., Colour, form, and number). The task demanded participants to uncover the correct categorization/sorting rule by trial and error and evaluations of feedback from examiner. When the subject finds the correct sorting rule, he is required not only to maintain the correct sorting rule across changing conditions, but to ignore the other, now unrelated stimulus condition also. The categorizing/sorting principle changes after every ten consecutive correct responses without warning and demands a flexible shift in the set. There is no time limit for the completion of the test and it requires either sorting until the last card or a maximum of six correct categories have been completed. Standardized procedure for test administration, recording of the response and scoring was followed. Percentage of various scoring criteria such as perseverative responses, perseverative errors was accounted for analysis in present study, because percentage reflects the density or concentration of scores in relation to overall test performance. Higher the scores on perseverative responses, perseverative and non-perseverative errors, higher the switch costs and vice-versa. Another criterion of WCST used in the study was Number of Categories Completed. Higher the score on this criterion, more is set switching as well as set maintenance and vice-versa.
- **Color-Word Stroop Test:** The interference caused by two competing tasks has been studied extensively using the Stroop paradigm. The Stroop test measures one's mental capacitance to switch between conceptually different thoughts through cognitive processing. It also tests the capability to think about multiple concepts simultaneously, known as cognitive flexibility, and processing speed. Standardized

procedure for test administration, recording of the response and scoring was followed for the task. Scoring of responses on this task was completed by using the formula for calculating the Color-Word scores. Higher scores on Color-Word task represent higher cognitive flexibility or less cognitive interference and lower scores represents lower flexibility or higher interference.

- **Numerical Problem-Solving Task:** The findings from the earlier studies of task switching (Jersild, 1927; Spector & Biederman, 1976) motivated us to examine the phenomenon of set switching using arithmetic tasks. With reference to previous findings and from observations of the pilot study, this task involved solving simple mathematical 'number series' problems structured on a rule based (or defining feature based) manner. Two blocks of problem were used which consisted of 20 problems (10 each). First block involved first ten problems (1 to 10) based on the rule of 'addition' and second block involved remaining 10 problems based on the rule of 'subtraction'. This task demanded participants to uncover the correct sorting rule by trial and error and evaluations from examiner's feedback. When the subject finds the correct sorting rule, he is required not only to maintain the correct sorting rule across changing conditions, but to ignore the other, now, unrelated stimulus condition also. The sorting/learned principle changed after first ten problems or completion of one block, without warning and demands a flexible shift in the set by responding according to the new sorting rule. Number of perseverative errors and number of 'blocks/categories completed' were considered as the source of switch costs. Consecutive correct responses for problem 6 to 10 (in First block) and for problem 16 to 20 (in Second block) were considered as evidence of set maintenance and a crash in the same was considered as a failure in set maintenance. Perseverative errors were traced (in total numbers) from trial/problem number 11 to 14 when subject made a response that would have been correct using the previous sorting criteria, but is now incorrect. More score on perseverative responses indicates higher switch costs, while increase in number of categories completed indicates more/higher set switching.

Procedure

Pilot Study: Before the final administration, a pilot study was carried out. The purpose of the pilot study was to try out for the selection of numerical problem-solving task, selection of material/items for this task, exposure time, set of instructions, procedure to be followed and responses to be recorded for the same task. This task was administered separately on a sample of 25 healthy subjects who were within the age range of 12 to 15 years. The subjects of this study were screened by Jalota's group test of general mental ability. This sample was limited only for achieving our preferred aim of task selection and standardization; and was not used in the final study. This task was structured on a rule based (concept learning as rules for discriminating as categories of objects) manner.

Final Study

All the three tasks/measures i.e., WCST, Numerical problem-solving task and Color-word Stroop test were administered individually on each subject. The order of presentation for each task was different, i.e., independently randomized for each subject for balancing/neutralizing the carry over effect. When subject (already consented) was brought to the room, first of all, rapport was established with him/her. Then a set of general instructions was given to the subject.

RESULTS

For testing the hypotheses of the present study Pearson's correlation was accounted for measures of Set-Switching (verbal and non-verbal) and cognitive flexibility (Table 1)

Table 1 Correlation Matrix (N=296)

Variables	**CF**	**% P R**	**% P E**	**NOCC**	**NCC**	**NPE**
CF (Cognitive Flexibility)	1	-.301**	-.316**	.159**	.366**	-.355**
% PR (Perseverative Response) WCST		1	.984**	-.712**	-.466**	.609**
% PE (Perseverative Error) WCST			1	-.714**	-.478**	.631**
NOCC (Number of Categories Completed) WCST				1	.458**	-.539**
NCC (Numerical Categories Completed)					1	-.576**
NPE (Numerical Perseverative Error)						1

p< .01 *p<.05

From the correlation table (1), it is evident that significant correlation was observed between set switching measures (both verbal and non-verbal) and cognitive flexibility. Results revealed significant negative correlation between variables of non-verbal measures of set-switching i.e., WCST and verbal measure i.e., numerical task with cognitive flexibility. A significant negative correlation was found between variables representing switch cost among WCST such as % perseverative response (-.30), % perseverative error (-.32) and Numerical perseverative error (-.36) with cognitive flexibility. These results indicate that with a decrease in cognitive flexibility/facilitation (or with high cognitive interference), an increase in perseverative responses and errors took place not only on WCST but also on numerical task. Results further revealed significant positive correlation between cognitive flexibility and number of categories completed on WCST and numerical task (0.16 and 0.37 respectively). These results indicated that with increase in cognitive flexibility/facilitation (or with low cognitive interference), an increase in number of categories completed took place not only on WCST but also on numerical tasks. In other words, individuals with more flexible cognitive system (or with low cognitive interference), exhibits an increase in number of categories completed not only on WCST but also on numerical task. It means such individuals have less switch costs and have high set-switching. Significant correlation was also exhibited between verbal and non-verbal measures of set-switching. These findings strengthen the validity of our numerical problem-solving task of set-switching. **S**ignificant inter-measure correlation was also observed between various variables of WCST.

The above stated findings led us to formulate following conclusions regarding cognitive flexibility and measures of set-switching (verbal and non-verbal) – Subjects who have low scores on cognitive flexibility/facilitation (i.e., have high cognitive interference) dimension, committed more perseverative responses, perseverative errors not only on WCST, but also on numerical task. On the other hand, subjects who have high scores on this dimension, completed more number of categories on WCST, as well as on numerical task. These finding indicated that more flexible cognitive system helps individuals in formation of a set, its maintenance and change in it whenever required and thus ultimately lead to less switch costs and more number of categories completion. Thus, from these findings both of our research hypothesis stating that, people high on cognitive flexibility will have fewer difficulties in set-switching on verbal and non-verbal measures of set-switching are accepted.

DISCUSSION AND CONCLUSION

The findings of the correlation analysis exhibited significant association among verbal and non-verbal measures of set switching with cognitive flexibility. It was found that subjects high on cognitive flexibility/facilitation or low on cognitive interference have less switch costs in the form of perseverative responses and perseverative errors and higher numbers of categories completed. With relation to cognitive interference and perseverative errors, current findings are in line with Bull and Scerif (2001) and Schiebener et al. (2014) study in which 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 interfere with performance on a nearby competing task) and higher switch costs on switching to a stronger and dominant task. Another study by Schiebener et al. (2014) also revealed that perseverative and non-perseverative errors exhibited significant correlation with interference scores. Similar findings were also observed in an Indian study conducted by Sinha, Sagar and Mehta (2008), in which ADHD group had more perseverative errors and interference than the control group. With relation to cognitive flexibility, mathematical performance and perseverative errors, present findings are in correspondence with Rourke (1993), Bull & Scerif (2001) study. Study conducted by Rourke (1993) reported that children who exhibited difficulty in solving arithmetic problems with a pattern of neuropsychological weakness have difficulty in shifting psychological sets. Similar results were also reported by Bull and Scerif (2001) where they found that higher mathematical ability was related with lower interference and interference was positively correlated with perseverative errors on WCST. Thus, it may be concluded that a flexible cognitive system accounts to a more dynamic executive system having high set switching and low switch cost (in form of less perseverative responses and errors and more number of categories completed) not only on verbal tasks but also on non-verbal tasks.

Implications

Obtained findings from the study may lead us to find out those individuals who committed more switch costs or have difficulty in set-switching and then to have some intervention planning for them so that it will help them to deal effectively according to the changing demands or requirements of the environment. 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 and other performance task/activities by early neuropsychological assessment. So, there may be some long-term educative implications and even an enhancement in the feeling of self-efficacy.

Limitations

Present study was limited in using a non-standardized test measuring verbal set switching, i.e., numerical problem-solving task. The study is also limited in the aspect of assessing only the switch costs, and not mixing costs. Though the findings revealed concurrent and construct validity of the new task.

Future Directions

More such standardized tasks measuring switch costs related to educational curriculum should be made.

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Conflict of Interest

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