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Comparing Preparation Effect in Predictable and Random Task Switching

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Humans can flexibly shift between two or more competing tasks to meet the changing need of environment and accomplish their desired goal. However, this benefit can be achieved with high reaction times and error rates. The present study compares the cost when switching from one task to another in two different predictability conditions. In first condition task switched in predictable and predetermined sequence. This condition utilized implicit spatial cues whereas, in other condition, the task switched randomly and an explicit cue informed regarding upcoming task. Three response stimulus intervals were provided as preparation time to improve performance. Results revealed that task predictability is an important factor in determining the task switch cost. The overall performance was better in predictable task switching condition while switch costs were smaller in random switching condition. Preparation time improved performance in both switch condition but it reduced switch cost more in random than in predictable switch condition.

Keywords: Task switching, Switch cost, Predictable, Random, Preparation.

The ability to switch flexibly between tasks not just allows us to adapt to changing demands in the environment but it also allows approaching the same situation from different perspectives. Nevertheless, our daily life often requires performing multiple tasks either simultaneously or in rapid alternation, as when a mother prepare meal while tending her children or when you drive car while talking on mobile phone (Rubinstein, Meyer & Evans, 2001). Even in the present era organizations also demand for multitasking staffs to handle the multiple task responsibilities.

Task switching studies enlighten our knowledge towards our ability to perform multiple tasks either in alternation or simultaneously. In a typical task switching experiment participants are required to switch back and forth between two or more tasks afforded by the same class of stimulus. Performance on trials immediately following a task change (switch trial) is generally slower and less accurate than non-switch or task repeat trials. The slowing of responses and reduced accuracy on switch trials has been termed as switch or shift cost. Several other phenomena like preparation effect, residual switch cost and mixing cost were also studied along with shift cost in various studies.

Predictable and Random Task Switching

Generally predictable and random task switching procedures have been used in various paradigms to explore different phenomena associated with task switching. The most popular and widely used "Alternating-runs paradigm" (Roger & Monsell, 1995) employs predictable and well acknowledged procedure in switching tasks. In this paradigm trials are grouped in predictable run-length that alternate between tasks (e.g. AABBAABB…). In few studies (e.g. Roger & Monsell, 1995) stimuli were presented clockwise in four locations and two adjoining locations were associated with the task A and other two locations were associated with the task B. Thus, spatial location of stimuli and position of run of trials served as a cue to keep participants on track of trials. Unlike to Roger and Monsell (1995), other studies also used single location for yielding predictable sequence of task switching (e.g. Monsell, Sumner & Waters, 2003). Switch cost in alternating-run is measured by comparing the trial in position 1 of a run to the trial in position

2 as the position 1 trial is the switch trial and the position 2 trial is repeat trial. These researchers attributed switch cost as time consumed by task set reconfiguration (TSR). TSR can include shifting attention between stimulus attributes or elements, or between conceptual criteria, retrieving goal states (what to do) and condition–action rules (how to do it) into procedural working memory (or deleting them), enabling a different response set and adjusting response criteria. Other possible sources of switch cost in literature are either inappropriate states of activation and inhibition of task-controlling representations that are persistent (Altmann & Gray, 2008; Schneider & Logan, 2005; Yeung & Monsell, 2003b; Meiran, 2000a; Mayr & Keele, 2000) or/and proactive interference resulting from having previously performed a competing task (Allport, Styles, & Hsieh, 1994).

Prespecified task sequence paradigm also present an alternative to alternating-runs method in which participants are given short sequence of trials in prespecified order (see Allport, Styles, & Hsieh, 1994; Mayr & Keele, 2000). For random switching, "Explicit-cuing paradigm" is frequently used in which task to be performed on next trial is still unknown until an explicit cue indicate the participants about the impending task, thus, cue proceeds or accompanies every trials (e.g. Meiran, 1996; Shaffer, 1965). Unlike the alternating-runs, explicit cuing compare switch and repeat within position 1. Sometimes in explicit cuing paradigm cue does not appear prior to the onset of target in fact it appears along with the target, and then it is called as random task switching paradigm. In this procedure no foreknowledge of the upcoming task is provided. Intermittent-instruction paradigm is also used when task sequence is random.

Preparation in Task switching

Switch cost is reduced when advance knowledge of the upcoming task is provided, known as preparation effect. However, preparation does not eliminate the switch cost completely but residual cost is found with longer preparation interval (Nieuwenhuis & Monsell, 2002; DeJong, 2000).

Task preparation has been mainly examined in studies by manipulating the time intervals prior to target onset. The relative merits of predictable and random switching can be understood here in relation to the preparation effect. In predictable-switching paradigms (e.g., alternating runs), the interval between the response in the preceding trial and the onset of the next task stimulus (response-stimulus interval, RSI) can be increased to provide ample time for preparation. Researches using shorter to longer RSIs with predictable switching paradigm (Monsell, Sumner, & Waters, 2003; Nieuwenhuis & Monsell, 2002; De Jong, 2000; Rogers & Monsell, 1995) found a substantial reduction in switch costs. Roger and Monsell (1995) attributed this preparation effect to active endogenous task-set reconfiguration (TSR) in anticipation of a task switch. They also found that preparation did not eliminate the alternating-runs switch cost completely even when 5 sec or more was provided for the preparation. Roger and Monsell (1995) suggested that part of TSR cannot be done until exogenously triggered by the stimulus attributes that are associated with the task.

In the explicit-cuing paradigm, the interval between cue and stimulus (CSI) as well as the interval between response in the preceding trial and onset of the cue (RCI) can be varied independently. By using these procedures researchers are able to demonstrate the active preparation for the next task (CSI) and passive dissipation of previous task (RCI) (Meiran, Chorev, & Shapir, 2000; Meiran, 2000a; Meiran, 2000b; Meiran, 1996) Explicit-cuing method also allows varying CSI and RCI while keeping RSI constant (Altmann, 2004).

An important issue regarding preparation is how it is manipulated. Literature suggests that preparation time, checks switch cost when it is manipulated as within participant factor (Monsell, Sumner, & Waters, 2003; Sohn & Anderson, 2001; Meiran, 2000a; De Jong, 2000; Meiran, 1996; Roger & Monsell, 1995), but no effect was found when manipulated as between participant factor (Sohn & Anderson, 2003; Arrington, 2002; Koch, 2001) .

Task Predictability and Preparation

Predictable and random task switching procedures have been used to explore various phenomena of task switching, but very few studies have attempted to combine the two procedures in a single study. Tornay and Milan (2001) were the first who thoroughly investigated task predictability with preparation interval and task predictability was treated as within subject variable and manipulated between blocks. In their study switch cost was reliable for both smaller and larger RSI in predictable switching, whereas, in random switching only shorter RSI produced reliable switch cost. This indicates that participants prepare better for the next task in random switch condition (RSC) than in predictable switch condition (PSC) when adequate time is provided. Error cost for RSC was found greater than PSC, indicating speed-accuracy trade-off.

Monsell et al. (2003) used predictability as within subject variable and found that RT reduced upto 50% (from 263 to 123 ms) as the time available for preparation (RSI) was to 650 ms, but no improvement was noticed beyond this even after increasing RSI to 1,250 ms, Whereas in RSC switch cost is independent of task switching in short RSI but with increasing RSI (1,250 ms) continuous reduction in switch cost was found. Milan, Sanabria, Tornay and Gonzalez (2005) studied effect of task predictability on switch cost and found that switch cost was reliable only in PSC not in RSC. However, they observed a significant reduction in RT between the first and second repetition of the new task in random task switching.

Nikolaos Andreadis (2010) used RSI as between group factor and found no statistical significance of the same. Responses were slower on switch than non-switch trials; and slow overall response in unpredictable than predictable condition was reported. However switch cost was smaller in the unpredictable case. By using hybrid procedure Altmann (2007) concluded that alternating-runs switch cost (ARS) appears to include both the costs of switching tasks and switching-independent cost specific to the first trial of a run, with the implication that it should be larger than explicit-cueing switch cost (ECS) in general. They further examined the empirical evidence from closely matched studies and unmatched studies. Closely matched studies were those in which both alternating-runs and explicit cuing methods were used simultaneously, whereas, in unmatched studies either of the procedure was used.

Current Study

This study intends to elucidate the difference between two types of switching condition and its effect on ability to prepare for new task. Literature suggests that these two procedures somehow utilize different system of switching i.e different trend of switch costs and preparation effect were found. No study has used task predictability as a between subject factor. Present study aims to use both predictable and random switching to find out their effect on preparatory process. Hypothesis was formulated stating that there would be larger switch cost in predictable than in random switching and different pattern of preparation will be found in predictable and random switching.

Method

Participants:

Total of 60 participants (19 to 26 years) with the mean age of 21.5 years participated in this experiment. Participants were randomly assigned into two experimental conditions (30 in predictable task switching and 30 in random task switching). All the participants had normal or corrected-to-normal visual acuity of 6/6 based on performance on a Snellen acuity chart and were reported mentally and physically fit at the time of participation in the experiment.

Experimental Task:

Task switching paradigms

Alternating-runs paradigm and explicit cuing paradigm were used for task switching. Participant's task was to classify a digit as odd/even or letter as vowel/consonant. In alternating-runs experiment, an 8-cm square divided into four quadrants was displayed on the computer screen. On each trial a character pair (e. g.

3M) was displayed in one such position. On successive trials, the position moved to the next square clockwise. Target stimuli were a character pair (bivalent stimuli) consisting a letter and a digit both. Participant has to perform digit task whenever stimuli appeared in the upper quadrants and letter task when stimuli appeared in lower quadrants. Depending on the task, relevant character was either a letter or a digit. For the letter task consonants were sampled from the set G, M, and R, vowels from the set A, E, and U, for the digit task, even digits from the set 4, 6, and 8, and odd digits from the set 3, 5, and 9, were used.

In explicit cuing paradigm task was same as in alternating-runs, with only difference being introduction of cue. Task to be performed in next trial was explicitly cued by “DIGIT” for odd-even task and “LETTER” for vowel-consonant task. Tasks appeared randomly on the screen.

Sequences of stimuli were constructed with the restriction that the same character does not appear on two successive trials. For half of the participants left key was assigned to indicate “odd” or “vowel” and right key to indicate “even’ or “consonant” mentioned in response pad. For the other half, reverse stimulus key mapping was used. Each participant was randomly assigned to either mapping.

Design:

A 2 (Task predictability: predictable & random) x 2 (Task type: digit & letter) x 2 (Trial type: repeat & switch) x 3 (RSI: 200, 600 & 1000 ms) mixed factorial design was employed with repeated measure on last three factors. Two forms of task predictability (predictable and random) were used as between subject factors. Task type (digit and letter), trial type (repeat and switch trial) and RSI were treated as a within subject factors. Three RSIs, 200 ms, 600 ms and 1000 ms were manipulated between blocks. Overall, 4 blocks consisting 72 trials for each RSI were used.

Procedure:

Consent from participants was acquired before participating in this study. Then participants were tested for their normal visual acuity using Snellen chart and biographical information regarding their age, gender, education, weight, knowledge of computer, medication, were collected from the participants. Then instruction with brief introduction about the task was imparted lucidly to all the participants. Then participants were randomly assigned into alternating-runs task or explicit cuing task of task switching in which their task was to either classify digit as odd/even or letter as vowel/consonant. At first participants were given practice task comprising of 4 blocks, then, they were given 12 blocks of 72 trials each in final session. First 2 practice blocks were pure blocks having 32 trials for each task (letter and digit task) and last 2 blocks were mixed-trial blocks consisting of 72 trials in which participants performed both tasks alternately. Participants who secured at least 75% accuracy were selected to participate in the final session of 12 blocks. In alternating-runs task, trial started with fixation (+) at the centre of the screen followed by target i.e. a character pair appearing in rightmost quadrant of square and target remained on screen until participant responded or 2,500 ms, whichever was earlier. After variable RSI (200, 600 or 1000 ms) next target appeared in adjoining quadrant in clockwise pattern. Sequence of task was predictable i.e. AABB, therefore position of trials in run and spatial location of target served as a cue for impending task. In explicit-cuing experiment trial started with fixation (+) then a cue appeared at the centre of the computer screen for 200ms, 600ms or 1000ms, followed by target, which remained on the screen until participant responded or 2,500 ms whichever was earlier. These RSIs were constant within a block. Participants were instructed to use available time (RSI) to prepare for the next stimulus. Experiments lasted about 35-50 minutes depending on the performance of the participants.

Statistical analysis:

Reaction time (RT) and accuracy were taken as performance measure. Time switch cost was computed by subtracting the mean RT on repeat trials from corresponding values on switch trials (Switch trials RT – Repeat trials RT). Accuracy switch cost was calculated by subtracting the mean accuracy on switch trials from corresponding repeat trials (Repeat trials – Switch trials). Analysis of variance (ANOVA) and t test were computed to examine main effect and interaction effects of independent variables.

Results

Trial Type and Task Type

The main effect of trial type on reaction time (RT), F(1, 58) = 296.72, p<.000, partial eta2 = 0.84 and accuracy F(1, 58) = 71.24, p<.000, partial eta2 = 0.551, was found significant indicating that performance was notably slower and less accurate on switch trials than repeat trials. The main effect of task type on accuracy performance F (1, 58) = 73.17, p<.000, partial eta2 = 0.558 was significant indicating that performance on digit task (Predictable: M=90.88%, Random: M=88.21%) was less accurate in comparison to letter task (Predictable: M= 94.97 %, Random: M=92.05%). RT performance was found marginally (F (1, 58) = 3.099, p<.084, partial eta2 = 0.051) slower on digit task (Predictable: M=899.20 ms, Random: M= 973.75 ms) than letter task (Predictable: M= 895.37 ms, Random: M= 964.75 ms).

Task Predictability

The main effect of task predictability on RT performance was found significant, F(1, 58) = 5.35, p< .024, partial eta2 = .085. Figure (1) indicates that different pattern of RT performance was found in these two switch conditions. Participants took less time in predictable task switching (M= 897.29 ms, SD= 89.75) than random task switching (M= 969.25 ms, SD= 163.24). Two way interaction of task predictability and trial type was found significant (F (1, 58) = 24.17, p<.000, partial eta2 = 0.294) indicating that task predictability has different effect on RT in switch and repeat trials. A separate ANOVA 2 (Task predictability: predictable and random) x 2 (task type: digit and letter) x 3 (RSI: 200, 600 and 1000 ms) was conducted for repeat and switch RT. Main effect of task predictability on repeat trials was found significant (F (1, 58) = 12.75, p< .001, partial eta2 = .180, indicating that RT for repeat trials was faster in PSC than RSC. However, this effect was not found reliable for switch RT, (F (1, 58) = 1.14, p< .290, partial eta2 = .019. Similar to RT performance, the accuracy in predictable switching (92.93%) was larger (marginally) than random switching (90.13%), F (1, 58) = 3.12, p<.083, partial eta2 = 0.051. The interaction of task predictability and trial type for accuracy was not significant, F (1, 58) = 1.18, p = .28.

Preparation Effect (RSIs)

The ANOVA on RT revealed significant main effect of RSI (F (2,116) = 104.92, p<.000, partial eta2 = 0.644), significant two way interactions of RSI and task predictability (F (2,116) = 6.624, p< .002, partial eta2 = 0.102) & RSI and trial type, (F (2, 116) = 21.99, p<.000, partial eta2 = 0.275). In both switch conditions, performance improved as RSI increased (Predictable: 200 RSI= 976. 57 ms, 600 RSI= 892.37 ms, 1000 RSI= 822.93 ms; Random: 200 RSI, M= 1021.11 ms, 600 RSI, M= 957.94 ms, 1000 RSI M=928.70 ms). The interaction effect indicates that RSI affected RT performance differently in PSC and RSC and RSI produced distinguished effect on repeat and switch trials.

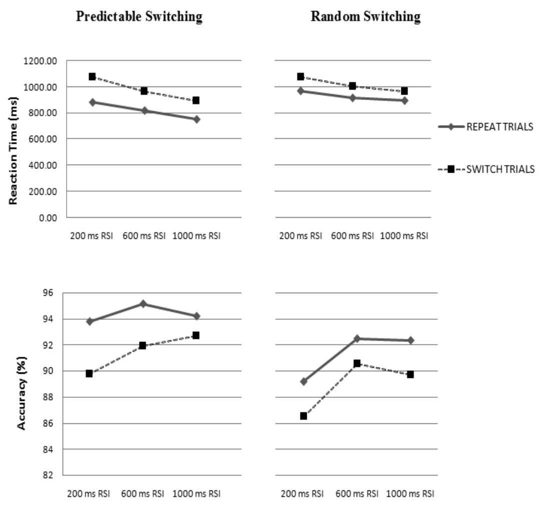

Figure 1: Mean correct RT and accuracy rate as a function of the predictability of task switches, preparation interval and trial type.

Main effect of RSI on accuracy was significant, F(2,116) = 19.66, p<.000, partial eta2 = 0.253 which indicates that with increase in RSI (Predictable: 200ms, M=91.79, 600ms, M=93.53, 1000ms, M=93.45; Random: 200ms, M=87.85, 600ms, M=91.53, 1000ms, M=91.03) accuracy has improved. The two way interaction of RSI and trial type (F (2,116) = 88.81, p<.000, partial eta2 = 0.605) and RSI and task type (F (2,116) = 10.25, p<.000, partial eta2 = .150) were significant. Figure 1 shows that RSI differently affected accuracy on repeat and switch trials as well as digit and letter task. The interaction of RSI and predictability was marginally significant, F (2,116) = 2.69, p<.072, partial eta2 = 0.044.

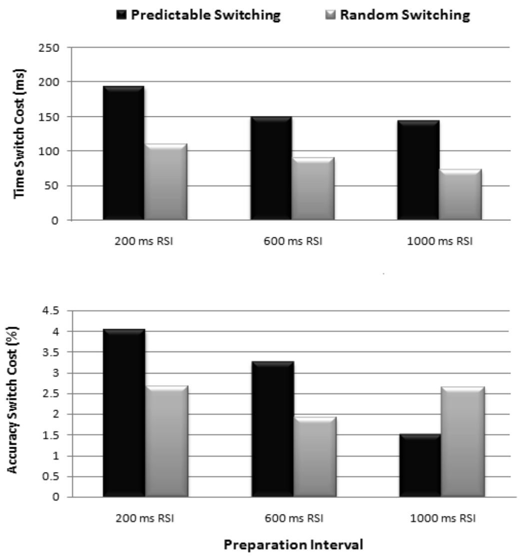

Figure 2. Switch costs as a function of task predictability and preparation time.

Switch cost

Time and accuracy switch cost was analyzed as 2 (Switch type: Predictable & Random) x 2 (Task type: Digit & Letter) x 3 (RSI: 200ms, 600ms & 1000ms) analysis of variance (ANOVA) with repeated measure on last two factors.

The main effect of predictability (F(1, 58) = 24.17, p<.000, partial eta2 = 0.294) and RSI on time switch cost was significant, (F(2,116) = 21.99, p<.000, partial eta square= 0.27). In predictable-switching, time switch cost dropped rapidly (t (29)= 4.40, p< .000, r = .85) from 193.99 ms to 149.99 ms as time available for preparation (RSI) was increased from 200 to 600 ms, but further increase in RSI (1,000 ms) was unable to produce any reduction in time switch cost (t (29)= .63, p= .53, r = .78)(144.71 ms). In random switching similar pattern was found, when RSI increased from 200 to 600 ms RT switch cost decreased significantly (t (29) = 2.09, p< .045, r = .27) from 109.6 to 89.87 ms. However unlike in predictable condition, reduction in switch cost continued in random condition and reached to 72.23 (t (29) = 2.33, p< .03, r = .47) with increase in RSI (1,000 ms). The interaction of RSI and switch type was not significant, F(2,116) = 1.61, p= .205, i.e RSI reduced time switch cost in both switch conditions (see Figure 2).Significant differences were found between repeat and switch trials at each level of RSIs in both switch conditions. Time switch cost was significantly larger in predictable than random switching at each level of RSI. None of the terms of the ANOVA performed with the accuracy switch cost data reached significant.

Discussion

The present study has replicated the findings of previous researches. The overall performance is better in predictable switch condition in comparison to random switch condition. Tornay and Milan (2001), Monsell et al. (2003), and Andreadis (2010) have similar type of findings in their studies. In contrast with these studies, present study use two different participant groups for performing predictable and random switches. Thus, it can be said that irrespective of how task predictability is manipulated, it yields similar results. Further analysis of data reveals that performance on repeat trials is a major reason of difference between these two switch conditions. Separate analysis for repeat and switch trials also confirm this repetition benefit. It is found that on switch trials, performance is similar in both switch conditions, but on repeat trials, performance is significantly better in predictable switch condition. Random switches often requires more than one repeat trials to recover from task switching, whereas in predictable switching single repeat trial is sufficient to remove the disruption of task switching (Andreadis, 2010; Milan, Sanabria, Tornay, & Gonzalez, 2005; Monsell, Sumner, & Waters, 2003; Tornay & Milan, 2001). It is therefore suggested that whenever a cueing paradigm is used data should be analyzed by position in run, taking all repetitions into account. Moreover performance is better in predictable switch condition but switch cost is found lower in random switching. This result is in accordance with previous findings (Andreadis, 2010; Altmann, 2007; Monsell, Sumner, & Waters, 2003; Tornay & Milan, 2001). Altmann (2007) further suggested that alternating-runs switch cost (ARS) would be higher than explicit-cuing switch cost (ECS) because ARS appears to include both the costs of switching tasks and switching-independent cost specific to the first trial of a run.

Preparation effect is investigated in this study along with task predictability. The results of present study also reveals that time given for preparation improves all performance measures and preparation also reduces switch costs, thus, supporting previous findings (Monsell, Sumner, & Waters, 2003; Nieuwenhuis & Monsell, 2002; De Jong, 2000; Meiran, 2000a; Meiran, 2000b; Meiran, Chorev, & Shapir, 2000; Meiran, 1996; Rogers & Monsell, 1995). There is significant reduction in time switch cost in predictable switching when RSI increase from 200 to 600 ms, afterwards reduction is negligible with RSI increases upto 1,000 ms, similar. In random switching preparation tends to reduce time switch cost even when RSI is increases further to 1000 ms and preparation reduces switch cost more in random switching (34.1 %) than in predictable switch condition (25.4 %). This finding has its support from Tornay and Milan (2001) who considered that there is more complete task set reconfiguration in random than predictable switches. In the present study, switch trials are significantly slower than repeat trials at each level of RSI. Preparation has improved repeat trials performance along with switch trials performance due to residual cost remained in both switch conditions. There is a possibility of further reduction in switch cost while random switching provided more number of repetitions of the same task and larger preparation time are given.

Thus, the obtained findings suggested that pattern of task-set reconfiguration depends on predictability of the task. Switch cost is higher in predictable switching mainly because of the large performance benefits that accrue on non-switch trials. It seems that cognitive system adopts a more flexible strategy under unpredictable situations at the expense of overall speed and accuracy. This study has insightful implications in understanding of our daily life working and office working where several tasks are performed and continuous switching occurs usually.

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