Priority instruction effects in the magnitude of residual cost with regular task switching sequences

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Date: October 17, 2005

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Abstract

Switching between two different tasks results in an impairment in RT and accuracy known as a switch cost. This cost is the behavioural manifestation of the task set reconfiguration processes that are necessary to perform the upcoming task. There are two different components in switch cost. One of them is called the 'non-residual component' and the other the 'residual component'. The former can be eliminated by an active (endogenous) process of preparation, while the latter can only be eliminated in the presence of the target in the new task. The purpose of this work is to study the nature of the residual cost. We explored whether the residual switch cost is affected by the instructions of the tasks. We manipulated the instructions given to the participants emphasizing accuracy or speed in their responses. According to the stimulus-cued completion hypothesis (Rogers and Monsell, 1995) we expect differences between these groups, with a higher cost in the accuracy one. Nevertheless, the response-cued completion hypothesis (Gónzalez et al., in press) predicts a higher residual cost in the speed priority group. The results showed a similar switch cost in all groups. The implications of this finding are discussed in relationship with the controlled or automatic nature of the processes underlying to the reconfiguration necessary to switch between two different cognitive tasks.

Key words: task switching, task-set reconfiguration, residual cost

1. Introduction

One important psychological issue has to do with how people reorganize their actions when they have to switch between two different cognitive tasks. In order to study this question, psychologists need to design experimental paradigms that isolate the workings of individual processes from the general organization of the processing. A paradigm that has proved useful in this respect involves switching between two or more different tasks with similar cognitive demands.

When people have to switch from one activity to another, there is a transient impairment in performance, which can be measured both as a decrease in accuracy and as an increase in reaction time (RT). Task switching effects are related to a general issue of psychology: They act as an index of the influence of a previous mental state on a subsequent one.

1.1 The switching paradigm

In a typical laboratory situation, it is usual to ask participants to carry out a simple task. The same processes can be linked in different ways in different tasks, even if they share the same stimulus and response sets. Besides, these tasks may demand both common and specific processes. A task set is a particular set of processes, linked together in a certain way. When the task set has to be reconfigured to perform a new task, we term it a 'set switch'. A set switch, whether voluntary or not, involves changing the processing priorities to face a new situation. Our everyday interaction with the environment requires us to change our task sets or processing priorities continuously to solve problems and adapt to changing circumstances.

In 1976, Spector and Biederman took up the paradigm of switch of mental set again (after Jersild, 1927) and obtained similar results in terms of switch cost. They interpreted their results as evidence that the major determinant of switch cost is the extent to which the appearance of the new stimulus provides an effective cue for the task required in a given trial. Allport, Styles, and Hsieh (1994) also employed this paradigm. Since the publication of these studies, the topic has recovered importance and many new studies have been undertaken. Allport et al. carried out a series of experiments where two stimulus ensembles were used. One ensemble consisted of incongruent Stroop colour words (the participants were required to name either the colour of the ink or the word, which were always incongruent with respect to each other), and the other was a set of displays each containing between 1 and 9 tokens of the same digit (the participants were required to name either the digit value or the number of digits, also under incongruent conditions). They found bigger switch costs when participants had to switch task within ensembles. These results agree with the assumption that task switching is easier when the stimulus provides an effective cue for the new required task. Allport et al. interpreted the cost observed when participants switched between two tasks involving different stimuli as a form of "pro-active interference" from a recently adopted task set afforded by the same stimulus type. This is what they called 'task set inertia', and it would only dissipate after several minutes of performing other tasks. Rogers and Monsell (1995) did not agree with this assumption. They carried out a series of experiments to explore the preparation for a new task. They made sure that no differences in either stimuli or responses existed between the tasks. A stimulus pair consisting of a number and a letter was presented on every trial, and participants were asked to respond either to the letter or to the number. Both tasks shared the same set of responses. The two tasks alternated every two trials (except in their last experiment, which will be explained later), so that the experiment consisted of repetitions of four-trial sequences: letter-letter-number-number (LLNN). On each trial within a given sequence the stimuli were presented on different screen quadrants. This allowed participants to keep track of the task required on that trial. Rogers and Monsell's results showed a reliable decrease in switch cost as preparation time increased. However, the cost never vanished, even when very long foreperiods were used.

1.2 Two components in switch costs

Based on these results, Rogers and Monsell (1995) concluded that there are two different components in switch cost. They called one of them the 'non-residual component' and the other the 'residual component'. The former can be eliminated by an active (endogenous) process of preparation, while the latter cannot be eliminated.

In their Experiment 6, Rogers and Monsell (1995) explored the nature of the residual component of cost. In this experiment, the tasks alternated every four, rather than every two trials, which produced eight-trial sequences (LLLLNNNN). Stimuli were presented in different sectors of a circle divided into eight parts. The results of this experiment indicated that the residual cost dissipated after the first repetition trial, so that no further improvement occurred on subsequent repetitions. An explanation of the residual cost in terms of task set proactive interference or mental inertia (Allport et al., 1994) would have predicted a gradual decrease of cost as this inertia dissipated. An account based on an improvement in performance by means of trial-by-trial feedback or retroactive adjustment (micropractice hypothesis, Meiran, 1996; Meiran et al., 2000) would also imply that the decrease takes place on more than one trial. Rogers and Monsell (1995) explained the abrupt disappearance of cost on the first trial by assuming the existence of two different reconfiguration processes: An endogenous, anticipatory process, which is responsible for the non-residual component and which can only achieve part of the reconfiguration; and an exogenous process triggered by the stimulus associated with the task.

The fact that it is not possible to attain a complete endogenous task set reconfiguration is a surprising finding. It hints at the existence of an absolute cognitive limitation for anticipating a change of the task set. Subsequent studies have also found evidence of a switch cost component that does not disappear as preparation time increases (i.e., Dreisbach, Haider, Kawski, Kluwe, & Luna, 1998; Sohn & Anderson, 2001; González et al., in press; Milán et al, 2005).

It has been usual to assume that the appearance of a task-related stimulus is the key feature for cost to vanish. Rogers and Monsell's opinion is that this cost is related to the appearance of a stimulus related to the new task. The appearance of the target would trigger a so-called 'exogenous reconfiguration process'. This is what they called the 'stimulus-cued completion hypothesis'. A similar position about the importance of the stimulus is that adopted by Pösse and Hommel (1998). Stablum, Leonardi, Mazzoldi, Umiltá, and Morra (1994) also agreed with a stimulus-based explanation: They argued that mental reconfiguration always waits for a new stimulus before completion. In their opinion, an exogenous component, reflected in the residual cost with long RSI, and triggered by stimulus presentation would consist of a bottom-up completion of task set reconfiguration.

1.3 Hypotheses and overview of the experiments.

The present studies intended to tackle the following issues. We wanted first to verify the disappearance of residual cost after the first repetition trial and second, to determine the real nature of this component. For these objectives, we made several modifications of the instructions in the switch cost paradigm. In theses studies, our starting point is the hypothesis proposed by Tornay and Milán (2001), Milán and Tornay (2001), González et al. (in press) and Milán et al. (2005). We hypothesized that the response, rather than the stimulus, is the key triggering factor for the exogenous reconfiguration process. A plausible explanation of the abrupt cost disappearance pattern would be to suppose that making a less than optimal response (making an error or responding more slowly than usual) activates negative feedback systems, such as the so-called corollary discharge (e.g., Sperry, 1943; 1950), which may inhibit the interfering previous task set and, thus, eliminate the cost. Such a hypothesis assumes that cost dissipates as soon as the response is made, i.e., after the switch trial, and seems to fit the basic pattern of results better than a stimulus-based interpretation.

In this study, we presented one experiment, comparing three basic conditions. One of the conditions was a replication of the usual procedure in which the abrupt cost disappearance effect was found: predictable switch with more than two-trial sequences and with instructions to respond as quickly as possible but avoiding errors at the same time. We compared this condition with another in which participants were asked to respond as quickly as possible but without taking into account accuracy. In the third condition, the participants were asked to avoid errors overall.

The Stimulus-cued completion hypothesis (Rogers and Monsell, 1995) assumes that the appearance of a task-related stimulus is the key feature for cost to disappear. In a certain way, this hypothesis associates the residual cost with a control process to avoid errors (subjects wait until the stimulus appearance to complete reconfiguration). The response cued completion hypothesis (González et al., in press) explains that nothing except the execution of the pertinent response required to do up the task completes the process of reconfiguration. In this view, residual cost is associated with an automatic effect of negative feedback, and can be consider like a continuous measure of error.

The first hypothesis allows us to predict differences in the residual cost obtained, so in conditions where we emphasize accuracy in the instructions given to the participants we will obtain higher cost than in conditions in which we ask for speed. The second hypothesis predicts a higher cost in the speed priority condition, it means the reverse pattern.

2. Method

2.1 Participants

Thirty three undergraduate students from the University of Granada took part in this experiment. They were given course credit in exchange for their participation. All the participants reported normal or corrected to normal vision.

2.2 Design

We used a repeated-measures design with four independent variables: Instruction, as a between-subject variable, with three levels (speed priority, accuracy priority and control or no priority instructions), with 12 participants in speed and accuracy groups, and 11 participants in the control group; and three more within-subject variables: Task (number vs letter), Number of Repetitions, with three levels: 0 repetition (trials in which the task was different from that on the previous trial), 1st repetition (trials in which the task was the same as that on the previous trial) and 2nd repetition (trials in which the task was the same as that on the two previous trial). The last variable was Congruency, which measured the compatibility between the two items presented in the screen and their respective response: congruent (the two items correspond to the same key), and incongruent (the two items correspond to different keys).

2.3 Apparatus and stimuli

The stimuli were presented on a computer screen controlled by a PC (Pentium III) that was also used to collect participants' responses. We used the E-prime program (Schneider, Eschman and Zuccolotto, 2002) to generate and control the stimulus presentation.

The stimulus consisted in a pair of marks consisting in a letter and a number (A6, 8G, 2D and so on). Previously, and acting as a fixation point, either an at-sign (@) or a dash (#) appeared on the centre of the screen indicating the task that the participants had to perform: letter and number respectively.

2.4 Procedure

Participants had to indicate either whether the letter was vowel or consonant (letter task) or whether the number was odd or even (number task). In both tasks participants were assigned randomly to all the different key combinations and associations between the two categories of responses: "b" key when the number was even and the letter was consonant (or vowel in other mapping), and "n" when the number was odd and the letter was vowel (or consonant). The remaining participants used the reverse stimulus mapping, and they were assigned randomly to every one. They were given a maximum of 3000 ms after the appearance of the stimulus pair to respond before proceeding the next trial. The Response Stimulus Interval (RSI) was 1200 ms, and corresponded to the presentation time of the fixation point. Tasks were alternated every three trials (LLLNNNLLL…). Subjects were assigned randomly to three groups, each with a different set of instructions: Speed, Accuracy and Control groups. The instructions given to the "Accuracy group" were: "Try to respond making the minimum number of mistakes. Be as slow as you need but avoid errors". After every trial, we showed them visual accuracy feedback and a sound feedback in the incorrect trials and in omissions. The instructions given to the "Speed group" were: "Try to respond as quickly as possible. Get faster with practice". We gave response time feedback in every correct answer, and no feedback in omissions and errors trials. In the control condition we gave the participants the usual instructions in RT experiments: "Try to respond as quickly as possible but try to avoid errors at the same time". We gave the participants a sound feedback in error trials and omissions. Prior to the experimental session the participants completed a practice block with sixty trials in order to familiarize with the task. Then, they completed 360 experimental trials separated with a short break.

3. Results and discussion

The RT for correct responses only and the accuracy data were submitted to a three way repeated measures analysis of variance (ANOVA) with the factors Congruency (congruent vs incongruent), Task (letter vs number) and Repetitions (0, 1, 2). The instruction condition or group variable was manipulated between-subjects. Only trials with response times included between 250 ms and two statistic deviations above the mean of each subject were considered in the analysis.

The analysis of accuracy showed a significant effect of instructions manipulations, $F(2,29)=11.31$, MSE=.016, $p<.000$. Subsequent Post-hoc analysis (Tukey HSD) revealed differences between Speed and Accuracy groups, $p<.000$, and between Speed group and Control group, $p<025$. There was a marginal effect of Number of repetitions, $F(2,58) = 2.71$, MSE=.004, $p<.075$. The analysis revealed also a main effect of Task, $F(1,29)= 9.86$, MSE=.003, $p<.004$.

The analysis of the RT data revealed a significant main effect of instruction manipulation, $F(2,29)=4.85$, MSE=337655.29, $p<.015$. Post-hoc test (Tukey HSD) revealed a significant difference between Speed and Accuracy groups, $p<.014$. The analysis revealed a significant main effect of Number of Repetitions, $F(2,58)=21.74$, MSE=6178.94, $p<.000$. Subsequent post-hoc analyses (Tukey HSD) revealed that the difference between 0 and the 1st repetition trial, $p<.000$ and the difference between 0 and the 2nd repetition trial, $p<000$, were statistically reliable. No more variable neither interaction was significant. The interaction Number of repetitions x Instruction manipulation was not significant neither in RT data, $p<.926$, nor in accuracy analysis, $p<.385$.

Insert Figure 1 and Figure 2

We have obtained statistically reliable differences in RT and accuracy data in the three groups, so we can say that our experimental manipulation has been successful. In RT data, we obtained residual switch cost in the three groups, but the instructions of priority did not have any differential effect in the magnitude of the switch cost in any of the three groups. The switch cost disappeared abruptly in all of the groups in the 1st repetition trial.

4. General Discussion

With respect to the current discussion about the relationship between endogenous and exogenous components of switch cost (Sohn and Anderson, 2001; Rubinstein, Meyer and Evans, 2001), we believe that they are not completely independent. According to Rogers and Monsell (1995) the endogenous component represents the activation of the intention to switch the task. This intention cannot be completed before the stimulus onset. Rogers and Monsell concluded that "although task-set reconfiguration can be initiated endogenously, the exogenous trigger of a stimulus attribute associated with a task is needed to complete the process of reconfiguring to perform that task". So, reconfiguration can start endogenously, but exogenous factors associated with the stimulus are the key to completing this process. If the residual cost reflects the time necessary to complete a processing control operation, its magnitude would be higher in the accuracy priority condition. Nevertheless, if the residual cost is the result of an automatic process of negative feedback, and a continuous measure of error, its magnitude would be higher in speed priority condition. Our everyday interaction with the environment demands us to change our task sets or processing priorities continuously in order to solve problems and adapt to changing circumstances. Switch cost can be viewed as the continuous counterpart of action slips (Baars, 1992). It allows a precise measurement of the relative contribution of automatic tendencies and control mechanisms. The execution of the task-relevant response seems to activate a feedback process that informs participants of their behaviour concerning the task at hand. This feedback has a main consequence: in first repetition trials there is a perfect adjustment to switch intentions. This process could be an instance of a negative feedback loop or servomechanism (Rosenbaum, 1991). In other words, the residual cost seems to reflect a corollary discharge. "Corollary discharge...thus represent a formulation of the fact that the nervous system can inform itself about its current state and use this information to monitor and regulate its own activity" (Jeannerod, 1997, p. 168). But we have obtained no difference between the groups, so we can interpret that switch cost does not reflect neither a control operation of processing to avoid errors, nor a tendency to make errors. Residual Switch cost is not affected by the priority instructions. At least, this invariability can support its interpretation as the behavioural manifestation of a strong automatic process.

Figure legends

Figure 1. Mean RT in responding to the target stimuli as a function of the Number of the repetitions factor and the Instructions given to the participants.

Figure 2. Mean percentage of errors in responding to the target stimuli as a function of the Number of the repetitions factor and the Instructions given to the participants.

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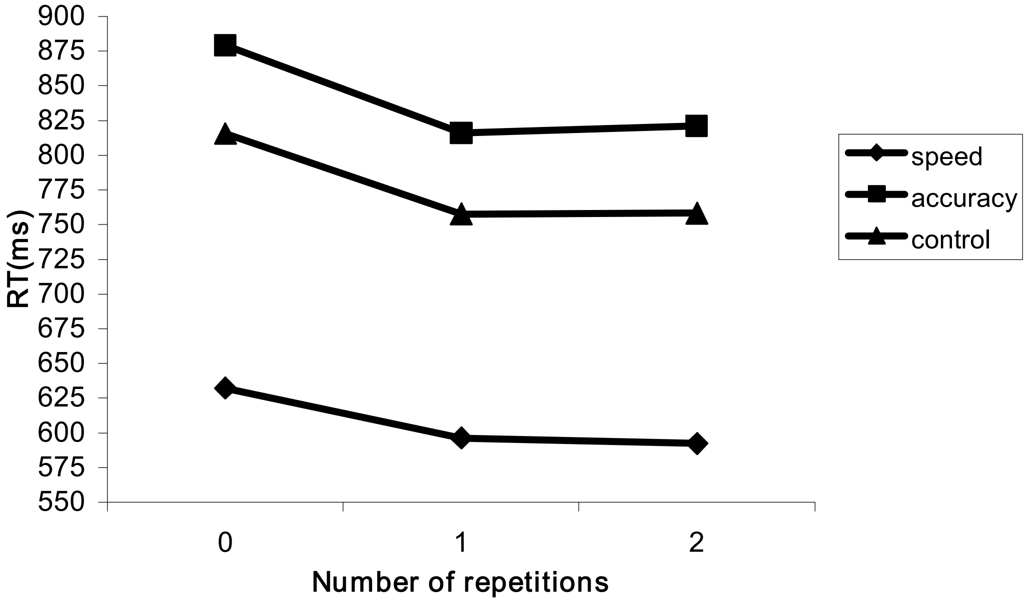
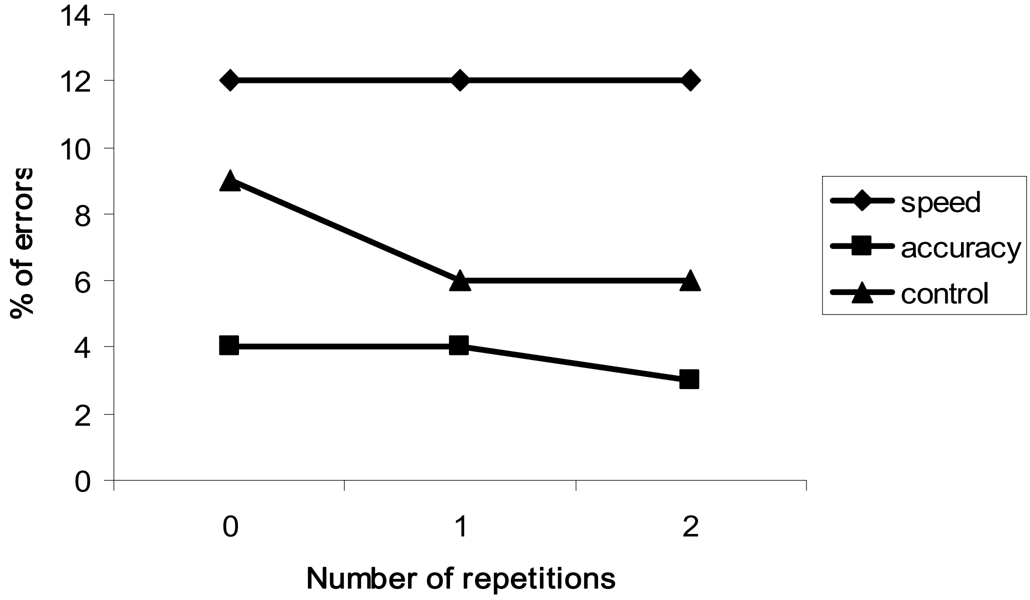
Figure 1



900
875
850
825
800
775
750
725
700
675
650
625
600
575
550
RT(ms)
0
1
2
Number of repetitions
speed
accuracy
control

Figure 2


14
12
10
8
6
4
2
0
% of errors
0
1
2
Number of repetitions
speed
accuracy
control

Author note

This study was supported by the research project BSO2002-02166 from the Ministerio de Ciencia y Tecnología, Dirección General de Investigación.