RUNNING HEAD: SEQUENTIAL EFFECTS IN DEDUCTION

Attentional Effects in deduction: Cost of inference shift

Emilio G. Milán (1), Sergio Moreno-Ríos (1), Orlando Espino (2), Matej Hochel (1) and Carlos Santamaría (2)

(1)Departamento de Psicología Experimental, Universidad de Granada, Spain

(2)Departamento de Psicología Cognitiva, Universidad de La Laguna, Spain

CORRESPONDENCE TO: Emilio G. Milán, Departamento de Psicología Experimental, Universidad de Granada, Campus Cartuja s/n, 18071, Granada, Spain.
E-MAIL: egomez@ugr.es

KEYWORDS: TASK SWITCHING; COST SWITCH; MODUS PONENS; MODUS TOLLENS; COST OF INFERENCE SWITCH; FOCUSING IN DEDUCTION

***SUBMITTED TO**: JOURNAL OF EXPERIMENTAL PSYCHOLOGY: GENERAL*

ABSTRACT

The task-switch paradigm has helped psychologists gain insight into the processes involved in changing from one activity to another. The literature has yielded consistent results about switch cost reconfiguration (abrupt offset in regular task-switch vs. gradual reduction in random task-switch; endogenous and exogenous components of switch cost; cost asymmetry...). In this study we present several experiments in which we investigated the reconfiguration process elicited by task switching between Modus Ponens and Modus Tollens. We found that the switch from one inference to a new one produces an impairment in accuracy as an increase in reaction time (cost of inference switch). Moreover, we found a gradual improvement in Modus Tollens with random sequences and a long response stimulus interval with task repetitions. Both results are compatible with the task reconfiguration hypothesis.

Inferences are necessary for our understanding of the world. The psychology of reasoning is interested in explaining how people make inferences (see, e.g. Braine and O'Brian, 1998; Johnson-Laird and Byrne, 1991; Rips, 1994). However, inferences are rarely made in isolation. To understand the plot of a film or a novel, or to carry out the correct interpretation of a legal text we need a chain of inferences. In this paper we will try to investigate sequential effects in inference making. That is to say, how the production of an inference is influenced by previous inferences. For this purpose we will make use of a method which is novel in the psychology of reasoning: the "task-switch" paradigm from the psychology of attention.

One of the most robust results in conditional reasoning is the difference in difficulty of the two valid inferences: Modus Ponens (MP) and Modus Tollens (MT). The conditional statements are the same in both inferences, but the premise and the conclusion are different. The following is an example of the two kinds of arguments:

MP: If p then q, p therefore q

(1) If there is a vowel, then there is an even number,
There is a vowel,
Therefore, there is an even number

MT: If p then q, not q, therefore not p

(2) If there is a vowel, then there is an even number,
There is not an even number,
Therefore, there is not a vowel.

MP is easier and is made faster than MT (for a review, see Evans, Newstead & Byrne 1993; pp. 35-39). Differences in difficulty have been central to deductive theories, which try to explain them in different ways. However, our main interest focuses on one aspect: it is usually assumed that MP and MT inferences constitute the same task (the inference task; e.g. evaluation task) but with different degrees of difficulty. A central aim in this study is to evaluate whether they really are the same task with different levels of difficulty or if they might be different tasks.

The main reasoning theories (Braine and O´Brian, 1998; Johnson-Laird and Byrne, 1991; Rips, 1994) try to explain the differences in difficulty between these two inferences based on the use of different mental algorithms but they cannot answer our main question clearly. Basically, they all assume that something more is needed to make the MT inference. In the case of mental rules theories, the connective “if then” and the form of the argument call for the activation of mental rules. MP is easier because MT requires the application of an additional rule (e.g., Brain & O’Brian, 1998; Rips, 1994). The mental model theory (Johnson-Laird and Byrne, 1991) assumes that people construct a representation that is a mental model of the statement and the premises. For the MP inference, the conclusion can be evaluated directly by matching the information given with this representation or mental model, but this is insufficient for the MT inference. In the latter case a new operation is required: the fleshing out of the implicit model or, in other words, the search for alternative situations.

Our main goal in this study is to test whether when people solve MP and MT inferences they are carrying out the same task with different degrees of difficulty or they are doing different tasks. Unfortunately, the common experimental procedures used in reasoning cannot help us in this case. However there is a paradigm called “Task switch” used in other areas of cognitive science to study the properties of a task set. In particular, there is a set of behavioural components (see Table 1) that appears only when someone engaged in a task has to change to a different task, but not when they continue doing the same task. Following this logic, the set of behavioural components cited will be shown when people make MP after MT inferences (or vice versa) only if the two tasks are different.

Therefore, using this paradigm will enable us to obtain the results of sequential effects in deduction. How people make inferences after making other inferences has not been systematically studied in reasoning. Also, there are no explicit predictions from the main deductive theories. The apparent lack of a study of sequential effects in deductions is surprising considering the relevance this has in daily life where inferences are not usually made in isolation. To understand what is happening (for example, the intentions of our interlocutors, the plot of a story), we need to make multiple linked inferences. Inferences have to be made quickly when the information is given by an online device, such as when driving using in-car navigation systems. We think this study can also contribute by providing data on sequential effects in deduction.

It is more difficult to explain sequential effects from the psychology of reasoning because there are no specific predictions about the function of the control mechanism and the cognitive operations of mental set reconfiguration to shift from one inference to another. Sequential effect has been studied with the paradigm known as "the task switch cost paradigm". In the last few decades, it has been demonstrated that when one has to switch from one activity to a new one, there is usually an impairment in performance (the switch cost), which can be measured both as a decrease in accuracy and an increase in reaction time (RT; e.g., Allport, Styles, & Hsieh, 1994; Allport & Wylie, 1999; Gilbert & Shallice, 2002; González, Milán, Tornay, & Sanabria, 2002; Meiran, 1996; Meiran, Chorev, & Sapir, 2000; Rogers & Monsell, 1995; Spector & Biederman, 1976; Tornay & Milán, 2001; see Jersild, 1927, for an early study). To investigate such impairment in the laboratory, participants are typically asked to alternate between two simple tasks (i.e., task switch). It has been suggested that in order to perform each of the experimental tasks, participants have to set up and link a number of component processes that connect sensory analysis to motor response (e.g., Monsell, 1996). However these processes can be linked in different ways depending on the demands of the task, giving rise to a *task-set*, that is, a particular set of processes linked in a certain way in order to achieve the goals of a particular behaviour.

In a seminal paper on task switching, Allport, Styles, and Hsieh (1994) interpreted the switch cost reported in their study as a form of ‘proactive interference’ from a recently adopted task-set elicited by the same stimulus type. They called this phenomenon task-set inertia. They also found cost asymmetry (in the shift trials, the switch cost was greater if the easier of the two alternating tasks was performed after the more difficult task). In a different study, Rogers and Monsell (1995) reported a reliable decrease in switch cost as preparation time (i.e., response-stimulus interval or RSI) increased. However, in Rogers and Monsell’s (1995) study, the switch cost never vanished, even when a long RSI was used. They concluded that there are two different components in switch cost: one endogenous component that can be eliminated by an active process of reconfiguration (i.e., one that acts during the RSI) and another that cannot (i.e., residual cost). In order to investigate the nature of this so-called residual component of the switch cost, Rogers and Monsell conducted a different experiment (1995, Experiment 6). Interestingly, the results showed that the residual cost disappeared after the first repetition trial after a task shift trial, so that no further improvement occurred in subsequent task repetitions. Rogers and Monsell explained the abrupt disappearance of the switch cost in the first task repetition trial by assuming an exogenous process triggered by the stimulus associated with the task, which eliminates the remaining switch cost (i.e., *cued-stimulus completion hypothesis*).

Although different studies have also found evidence of a switch cost component that does not disappear as preparation time increases (e.g. Dreisbach, Haider, Kawski, Kluwe, & Luna, 1998; Gilbert & Shallice, 2002; Gonzalez et al., 2002; Gopher, Armony, & Greenspan, 1998; Ruthruff, Remington, & Johnston, 2001; Sohn & Anderson, 2001), a different conclusion emerged from the work reported by Meiran (1996). He conducted a series of experiments using a paradigm similar to that of Rogers and Monsell (1995), showing that participants could prepare for the subsequent task to a greater extent than in Rogers and Monsell's study. However, there was an important difference between Rogers and Monsell's (1995) and Meiran's (1996) paradigms. While in Rogers and Monsell's study, tasks switched in a predictable manner, in Meiran's study they switched at random. Therefore, given that Meiran found a complete reconfiguration of the task-set in his study compared to the results reported by Rogers and Monsell, one might argue that random task switch results in a more complete reconfiguration of task-set. Relevant to the purposes of the present study is an investigation reported by Tornay and Milan (2001). The authors tried to investigate the nature of the residual component of the switch cost by using three-trial sequences and analysing the effect of number of repetitions in the random and the predictable conditions with short and long RSI. The RT data in the predictable switch condition replicated the pattern of results of Rogers and Monsell's (1995) study, that is, the switch cost dissipated after the first repetition trial. However, the random switch condition led to a different conclusion. The data showed that with long RSI, the difference between task switch and task repetition trials did not reach significance and that with short RSI there was no abrupt disappearance of switch cost but a more gradual decrease with the number of task repetitions overall (Milán, Sanabria, Tornay & González, 2005). These data are consistent with the idea that most of the switch cost in the random condition in Tornay and Milan's study disappears during the RSI, before the first repetition trial.

Tornay and Milan (2001) interpreted the difference between random and predictable switch conditions by noting that the random switch condition produces more uncertainty about what the next task will be. This particular feature has been shown to activate the anterior cingulate cortex, and the prefrontal cortex, which, in turn, have been associated with attentional or control mechanisms (e.g., Eslinger & Grattan, 1993; Pardo, Pardo, Janer & Raichle, 1996; Sohn, Ursu, Anderson, Stenger, & Carter, 2000). Therefore, it is possible that the random switch condition in Tornay and Milan's investigation elicited a more attentional or controlled processing, resulting in a suppression of the current task-set if enough time was allowed. In keeping with this idea, the authors suggested the existence of a greater weight of endogenous processes of reconfiguration of the task-set in the random switch condition than in the predictable switch condition. Conversely, the results in the predictable switch condition suggested that the exogenous process of reconfiguration had a greater weight. See Table 1 for an abstract of the main results with the task switch cost paradigm.

TABLE 1 ABOUT HERE

The aim of the present studies was to tackle the following issues. First, we wanted to verify whether there is task set reconfiguration (Cost of Inference Switch or CIS) between Modus Ponens and Modus Tollens (Experiments 1 and 2). If so, we should consider these inferences as different tasks. To ensure that the proactive interference obtained between the two Modus acts is equal to the mental inertia (Allport et al. 1994; Milán et al. 2005) between any two single tasks, we also tested whether the switch cost between MP and MT fulfils all the main characteristics of the task switching cost in the following experiments, such as cost reduction with long RSIs, cost asymmetry, residual cost with predictable sequences but not with random sequences, the disappearance of residual cost after the first repetition trial, etc. (See Table 1).

Our second goal (Experiments 3, 4a and 4b) was to determine whether sequential effects could affect the difficulty of MT under certain circumstances, following Legrenzi, Girotto and Johnson-Laird's (1993) interpretation of the effect of "focusing" in deduction. These authors maintain that differences between MP and MT depend on what information is focused on initially. MP inferences can be drawn with a focus on the initial models of the conditional premise: the major premise is at the centre of the mental focus, and the categorical premise matches this initially represented information. However, for MT inferences, the representation being focused on must be discarded; fleshing-out is needed to find a new model that matches the categorical premise. In other words, attention must be refocused in MT. For a sequence of repeated MP inferences we could expect less intervention by the attentional mechanism than for repeated MT inferences. In the present study we are interested in analysing what happens when the sequence mixes the two kinds of inference. In the case of random sequences of inference shifting, particularly with long RSI, the uncertainty should demand a greater involvement of the central executive or attentional mechanism. At the same time the central executive should have enough time to complete a control operation (because of the long RSI) with the possible effect of eliminating proactive interference from the previous task-set (in other words, a full endogenous reconfiguration was expected). A collateral effect could be to discard the initial models of the conditional premise (the major premise is at the centre of the mental focus in MP) and to activate the fleshing out to find a new model that matches the categorical premise. In short, a potential effect with random sequences of inference switch and long RSI could be to make MT easier.

Experiment 1

The goal of Experiment 1 was to investigate the nature of mental-set reconfiguration processes for MP and MT switch. As noted above, we used a short RSI, in order to maximise the probability of obtaining a significant switch cost, with predictable switch sequences; we also predicted that the switch cost would dissipate after the first repetition of the same task (same inference), suggesting that the appearance of the stimuli would be highly relevant for the complete reconfiguration of the task-set (cued-stimulus completion hypothesis). We also expected cost asymmetry (a bigger cost in the easier task, in this case MP).

Method

Participants. 40 undergraduate students randomly assigned to any of the three following experiments. All experiments were run at the same time in different rooms. 10 undergraduate students (5 women, 5 men) from the University of Granada took part in Experiment 1. They were given course credits in exchange for their participation. All the participants reported normal or corrected-to-normal vision.

Design. We used a repeated-measures design with two independent variables. Both of these varied on a trial by- trial basis: Inference (MP vs. MT), and Number of repetitions, which had three levels: 0 (trials in which the inference was different from that of the previous trial), 1 (trials in which the inference was the same as that of the previous trial) and 2 (trials in which the inference was the same as that of the two previous trials).

Apparatus and stimuli. The stimuli were presented on a computer screen controlled by a Pentium III computer, also used to collect participants' responses. We used the MEL program (Schneider, 1988) to generate and control the stimuli presentation. The participants sat in comfortable chairs, in a dimly-illuminated room while conducting the experiment.

In every trial, a plus sign (+) appeared in the centre of the screen. The sign subtended 1.5° x 1.5° of visual angle. Later in the trial, a first stimulus (1.5° x 1.5°), consisting of a letter or a number, was presented on the left-hand side of the screen, 2° of visual angle from the fixation point. A second stimulus, also a letter or a number, was presented later, to the right of the fixation point. We manipulated the interval between fixation point and first stimulus, and between first and second stimuli, as will be explained later. The stimulus pair remained on the screen until the end of each trial.

Procedure. Participants were asked to perform one task. They had to indicate whether the two consecutive stimuli followed the law: if vowel, then even (if there is a vowel, then there is an even). The first stimulus appeared 200 ms after the appearance of the fixation point and was an odd number (in the case of MT) or a vowel (in the case of MP). The second stimulus - or target - appeared 400 ms later and was a number or a letter. The participants responded (true or false) by pressing either the “b” or the “n” key on the keyboard. The reverse stimulus-key mapping was used for the remaining half of the participants. Thus, both inferences shared the same stimuli and responses. Each participant was randomly assigned to one mapping or the other. If the target was an odd number, the participant had to press the response “false” in the case of Modus Ponens. The correct response to an even number was “true” for the MP. In the case of MT, the correct response for a consonant-like target was also “true”. A vowel target should elicit the “false” response in the case of Modus Tollens. The participants were given a maximum of 3,000 ms after the appearance of the second stimulus to submit the response before proceeding to the next trial. A tone was used as error feedback. The RSI was 600 ms, a result of adding the first Stimulus Onset Asynchrony (SOA; i.e., the time interval between the fixation point and the first stimulus), which was 200 ms, and the second SOA (interval between the first stimulus and the target stimulus), which was 400 ms.

In the predictable switch condition of Experiment 1, tasks were alternated every 3 trials (e.g., MP-MP-MP/MT-MT-MT sequences). The participants completed 15 blocks of 21 trials, separated by a short rest. Prior to the experimental session, participants completed a practice block of 70 trials in order to familiarise themselves with the task. The data from this block were not considered in the analysis.

In each block, all possible combinations of stimuli (even-vowel, e.g., 4A; even-consonant, e.g., 4B; vowel-odd, e.g., A5; vowel- even, e.g., A4) were presented. Participants were instructed to respond as quickly as possible while trying to avoid errors.

Results and Discussion

The RT (only for correct responses) and the accuracy data were submitted to a two-way repeated-measures analysis of variance (ANOVA) with the factors Inference (MP vs. MT), and Number of repetitions (0, 1, and 2).

The ANOVA of the RT data revealed a significant interaction between Inference and Number of repetitions, *F*(2, 18) = 4.76, *MSE* = 2135.74, $p<.02$, (Table 2). The switch cost (i.e., the difference in RT between 0 repetition trials and 1 repetition trial) was marginally significant in MP, *F*(1, 9) = 4.44, *MSE* = 2150.45, $p<.054$, and MT, *F*(1, 9) = 3.40, *MSE* = 2692.497, $p<.09$. However, the difference between 1 repetition trial and 2 repetition trials did not reach significance in any case where $F<1$. The difference in RT between MP and MT was reliable only for repetition trials, *F*(1, 9) = 6.80, *MSE* = 8504.24, $p<.02$.

Insert Table 2 about here

Analysis of the accuracy data showed a significant main effect of Inference, *F* (1, 9) = 19.57, *MSE* = 191.26, $p<.001$. The interaction between Number of repetitions and Inference reached significance, *F*(2,18) = 4.36, *MSE* = 20.68, $p<.02$ (Figure 1). The switch cost was significant in MP, *F* (1,9) = 20.55, *MSE* = 9.05, $p<.001$, but not in MT, $F<1$. However, the difference between 1 repetition trial and 2 repetition trials did not reach significance in any case where $F<1$. The difference in accuracy between MP and MT was reliable for 0, 1 and 2 repetition trials, *F*(1, 9) = 10.51, *MSE* = 56.49, $p<.01$; *F*(1, 9) = 24.71, *MSE* = 69.25, $p<.0001$; and *F*(1, 9) = 15.15, *MSE* = 106.88, $p<.003$, respectively.

Insert Figure 1 about here

The main conclusions to be drawn from Experiment 1 are that we found CIS and that a different pattern of switch cost reduction was reported depending on the type of inference. The results in the MP condition showed the typical presence of a reliable decrease in RT (and errors) between 0 and 1 repetition trials, and the lack of a further decrease between 1 and 2 repetition trials. This result replicated the previous findings reported in the literature with single task switch (e.g., Gonzalez et al., 2002; Rogers & Monsell, 1995; Tornay & Milan, 2001). However, the MT condition (being the more difficult task) led to a different pattern of results (null cost). In other words, this difference in mental set reconfiguration between MP and MT is an example of switch cost asymmetry, the cost being significant only for the easier task (MP). Therefore, we contend that the results of Experiment 1 confirm Tornay and Milan's suggestions about predictable shift and agree with Rogers and Monsell's exogenous account of task-set reconfiguration.

Experiment 2

Experiment 2 was the same as Experiment 1 except in the RSI value. Here we used a long RSI instead of a short one. In fact, the RSI was introduced as a between-experiments variable. Our main goal was to replicate the previous results and to study the RSI effect in the switch cost. We expected a reduction of switch cost with the long RSI (the endogenous component of mental set reconfiguration) but residual cost (the exogenous component of mental set reconfiguration).

Method

Participants: 10 undergraduates (6 women and 4 men) from the University of Granada, who received course credits for their participation. None of them had participated in Experiment 1. All reported normal or corrected-to-normal vision.

Design. We used the same design as in the previous experiment, the only difference being for the second SOA, which had an RSI value of 1,200ms (200ms for the first SOA as in Experiment 1, plus 1,000ms for the second SOA) and the analysis of RSI as a between-experiments variable.

Procedure. The procedure was identical to that used in Experiment 1.

Results and Discussion

The RT (for correct responses) and accuracy data were submitted to a three-way ANOVA with the factors RSI (short and long), Inference (MP vs. MT), and Number of repetitions (0, 1 and 2). The analysis showed the main effects of RSI, *F* (1, 18) = 7.66, *MSE* = 206266.1, *p*<.01, and Inference, *F*(1, 18) = 13.86, *MSE* = 11148, *p*<.001. Finally, the interaction between Number of repetitions and Inference reached significance, *F* (2,36) = 6.62, *MSE* = 2069.7, *p*<.003 (see table 3). The switch cost was significant in the MP, *F* (2,18) = 7.81 , *MSE* = 1673.2, *p*<.03, but not in the MT, *F*<1. However, the difference between 1 repetition trial and 2 repetition trials did not reach significance in any case where *F*<1. See Table 3.

Insert table 3

Analysis of the accuracy data showed a significant main effect of Inference, *F* (1, 18) = 8.63, *MSE* = 389.23, *p*<.008. The interaction between Number of repetitions, RSI and Inference reached significance, *F*(2,36) = 4.16, *MSE* = 24.307, *p*<.02 (see Figure 2). In the long RSI, the interaction between Inference and Number of Repetitions was significant, *F*(2,18) = 6.83, *MSE* = 18.105, *p*<.006. The switch cost was significant in the MP, *F*(1,18) = 21.05, *MSE* = 13.09, *p*<.0002, but we found switch benefit in MT, *F*(1,18) = 7.42, *MSE* = 8.25, *p*<.02 . However, the difference between 1 repetition trial and 2 repetition trials did not reach significance in any case where *F*<1.The switch cost (the difference between 0 and 1 repetition trials) was shorter in the long RSI than the short RSI in the MP, *F*(1,18) = 5.17, *MSE* = 15.31, *p*<.03.

Insert figure 2 about here

The results of Experiment 2 confirmed the pattern of data obtained in Experiment 1 (a significant CIS with abrupt offset and cost asymmetry). The RSI effect in the magnitude of the switch cost and the significant residual cost confirm the existence of the usual endogenous and exogenous components in mental set reconfiguration between tasks and also between MP and MT.

Experiment 3

Experiment 3 was the same as Experiment 2 except for the introduction of a new between-experiments variable: regular vs. random sequences of Inference shifting. Tornay and Milán (2001) and Milán et al. (2005) showed that a different pattern of switch cost reduction was reported depending on the predictability of the task. Their results in the predictable switch condition showed the typical presence of a reliable decrease in RT (and errors) between 0 and 1 repetition trials, and the lack of a further decrease between 1 and 2 repetition trials. However, the random switch condition led to a different pattern of results. Namely, there was a progressive decrease of RT (and errors) with the number of repetitions of the same task in short RSI and a null cost (the difference between task switch trials and first task repetition trials) in long RSI.

Our main goal here was to replicate these results with inference shift instead of task shift. We expected a reduction of switch cost with the long RSI in both cases but residual cost only in the predictable sequence. In the short RSI, we expected cost abrupt offset in regular task-switch vs. cost gradual reduction in random task-switch. As well as trying to reproduce the complete pattern of task switch cost with the CIS (see again Table 1), we also considered that the main theories of reasoning (Mental Models and Mental Logic) agree in suggesting an attentional explanation for the MT difficulty (but with different algorithms). For the Mental Models theory, MT difficulty is a problem of wrong attentional engagement (focusing) in the initial premises or in other words a problem of mental inertia (proactive interference). For Mental Logic theories, MT resembles controlled processing and MP automatic processing (Scheneider and Shiffrin, 1977). Here we tested the global common attentional hypothesis of MT difficulty and tried to evaluate the algorithms of both reasoning theories. In Experiment 3, the random sequences of inference switch should produce a higher activation of the central executive with the following possible collateral effects: a) defocusing (CIS elimination or sequential effects elimination) and/or b) control of information processing (reducing the MT difficulty: if you put more attentional resources into controlled processing you can do it better). The Mental Logic theory can predict “option b” but not “option a” as a general attentional effect. The studies of task switching cost predict “a” but not “b”, because the difficult task never becomes easier and equal in difficulty to the weaker task with the random task switch through repetitions trials. From the perspective of the theory of the central executive mechanism (Fan, McCandliss, Sommer, Raz & Posner, 2002), both effects “a” and “b” are executive functions, and the central executive must be divided between them, performing both control operations less well. Only the Mental Models theory can predict both “a” and “b” effects because if MT is a problem of defocusing, collateral effect “b” is a natural consequence of effect “a”.

Method

Participants: 20 undergraduates (13 women and 7 men) from the University of Granada, who received course credits for their participation. None of them had participated in Experiments 1 and 2. All reported normal or corrected-to-normal vision.

Design. We used the same design as in the previous experiments, the only difference being the random Inference switch. We had two blocked variables (Predictability of task switch and RSI) and two that varied on a trial by- trial basis (Modus and Number of Repetitions).

Procedure. The procedure was identical to that in Experiment 1 but half the participants completed an experimental session with short RSI (600 ms) and the other half an experimental session with long RSI (1200 ms). In both sessions tasks were switched at random.

Results and Discussion

The RT (for correct responses) and accuracy data were submitted to a four-way ANOVA with the factors: Predictability (regular –Experiments 1 and 2- vs. random – Experiment 3), RSI (short and long), Modus (MP vs. MT), and Number of repetitions (0, 1, and 2). The analysis showed the main effects of RSI, $F(1, 36) = 10.06$, $MSE = 167980.9$, $p<.003$, and Inference, $F(1, 36) = 8.34$, $MSE = 12152.1$, $p<.006$. The interactions between Number of repetitions and Inference reached significance, $F(2,72) = 4.79$, $MSE = 3869.3$, $p<.01$, and between Predictability and Inference, $F(2,72) = 4.67$, $MSE = 12152.1$, $p<.03$ (see Table 4). The switch cost was significant in MP only for the short RSI, $F(1,9) = 14.54$, $MSE = 632.82$, $p<.004$, but not in MT in any RSI where $F<1$. However, the difference between 1 repetition trial and 2 repetition trials did not reach significance in any case where $F<1$. The difference in RT between MP and MT was significant for predictable sequences, but only for 1 repetition trial, $F(1,36) = 12.75$, $MSE = 12152$, $p<.001$, and 2 repetition trials, $F(1,36) = 20.61$, $MSE = 4841.90$, $p<.0001$, and not in the random Inference shift for 0, 1 and 2 repetition trials, $F<1$.

Insert Table 4

Analysis of the accuracy data showed a significant main effect of Inference, $F(1, 36) = 27.53$, $MSE = 343.22$, $p<.0001$. The interaction between Number of repetitions and

Inference reached significance, *F* (2, 72) = 4.19, *MSE* = 21.85, *p*<.01, also the interaction between Predictability, Inference and Number of repetitions, *F* (2, 72) = 7.03, *MSE* = 21.85, *p*<.001, and the interaction between Predictability, Inference, Number of repetitions and RSI, *F* (2, 72) = 2.98, *MSE* = 21.80, *p*<.05. Therefore, we analysed the data for random shift with short and long RSI, excluding the data from Experiments 1 and 2 (regular shift). For random shift, the interaction between RSI, Inference and Number of Repetitions was significant, *F*(2,36) = 7.03, *MSE* = 24.44, *p*<.002. See Figure 3. With the short RSI, the interaction between Inference and Number of Repetitions was significant, *F* (2, 18) = 4.36, *MSE* = 20.68, *p*<.02. The switch cost was significant only in the MP, *F*(1,18) = 6.39, *MSE* = 13.13, *p*<.02. However, the difference between 1 repetition trial and 2 repetition trials did not reach significance in any case where *F*<1. In the long RSI condition, the interaction between Inference and Number of repetitions was also significant, *F*(2,18) = 3.72, *MSE* = 28.20, *p*<.04, but the switch cost was not significant in the MP, *F*<1; only the gradual improvement of accuracy with the number of repetitions in the MT, *F* (1, 9) = 15.89, *MSE* = 16.31, *p*<.003 was significant. The difference in accuracy between MP and MT was not significant with the long RSI for 1 and 2 repetition trials, *F*<1, but was significant for 0 repetition trials, *F*(1,9) = 5.44, *MSE* = 155.22, *p*<.04. However, this difference in accuracy between the two inferences was significant with short RSI for 0, 1 and 2 repetition trials, *F*(1,9) = 10.51, *MSE* = 56.49, *p*<.01; *F*(1,9) = 24.71, *MSE* = 69.25 *p*<.0007; and *F*(1,9) = 15.15, *MSE* = 106.88, *p*<.003, respectively.

Insert Figure 3 about here

Again the main conclusion to be drawn from the previous three Experiments is that a different pattern of switch cost reduction was reported depending on the predictability of the task. The results in the predictable switch condition showed the typical presence of a reliable decrease in RT (and errors) between 0 and 1 repetition trials, and the lack of a further decrease between 1 and 2 repetition trials. Note that this result replicated the previous findings reported in the literature (e.g., Gonzalez et al., 2002; Rogers & Monsell, 1995; Tornay & Milan, 2001). However, the random switch condition led to a different pattern of results. Note that this last result also replicated the previous findings reported in the literature (e.g., Meiran, 1996; Tornay & Milan, 2001; Milán, et al., 2005). Namely, there was a progressive increase of accuracy with the number of repetitions of the same task. The difference from previous studies was that this time the accuracy increase happened for the difficult task. Note that while the pattern of results in the predictable switch condition appeared to agree with Rogers and Monsell's exogenous account of task-set reconfiguration, the results in the random switch condition suggest the need for an attentional explanation: The RSI effect was bigger in the random condition, where there was no residual cost. The central executive operation in the random condition with long RSI produced two effects: a) the elimination of CIS, and b) the elimination of the difference in RT and accuracy between MP and MT, due to the improvement of participants´ performance in the Modus Tollens with the number of repetitions. Only the mental models theory can explain both results.

Experiment 4a

Experiment 4a was equal to Experiment 3 except for the introduction of a new between-experiments variable: Time of presentation (short in Experiment 3 or long in Experiment 4a) and the exclusion of the between-experiments variable, Predictability. Here we ran only random sequences of Modus shifting with short and long RSI. Although in some day-to-day situations, premises are shown with short exposition times (linguistically or visually), traditional deductive tasks have used longer presentation times. One could argue that in the task used in this study, the time allowed for a trial is too short to complete deductive mental operations, particularly those that make MT different from MP (fleshing-out or applying additional mental rules). For this reason, in Experiment 4a we gave participants enough time between trial events to complete cognitive operations. However the trial time used in Experiment 3 was the usual one for RT methodology and attentional tasks. Our main goal here was to replicate the results of Experiment 3 under these new circumstances.

Method

Participants: 20 undergraduates (11 women and 9 men) from the University of Granada, who received course credits for their participation. None of them had participated in Experiments 1, 2 and 3. All reported normal or corrected-to-normal vision.

Design. We used the same design as in Experiment 3, the only difference being in the timing of a trial sequence. We had two blocked variables (Time for presentation, short or long, and RSI) and two that varied on a trial-by-trial basis (Inference and Number of Repetitions).

Procedure. The procedure was identical to that in Experiment 3. With regard to the timing of a trial, the first stimulus appeared 800 ms after the fixation point. The second stimulus appeared 600 ms (Short RSI) or 3,000 ms (long RSI) later. The participants were given a maximum of 5,000 ms after the appearance of the second stimulus to emit the response before proceeding to the next trial. A tone like error feedback was used.

Results and Discussion

The RT (for correct responses) and accuracy data were submitted to a four-way

ANOVA with the factors: Time for presentation (short and long), RSI (Short and long), Inference (MP vs. MT), and Number of repetitions (0, 1, and 2). The analysis of RT showed significant main effects of RSI, *F* (1, 36) = 17.21, *MSE* = 114373, *p*<.0001, and Time of presentation, *F* (1, 36) = 26.07, *MSE* = 1243.22, *p*<.00001. The interactions between Number of repetitions and RSI reached significance, *F* (2, 72) = 4.06, *MSE* = 4419.85, *p*<.02, and between Time of presentation and Number of repetitions, *F* (2, 72) = 5.40, *MSE* = 4419, *p*<.006. With the short RSI, the interaction between Time for presentation and Number of repetitions was significant, *F* (2, 36) = 5.87, *MSE* = 1541.1, *p*<.006. For the long presentation Time, the only significant effect with the short RSI was Number of repetitions, *F* (2, 18) = 12.02, *MSE* = 1893.52, *p*<.004. The switch cost was significant, *F* (1, 18) = 4.47, *MSE* = 1712.39, *p*<.04, and the difference between 1 repetition trial and 2 repetition trials also reached significance, *F* (1, 18) = 5.14, *MSE* = 1417.85, *p*<.03, which implies a gradual cost decrease with the number of repetitions. With the long RSI for both presentation times there were no significant effects of Inference or Number of repetitions and the interaction between them was not significant either, *F* < 1. See Table 5.

\---

Insert table 5

\---

Analysis of the accuracy data showed main effects of Number of repetitions, *F*(2, 72) = 11.32, *MSE* = 29.96, *p*<.0001, and Inference, *F*(1, 36) = 19.09, *MSE* = 229.25, *p*<.0001. The only interaction to reach significance was between RSI, Inference and Number of repetitions, *F* (2, 72) = 7.24, *MSE* = 28.93, *p*<. 001. See Figure 4. With the short RSI, the interaction between Inference and Number of repetitions was marginally significant, *F* (2, 38) = 2.45, *MSE* = 19.64, *p*<.09. With the long RSI, the interaction between Inference and Number of repetitions was significant, *F* (2, 38) = 5.09, *MSE* = 36.57,

$p<.01$. The switch cost was significant in the MP for the short RSI, $F(1, 19) = 7.35$, $MSE = 22.88$, $p<.01$, but not for the long RSI, $F<1$. However, the difference between 1 repetition trial and 2 repetition trials did not reach significance in any case where $F<1$. The switch cost was not significant in the MT for the short RSI, $F<1$. However, for the long RSI for MT there was a gradual increase of accuracy with the number of repetitions, the difference between 0 and 2 repetition trials being significant, $F(1,19) = 6.05$, $MSE = 52.75$, $p<.02$. The difference between MP and MT was significant only for 0 repetition trials, $F(1,19) = 11.98$, $MSE = 103.69$, $p<.002$.

Insert Figure 4 about here

The main conclusion to be drawn from Experiment 4a is the replication of the results of Experiment 3 but with different trial timing: a premise exposition time more similar to that of traditional deductive tasks. We confirm once again a different pattern of switch cost reduction depending on the predictability of the task. The random switch condition leads to a gradual cost offset. We also replicate the progressive increase in accuracy with the number of repetitions in MT. The difference in difficulty between MP and MT disappears with the long RSI with random shift. Deductive reasoning theories maintain that MP inferences can be made easily (almost automatically, even by young children). In contrast, MT inferences require additional operations (more controlled processing). The MT repetition effect obtained in this experiment may be consistent with this interpretation. Only under circumstances in which the activation of the central executive is high (random shift or activation by uncertainty) and there is enough time for a control operation (long RSI), can the MT inference be made easily.

Experiment 4b

Experiment 4b consisted of a re-analysis of Experiments 1 (regular shift and short timing) and 4a (random shift and long timing) in order to study practice and learning effects due to the trial error feedback in variable contexts. The accuracy data in MT were higher than usual in all the experiments (but overall in the case of random shift and long RSI); therefore, we explored these effects.

Results and Discussion

The accuracy data were submitted to a two "two-way" ANOVA, first with the factors: Inference (MP vs. MT) and Block (0 to 15 blocks) in Experiment 1. Second, with the factors: Number of Repetitions (0, 1 and 2) and Block, also for Experiment 1. The first analysis showed main effects of Block, $F(14, 126) = 2.51$, $MSE = 217.53$, $p < .003$, and Inference, $F(1, 9) = 26.83$, $MSE = 915.74$, $p < .0005$. The interactions between Block and Inference reached significance, $F(14, 126) = 2.34$, $MSE = 175.64$, $p < .006$. The Block effect was significant in MT, $F(1, 14) = 3.03$, $MSE = 258.80$, $p < .0004$, but not in MP, $F < 1$. See Figure 5. The second analysis showed that the interaction between Response Repetition and Block was not significant, $F < 1$.

Insert Figure 5

In Experiment 4a, the accuracy data were submitted to the same two-way ANOVAs, first with the factors: Inference (MP vs. MT) and Block (0 to 10 blocks). The analysis showed main effects of Block, $F(9, 81) = 5.26$, $MSE = 172.42$, $p < .0001$, and Inference, $F(1, 9) = 13.81$, $MSE = 299.68$, $p < .004$. The interactions between Block and Inference reached significance, $F(9, 81) = 2.99$, $MSE = 110.68$, $p < .003$. The Block effect was significant in MT, $F(1, 9) = 5.74$, $MSE = 193.61$, $p < .00004$, but not in the Modus Ponens, $F < 1$. The difference in accuracy between MP and MT was significant in blocks

1 to 6, *F* (1, 9) = 11.68, *MSE* = 413.22, *p*<.007, but disappeared in blocks 7 to 10, *F*<1. See Figure 6. With respect to the second analysis, again the switch cost was not affected by practice, *F*<1.

Insert Figure 6

The main conclusion to be drawn from the previous analysis is a clear practice effect in MT. MP reached maximum accuracy from the first block. The trial feedback helped participants to increase accuracy in MT to reach MP performance in the last blocks under variable contexts (random versus regular; short versus long trial timing). However, as usual with single RT tasks, switch cost was unaffected by practice (Milán et al., in press; Pereda et al., submitted). The practice effect was identical in all the experiments and therefore cannot explain the different results obtained for each. We have found a combination of three methods for improving performance in MT: 1. Practice with error feedback. 2. Mental effort or central executive involvement (high activation and enough time to complete a control operation –random shift and long RSI). 3. Sequential effects (inferring after inferring) or Inference shift. None of these alone can explain our results.

General Discussion

The difference in difficulty between making the two valid inferences, MP and MT, has been a central theoretical question in the psychology of thinking. The inference task has commonly been used to test the two inferences. The assumed typology of reasoning tasks (e.g. see Evans, et. al, 1993) includes the inference task but does not treat MP and MT as different tasks. However, in cognitive psychology, “what is a task?” is an empirical question. Testing whether MP and MT are the same or different tasks can help us to a better understanding of their components. More specifically, when people change from one task to another, they show a specific behavioural pattern (see Table 1). This pattern is not shown when they do a different version of the same task that differs in difficulty, stimuli, responses, etc. The results in this study match all the requirements shown in Table 1 and we can therefore say that MP and MT are different tasks.

In short, the most important result to emerge from the present study is that the pattern of Modus-set reconfiguration follows all the main characteristics of the task switching cost. The Cost of Inference Shift or CIS depends on the predictability of the inference shift. Experiment 1 showed that the switch cost was completely eliminated after the first repetition trial in the predictable switch condition, replicating previous findings. However, the random switch condition produced a more gradual reduction of the switch cost over the number of repetitions of the same task, as was shown in experiments 3 and 4a. In fact, by comparing the two main experimental procedures found in the literature (i.e., random and predictable task switch) we demonstrated again that a different pattern of task-set reconfiguration must be involved depending on the predictability of the next task. Furthermore, as suggested by Tornay and Milan (2001), it is very likely that different mechanisms are implicated depending on the switch condition. While the results of the predictable condition in Experiment 1 appear to conform to an exogenous account of the process of task-set reconfiguration (e.g., Rogers & Monsell, 1995), the result in the random switch condition suggests an endogenous account. Further, the results in the random switch condition in the current study tell us a lot about deduction and about how it is influenced by attention, as we explain below.

The main result in the traditional inference task was replicated in all our experiments: MP was made more easily (faster and with fewer errors) than MT. The current task differed from traditional reasoning tasks in two aspects: a short presentation time for the inferences and many inferences made one after another. Actually these two characteristics are frequent in day-to-day life, where inferences are not usually made in isolation. As was shown in Experiment 4a, the basic results of Experiment 3 are replicated when participants are given a longer time for presentation of the premises. The sequential presentation of inferences in this study allowed us to carry out an interesting test.

One might expect that making an inference would have an effect (facilitative or not) on making the next inference. However, sequential effects have never been systematically studied in reasoning (maybe due to the characteristics of classical tasks). Results have shown that regardless of the kind of conditions, in all experiments with error feedback, the difference in difficulty between MP and MT was reduced with practice.

Mental rule theories and Mental model theory explain the difference in difficulty by the fact that MT requires more controlled processing than MP. Mental rule theories assume that MT is made with the same rule as MP but with an additional more complex mental rule. However, mental model theory explains the difference in another way: people not only have to perform an additional operation in MT (search for the right mental model), unnecessary for MP inferences, but in addition, MT requires them to eliminate their tendency to use the wrong initial mental model (defocusing), which they must then discard. Actually, Legrenzi et al. (1993) and Girotto et al. (1997) facilitated MT inferences using a manipulation that helps to defocus. The manipulation consisted of inverting the order in premise presentation to prevent focusing on the wrong mental model. Therefore, from the two groups of theories we would expect a reduction in difficulty of making MT inferences in a condition that involves more attentional resources (the general attentional hypothesis).

Our results partially confirmed the general attentional hypothesis, but not completely. The difference in difficulty between MP and MT disappeared in the random switch condition in some circumstances but not in all. In short RSI trials, the difference remained, shown in both reaction time and accuracy, maybe because there was insufficient time allowed in this high activation condition to complete the control operation. The difference disappeared in long RSI trials but only when the MT inference was preceded by a previous MT inference (in the first and second repetitions).

Therefore it seems that the higher activation of attention in the random switch condition is a necessary condition for eliminating differences between MP and MT but is not sufficient in itself. The sequential effect of the repetition of MT inferences on its own does not eliminate the difference (as is shown in Experiments 1 and 2), but with enough time (long RSI) and with attentional resources (random switch condition) the inertia (of focusing on the wrong initial model) can be overcome.

One interesting aspect of this study is that it contributes to the connecting of traditional studies of inference with studies of other areas in cognition. For example, this study shows that the term “task” frequently used in reasoning does not fit with the criteria used in other areas of cognition to denominate “task”. Actually, applying these criteria, MP and MT are shown as different tasks. Another example comes from the use of sequences of inferences that allow us to study the practice effect and sequential effects in making inferences, and provide us with a way of testing how attention influences the making of an inference. All these effects can help us to understand more about the algorithms for making inferences and maybe to test theories of reasoning. Reasoning theories should at least explain all these effects. Mental model theory seems to fit the present results well but more tests need to be done. Mental rule theories could also fit the present results, maybe assuming directionality in reasoning, as did Rips (1994) in his theory to explain the inertia effect.

References

Allport, A. D., & Wylie, G. (1999). Task-switching: positive and negative priming of task set. In G., Humphreys, J. Duncan, & A. Treisman, (Eds.), *Attention, space, and action: Studies in cognitive neuroscience.* Oxford: University Press.

Allport, A., Styles, E. A., & Hsieh, S. L. (1994). Shifting intentional set: Exploring the dynamic control of tasks. In C. Umiltá & M. Moscovitch (Eds), *Attention and performance XV.* Cambridge, MA: MIT Press.

Braine, M. D. S., & O'Brien, D. P. (1998). *Mental Logic.* Mahwah, NJ:Erlbaum.

Dreher, J.C., Koechlina, E., Omar Ali, S. & Crafman, J. (2002). The roles of timing and task order during task switching. *Neuroimage, 17*, 95-109.

Dreisbach, G., Haider, H., Kawski, S., Kluwe, R. H., & Luna, A. (1998). Facilitory and inhibitory effects of cues on switching tasks. Paper presented at the *X Congress of the European Society for Cognitive Psychology*, Jerusalem, Israel.

Eslinger, P. J., & Grattan, L. M. (1993). Frontal lobe and frontal-striatal substrate for different forms of human cognitive flexibility. *Neuropsychologia, 31*, 17-28.

Evans, J.St.B.T. & Over, D.E. (1997). Rationality in reasoning: the case of deductive competence. *Current Psychology of Cognition, 16*, 3-38.

Evans, J.St.B.T. (2002). Logic and human reasoning: an assessment of the deduction paradigm. *Psychological Bulletin, 128*, 978-996.

Evans, St. B. T., Newstead S. E. y Byrne R. M. J. (1993). *Human Reasoning.* Hove (UK): Lawrence Erlbaum Associates.

Fan, J., McCandliss, B.P., Sommer, T., Raz, A. & Posner, M.I. (2002). Testing the efficiency and independence ofattentional networks. *Journal of Cognitive Neuroscience, 14*, 340-347.

Gilbert, S. J. & Shallice, T. (2002). Task switching. A PDP model. *Cognitive Psychology, 44*, 297-337.

González, A., Milán, E., Tornay, F. J., & Sanabria, D. (2002). Naturaleza ideomotora del coste residual [Idiomotor nature of the residual cost]. Poster presented at the *IV meeting of the Sociedad Española de Psicología Experimental* (Spanish Society of Experimental Psychology), April 18-20, Oviedo, Spain.

Gopher, D., Armony, L., & Greenspan, Y. (1998). Switching tasks and attention policies and the ability to prepare for such shifts. Paper presented at the *X Congress of the European Society for Cognitive Psychology*, Jerusalem, Israel.

Jersild, A.T. (1927) Mental set and shift. *Archives of Psychology, 89*.

Johnson-Laird, P. N., & Byrne, R. M. J. (1991). *Deduction*. Hillsdale, NJ: Erlbaum.

Legrenzi, P., Girotto, V., & Johnson-Laird, P.H. (1993). Focussing in reasoning and decision making. *Cognition, 49*, 37-66.

Meiran, N. (1996). Reconfiguration of processing mode prior to task performance. *Journal of Experimental Psychology: Learning, Memory and Cognition, 2*, 1423-1442.

Meiran, N., Chorev, Z., & Sapir, A. (2000). Component processes in task switching. *Cognitive Psychology, 41*, 211-253.

Milán, E.G., Sanabria, D., Tornay, F. & González, a. (2005). Exploring task set reconfiguration with random task sequences. *Acta Psychologica, 118*. 319-339.

Milán, E.G, González, a., Salazar, E. & Tornay F. (in press). El coste por cambio de la disposición mental. *Lecturas en Psicología Experimental.* SEPEX.

Monsell, S. (1996). Control of mental processes. In V. Bruce (Ed.), *Unsolved mysteries of the mind*, 93-148. Hove: Erlbaum.

Monsell, S., Yeung, N., & Azuma, R,. (2000). Reconfiguration of task set: Is it easier to switch to the weaker task? *Psychological Research, 63*, 250-264.

Monsell, S., Summer, P. & Waters, H. (2003). Task set reconfiguration after a predictable or unpredictable task switch: Is one trial enough? *Memory & Cognition, 31*, 327-342.

Nieuwenhuis, S. & Monsell, S. (2002). Residual cost in task switching: test the failure to engage hypothesis. *Psychonomic Bulletin & Review, 9(1),* 86-92.

Pardo, J. V., Pardo, P. J., Janer, K. W., & Raichle, M. E., (1990). The anterior cingulate cortex mediates processing selection in the Stroop attentional conflict paradigm. *Proceedings of the National Academy of Science, 87*, 256-259.

Pereda, A., Torralbo, A., Milán, E.G. & González, a. (submitted). Practice effects in residual cost. *Perception and psychophysics.*

Rips, L. J. (1994). *The psychology of proof.* Cambridge, MA: Routledge.

Rogers, R. D., & Monsell, S. (1995). Cost of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General, 124*, 207-231.

Ruthruff, E., Remington, R. W., & Johnston, J. C. (2001). Switching between simple cognitive tasks. The interaction of top-down and bottom-up factors. *Journal of Experimental Psychology: Human Perception and Performance. 27*, 1404-1419.

Schneider, W. & Shiffrin, R.M. (1977). Controlled and automatic human information processing: Detection, search and attention. *Psychological Review, 84*, 1-66.

Schneider, W. (1988). Micro Experimental Laboratory: An integrated system for IBM PC compatibles. *Behaviour Research Methods, Instruments, & Computers, 20*, 206-271.

Sohn, M. H. & Anderson, J. R. (2001). Task preparation and task repetition: two component model of task switching. *Journal of Experimental Psychology: General, 130*, 764-778.

Sohn, M. H., Ursu, S., Anderson, J. R., Stenger, V. A., & Carter, C. S. (2000). The role of prefrontal cortex and posterior parietal cortex in task switching. *Proceedings of the National Academy of Sciences of the USA. 97*, 13448-13453.

Spector, A., & Biederman, I. (1976). Mental set and mental shift revisited. *American Journal of Psychology, 89*, 669-679.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643-662

Tornay, F. J., & Milán, E. G. (2001). A more complete task-set reconfiguration in random than in predictable task switch. *The Quarterly Journal of Experimental Psychology A, 54*, 785-803.

Yeung, N. & Monsell, S. (2003). Switching between tasks of unequal familiarity: The roles of stimulus attribute and response set selection. *Journal of Experimental Psychology: Human Perception & Performance, 29 (2)*, 455-469.

ACKNOWLEDGMENTS

This study was supported by a grant from the Ministerio de Ciencia y Tecnología, Dirección General de Investigación (BSO2002- 02166) to Emilio G. Milan, and BSO2003-08941 to Carlos Santamaría. Correspondence regarding this report should be directed to: Emilio G. Milán, Departamento de Psicología Experimental, Universidad de Granada, Campus Cartuja s/n, 18071, Granada, Spain

FIGURE CAPTIONS

Figure 1. Graph showing the mean Accuracy in responding to the target stimuli in Experiment 1 (regular shift with short RSI), as a function of the Inference and the Number of repetitions factors.

Figure 2. Graph showing the mean Accuracy in responding to the target stimuli in Experiment 2 (regular shift with long RSI), as a function of the Inference and the Number of repetitions factors.

Figure 3. Graph showing the mean Accuracy in responding to the target stimuli in Experiment 3 (random shift), as a function of the Inference, the Number of repetitions and RSI factors.

Figure 4. Graph showing the mean Accuracy in responding to the target stimuli in Experiment 4 (random shift with long Timing), as a function of the Inference, the Number of repetitions and RSI factors

Figure 5. Graph showing the mean Accuracy in responding to the target stimuli in Experiment 1 (regular shift with short RSI), as a function of the Inference and block factors.

Figure 6. Graph showing the mean Accuracy in responding to the target stimuli in Experiment 4 (random shift with long Timing), as a function of the Inference and the block factors.

Table 1. Summary of the main results with the task switch cost paradigm.

RESULTS WITH THE TASK SWITCH PARADIGM	HYPOTHESIS	EXPECTED STATISTICAL RESULT	RELEVANT REFERENCES	TESTED IN THIS STUDY:
1) Task switch cost	Cost of Inference Switch (CIS) in our study	Significant difference between 0 task repetition and 1 task repetition trials	Jersild (1927). Spector and Biederman (1976). Allport et al. (1994). Roger and Monsell (1995).	Experiments 1 to 4
2) Cost asymmetry	Cost only in the easier task (MP in our study)	Significant interaction between Modus and Number of repetitions	Allport et al. (1994). Monsell, Yeung and Azuma (2000). Tornay and Milan (2001). Yeung and Monsell (2003).	Experiments 1 to 4
3) Two components of cost in regular switch: a)Endogenous b)Exogenous	a) Cost reduction with longer preparation interval b) Abrupt offset of cost	a) Significant interaction between RSI and Number of repetitions b) No differences between 1 and 2 repetition trials	Rogers and Monsell (1995). Tornay and Milán (2001). Nieuwenhuis and Monsell (2002).	Experiment 2
4) Different pattern of mental set reconfiguration in regular versus random sequences of task switch.	Significant cost in short RSI in both regular and random switch. Significant cost in long RSI only for regular switch. Random switch: a) Gradual offset of cost with task repetitions b) Null cost in long RSI	Significant interaction between Predictability, Number of repetitions and RSI. Random Switch: a) Linear trend between 0, 1, 2 repetition trials b) No significant differences between 0 to 1 repetitions in long RSI	Meiran (1996). Tornay and Milán (2001). Dreher et al (2002). Monsell, Summer and Waters (2003). Milán et al. (2005).	Experiments 3 & 4

Table 2. Response time in Experiment 1, as a function of the Inference (MP and MT) and the Number of repetitions factors.

	Inference	
Repetitions	MP	MT
0	520	542
1	477	584
2	485	565

Table 3. Response time in Experiment 2, as a function of the Inference (MP and MT) and the Number of repetitions factors.

	Inference	
Repetitions	MP	MT
0	408	433
1	365	457
2	361	450

Table 4. Response time in Experiment 3, as a function of the Inference (MP and MT), the Number of repetitions and the RSI factors.

	Short RSI (600ms)		Long RSI (1200ms)	
	Modus		Modus	
Repetitions	MP	MT	MP	MT
0	545	546	419	400
1	497	557	394	433
2	516	551	461	444

Table 5. Response time in Experiment 4, as a function of the Inference (MP and MT), the Number of repetitions and the RSI factors.

	Short RSI (600ms)		Long RSI (1200ms)	
	Modus		Modus	
Repetitions	MP	MT	MP	MT
0	690	712	492	490
1	657	708	475	508
2	640	689	511	509

Figure 1. Graph showing the mean Accuracy in responding to the target stimuli in Experiment 1 (regular shift with short RSI), as a function of the Inference and the Number of repetitions factors.

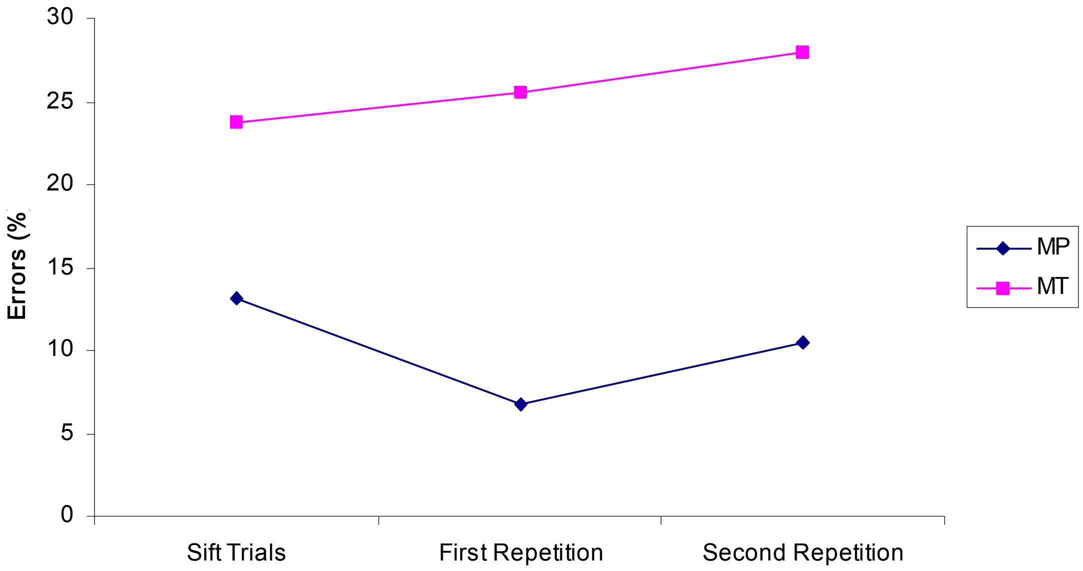


Figure 2. Graph showing the mean Accuracy in responding to the target stimuli in Experiment 2 (regular shift with long RSI), as a function of the Inference and the Number of repetitions factors.

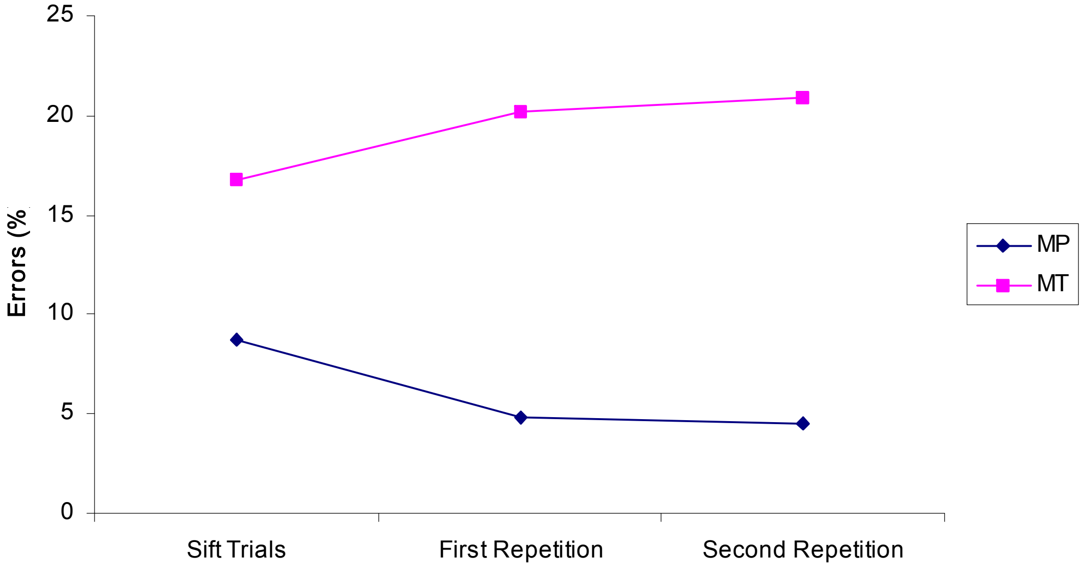
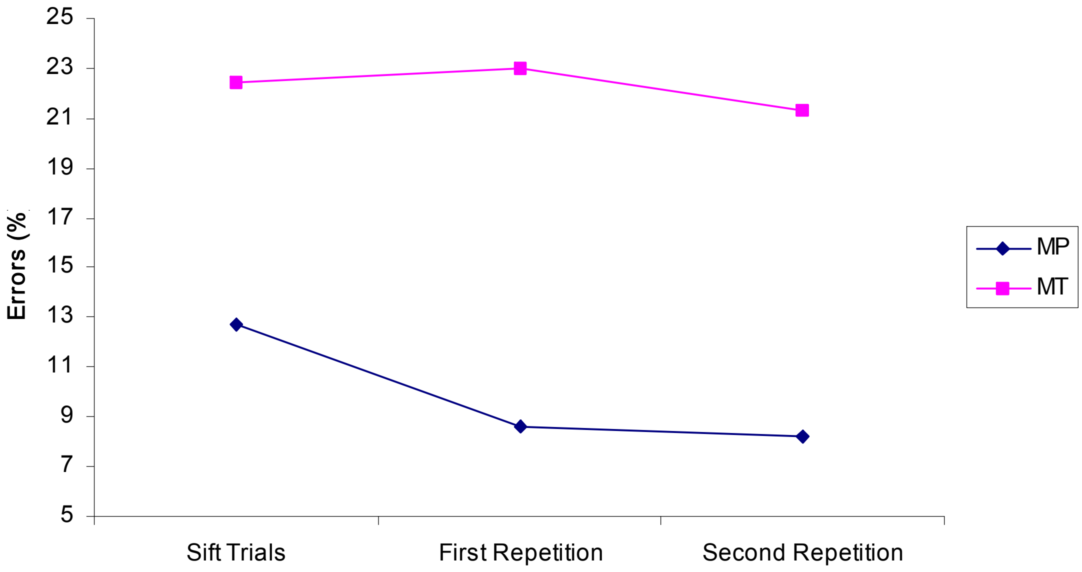


Figure 3. Graph showing the mean Accuracy in responding to the target stimuli in Experiment 3 (random shift), as a function of the Inference, the Number of repetitions and RSI factors.

Short RSI



Long RSI

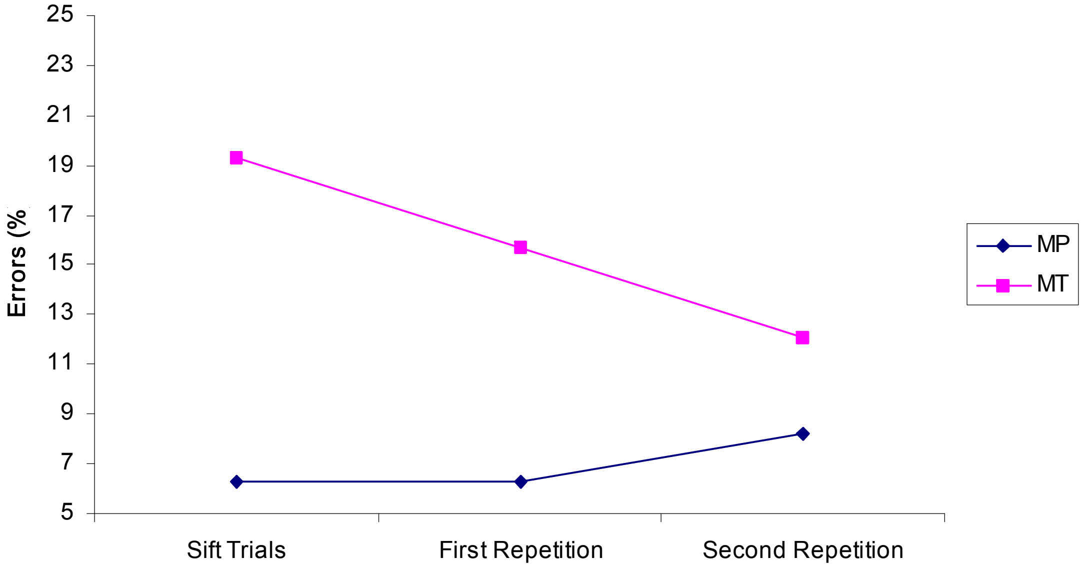
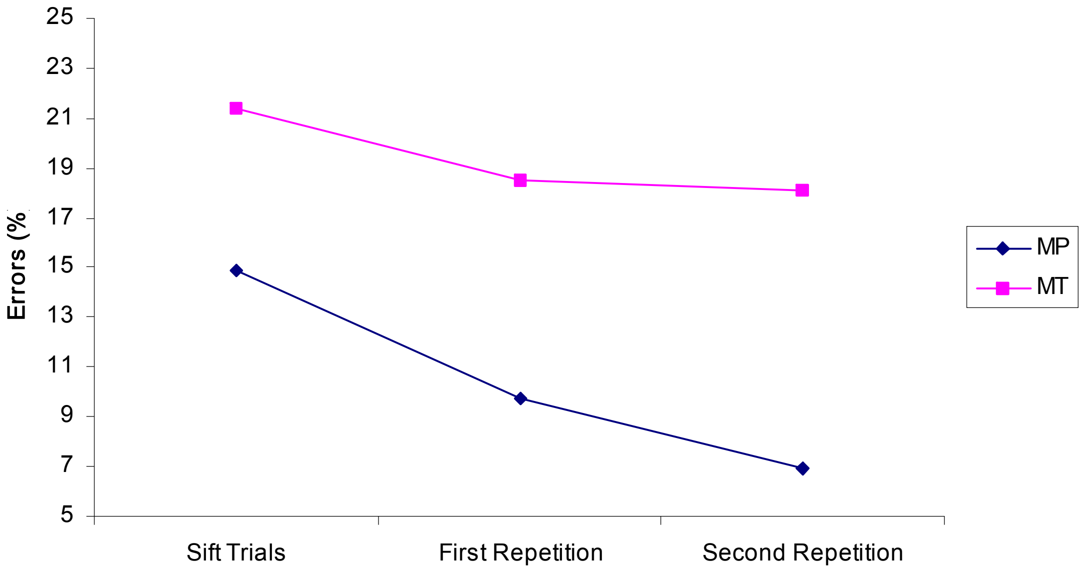


Figure 4. Graph showing the mean Accuracy in responding to the target stimuli in Experiment 4 (random shift with long Timing), as a function of the Inference, the Number of repetitions and RSI factors

Short RSI



Long RSI

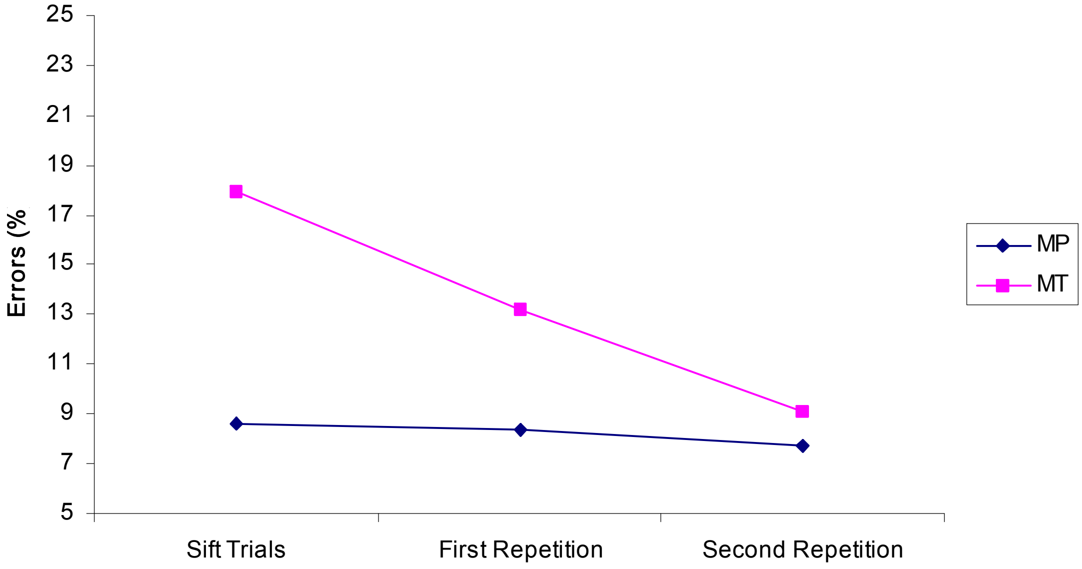


Figure 5. Graph showing the mean Accuracy in responding to the target stimuli in Experiment 1 (regular shift with short RSI), as a function of the Inference and block factors.

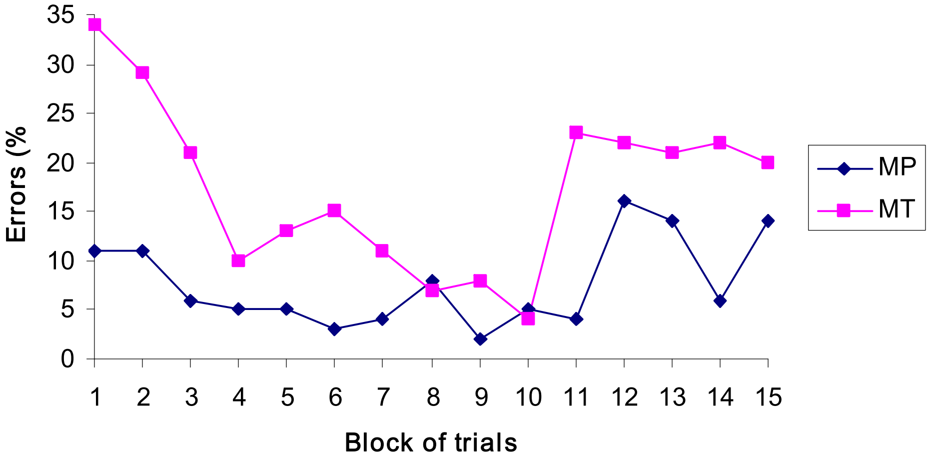


Figure 6. Graph showing the mean Accuracy in responding to the target stimuli in Experiment 4 (random shift with long Timing), as a function of the Inference and the block factors.