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Practice effects in task-set switching costs. Group and single-case studies.

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Abstract

This study aims to study the nature of residual task-switching costs, that is, the impairment in performance usually observed when switching between two different tasks, when long preparation times for the shift are allowed. It is widely believed that this cost reflects an invariant feature of the cognitive system. We assume that if this residual cost is such an automatic process, it should not be affected by the amount of practice acquired in this switching situation. We address this question in two experiments, the second being a single-case study, in which we have a participant switching between performing two different tasks. In both experiments, participants perform a large number of trials in order to account for any possible practise effect. The results show that switching costs are indeed very resistant to practice, however, in certain conditions (when the target stimulus is a cue for the task at hand) there is a certain amount of improvement on the early stages of practice which seems to affect in the same amount both components of this effect. The results show as well that females are more vulnerable to these switching costs.

KEYWORDS: ATTENTION, TASK SWITCHING, TASK-SET RECONFIGURATION, RESIDUAL COSTS, PRACTISE EFFECTS.

Practice effects in task-set switching costs. Group and single-case studies.

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). It is the switch cost. 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.

The switching paradigm

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. Rogers and Monsell (1995) 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.

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.

The fact that it was not possible to attain a complete endogenous task set reconfiguration was a surprising finding. It hinted 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., Sohn & Anderson, 2001; González et al., in press; Milán et al, 2005).

Hypotheses and overview of the experiments.

The main hypothesis was a very simple one, if the assumption that the residual cost reflects an automatic completion of task-set reconfiguration is true, this cost should not have been affected by the amount of practice acquired in performing the experimental task. Similar findings have been made in the context of research with the PRP paradigm (psychological refractory period, see e.g. Pashler, 2000; Meyer & Kieras, 1997, for reviews). The PRP paradigm implies the performance of two tasks almost simultaneously (rather than sequentially, as in the task switching paradigm), participants are shown two stimuli in succession, having to respond to both of them as fast as possible. What is often observed is a progressive slowing of the second response as the interval between the presentations of the stimulus is narrowed, and that this interference is not reduced with practice, fact interpreted as reflecting the existence of a structural cognitive limitation (e.g., Pashler, 2000). Therefore, our research question was straightforward; could the residual switching cost be reduced, or even eliminated, after an extensive practice? We addressed this question in two experiments.

In the first experiment we had our participants performing the experimental situation during one hour on four consecutive days, with two levels of RSI, a short and a long one, respectively supposed to tap each of the two components of the switch cost (see *Introduction*). In this experiment we also included the gender of the participants as a variable. The second experiment was a single-case study in which we had a participant performing four daily sessions of the experimental situation along ten consecutive days.

Experiment 1

Method

Participants

Twelve undergraduate students (six male, six female) took part in this experiment and received course credit in exchange for their participation. Their vision was normal or corrected to normal.

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 stimuli were 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. Both stimuli and fixation points subtended 1.5 x 1.5 degrees of visual angle.

Design

We used a repeated-measures design with four independent variables. Three within-participants: session, with four levels corresponding to each of the four daily experimental session; RSI, with two levels: 400 and 1200 milliseconds; and 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). As the majority of psychology students in Spain are females, we also included the gender of the participants as a variable in order to ensure that the results obtained were fully generalizable.

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, and “n” when the number was odd and the letter was vowel. 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 either 400 or 1200 ms, and corresponded to the presentation time of the fixation point (with a between-blocks manipulation). Tasks were alternated every three trials (LLLNNNLLL…). Participants performed these tasks in sessions of one hour duration during four consecutive days, this involved performing 30 blocks a day, 21 trials per block. Previous to every session there was a short number (30) of warm-up trials which were not considered in the final analyses. Participants were encouraged to respond as fast and accurately as possible.

Results and discussion

The RT for correct responses and the accuracy data were submitted to a four way repeated measures analysis of variance (ANOVA) with the factors session, RSI, number of repetitions, and gender as a group factor (see *Design*). Only trials with response times included between 2 standard deviations around each participant mean were considered in the RT analysis.

The analysis of RT data showed again the main effect of number of repetitions, $F(2, 20) = 32.03$, $p < .00$, with responses on the first and second repetition trials being 100 ms. faster than on the switch trial (see figure 1). The main effect of RSI was marginal, $F(1, 10) = 4.79$, $p < .053$, but it aimed in the usual direction (responses were about 30 ms. faster in long RSI trials). There was also a main effect of session, $F(3, 30) = 9.86$, $p < .0001$, with reaction times decreasing along the four sessions (720, 660, 640 and 620 ms. respectively). However, there were no interactions involving the variable session. A marginally significant interaction was found between the variables gender and number of repetitions, $F(2, 20) = 3.30$; $p < .057$, the switching costs were far more pronounced in females[1]. Finally, a two-way interaction involving the variables gender, RSI and number of repetitions was found, $F(2, 20) = 4.26$; $p < .028$, due to the greater effect of the RSI manipulation on females, that is, whereas for males the reduction in RSI does not affect the magnitude of the cost (around 60 ms. in both levels of RSI), for females there is a clear effect of the RSI manipulation on the cost (230 ms. with short RSI, 150 ms. with long RSI).

The analysis of accuracy showed a significant main effect of the number of repetitions, $F(2,20) = 32.02$, $p < .01$. As expected, accuracy was significantly better (around a 4%) in the first and second repetition trials compared to the switch trial, and no difference was found between the first and second repetition trials (see figure two). The analysis revealed also a main effect of RSI, $F(1, 10) = 8.37$, $p < .016$, the accuracy being slightly higher for the long RSI. There were not main effects or interactions involving the variables session and gender.

Thus the only effect of practice found in this experiment is the main effect on reaction time, but there are no interactions of this variable with the RSI or number of repetitions variables, so it can be said that the level of practice affects neither of the two components of the task switching costs. The data also revealed that female participants

[1] With female participants the reaction times were 787, 698 and 694 ms. for the switch, first and second repetition respectively, whereas for male participants the reaction times were 630, 577 and 571 ms.

were slower overall, showed a greater switching cost and were more affected by the RSI manipulation, we discuss these results further in the last section.

Experiment 2

In Experiment 2, we tried to find practise effects again in the magnitude of the switch cost but with a single case design under different circumstances (in order to assess the generazibility of the previous results) and with more practise levels. Our participant run the experiment four times every day during ten days. The main differences with Experiment 1 were the following ones: 1. The alternating tasks were easier. 2. The target stimulus provided an effective cue for the required task. 3. We used a long RSI only. 4. The task alternated every two trials.

Method

Participants

An undergraduate psychology student (male, 30 years old) from the University of Granada took part in this experiment and received course credits in exchange for his participation. His vision was normal.

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 were presented on the centre on the screen and consisted of the letters *X* and *O*, and the numbers *5* and *2*, Previously, and acting as a fixation point, a dash (#) appeared on the centre of the screen. Both stimuli and fixation points subtended 1.5 x 1.5 degrees of visual angle.

Design

The design we used for the analysis of the practice effect in our participant was the simplest single-case design, a simplified time series analyzed by means of the C-statistic (see e.g., Young, 1941; Suen & Ary, 1989). With this statistic we can assess whether our time series is horizontally stable or rather it shows any evident trend. This statistic does not indicate the direction of the trend when this is present, however, this may be evident in graphic representations of the data.

For the analyses of the usual variables involved in the task switching paradigm we used a repeated measures design in which the experimental sessions are treated as cases, with the only variable being the number of repetitions, with two levels, 0 repetition (trials in which the task was different from that on the previous trial), and 1st repetition (trials in which the task was the same as that on the previous trial).

Procedure

In this experiment we presented two discrimination tasks alternating every two trials. In every trial only the critical stimulus was presented. The participant had to indicate either whether a letter was an X or and O (letter task) or whether a number was a 2 or a 5 (number task). He had to respond with the keys `b´ (2 or O) and `n´ (5 or X), and was allowed a maximum of 3000 ms after the appearance of the stimulus pair to respond before proceeding the next trial. The Response Stimulus Interval was 1200 ms, and corresponded to the presentation time of the fixation point. Tasks were alternated every two trials (LLNNLL…). The participant performed this task in sessions of 350 trials, four times a day, during ten consecutive days, previous to every session there was a short number of warm-up trials which were not considered in the final analyses. Both speed and accuracy were emphasized.

Results

As explained in the section *Design,* we run two types of analyses both for accuracy and reaction time for accurate responses. For the analysis of practice effects, we devised a temporal series with ten points, every point corresponding to a day of practise. As every day involved the performance of four sessions, the points in the time series represented the daily mean of the four sessions. The horizontal stability of the time series was tested by means of the *C* statistic (see e.g., Young, 1941; Suen & Ary, 1989). The second analysis was a one-way ANOVA with the variable number of repetitions as factor and the average results for every session as cases.

The ANOVA for the RT data revealed a main affect of the variable number of repetitions, $F(1, 9) = 10.67$, $p < .009$, due to the repetition trials being in average 33 ms. faster than the switch trials (260 ms. vs. 227 ms.). The *C* statistic was significant both for the average RT, $C = .68$, $p < .008$, and the average switching costs, $C = .61$, $p < .01$, however, a simple visual inspection of the data (see figure three), shows that the greater amount of improvement in both cases occurs between the first and second days of practice. Indeed, when we do not consider the first day in the analyses, the *C* statistic for the mean RT is marginally significant, $C = .46$, $p < .059$, and non-significant for the average switching costs, $C = .16$, $p < .29$, while these costs remain significant, $F(1, 8) = 21.31$, $p < .0001$.

The ANOVA on the accuracy data reflected a main effect of number of repetitions, $F(1, 9) = 6.33$, $p < .032$, with the repetition trials being a 2% more accurate than the switch trials (97% vs 95% accuracy). The *C* statistic was non-significant either for the average accuracy, $C = -.11$, $p < .68$, and the average switching costs, $C = -.08$, $p < .38$.

It is worth noting that in order to ensure that in this experimental conditions the usual pattern of switching costs was obtained (with an endogenous and an exogenous component and with the abrupt dissipation with the RSI manipulation), we previously run a control group of five participants whom performed this experiment in a single sessions with the only differences of the number of repetitions, which in this group was two instead of one (LLLNNN), and the exposition to a short RSI (300 ms.) in addition to the long one. Indeed, we observed the usual pattern, reaction times were 520, 480 and 470 ms. for the short RSI and 440, 415 and 420 ms. for the long RSI, the main effect of number of repetitions was significant, $F(1, 4) = 8.34$, $p < .044$, as was the interaction between RSI and number of repetitions, $F(1, 4) = 18.96$, $p < .01$. Under the light of these results, we decided to use only two repetitions in the single-case experiment, as the first and second repetition trials in the control group did not differ, thus permitting us to better observe the evolution of the switching costs across sessions (see figure 3).

General Discussion

Before making reference to the practice effects, we should mention the effect of gender found in experiment 1. The reaction time data in this experiment reveal that female participants are slower overall, show greater switching costs, and benefit more from a larger preparation time. There are claims in the literature about the larger size of the *corpus callosum* in women (e.g., Allen, Richey, Chai & Gorski, 1999; De Lacoste, Adesanya & Woodward, 1990, but see, e.g., Sullivan, Rosenbloom, Desmond & Pfefferbaum, 2001), this area being the responsible for the communication between cerebral hemispheres. It is possible that, as an effect from the latter, women are more prone to interference than men. Supporting evidence for the last may come from studies showing absence of task switching costs in callosotomy patients (e.g., Ivry and Hazeltine, 2000).

Turning to the central issue in this paper, the only effect of practice in switching costs is the one found on the reaction time data from experiment 2. In experiment 1, as predicted, the residual switch cost is not reduced by practice but, maybe surprisingly, this is also true for the non-residual component, which is supposed to be subject to active task-set reconfiguration (e.g., Rogers & Monsell, 1995). In experiment 2, using an easier paradigm in which our participant had to switch between to discrimination tasks (without ambiguous stimulus presentation, as is usual in the task switching paradigm), we still find a significant residual switching cost. This cost is reduced by practice in the reaction time data, as is the overall reaction time, but further analyses show that this reduction is only significant between the first and second days of practice, while the cost remains significant along all sessions.

A main difference between the two experiments presented in this paper concerns the role of the stimuli as a cue to the task requested, that is, while in experiment 1 stimuli were ambiguous in this respect, in experiment 2 the stimuli were an effective cue for the task to be performed. In this respect, we should consider the possibility of a different nature for the costs observed in both situations (ambiguous vs. cuing stimuli), given the differential effect of practise.

So we have to conclude that, at least in the conditions present in the experiment two, there is a reduction with practice of an effect supposed to reflect an automatic reconfiguration process (e. g., Rogers & Monsell, 1995). However, this effect is limited to the very early practice stages and the cost is never eliminated. Should we consider the possibility of a further division of the residual component of the switching costs regarding its suitability to practice effects? This question clearly deserves further research.

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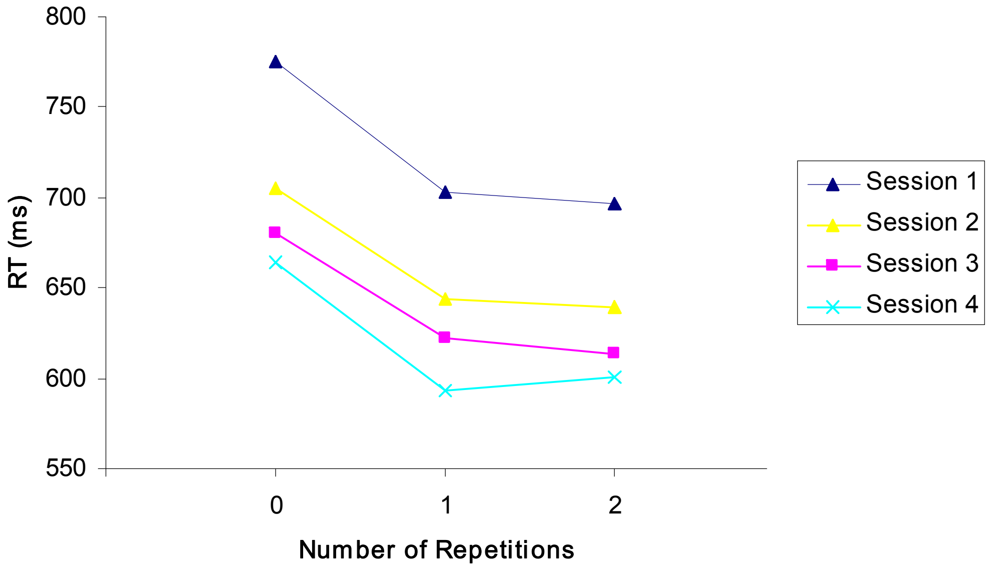
Figure Captions

Figure 1. Mean RT in experiment 1 as a function of the Number of Repetitions variable.

Figure 2. Mean accuracy in experiment 1 as a function of the Number of Repetitions variable.

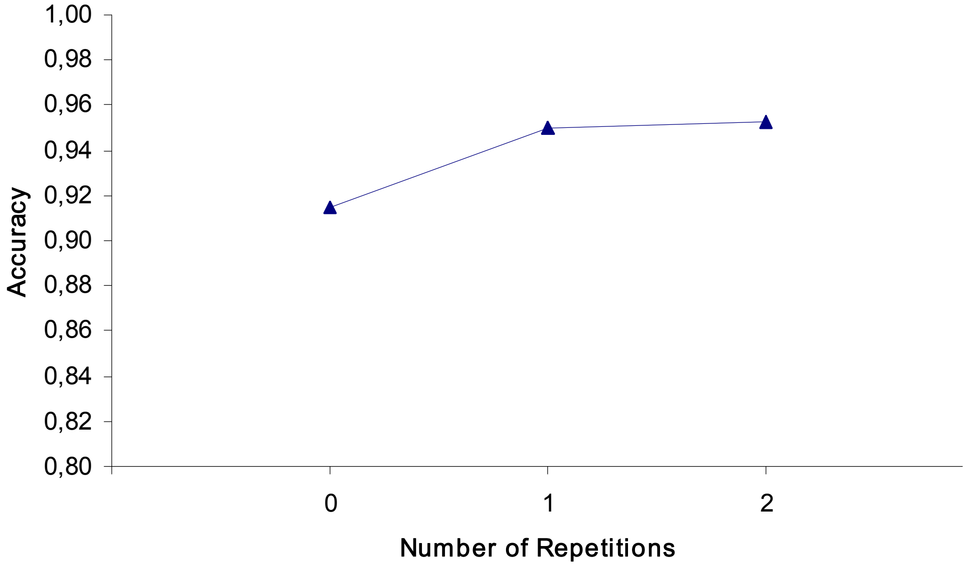
Figure 3. Mean RT (above) and switching costs (below) for the ten days of practice in experiment two.

Figure 1



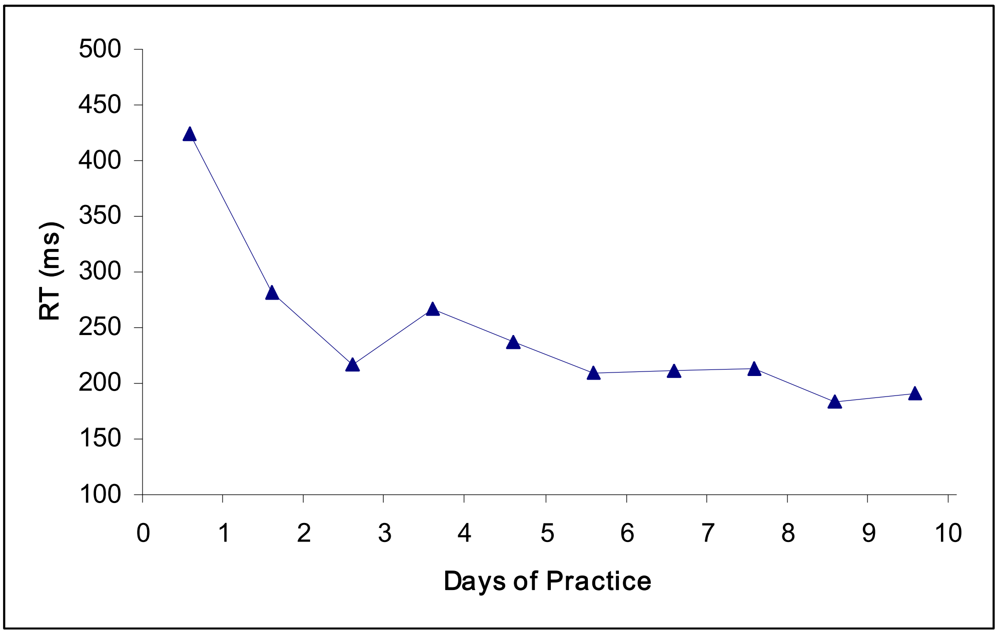
800
750
700
650
600
550
RT (ms)
0
1
2
Number of Repetitions
Session 1
Session 2
Session 3
Session 4

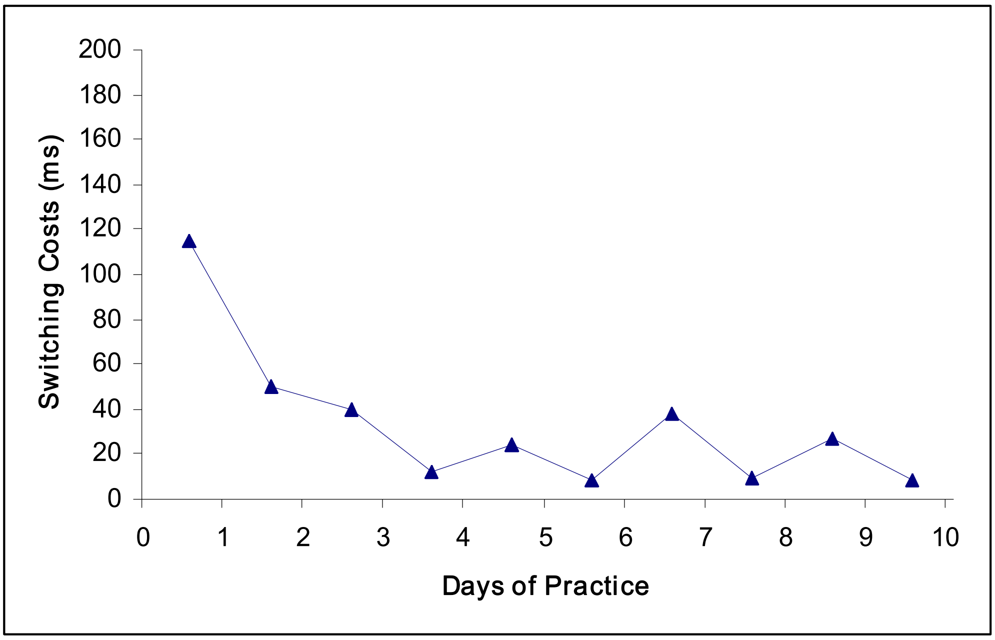
Figure 2



1,00
0,98
0,96
0,94
0,92
0,90
0,88
0,86
0,84
0,82
0,80
Accuracy
0
1
2
Number of Repetitions

Figure 3


500
450
400
350
300
250
200
150
100
RT (ms)
0
1
2
3
4
5
6
7
8
9
10
Days of Practice


200
180
160
140
120
100
80
60
40
20
0
Switching Costs (ms)
0
1
2
3
4
5
6
7
8
9
10
Days of Practice