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# *The Benefit of Directed Forgetting Can Be Improved by Training*

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***Abstract:*** Forgetting invalid information is essential for information updating and directed forgetting can make the memory more effective. But it is not clear whether the benefit of directed forgetting could be improved by training or not. In this work, the effectiveness of directed forgetting is measure by the item statutory directed forgetting paradigm and then compare the recognition correctness (RC) and reaction time (RT) before and after training. This work could provide useful information to fill the gap of whether the effectiveness of directed forgetting could be improved by training. In terms of the mechanism of directed forgetting, this work also provides evidence for the active inhibition theory of directed forgetting.

***Keywords:*** directed forgetting, active inhibition theory, memory effectiveness

## 1. Introduction

### 1.1. Directed forgetting

The main function of the memory system is to remember and forget. Forgetting invalid information is essential for information updating and unnecessary memory traces eliminating. The researches about directed forgetting reveal whether useless information could affect the memory effectiveness of important information [1]. Research on directed forgetting have lasted for more than forty years [2]. It was first proposed and studied by Muter (1995) and paradigms have been established for directed forgetting research. According to the paradigm, certain materials will be presented to the subjects, and some of them must be remembered (TBR) and some of them will be asked to be forgotten (TBF). The direct forgetting research follows the cost-benefit principle: if the performance of remembering items (TBR) is better than that of TBF, which means the directed forgetting effect is a benefit for the memory of special items [3].

### 1.2. Direct forgetting mechanism

The cognitive mechanism of forgetting is complex. Some forgetting occurs passively, while others are active. There are two opposing views on the mechanism of directed forgetting [4]. One is the passive attenuation theory, which holds the opinion that TBF items are not processed as TBR items, so they gradually fade from memory passively without cognitive effort. The other theory is the active inhibition theory, which believes that the forgetting of TBF items is the result of the processing of active inhibition.

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### 1.3. Research paradigms

There are two research paradigms: the item statutory directed forgetting paradigm and the list statutory oblivion paradigm [5]. Both paradigms contain two stages: the encoding stage and the extraction stage. The main difference between the two paradigms lies in the presentation mode of materials in encoding stages. For the item paradigm, the learning items are presented one by one, and the indicators of "forget" or "remember" will appear after each item is presented and subjects are required to remember or forget the learning item according to the indicators. For the list paradigm, the learning items are divided into lists and the indicator appears after all the items in the list were presented. Since most of the research on directed forgetting is based on the item paradigm, this work also use the item paradigm [6].

## 2. Goal

So far, there are not enough studies to show that the effect of directed forgetting on improving memory can be strengthened through practice. This work could further confirm that directed forgetting does improve memory efficiency through repeated studies on directed forgetting. In our experiment, participants in the experimental group will participate in directed forgetting tests (item statutory directed forgetting paradigm) twice with an interval. Whether the effect of directed forgetting can be strengthened through acquired training can be reflected by the correctness and reaction time. This result will not only useful in the application of directed forgetting but also provide evidence for us to reveal the mechanism of directed forgetting.

## 3. Hypothesis

The null hypothesis is that there is no difference in the effectiveness of directed forgetting before and after the exercise

The alternative hypothesis is that there is a significant difference in the effectiveness of directed forgetting before and after training.

## 4. Methods

### 4.1. Participants

All participants were 19 Chinese university students, aged 19 to 22. The average age is 20.47 and the standard deviation is 1.12. All the participants have normal visual acuity without any color blindness or chromatic aberration and they are all native Chinese speakers (Mandarin). Before they participate in the test, they all have already understood the instructions and the procedures. All the participants were voluntary.

### 4.2. Design

First participants would not be asked to do directed forgetting, but would simply be asked to complete a control remembering task. This set of data will be used as a reference to determine whether the benefits of directed forgetting exist. The independent variables for the design are the memory instruction (R vs. F) that followed each encoding item and whether the probe item was a repetition of the encoding item (repeated vs. novel). The dependent variables are recognition correctness (RC) and reaction time (RT) of this group and they will be recorded.

The other is the experimental group. Participants in this group will be asked to take two directed forgetting tests, the first one named pre-DF and the second one named post-DF. Participants' RC and

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RT for TBF and TBR items were recorded during the two tests to determine whether there was a significant difference in the benefits of directed forgetting.

### 4.3. Behavioral task

Firstly, participants are asked to complete a control memory task without directed forgetting and then they will be asked to complete two directed forgetting tasks within one hour and there is a 10-minute interval between each task for participants to rest. Each directed forgetting task contains an encoding and retrieval block.

In the control memory task, the first stage is encoding, in which participants are presented randomly with 36 mandarin words (two characters, selected from the "Modern Chinese frequency Dictionary", the same hereinafter) and they are asked to remember them [7]. After 36 words are presented, participants will have a break (one minute) and during the break, they are asked to do some algorithmic tasks, which make them cannot consolidate their memory. The second stage is the retrieval stage, which is to tests participants' memory. In the second stage, they will be presented with 36 words, including 16 words that have been presented in the first remembering task and the other 16 words are novel. Participants select whether the word is repeated or novel by button press. The reaction time of pressing the button will be recorded as RT. (Figure 1)

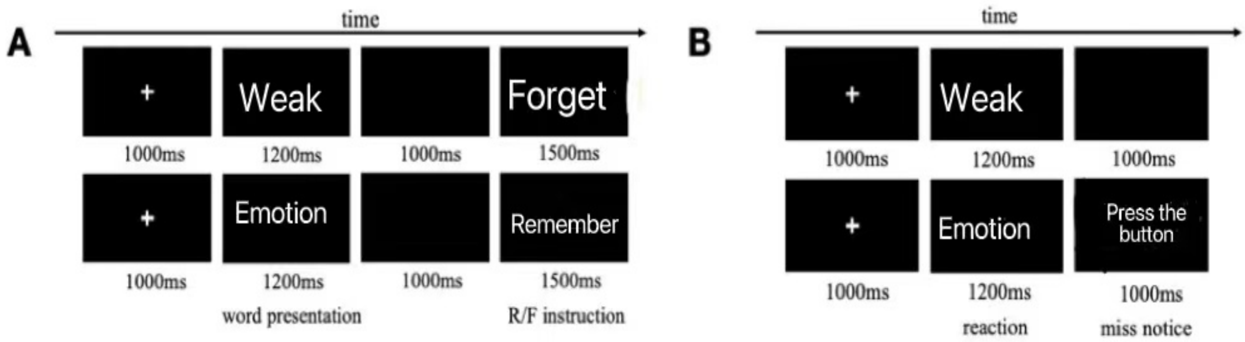


Figure 1: Example of experimental blocks of memorization and recognition. Word presenting sequence in all blocks are fully randomized and balanced. (A) Experimental design of memorization part. Two horizontal sequences each represent remember/forgetting cue during the R/F instruction. (B) Experimental design of recognition part. Subjects are required to reach on keyboard during reacting phase marked blow.

The first directed forgetting task (pre-DF) and the second directed forgetting task (post-DF) also include the same stages as the control memory task. But in pre-DF and post-DF, directed forgetting instructions are added into the encoding stage. In the encoding stage, participants will not only be presented with 36 items but also be instructed to remember or forget the word. (The ratio of remembering instruction to forgetting instruction is 1:1). The break stage and the second retrieval are similar to the control task.

## 5. Result

### 5.1. Result data

The data collected included the RC and RT for 19 participants in control groups and the RC, RT both for TBR and TBF for 19 participants in the pre-DF and the post-DF (Figure 2).

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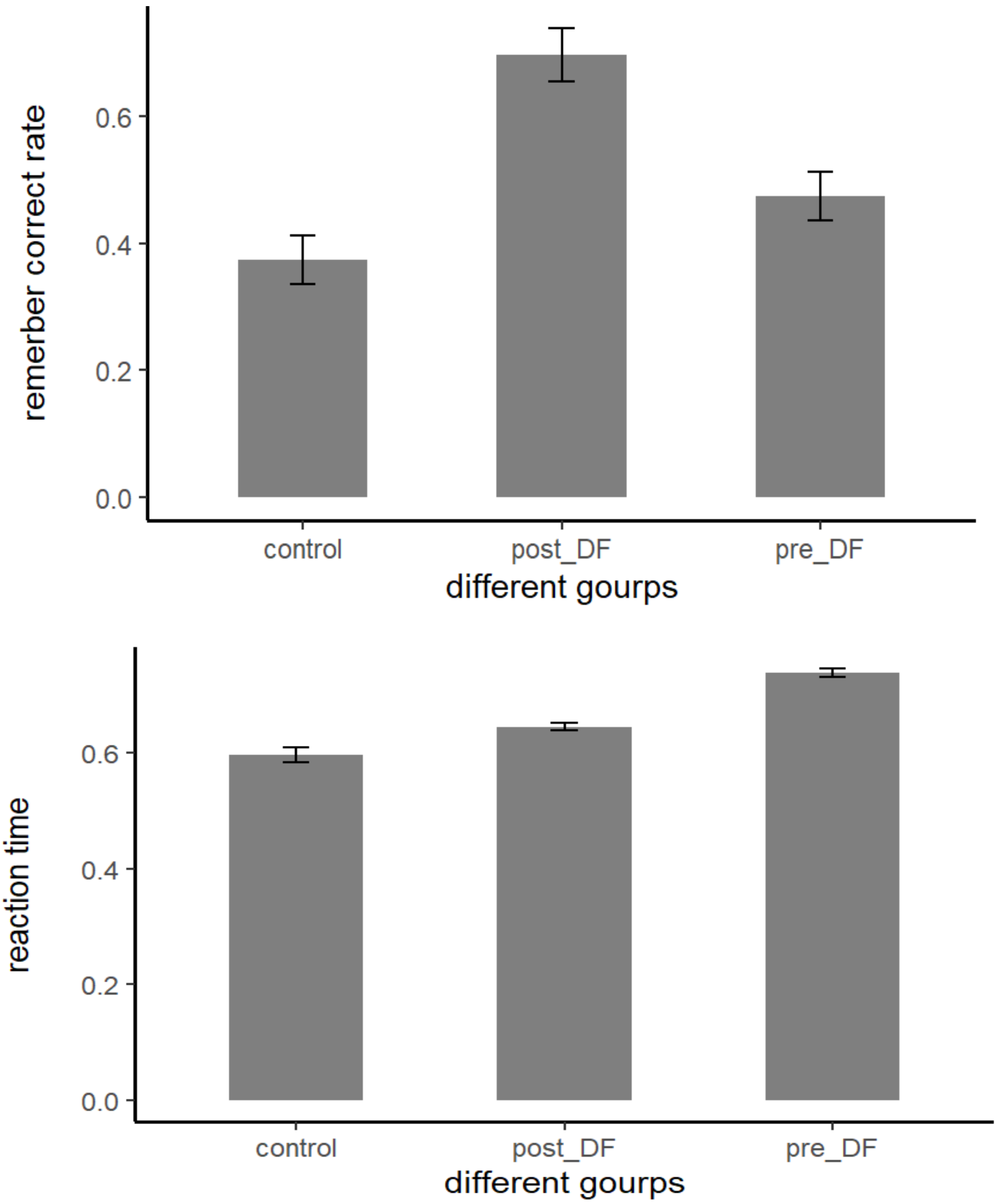


Figure 2: The hist plot of average RC and RT in tree different datasets.

This figure shows the difference of RC among control, pre-DF and post-DF. The average and standard derivations are indicated in the figure.

### 5.2. Analysis of Variance for the RC(control, pre-DF, and post-DF).

Because there are more than two groups of recognition correctness (we have three groups: the control group and two groups of data from pre-DF and post-DF), ANOVA is selected to test whether there is any significant difference between the three groups.

DOI: 10.54254/2753-7048/3/2022387

### 5.3. Shapiro test and QQ plot.

Before ANOVA, the Shapiro test in R was used to test if the data of recognition correctness is a normal distribution. The p-values of the Shapiro test for the RC in control, pre-DF, and post-DF are 0.09543, 0.01471, and 0.4977 respectively. Because the p-value for the pre-DF is less than 0.05 so next the QQ plot is made and the figure shows that although the p-value < 0.05, most data points are in the range of normal distribution. (Figure 3)

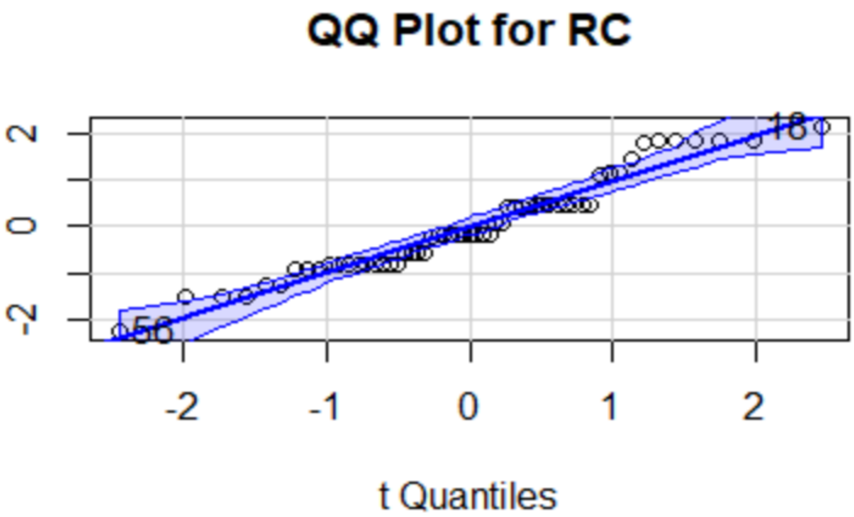


Figure 3: The QQ plot of RC data points in control, pre-DF, and post-DF.

The points on the blue line are strictly in a normal distribution and the probability of conforming to a normal distribution for the points within the blue range is > 95%. Five points that are not in the blue range which means this data set does not strictly conform a normal distribution.

### 5.4. Levene's test and outlier test.

Levene's test and outlier test in R are used to check if our data sets fulfill the homogeneity of variance assumption before the ANOVA. The result shows that there is no obvious outlier in the RC data points and the homogeneity of variance is satisfactory for ANOVA.

### 5.5. Result of ANOVA.

The F-value of ANOVA is 17.3, which means the mean-variance between groups is much greater than the mean-variance within groups and then Duncan's Multiple Range Test (DMRT) is used, which provides significance levels for the difference between any pair of means in ANOVA. The result of DMRT shows that there is no significant difference between the control and pre-DF data set, but the differences of post-DF vs control and post-DF vs pre-DF are obvious. (Figure 4)

```
> summary(aov)
            Df Sum Sq Mean Sq F value   Pr(>F)    
group        2  1.031  0.5153    17.3 1.56e-06 ***
Residuals   54  1.609  0.0298                     
---
Signif. codes:  
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 4: The ANOVA result of RC among control, pre-DF and post-DF

### 5.6. ANOVA for the RT(control, pre-DF, and post-DF)

The reason for using ANOVA is the same as the reason above and the steps are similar. The p-values of the Shapiro test for the RT in control, pre-DF, and post-DF are 0.2347, 0.6149, and 0.5431 respectively. The QQ plot also shows almost all data points are in the range of normal distribution. The result of Leven's test and the outlier test show that the ANOVA requirements are fulfilled. The F- value of ANOVA is 60.16, which means the mean variance between groups is much greater than the mean-variance within groups and the DMRT result shows that the difference between any two groups among the three groups is obvious. (Figure 5)

```
> summary(rt_anova)
            Df  Sum Sq Mean Sq F value   Pr(>F)    
group        2 0.19654 0.09827   60.16 1.81e-14 ***
Residuals   54 0.08821 0.00163                     
---
Signif. codes:  
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 5: The ANOVA result of RC among control, pre-DF and post-DF

### 5.7. Paired t-test for the RC, RT, for-RC, and for- RT (pre-DF and post-DF)

Because we are interested in the differences between directed forgetting effectiveness before and after training, and the two tests are done on the same group of participants. The Shapiro test is done for each data set and the result shows that only the RC for TBF in the pre and post-group do not in a normal distribution. So we do Wilcox test for this pair of data points and do the paired t-test for other groups.

### 5.8. Result of paired t-test.

The p-value of paired t-test of RC and RT for TBR between pre-DF and post-DF are 7.034e-05 and 1.702e-09 respectively, which means there is obvious difference in memory effectiveness before and after training. The p-value of paired t-test of RT for TBF between pre-DF and post-DF is 3.782e-0 5, which means there is an obvious difference in forgetting response time before and after training.

### 5.9. Result of Wilcox test.

The p-value of the Wilcox test of RC for TBF between pre-DF and post-DF is 0.01208, which means there is an obvious difference of forgetting correctness before and after training.

## 6. Conclusion

The benefit of directed forgetting (including recognition correctness and reaction time) can be improved by training.

### 6.1. Discussion

There are two opposing views on the mechanism of directed forgetting. One is the passive attenuation theory, which holds the opinion that TBF items are not processed as TBR items, so they gradually fade from memory passively without cognitive effort [4]. The other theory is the active inhibition theory, which believes that the forgetting of TBF items is the result of the processing of active inhibition.

At present, there are still controversies between these two theories. But our results provide evidence for the active inhibition theory.

If the theory of passive forgetting is correct, forgetting is passive without cognitive control, which means that the effect of the second directed forgetting should not be significantly different from the first one. However, in our experiment, directed forgetting' benefits of the second directed forgetting test were significantly higher than those on the first, suggesting that directed forgetting benefit can be improved through training. This suggests that people can be trained to enhance the effect of directed forgetting on our memory and provide supportive evidence for the active inhibition theory [8].

There are some experimental evidences that are supportive of our result. Event-related potential (EPRs) studies found that TBF items could induce more directed EPRs than the TBR items in the prefrontal cortex during the directed forgetting test, reflecting the active inhibition of memory [5].

In addition to EPR evidence, brain imaging studies also support that directed forgetting is an active inhibition process. During directed forgetting test, the activity of the right upper frontal cortex is negatively correlated with the activity of the medial temporal lobe (MTL), but during accidental or passive forgetting, there is no negative relationship between MTL and frontal cortex, which also indicates that the forgetting in directed forgetting test is complex [9].

The mechanism of how the benefit of directed forgetting is improved is not clear, but previous research may provide possible information, it may be new synaptic establishment in the related brain encephalic regions that enhanced the active inhibition in directed forgetting.

### 6.2. limitation

All participant in our experiments are Chinese teenagers but previous researches have found that the working memory capacities of elderly individuals and young adults are quite different [6]. Therefore, our conclusion may not true for other age groups

In our experiment, directed forgetting training was only performed once. The problem was that the repetitions were not enough to reflect the effect of long-term training on the benefits of directed forgetting.

The time interval between every directed forgetting test (10min) is too short, which means participants need to take high-intensity tests in a short period, and it may lead to a large memory burden of subjects and affect the final results.

The Shapiro test result shows that the RC data set for TBR in pre-DF does not strictly conform to the normal distribution (p-value of Shapiro test is $0.01471<0.05$). Therefore, strictly speaking, ANOVA is not suitable for the analysis of this kind of data set. So the Kruskal Wallis test is used, a rank-sum test that does not require data distribution type. The p-value of Kruskal Wallis test is 2.089e-05<0.05. This result means there is a significant difference in the RC between pre-DF and post-DF, which is consistent with the conclusion of ANOVA.

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### 6.3. Further direction

The times of repetition in our research are limited, so more repetition is necessary to provide more information about whether long-term training of directed forgetting could further improve the benefit or not.

The participants in our test are all Chinese young adults, so it will be better if more data could be collected from more participants of different ages to see if age could influence our conclusion. The time travel between each test in this research is too short, so it will be better to prolong the time travel in further validation to make sure the memory burden is acceptable for participants.

Although our result is supportive of the active inhibition theory, there is no experimental evidence for the mechanism of how directed forgetting is improved. The direction of further research is to use brain imaging or electroencephalogram (EEG) to analyze brain activity before and after directed forgetting training [10].

Our study found that the benefit of directed forgetting could be enhanced by training, so this work can be applied into teaching and learning. Further research could focus on how to make the training of directed forgetting more effective and find a method to improve learning and memory effectiveness by directed forgetting training.

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