

# Working Memory Experiment Laboratory Manual

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## Introduction to Working Memory Experiment

Suppose that you are a pilot who has just received a list of flight control instructions from your en-route flight controller. You need to enter this received data while simultaneously concentrating on other flight details. What is the likelihood of your making an error? You just looked up a long distance telephone number and are about place the call. How long a number could you remember for the length of time needed to dial the number? These questions tap the properties of our working memory. Working memory is the storage mechanism that we use to temporarily hold information that is occupying our attention. We also possess a long-term memory where knowledge about everything that we know is stored. Working memory is like the driveway in and out of permanent memory. All information must pass through working memory before it can be placed in or retrieved from permanent memory.

Working memory has at least two interesting properties. First, there are limits to the amount of information that can be held in working memory and how long that information will be available unless reentered. Second, information in working memory seems to be coded in more than one way. This project allows us to study both these properties of working memory. The participant's task is to recall a stimulus composed of a list of consonants or numbers. The stimulus is flashed briefly, and after a random time interval, a recall signal is given. The participant is instructed not to rehearse the memory stimulus (i.e., not to mentally repeat it over and over). In order to prevent rehearsal, the participant simultaneously performs a subtraction task. This task requires the participant to rapidly check on the subtraction of two three-digit numbers. The project records the performance on both tasks as a function of the trial conditions and recall interval.

## Instructions

There are two simultaneous tasks to perform in this experiment. The primary task is the subtraction task and the secondary task is the recall task. You are supposed to concentrate on performing the subtraction task as accurately as possible.

The recall task: Each trial of the experiment begins with the recall stimulus being flashed briefly on the screen. After a variable period of time, called the recall interval, you will be cued to recall this stimulus. At that time, you should try to type the recall stimulus in the box on the screen. After you type in the recall stimulus, press the space bar or enter key or click on the enter button. If you can't remember the recall stimulus, type in the parts that you remember and press the space bar or enter key or click on the enter button. Do NOT repeat the recall stimulus over and over in your mind during the recall interval. Doing so will cause your performance in the subtraction task to fall below the desired level.

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The subtraction task: The subtraction task is performed during the recall interval described previously. You will see a screen box that contains a math problem with 3 subtracted from a 3-digit number:

$$\begin{array}{r} 258 \\ -3 \\ \hline 255 \end{array}$$

About half of the time, the answer shown will be incorrect. Using the buttons on the mouse, you are supposed to indicate whether or not the answer is correct. If so, click on the left mouse button. If incorrect, click on the right button. You will have only a few seconds to answer before a new problem will appear. A new problem will appear immediately after you answer. Therefore, by answering quickly, you will be presented with more problems and have the opportunity to score higher. However, note that wrong answers will be subtracted from your score.

To start a new block of trials, click on the Start block button or press the ENTER key or SPACE bar. To examine your performance, click on the peek/reset block key. (NOTE: Clicking on the peek/reset key resets the trial counter to the next block of trials.)

### Parameters and Procedure

The experimenter can set the number of blocks and the number of trials per block. Note that the number of trials is set in increments of 5. The stimulus duration parameter controls the length of time that the recall stimulus appears in the stimulus window. The subtract timer parameter determines the rate at which the subtract task is presented. Shorter subtract times mean a faster presentation of successive subtract problems.

The five recall interval boxes determine the intervals for recall testing. During an experimental trial, the program selects one of the five intervals at random. The recall stimulus is presented and tested for recall after the selected interval of time. Thus, the participant does not know how long the recall stimulus must be held in memory prior to testing. For most tasks, the five default settings will work well. However, for some tasks or participants, it may be necessary to increase or decrease the range of recall intervals.

The stimulus type box determines whether the nine digits (1,2,3,4,5,6,7,8,9) or the 20 consonants (b,c,d,f,g,h,j,k,l,m,n,p,q,r,s,t,v,w,x,z) will be used to construct the recall stimuli. The stimulus size box determines the size of the recall stimulus; this can be set to be from 1 to 7 items. The program constructs the stimulus from the selected set under the constraint that no items appear more than once.

You may want to examine the effects of different numbers of stimuli as well as different types of stimuli on recall. Another potentially interesting manipulation involves switching the stimulus type between blocks. Carefully design the sequence of experimental conditions (including any randomization of experimental parameters) so that the desired experimental tests and comparisons can be made. Then STEP to each block number and SET the desired parameters. After setting up the conditions for each block, it's a good idea to review all the block conditions by stepping through them with the STEP button.

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## Data Analysis

The data will be in the following form:

blk	block number
trial	trial number
subtime	time interval between subtract problems (milliseconds)
stmdur	duration of recall stimulus (milliseconds)
dely	recall delay interval (milliseconds)
stim	recall stimulus
resp	recall response
nrght	number of subtract problems that were answered correctly
totl	total number of subtract responses
hits	number of subtract hits (respond [left mouse button] that subtract was shown correctly when it was correct)
scrct	number of subtract problems shown correctly, i.e., number of signal+noise trials
fas	number of subtract false alarms (respond that subtract was correct when it was incorrect)
incor	number of subtract problems shown incorrectly, i.e. number of noise-alone trials

You should examine how the probability of recalling a stimulus varies with the type of stimulus and the recall interval. (Although the type of stimulus is not recorded directly, the *stim* column gives the precise stimulus on every trial). Sort the data by stimulus condition (type and size) and by recall interval. Then sum the number of correct recalls at each recall interval and stimulus size. Then plot percent correct recall as a function of the recall interval for each stimulus size. Repeat the process for other types of stimuli.

You may also wish to examine the type of errors that are made by the participant. Since each response is recorded, you can examine whether incorrect responses were due to extraneous letters being given versus out-of-sequence letters, etc. Interpretation of the type of errors may lead to explanations of the nature of the interference or forgetting involved. For example, a high rate of letter intrusions from the letters used in previous trial blocks would be evidence of interference from the earlier set.

You need to insure that performance in the subtraction task did not vary in a way that could confound the interpretation of the effects of the recall variables (recall interval or type of recall stimulus). That is, you should check that subtraction performance did not change in an orderly way that could have produced (or masked) the effect of recall interval or stimulus type. So, you should examine how the behavior in the subtraction task varied as a function of the stimulus condition and recall interval. Several measures of subtraction performance are provided for making this check. A simple method is to examine the overall rate of correct subtraction responses,  $nrght/totl$ . This will provide a general idea of the accuracy and effort in the subtraction task as a function of the recall conditions. Alternatively, if a more extensive analysis of the participant's detection performance is desired (sensitivity and response bias) in the subtraction task, hit and false alarm values can be computed from the data as follows:

$$\begin{aligned} \text{probability of a hit} &= \text{hits}/\text{scrct} \\ \text{probability of a false alarm} &= \text{fas}/(\text{incor}) \end{aligned}$$

Here are some typical lines of data:

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blk,trial,subtime,stmtdur,dely,stim,resp,nrght,totl,hits,scrct,fas,incor  
 1,1,2000,1000,15000,XMW,XMW,8,8,3,3,0,5  
 1,2,2000,1000,5000,XMC,XMC,4,5,2,3,0,2  
 1,3,2000,1000,2000,DRN,DRN,0,1,0,1,0,0  
 1,4,2000,1000,100,HXR,DDF,0,0,0,0,0,0  
 1,5,2000,1000,10000,PQS,PQS,4,6,2,3,1,3  
 2,1,2000,1000,2000,WNF,WNF,0,2,0,0,2,2  
 2,2,2000,1000,10000,DRM,DRM,8,8,4,4,0,4  
 2,3,2000,1000,5000,QHM,QHM,4,4,0,0,0,4  
 2,4,2000,1000,15000,QNH,DDD,13,13,7,7,0,6  
 2,5,2000,1000,100,XKG,DDD,0,0,0,0,0,0

Example: On trial 5 of block 1, the maximum time interval between subtract problems was 2000 ms and the duration of the recall stimulus was 1000 s. On this trial, the recall stimulus was correctly recalled after an interval of 10 seconds. The performance on the subtract task was:

total of 4 correct out of 6 tries  
 hit rate=2/3=0.67  
 false alarm rate=1/3=0.33

### Sample Spreadsheet Analysis

The data in this experiment are analyzed within individual blocks. Below is a sample of the data obtained in a condition employing 3 consonants as the recall stimulus. The red-highlighted columns must be added to the spreadsheet after the data has been read into the spreadsheet. The ce column is constructed by inserting the formula

=IF(F2=G2,1,0)

into the first cell in the ce column (N2). This puts a 1 in the cell if the response agrees with the stimulus and a 0 if not. The psub column is constructed by entering the formula

=H2/I2

into the first cell in the psub column (O2). This calculates the percent correct for the subtract task. Copy these two formulas down the entire ce and psub columns. (#DIV/0! indicates that the program tried to divide by zero because there were no occurrences of the subtract task.)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	blk	trial	subtime	stmtdur	dely	stim	resp	nrght	totl	hits	scrct	fas	incor	ce	psub
2	1	1	2000	1000	100	ZWG	zwg	0	0	0	0	0	0	1	#DIV/0!
3	1	2	2000	1000	10000	XBG	xbg	9	9	2	2	0	7	1	1.000
4	1	3	2000	1000	2000	RNC	rnc	1	1	0	0	0	1	1	1.000
5	1	4	2000	1000	15000	CQG	cqg	8	12	2	4	2	8	1	0.667
6	1	5	2000	1000	5000	NZV	nzv	3	3	1	1	0	2	1	1.000
7	1	6	2000	1000	5000	JSL	nsl	2	3	1	1	1	2	0	0.667
8	1	7	2000	1000	15000	NXM	ddd	10	12	5	5	2	7	0	0.833
9	1	8	2000	1000	2000	TSV	tsv	1	1	0	0	0	1	1	1.000
10	1	9	2000	1000	10000	WRS	ddd	4	6	3	3	2	3	0	0.667
11	1	10	2000	1000	100	WTF	wtf	0	0	0	0	0	0	1	#DIV/0!
12	1	11	2000	1000	10000	CRW	cwn	6	6	2	2	0	4	0	1.000
13	1	12	2000	1000	100	KJW	eee	0	0	0	0	0	0	0	#DIV/0!

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Now, construct a pivot table by clicking on the pivot table item in the toolbar Data menu. Select delay for the table row headings (place in the left column of the pivot table) and select response for the column headings (place in the top row of the pivot table). Select response as the table entry and double-click on response and select count as the pivot table method (rather than sum or average). This will enable the table to count the number of times a trial occurred at each recall delay interval and whether the response was correct or incorrect. Place the pivot table output in a convenient place in the spreadsheet.

	A	B	C	D	E
1	Count of response				
2	delay	0	1	Grand Total	p(c) recall
3	100	0	10	10	1
4	2000	3	7	10	0.7
5	5000	6	4	10	0.4
6	10000	10	0	10	0
7	15000	9	1	10	0.1
8	Grand Total	28	22	50	0.44

Add the red-highlighted column to the pivot table by adding the column labeled p(c) recall and inserting the formula

=C3/D3

in cell E3; copy the formula down the entire column. This will calculate the percent correct recall at each delay. Plotting percent recall as a function of delay yields the following graph.

It is important to check whether or not the performance in the subtraction task varied in a systematic way with the delay interval (or with other parameters of the conditions run). To do so, we will calculate the percent correct in the subtract task as a function of the delay condition and whether the recall response was correct or incorrect. (A simpler analysis could use the previously calculated p<sub>sub</sub> values; that would combine the effect of correct/incorrect on the recall task.) Generate two new pivot tables in the same way as before, but using total and correct, respectively, as the table entries (instead of response). Use the sum pivot method instead of the count method. This will produce a table with the total number of subtraction trials and the number of correct subtract trials, respectively. Place the pivot tables side by side each other in the spreadsheet. Then add two columns (the red-highlighted columns, below) to calculate percent correct subtract, by adding formulas

=F3/B3

=G3/C3

=H3/D3

to the cells in row 3 of columns I, J, and K respectively. Copy the formulas down all cells in each column. In this case, performance in the subtract task does not seem to vary systematically with the recall delay or with being correct on the recall task.

It may be interesting to perform more extensive analyses of the performance obtained in the recall and subtraction tasks. For example, one could examine the nature of error responses in the memory task: Do specific letter intrusions depend on the stimuli used in prior conditions? Also, suppose that one computed  $d'$  and criterion values for performance in the subtraction task:

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Do these indices vary in an interpretable way as a function of delay condition and recall outcome?

## Technical Details

### Trial Sequence and Timing

The trial begins with presentation of the recall stimulus for a duration determined by the stimulus duration parameter. Presentation of the recall stimulus is followed by a blank period of 100 ms. After the blank interval, the recall duration time interval begins. The five possible recall intervals are chosen randomly from among the set values in the five recall interval boxes. When the recall interval ends, a recall signal (and beep) is presented to the participant. The participant then attempts to enter the recalled stimulus.

The first subtract problem is presented simultaneously with the beginning of the recall interval time period. If the participant does not make any subtract response (mouse button click), the subtract problem is automatically updated to a new problem at an interval determined by the subtract timer parameter. When the participant does respond to the subtract problem (mouse button click), the subtract problem is immediately updated to a new problem. The presentation of the recall signal (and beep) to recall the stimulus, interrupts (takes precedence over) the ongoing subtract problem. After presenting the recall signal, the program waits until the participant has made a recall response. A feedback period of 1.2 s follows the response. Following the feedback, there is about a 100 ms blank period before the onset of the next trial.

### Recall Task Stimuli

The stimulus type parameter determines whether the nine digits (1,2,3,4,5,6,7,8,9) or the 20 consonants (b,c,d,f,g,h,j,k,l,m,n,p,q,r,s,t,v,w,x,z) will be used to construct the recall stimuli. The stimulus size box determines the size of the stimulus; this can be set to be from 1 to 7 items. The program constructs the stimulus from the selected set, drawing randomly and without replacement (no item can appear more than once) from the full set.

### Subtract Task Stimuli

Each subtract problem consists of a math problem with 3 subtracted from a 3-digit number:

$$278 - 3 = 275$$

The first 3-digit number is drawn randomly from the interval 100 to 999. The program decides with probability 0.5, whether or not the second 3-digit number will be equal to the first number minus 3. If not, the program then sets a value for the second 3-digit number according to the following probability rule:

<b>value of second 3-digit number</b>	<b><u>probability</u></b>
first number-1	0.25
first number -2	0.25
first number -4	0.25
first number -13	0.25

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## References

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