APPLICATION OF DESIGN AND ANALYSIS OF 2^3 FACTORIAL EXPERIMENT IN DETERMINING SOME FACTORS INFLUENCING RECALL ABILITY IN SHORT TERM MEMORY

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ABSTRACT

In this paper, we consider a 2^3 factorial experiment of factors influencing recall ability in short – term memory. The factors of interest are word length, word list and study time; and these factors tested on a group of students. The data obtained from the experiment are analyzed using the analysis of variance (ANOVA) of 2^3 factorial experiment (Yates Algorithm). The results show that recall ability in short term memory depends on word list, word length, study time and the interaction effect of list length and word length.

KEYWORDS: 2^3 factorial experiment, word length, design of experiment, Yate's Algorithm, Analysis of Variance.

INTRODUCTION

Before now, complicated experiments, which involve many levels of factors were analyzed and concluded using certain descriptive statistics that could not give accurate and comprehensive interperations. Lawrence, A. J., (1996) designed a factorial experiment with students in order to investigate characteristics of short-term memory. He finally used binomial regression analysis to analyse the data collected from the experiment.

This work therefore seeks to design specifically a 2^3 factorial experiment and to employ the analysis of variance method (Yates Algorithm) other than any other method to analyse the result of the experiment. Montgomery (1976) defined factorial experiments as experiments in which each complete trial or replication of the experiment, involves investigation of all possible combinations of the levels of the factors. In other words, it is an experiment where the design consists of two or more factors, each with discrete possible values or 'levels' and where the experimental units take on all possible combinations of these levels across all such factors.

Thus experiments involving the influences of certain factors on recall ability in short – term memory are factorial. O'Brien (1994) defined a short-term memory as the ability to remember or recall over short periods of up to about one minute or thereabout. He also stated that short-term memory lasts for about 20 to 30 seconds without rehearsal of the information. More so, short-term memory is measured by recall from list of words under controlled condition. Unless passed from short-term memory (STM) to long term memory (LTM), items are forgotten by delay over time and replacement of interference from more recent items. Earlier experiments on short – term memory by Miller (1956) mainly concentrated on the memory span or storage capacity. He showed that average human memory span can be expressed as 7±2, which is regarded as the "magical number seven" in short-term memory. This means that people can remember about seven chunks (items), but normally remember between five and nine chunks in short-term memory. These Chunks or items could be numbers, letter, nonsense syllable or words. Although Miller's ambivalence was, at the time a sophisticated and cautious response to available evidence, a wealth of subsequent information suggests that there is a relatively constant limit in, the number of items that can be recalled in a wide variety of tasks; but that limit is only three to five items as the population average. Henderson (1972) cited various studies on the recall of spatical locations or of items in those locations, conducted by Scarborough (1971) and Posner (1969), to make the point that there is a "new magic number 4 ±1." Broadbent (1975) proposed a similar limit of 3 items on the basis of more varied sources of information including, for example, studies showing that people form clusters of not more than three of four items in recall. A similar limit in capacity was discussed, with various theoretical interpretations, by others such as Halford. Mayberry, and Bain (1988), Halford, Wilson, Philips (1998), Luck and Vogel (1997), and Schneider and Detweiler (1987).

According to some current theories, there is no limit in storage capacity per se, but a limit in the duration for which an item can remain active in short-term memory without rehearsal (Baddeley, 1986). This has led to debate about whether the limitation is a "magic number or magic spell" (Schweickert and Boruff, 1986) or whether rehearsal really plays a role (Brown and Huline, 1995).

One possible resolution is that the focus of attention is capacity –limited whereas various supplementary storage mechanisms, which can persist temporarily without attention, are time-limited rather than capacity – limited (Cowan, 1988).

Mclean and Gregg (1967) stated that if someone is given new material for immediate recall and can look at the material long enough before responding, new associations between the original items can be formed, resulting in larger Chunks, or at least, conglomerates with non-zero associations between items. Miller (1956) also said that the half life of short-terms memory is approximately fifteen seconds and its capacity is approximately seven items (chunks) of information. Many studies in short –term memory reveals that short-term memory is limited by the amount of time that has elapsed rather than by the number of items that can be held simultaneously (Baddley, 1986). Service (1998) stated that the effect of word length on recall depends on phonological complexity, not on articulatory duration. Possible factors influencing recall ability include the study time of the wordlist, delay time between viewing and recalling of words, length of words used or number of syllables in words, number of words presented in the list and simultaneous or sequential presentation (Lawrence A. J. 1996).

The statistical focus revolves around seeing the sense of varying several factors simultaneously in a small factorial design and then identifying the effects of the factors individually and looking for any combination (interaction)

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effects. Factorial designs have several advantages: They are more efficient than one-factor –at-a-time experiments. Furthermore, a factorial design is necessary when interaction may be present to avoid misleading conclusions. It also allows effects of a factor to be estimated at several levels of the other factors yielding conclusions that are valid over a range of experimental condition (Box, G. E. *et al* 2005).

The Design of 2^3 factorial experiments involves determination of what factors to use and at what factors to use and at what levels.

MATERIAL AND METHODS

In this work, study time, list length and word length are the factors under study. To design this experiment, subjects are shown a list of unconnected words that is then withdrawn. Sets of students that are randomly selected without replacements are asked to recall the words with primary result being number correctly recalled. The factors to be studied are made to be at two levels and these two levels are sufficiently different as to have an effect to avoid the experiment being a flop. The guiding requirement is that the subjects should have played no part in constructing the list on which he or she is tested. With the use of three factors-study times, list length of words and word length of two levels each; eight different types of test will be produced. This suggests a 2^3 factorial experiment. That is study time – two levels of 15 and 30 seconds respectively; list length of words-two levels of 12 and 6 words and words length- 3 syllables and 1 syllable as levels. This makes a total of eight treatment combinations. Six students using 48 from a group of 50 carry out each type of test. Fifty students were randomly selected without replacement from one hundred students of the same class. Thereafter six student were sub-sampled using the same method to carry out each type of test. This was done to avoid memory lag. Moreover, words were selected in such a way that there were no inter-item association, so as to avoid aiding retrieval or recall of those words.

The method of analysis used in analyzing this 2^3 factorial experiment is Yates Algorithm in Analysis of Variance (ANOVA) method, which tries to partition the total variation into individual variation of the factors and interactions involved. Yates Algorithm eases the use of complete formulae. The treatment combinations are always written down in standard order, and the column labeled "response" contains the corresponding observation (or total of all observations) at that treatment combination. The first half of column (1) is obtained by adding the responses in adjacent pairs. The second half of column (1) is obtained by changing the sign of the first entry in each of the pairs in the response column and adding the adjacent pairs.

After obtaining the sum of square for the effects on the contrasts, the total sum of squares SS_T is obtained using the usual formula:

$$SS_T = \sum_i \sum_j \sum_k Y^2_{ijk} - \frac{Y^2...}{n2^k}$$ where Y_{ijk} = each number

of words recalled in the experiment and Y … = grand total of the number of words recalled in the experiment.

The sum of squares of the effects (SS_{eff}) is given by

$$SS_{eff} = \frac{(Contrasts)^2}{n2^k}$$ Where k is the number of factors and

n is the number of replication. Also the sum of squares of error (SS_e) is obtained by subtracting all the sums of squares of effects from the total sum of squares.

It should be noted that the assumptions are that the factors are fixed, the design is completely randomized and the normality conditions are satisfied.

DATA ANALYSIS

The data obtained from the experiment are shown in appendix 1. They are further presented at each sublevel as:

Table 1: Number of words Recalled at each sublevel (Responses)

		LL			
	LL$^-$				LL$^+$
		WL		WL	
		WL$^-$	WL$^+$	WL$^-$	WL$^+$
ST	ST$^-$	6,4,5,6,4, (28)	5,5,3,6,3,5 (27)	9,11,12,6,8,10 (56)	4,2,8,5,6,5 (30)
	ST$^+$	4,5,5,6,5,4 (29)	6,5,3,6,5,6 (31)	12,10,8,9,8 (56)	8,6,10,9,10,5 (48)

The numbers in brackets are the total in each sublevel.
The Yates Algorithm employed provides the table below:

Table 2: Sum of squares of treatment combinations

Treatment Combinations	Response	(1)	(2)	(3)	Effect	Estimates of effect (3)÷n2^{k-1}	Sum of Squares (3)^2÷n2^k
Constant (1)	28	84	141	305	L	-	-
List length (II)	56	57	164	75	LL	3.125	117.188
Word length (wl)	27	85	31	-31	WL	-1.292	20.021
Interaction between list length and word length (llwl)	30	79	44	-35	LLWL	-1.458	25.521
Study time (st)	29	28	-27	23	ST	0.958	11.021
Interaction between list length and study time (list)	56	3	-6	13	LLST	0.542	3.521
Interaction between word length and study time (wlst)	31	27	-25	21	WLST	0.875	9.188
Interaction among list length, word length and study time (llwlst)	48	17	-10	15	LLWLST	0.625	4.688

SS_T = 2233-1938.021 = 294.98

$$SS_e = SS_T - SS_{st} - SS_{llst} - SS_{wlst} - SS_{llwlst}$$
$$= 294.989 - 117.188 - 20.021 - 25.521 - 11.021 - 3.521 - 9.188 - 4.688 = 103.831$$

The test for the significance of the factors is given in the Analysis of Variance (ANOVA) table below:

Table 3:   ANOVA TABLE

Source of variation	df	SS	MS	F	$F_{1,41,0.05}$
L	1	117.188	117.188	45.142*	4.08
WL	1	20.021	20.021	7.712*	4.08
LLWL	1	25.521	25.521	9.831*	4.08
ST	1	11.021	11.021	4.245*	4.08
LLST	1	3.521	3.521	1.356	4.08
WLST	1	9.188	9.188	3.539	4.08
LLWLST	1	4.688	4.688	1.806	4.08
ERROR	40	103.831	2.596		
TOTAL	47	294.979			

* significant at 5% level of significance.

RESULTS

Table III above indicates that at 5% level of significance, the number of words in a list to be recalled (LL) the number of syllables of the recalled words (WL) and the study time (ST) has significant influences on recall ability of human beings. Moreso, there is interaction effect between list length and word length on recall ability. However, there are no effects of other interactions on recall ability.

DISCUSSION

The above work goes a long way to ascertain the effects of various factors on recall ability as stated out by O'Brien (1994) and Lawrence, A. J. (1996). It also shows that 2^3 factorial experiment could be used to design such experiments and Analysis of Variance method used to test for the significant of main and interaction effects of factors

affecting recall ability in short-term memory; other than the method used by Lawrence, A, J. (1996) in his analysis.

CONCLUSION

Design and analysis of factorial experiments are powerful statistical techniques for more complicated and realistic experiments involving certain phenomena. Analysis of experiments of this type makes room for inference and valid conclusions on the results of most complicated experiments which involve many levels of factors in short-term memory. From the analysis of 2^3 factorial experiments involving short-term memory, it is observed that list length of words, word length, study time and the interaction between list length and word length influence recall ability. In time past, these type of experiments were analyzed and concluded using descriptive statistics that could not give accurate and comprehensive interpretations; but now the development of methods of analysis proffers solutions to this problem.

APPENDIX 1
Experimental Set of Student Data

Factor Level	Word Recalled By Six Students					
WL$^+$ST$^+$LL$^+$	8/12	6/12	10/12	9/12	10/12	5/12
WL$^+$ST$^+$LL$^-$	6/6	5/6	3/6	6/6	5/6	6/6
WL$^+$ST$^+$LL$^+$	4/12	2/12	8/12	5/12	6/12	5/12
WL$_+$ST$^-$LL$^-$	5/12	5/6	3/6	6/6	3/6	5/6
WL$^-$ST$^+$LL$^+$	12/12	10/12	8/12	9/12	9/12	8/12
WL$^-$ST$^+$LL$^-$	4/6	5/6	5/6	6/6	5/6	4/6
WL$^-$ST$^-$LL$^+$	9/12	11/12	12/12	8/12	8/12	10/12
WL$^-$ST$^-$LL$^-$	6/6	4/6	6/6	3/6	3/6	4/6

Where
WL   =   World Length: WL$^+$ = 3 Syllables, WL$^-$ = 1 Syllable
ST   =   Study Time: ST$^+$ 30 seconds, ST$^-$ = 15 seconds
LL   =   List Length, LL$^+$ = 12 words, LL$^-$ = 6words
K/N =   K words recalled out of N words

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