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Anagram Solution Times: A Function of Bigram Frequency and Versatility

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ANAGRAM SOLUTION TIMES: A FUNCTION OF BIGRAM FREQUENCY AND VERSATILITY

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There are many variables that may affect the speed of anagram solution time. Mayzner and Tresselt (1958; 1959; 1962; 1963) in a myriad of anagram studies have laid down several basic factors which they consider essential in the speed of solution. Solution word frequency of appearance in normal reading and speech affects response rates, higher frequency words being solved at a higher rate than low frequency words. The frequency or "uniqueness" of a solution word has in these studies and numerous others proven to be an important and stable, if not superordinate factor in anagram solution. Early studies on anagram variables also revealed such obvious relationships as increasing word length and the requiring of more letter moves to solution results in longer solution times.

More recent research on variables of anagram solution have focused on the characteristics of the bigram and trigram constituents of the solution words. Any sequence of successive two-letter combinations in anagrams or their solution counterpart may be considered a bigram. Past

studies on bigrams have used frequency counts taken from the printed English language in a manner of the Thorndike-Lorge (1944) word frequency count. These past studies focusing on the summed frequencies of successive bigrams in both word and anagram have yielded more equivocal results than the word frequency relationships. Mayzner and Tresselt (1959; 1966) generally found that high bigram frequency (BF) words and low anagram bigram totals facilitated solution. However, other studies including Dominowski and Duncan (1964) have not been able to consistently duplicate Mayzner and Tresselt's findings. As Dominowski (1967) suggests, "differences in problem difficulty produced by manipulating BF (in anagrams or solution words) have been small and unstable, suggesting the need for a new analysis of the problem."

Johnson (1966) hypothesizes that S in "the process of anagram solution, generates words, tests them against the anagram letters, and that bigrams are used as a basis for word production." If it is true that S selects bigrams as a basis for word production in the solution process of anagrams then the characteristics ofthe bigram used in this process becomes important in determining whether the anagram will be solved and in how much time the process will take.

Dominowski (1967) outlines the basis for a need for a new approach of bigram classification:

> "Ss production of bigrams must be somewhat restricted by the letters of the anagram. The use of general bigram frequency takes no account of such a restriction, and a more appropriate measure may be developed."

The impetus for the present study came from a consideration of the techniques and theory used in the calculation of

such frequency counts. It is proposed in this study that the bigram counts previously used are misleading and inappropriate in their use as predictors of ease of anagram solution.

The characteristics of the bigram in this study will be referred to as bigram versatility as opposed to bigram frequency. Bigram frequency counts, as is the case with word frequency counts, represent the relative frequency a particular bigram appears in the written English language. A high bigram frequency might represent the case of a bigram appearing in a large number of words, in a few words which appear a large number of times, or a combination of the two. In contrast, a bigram with what will be called high versatility would indicate that the bigram appears in a large number of different words. As an example the bigram "of" has a high frequency due to its appearance as the word "of". The versatility of the bigram of would not be expected to be as high as its frequency since the word of can only be included once in the versatility count.

Bigram versatility should be a better indicator of anagram solution time than bigram frequency if <u>S</u> uses the bigram to generate words and tests them with the letters in the anagram. The <u>S</u> would only be expected to test a bigram in an anagram once to see if it is a possible solution word. Thus the higher frequency bigrams with lower versatilities should generate fewer potential solution words (less interference) than their high frequency high versatile counterparts. The present study was designed to study the relationship between frequency and versatility and anagram solution times.

Method

Materials.--Bigram versatilities were calculated from a sample of one-tenth of the words throughout the Thorndike-Lorge word list of words of frequency one million and over. After a word was randomly selected from each block of 10 words each bigram in the word was recorded for its occurence. Table 1 shows the results of the distribution of the 12,344 bigrams recorded.

Insert Table 1 about here

Table 1 also shows the corresponding frequencies for the bigrams as found in Underwood and Schulz (1960).

Both the frequency and versatility counts were arbitrarily divided into classes containing the highest, second highest, third highest, and lowest quartile values. It was calculated that bigrams with frequencies of 600 and higher were in the top quarter of the frequency distribution and will be referred to as group F1. Table 2 shows the class limits of the first as well as the second, third, and fourth quarters (F2, F3, and F4) of the bigram frequency distribution.

Insert Table 2 about here

A versatility count of 36 and over was the calculated criteria for the top quarter of the versatility distribution and will be referred to as group V1. Table 2 shows group V1 and the second, third, and fourth quarters (V2, V3, V4) class limits of the distribution of bigram versatilities.

Each bigram was assigned an FV value according to its membership in each of the distributions. Table 3

Insert Table 3 about here

indicates the combined FV value for each particular bigram. It is on this basis of bigram classification that the present experiment was conducted.

To make sure or at least increase the possibility that the Ss used the bigrams selected, the bigram under study for each anagram was indicated above its anagram with only its position remaining undisclosed.

All anagram problems were constructed from five-letter words beginning with consonants, contained only one solution, and had no repeated letters. The anagrams differed slightly in terms of number and placement of consonants and vowels. The experiment was conducted with high frequency solution words, frequencies of A or AA (Thorndike & Lorge, 1944). The experiment was also replicated as close as possible for low frequency words, frequencies ranging from 5-37 per million.

All of the FV bigram combinations were not used since bigrams were not found in all the cells. As would be expected no bigrams were found in the F4V1 nor in the F1V4 condition. Other conditions were eliminated when at least two solution words could not be found containing a bigram from the condition. For the high frequency solution words the bigram conditions used were the "normal" conditions F1V1, F2V2, F3V3, plus conditions F2V1, F1V2, F3V2, F2V3, and F3V4. The F4 conditions had to be eliminated completely due to insufficient word samples. The low fre-

quency solution words contained bigrams from conditions F1V2, F2V1, F2V3, and F3V2.

When possible four anagrams from each condition were used. This enabled a sample from each bigram condition to appear at each of the four bigram positions (1-2, 2-3, 3-4, 4-5) in the solution word. No individual bigram was used more than once in a condition. Other than the bigram under study the other three bigrams of the solution words were always in the normal category. A total of 36 words were used in the experiment. Twenty-four of the words were high frequency solution words. Twelve words were used in the low solution word frequency condition. Table 4 lists all the stimulus materials for each condition.

Insert Table 4 about here

All 36 solution words had medium to high solution word bigram totals, mean solbitot= 4,947. Anagram bigram totals (anbitots) were not calculated. These totals would be misleading since one of the bigrams was correctly shown for each anagram. All of the anagrams were of the "hard" letter orders, requiring over two moves to solution. No bigram appeared in its correct sequential order in the anagram. Each anagram was typed individually on a 3 X 5 index card in a manner similar to that shown in Table 4.

Design and Ss.--The 36 anagrams were split into two lists of 18 anagrams so that each of the 24 introductory psychology students from Loyola University received half the words from each condition. The 24 Ss each served in conditions F1V1, F1V2, F2V1, F2V2, F2V3, F3V2, F3V3, F3V4 in the high

solution word frequency condition and in conditions F1V2, F2V1, F2V3, and F3V2 in the low solution word frequency condition. The words in each list were randomly ordered. The Ss were assigned to conditions in order of appearance at the laboratory. The order of the words in the lists were reversed for alternate Ss.

Procedure.--Each S was run individually. Instructions included an example of an anagram. It was stressed that the bigram indicated above the anagram could appear in any position in the word. For each of the 36 anagrams a maximum of 30 sec. was allowed. If S solved, he gave his answer orally and the solution time was recorded to the nearest tenth of a sec.; if S failed to solve, he was told the solution before the next problem was presented.

Results

Each condition contained bigrams under study at different letter positions in the solution words. Dominowski (1968) showed that the position of the presented bigram significantly affected response times. Positions 1-2 and 4-5 led to faster solution times than the middle positions 2-3 and 3-4. In the present experiment median times were calculated for each anagram. Medians were employed since there was an artificial ceiling of 30 sec. for each anagram. The anagrams were divided into the four position groups and the mean of the median times for each group (ns= 13, 6, 11, 6) were plotted as a function of position. The results as shown in Figure 1

Insert Fig. 1 about here

resemble those of Dominowski. The 1-2 and 4-5 positions were almost identical and were associated with faster solution times than in the 2-3 and 3-4 positions.

In comparing solution times across bigram conditions means of the median times for the words comprising each condition were calculated. Figure 2

Insert Fig. 2 about here

is a graphical representation of the trends in solution time with changing bigram frequency and versatility for the high frequency solution words. The low frequency solution word conditions were not plotted due to a lack of sufficient data. Inspection of Figure 2 reveals a decrease in mean solution time across frequency groups, F1-F2-F3, in the V2 versatility condition.

Table 5

Insert Table 5 about here

shows the mean of the means and mean of the median times for each condition. The fastest solution times for the high frequency solution words seen in the V2 condition also appear in the V2 condition in the low frequency solution word groups.

An appropriate and valid data analysis was exceedingly difficult in the present experiment due to missing cells and the necessity of the use of median times. Solution times however were compared between the V1 and V2 conditions where a consistent trend in times appeared. In the high frequency solution word condition there were significantly

faster times in the V2 condition as compared to V1, $p(t=3.38, df=11)<.01$. Also in the high frequency word condition, V2 times were faster than those in V4, $p(t=2.26. df=11)<.05$. The other comparisons in both the high and low frequency word conditions were not significant when mean scores were employed.

In looking at general trends in group median solution time, the presenting of a bigram of relative high frequency had a very slight facilitative if not minimal effect in anagram solution. Since the solbitots in the present experiment were somewhat heterogeneous (range 2,136-7,956) and the fact that the anbitots were not strictly controlled due to the design of the experiment, no conclusions will be drawn as to whether the presentation of high frequency bigrams is facilitative as compared to lower frequency bigram presentation in five-letter anagrams. It appeared at least in the present case that frequency of the presented bigram produced minimal effects. The low median time (9.6 sec.) in the F3 condition of the low frequency words no doubt was due to the use of bigrams in end positions of both the words in the condition.

The general trend in solution time and versatility level as mentioned earlier is a decrease in solution times in going from the V1 to V2 level. Levels V3 and V4 show a rapid increase in times with condition V3 showing slightly slower times than V1. For the low frequency solution words, after the decrease in times from condition V1 to V2, condition V3 also displayed a faster median time than group V1. Inadequate sampling again may have been the cause for this result.

Discussion

The results of the anagram solution times in the ver-

satility conditions across the frequency variable underscores the importance of bigram versatility in the anagram solution process. Bigrams which heretofore were considered equal in contribution to the solution process due to their equality in frequency are now shown to differentially affect the process when differences in versatility are taken into account.

The characteristic pattern of decline and rise in solution times in moving from high to low bigram versatility seems to confirm an earlier hypothesis that bigrams equal in frequency but differing in versatility will differentially affect the time needed for anagram solution. The facilitating effect of lower versatility bears a relationship to earlier theories as for example put forth by Ronning. Ronning's (1965) "ruleout factor" reasoned that when the letters of an anagram yield many nonoccuring bigrams or trigrams S is faced with fewer letter arrangements to try out and thus such anagrams will be easier to solve than anagrams with fewer letter combination ruleouts. The notion that a bigram of high versatility produces more solution possibilities, greater interference, and thus longer solution times seems to have been confirmed in the results of the V1 and V2 conditions. The results correspond closely to those of Dominowski (1967) in his use of bigram rank as a predictor of ease of anagram solution. Dominowski found "with S solving for words with widely varying BR, difficulty of solution was directly related to the degree of bigram interference." Dominowski's concept of bigrams with high relative frequency or interference was "assumed to be due to the number of more frequent bigrams with the same initial letter even though some of these

bigrams may require letters not present in the anagram." This is analogous to the present concept of high versatile bigrams appearing in more words than low versatile ones even though some of the words contain letters not present in the anagram. The nonmonotonic effect found by Dominowski when words with similar BR were used may caution the expectation of replication of the present results when groups receive bigrams of the same versatility level throughout the experiment. An interesting note is how the interfering effects of high bigram versatility found in anagrams, a problem situation where all the constituents of the word are given, can be contrasted with the free problem situation (unconstrained) where Duncan (1970) found that high frequency bigrams facilitated producing of acceptable responses, the production of a word. Here restrictive pool size is deleterious to solution time.

A final comment on the relationship between versatility level and solution time concerns the increase in response latency in conditions V3 and V4. It appears that as a bigram's versatility decreases to such a point where a lack of sufficient solution possibilities are generated then the solution process is hampered. Thus the facilitating effect in anagram solution of low versatile bigrams becomes negated when the level of versatility limits the generation of sufficient solution possibilities. Since versatility and frequency absolute differences in value diminish at the F & V 3 & 4 bigram levels, it can generally be said that presenting a bigram of low frequency or versatility (levels below the median distribution values) leads to relatively slower solution times than a bigram of higher frequency or versatil-

ity.

The low frequency solution word condition was included in the present study since it was desired to investigate whether the versatility effect would hold with all types of anagram word frequency situations. As mentioned earlier solution word frequency is immensely important in affecting solution times. Many anagram variables in the past have been lost in effectiveness when they are used with low frequency words. Solution times cannot be affected unless the anagram is solvable. It is difficult in the present study to make generalizations about the effects of bigram versatility on low frequency solution word anagrams since very few cells for the variable were filled. It does appear however that the same patterns hold with respect to versatility and solution time as was found with high frequency words.

The serial position effect of the presented bigram found in the present study concurs with Brown and McNeill's (1966) conclusion that "attention, storage, and subsequent retrieval favor the ends of the words over the middle. Thus, presenting a bigram from either end of the solution should aid retrieval of the word more than giving a middle bigram."

Subject's retrieval and versatility storage capabilities may not be as limited as general bigram pattern recognition. Subjects may actually have stored differences in bigram position versatilities. As Dominowski (1967) suggested "it would appear fruitful to combine the partially restricted approach exemplified by BR with an approach considering bigram position. For instance, in presenting _S_s five-letter

anagrams they may notice that certain bigrams are more likely to appear in a certain position than in other positions. It may have been more valid in the present study to have constructed a versatility count strictly from five-letter words. This procedure however would not have provided a large enough sample with which to construct a versatility count and there is no reason to suspect the distribution of bigram versatilities takes a radical departure when going from five-letter words to words of all lengths. Table 6

Insert Table 6 about here

was constructed from the original bigram versatility counts. Every time a bigram appeared in a five-letter word its occurence was recorded along with its position in the word. The table, for example, reveals that "FL" appeared in six five-letter words in the count and in all six instances appeared in the 1-2 position. In an opposite case was the bigram "LY" which appeared six times, all in the 4-5 position. Such position characteristics of bigrams and _S_s awareness of them may in the future aid to a further understanding of the anagram solution process. In any sense, bigram frequency as a sole explanation and predictor of the process would be misleading and inaccurate. Bigram versatility must share a position of importance with the frequency dimension.

Summary

The present study investigated the role of bigram versatility and frequency in the anagram solution process. Bigram versatility was defined as the relative number of different words in which a bigram appears in the English lan-

guage as opposed to bigram frequency which includes the appearance of bigrams without reference to whether the appearance involves different words or the same ones. Thirty-six five-letter anagrams were presented to 24 Ss. Each anagram was shown with one of its bigrams indicated above the anagram. The indicated bigrams each represented a level of bigram frequency and versatility.

Anagrams with bigrams presented in the end positions, 1-2 and 4-5 were solved faster than in the middle positions 2-3 and 3-4. Bigrams rated in the second quartile of the versatility count distribution led to the fastest solution times across the frequency variable for both the high and low frequency solution words. The frequency variable across versatility showed a slight increase in length of solution time with decreases in bigram frequency. This trend was reversed in the lowest bigram frequency category for the low frequency solution words. The trend may have been due to inadequate word sampling. The results of the versatility variable were interpreted as representing the process of S being able to limit the number of possible solutions (interference) generated by a bigram of reduced versatility.

References

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Versatility and Frequency counts of Bigrams (B) AA-MY

rsatility, NV=12,344 bigrams; F=Frequency (Underwood & Schulz, 1960)

NF=1,000 words from T-L + 15,000 words running text)

B	V	F												
AA	0	3	CI	47	603	ER	264	4034	HM	3	50	KO	2	13
AB	54	639	CK	36	676	ES	129	2222	HN	6	11	KP	0	1
AC	60	1218	CL	24	648	ET	71	1268	HO	54	1129	KR	1	9
AD	46	747	CO	109	1117	EU	7	32	HP	0	1	KS	2	55
AE	1	6	CQ	2	1	EV	28	377	HR	10	193	KT	0	1
AF	12	175	CR	36	432	EW	15	312	HS	0	12	KU	0	5
AG	36	588	CS	0	5	EX	21	603	HT	17	496	KY	2	34
AH	2	25	CT	46	607	EY	16	153	HU	19	478	LA	89	1307
AI	49	829	CU	29	459	EZ	0	35	HV	0	1	LB	2	14
AJ	1	147	CY	15	77	FA	21	420	HW	0	6	LC	5	55
AK	18	439	DA	28	342	FB	0	2	HY	8	46	LD	22	682
AL	152	1690	DB	1	1	FE	22	712	IA	61	421	LE	168	2794
AM	44	759	DD	11	75	FF	18	328	IB	17	80	LF	7	75
AN	181	3182	DE	119	1476	FI	37	721	IC	105	1309	LG	2	17
AO	0	1	DF	3	58	FL	17	148	ID	48	495	LH	1	1
AP	38	703	DG	5	98	FN	0	3	IE	40	670	LI	99	1271
AQ	0	1	DH	2	5	FO	33	710	IF	17	513	LK	5	24
AR	139	2389	DI	82	706	FR	22	303	IG	46	925	LL	82	1298
AS	61	1540	DK	0	35	FS	0	6	IK	3	49	LM	7	181
AT	164	2363	DL	16	140	FT	9	200	IL	67	1083	LN	0	9
AU	22	362	DM	6	99	FU	27	349	IM	44	441	LO	64	1054
AV	20	479	DN	4	56	FY	9	92	IN	229	3902	LP	8	175
AW	11	110	DO	29	397	GA	31	398	IO	126	1615	LR	2	6
AX	4	62	DP	2	2	GB	0	1	IP	23	234	LS	10	227
AY	17	198	DR	15	472	GD	1	7	IQ	5	13	LT	14	140
AZ	5	30	DS	8	95	GE	51	883	IR	37	1061	LU	27	290
BA	31	413	DT	6	1	GF	2	3	IS	105	2051	LV	6	127
BB	5	20	DU	20	165	GG	10	101	IT	114	1334	LW	0	13
BD	2	1	DV	4	83	GH	21	684	IU	6	11	LY	105	1100
BE	45	761	DW	1	29	GI	18	456	IV	46	594	MA	84	1210
BI	21	234	DY	9	152	GL	18	192	IW	0	1	MB	20	288
BJ	0	7	EA	80	2516	GM	1	59	IX	4	124	ME	72	1161
BK	0	1	EB	9	26	GN	17	47	IZ	14	50	MF	0	5
BL	62	747	EC	54	729	GO	23	164	JA	5	83	MI	48	720
BN	1	1	ED	88	1176	GP	0	5	JE	6	93	ML	2	4
BO	31	404	EE	40	1046	GR	38	490	JI	2	2	MM	18	52
BR	31	197	EF	25	201	GS	3	64	JO	6	204	MN	7	4
BS	9	58	EG	21	295	GT	2	112	JU	8	163	MO	45	852
BT	1	2	EH	4	54	GU	17	127	KA	6	51	MP	38	382
BU	20	522	EI	10	397	GY	10	59	KB	2	7	MR	0	11
BV	1	2	EJ	1	1	HA	55	1396	KD	0	2	MS	8	49
BW	0	5	EK	5	70	HB	0	5	KE	44	828	MT	1	1
BY	2	68	EL	100	1579	HD	1	2	KF	0	6	MU	14	148
CA	88	1055	EM	40	691	HE	75	2897	KG	0	1	MY	6	77
CC	9	225	EN	180	3203	HF	4	4	KH	0	3			
CE	68	1596	EO	12	89	HG	0	1	KI	12	205			
CG	0	2	EP	23	320	HI	54	1003	KL	6	34			
CH	64	1297	EQ	10	159	HL	5	18	KN	6	88			

Table 1 (cont'd.)

Versatility and Frequency counts of Bigrams NA-ZZ

B	V	F	B	V	F	B	V	F	B	V	F	B	V	F
NA	65	637	OW	36	676	SD	1	1	UI	24	244	XT	5	125
NB	3	16	OX	4	38	SE	90	1865	UK	1	3	XU	1	15
NC	62	795	OY	1	111	SF	2	20	UL	57	817	YA	1	96
ND	77	1650	OZ	1	5	SG	1	49	UM	30	288	YB	0	6
NE	103	1689	PA	48	1098	SH	59	1203	UN	79	1147	YC	4	12
NF	19	124	PB	1	4	SI	76	1057	UO	5	37	YD	2	19
NG	91	1998	PE	83	1263	SK	9	111	UP	18	311	YE	5	105
NH	5	18	PF	0	14	SL	20	349	UR	75	1304	YG	2	8
NI	60	574	PH	29	157	SM	17	90	US	90	1079	YH	0	2
NJ	2	8	PI	30	281	SN	7	47	UT	34	1137	YI	3	64
NK	13	142	PK	0	1	SO	43	920	UV	0	6	YL	2	84
NL	9	73	PL	30	498	SP	45	707	UX	3	10	YM	3	33
NM	4	25	PM	1	12	SQ	3	12	UY	0	6	YN	2	10
NN	17	235	PN	0	1	SR	0	1	UZ	0	7	YO	6	251
NO	32	728	PO	49	818	SS	83	1037	VA	26	379	YP	5	34
NP	2	3	PP	14	451	ST	136	3473	VE	104	2040	YR	8	23
NQ	3	69	PR	65	840	SU	40	598	VI	36	613	YS	10	56
NR	3	26	PS	4	32	SW	7	100	VO	10	122	YT	3	17
NS	55	466	PT	13	283	SY	9	180	VR	0	1	YV	0	1
NT	158	2852	PU	50	220	TA	88	913	VU	1	1	YW	1	19
NU	13	269	PY	3	72	TB	1	5	VY	0	12	YX	0	4
NV	7	155	QU	31	430	TC	10	163	WA	27	723	ZA	3	10
NW	2	13	RA	140	1488	TD	0	2	WB	2	6	ZE	14	88
NX	1	3	RB	9	70	TE	174	2899	WC	0	2	ZI	1	10
NY	11	85	RC	13	515	TF	5	19	WD	2	117	ZL	1	4
NZ	1	5	RD	31	354	TG	1	3	WE	15	779	ZO	3	8
OA	17	66	RE	210	3791	TH	71	2879	WH	14	700	ZY	2	7
OB	19	121	RF	6	126	TI	189	2497	WI	18	338	ZZ	2	9
OC	22	578	RG	15	165	TJ	0	1	WK	1	4			
OD	25	304	RH	1	9	TL	20	639	WL	6	17			
OE	5	93	RI	134	1515	TM	12	63	WM	1	1			
OF	8	737	RK	7	250	TN	4	16	WN	11	212			
OG	22	217	RL	19	277	TO	63	1213	WO	16	288			
OH	7	6	RM	18	365	TP	0	1	WP	2	1			
OI	14	113	RN	23	282	TR	66	1028	WR	5	64			
OJ	0	3	RO	97	1721	TS	8	342	WS	0	23			
OK	9	406	RP	12	28	TT	32	418	WT	1	6			
OL	64	950	RR	26	217	TU	39	472	WY	2	16			
OM	45	740	RS	31	470	TW	3	65	XA	4	102			
ON	220	3107	RT	57	687	TY	48	725	XC	4	62			
OO	46	716	RU	30	140	TZ	0	4	XE	2	71			
OP	24	268	RV	10	137	UA	19	171	XF	1	17			
OQ	0	1	RW	3	51	UB	15	90	XH	0	3			
OR	149	2260	RX	0	2	UC	23	205	XI	6	120			
OS	40	592	RY	35	459	UD	15	139	XL	1	10			
OT	37	738	SA	37	566	UE	17	320	XM	0	2			
OU	92	2118	SB	1	21	UF	6	171	XO	1	1			
OV	23	766	SC	36	329	UG	15	249	XP	7	237			

Table 2

Class Limits of the Frequency and Versatility Conditions

FREQUENCY		VERSATILITY	
Condition	Class Limits	Condition	Class Limits
F 1	600-	V 1	36-
F 2	100-599	V 2	10-35
F 3	10-99	V 3	3-9
F 4	0-9	V 4	0-2

Table 3

le distribution of Frequency and Versatility counts of Bigrams AA-MY

(F1=600-, 2=100-599, 3=10-99, 4=0-9; V1=36-, 2=10-35, 3=3-9, 4=0-2)

B	F	V																		
AA	4	4	BN	4	4	DM	3	3	EX	1	2	HA	1	1	IS	1	1	LF	3	3
AB	1	1	BO	2	2	DN	3	3	EY	2	2	HB	4	4	IT	1	1	LG	3	4
AC	1	1	BR	2	2	DO	2	2	EZ	3	4	HD	4	4	IU	3	3	LH	4	4
AD	1	1	BS	3	3	DP	4	4	FA	2	2	HE	1	1	IV	2	1	LI	1	1
AE	4	4	BT	4	4	DR	2	2	FB	4	4	HF	4	3	IW	4	4	LK	3	3
AF	2	2	BU	2	2	DS	3	3	FE	1	2	HG	4	4	IX	2	3	LL	1	1
AG	2	1	BV	4	4	DT	4	3	FF	2	2	HI	1	1	IZ	3	2	LM	2	3
AH	3	4	BW	4	4	DU	2	2	FI	1	1	HL	3	3	JA	3	3	LN	4	4
AI	1	1	BY	3	4	DV	3	3	FL	2	2	HM	3	3	JE	3	3	LO	1	1
AJ	2	4	CA	1	1	DW	3	4	FN	4	4	HN	3	3	JI	4	4	LP	2	3
AK	2	2	CC	2	3	DY	2	3	FO	1	2	HO	1	1	JO	2	3	LR	4	4
AL	1	1	CE	1	1	EA	1	1	FR	2	2	HP	4	4	JU	2	3	LS	2	2
AM	1	1	CG	4	4	EB	3	3	FS	4	4	HR	2	2	KA	3	3	LT	2	2
AN	1	1	CH	1	1	EC	1	1	FT	2	3	HS	3	4	KB	4	4	LU	2	2
AO	4	4	CI	1	1	ED	1	1	FU	2	2	HT	2	2	KD	4	4	LV	2	3
AP	1	1	CK	1	1	EE	1	1	FY	3	3	HU	2	2	KE	1	1	LW	3	4
AQ	4	4	CL	1	2	EF	2	2	GA	2	2	HV	4	4	KF	4	4	LY	1	1
AR	1	1	CO	1	1	EG	2	2	GB	4	4	HW	4	4	KG	4	4	MA	1	1
AS	1	1	CQ	4	4	EH	3	3	GD	4	4	HY	3	3	KH	4	4	MB	2	2
AT	1	1	CR	2	1	EI	2	2	GE	1	1	IA	2	1	KI	2	2	ME	1	1
AU	2	2	CS	4	4	EJ	4	4	GF	4	4	IB	3	2	KL	3	3	MF	4	4
AV	2	2	CT	1	1	EK	3	3	GG	2	2	IC	1	1	KN	3	3	MI	1	1
AW	2	2	CU	2	2	EL	1	1	GH	1	2	ID	2	1	KO	3	4	ML	4	4
AX	3	3	CY	3	2	EM	1	1	GI	2	2	IE	1	1	KP	4	4	MM	3	2
AY	2	2	DA	2	2	EN	1	1	GL	2	2	IF	2	2	KR	4	4	MN	4	3
AZ	3	3	DB	4	4	EO	3	2	GM	3	4	IG	1	1	KS	3	4	MO	1	1
BA	2	2	DD	3	2	EP	2	2	GN	3	2	IK	3	3	KT	4	4	MP	2	1
BB	3	3	DE	1	1	EQ	2	2	GO	2	2	IL	1	1	KU	4	4	MR	3	4
BD	4	4	DF	3	3	ER	1	1	GP	4	4	IM	2	1	KY	3	4	MS	3	3
BE	1	1	DG	3	3	ES	1	1	GR	2	1	IN	1	1	LA	1	1	MT	4	4
BI	2	2	DH	4	4	ET	1	1	GS	3	3	IO	1	1	LB	3	4	MU	2	2
BJ	4	4	DI	1	1	EU	3	3	GT	2	4	IP	2	2	LC	3	3	MY	3	3
BK	4	4	DK	3	4	EV	2	2	GU	2	2	IQ	3	3	LD	1	2			
BL	1	1	DL	2	2	EW	2	2	GY	3	2	IR	1	1	LE	1	1			

Table 3 (cont'd.)

rtile distribution of Frequency and Versatility counts of Bigrams NA-ZZ

B	F	V																		
NA	1	1	OI	2	2	PY	3	3	SK	2	3	TZ	4	4	WH	1	2	YN	3	4
NB	3	3	OJ	4	4	QU	2	2	SL	2	2	UA	2	2	WI	2	2	YO	2	3
NC	1	1	OK	2	3	RA	1	1	SM	3	2	UB	3	2	WK	4	4	YP	3	3
ND	1	1	OL	1	1	RB	3	3	SN	3	3	UC	2	2	WL	3	3	YR	3	3
NE	1	1	OM	1	1	RC	2	2	SO	1	1	UD	2	2	WM	4	4	YS	3	2
NF	2	2	ON	1	1	RD	2	2	SP	1	1	UE	2	2	WN	2	2	YT	3	3
NG	1	1	OO	1	1	RE	1	1	SQ	3	3	UF	2	3	WO	2	2	YV	4	4
NH	3	3	OP	2	2	RF	2	3	SR	4	4	UG	2	2	WP	4	4	YW	3	4
NI	2	1	OQ	4	4	RG	2	2	SS	1	1	UI	2	2	WR	3	3	YX	4	4
NJ	4	4	OR	1	1	RH	4	4	ST	1	1	UK	4	4	WS	3	4	ZA	3	3
NK	2	2	OS	2	1	RI	1	1	SU	2	1	UL	1	1	WT	4	4	ZE	3	2
NL	3	3	OT	1	1	RK	2	3	SW	2	3	UM	2	2	WY	3	4	ZI	3	4
NM	3	3	OU	1	1	RL	2	2	SY	2	3	UN	1	1	XA	2	3	ZL	4	4
NN	2	2	OV	1	2	RM	2	2	TA	1	1	UO	3	3	XC	3	3	ZO	4	3
NO	1	2	OW	1	1	RN	2	2	TB	4	4	UP	2	2	XE	3	4	ZY	4	4
NP	4	4	OX	3	3	RO	1	1	TC	2	2	UR	1	1	XF	3	4	ZZ	4	4
NQ	3	3	OY	2	4	RP	3	2	TD	4	4	US	1	1	XH	4	4			
NR	3	3	OZ	4	4	RR	2	2	TE	1	1	UT	1	2	XI	2	3			
NS	2	1	PA	1	1	RS	2	2	TF	3	3	UV	4	4	XL	3	4			
NT	1	1	PB	4	4	RT	1	1	TG	4	4	UX	3	3	XM	4	4			
NU	3	2	PE	1	1	RU	2	2	TH	1	1	UY	4	4	XO	4	4			
NV	2	3	PF	3	4	RV	2	2	TI	1	1	UZ	4	4	XP	2	3			
NW	3	4	PH	2	2	RW	3	3	TJ	4	4	VA	2	2	XT	2	3			
NX	4	4	PI	2	2	RX	4	4	TL	1	2	VE	1	1	XU	3	4			
NY	3	2	PK	4	4	RY	2	2	TM	3	2	VI	1	1	YA	3	4			
NZ	4	4	PL	2	2	SA	2	1	TN	3	3	VO	2	2	YB	4	4			
OA	3	2	PM	3	4	SB	3	4	TO	1	1	VR	4	4	YC	3	3			
OB	2	2	PN	4	4	SC	2	1	TP	4	4	VU	4	4	YD	3	4			
OC	2	2	PO	1	1	SD	4	4	TR	1	1	VY	3	4	YE	2	3			
OD	2	2	PP	2	2	SE	1	1	TS	2	3	WA	1	2	YG	4	4			
OE	3	3	PR	1	1	SF	3	4	TT	2	2	WB	4	4	YH	4	4			
OF	1	3	PS	3	3	SG	3	4	TU	2	1	WC	4	4	YI	3	3			
OG	2	2	PT	2	2	SH	1	1	TW	3	3	WD	2	4	YL	3	4			
OH	4	3	PU	2	2	SI	1	1	TY	1	1	WE	1	2	YM	3	3			

Table 4

Solution words used in experiment

(Bigrams underlined indicate the bigrams shown above the anagram)

FV value	Example of stimulus material: w h / iehtw
High frequency sol. words	**Low frequency sol. words**
F1V2: white cover power child	F1V2: whine covet vowel guild
F2V1: grand giant guide crown	F2V1: grind liver chide crank
F2V3: young broke	F2V3: joust choke
F3V2: doubt fancy	F3V2: smack chirp
F3V4: style heavy	
F1V1: black women since shake	
F2V2: human brave began music	
F3V3: write lying	

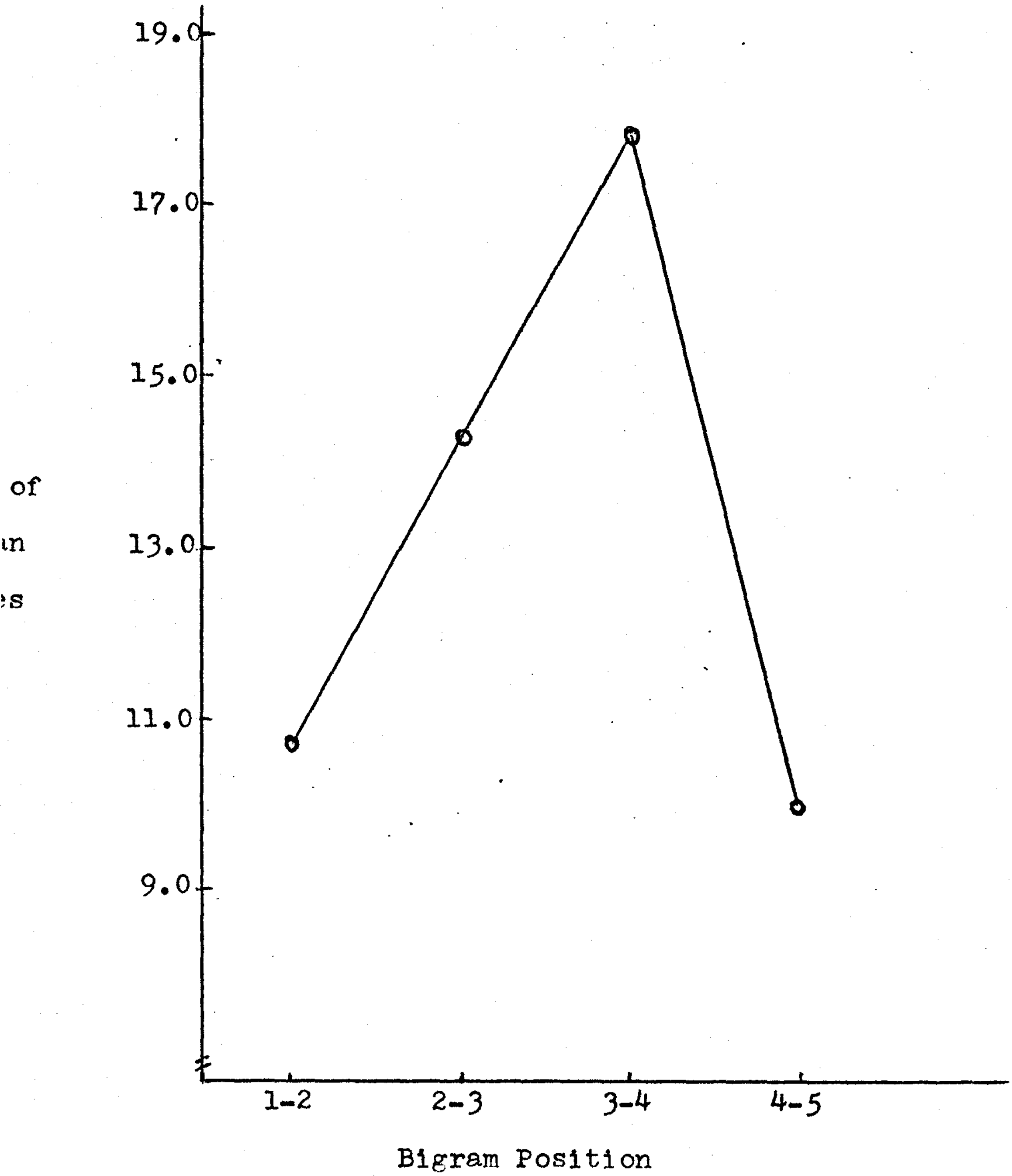

Fig. 1. Mean solution time scores as a function of bigram position

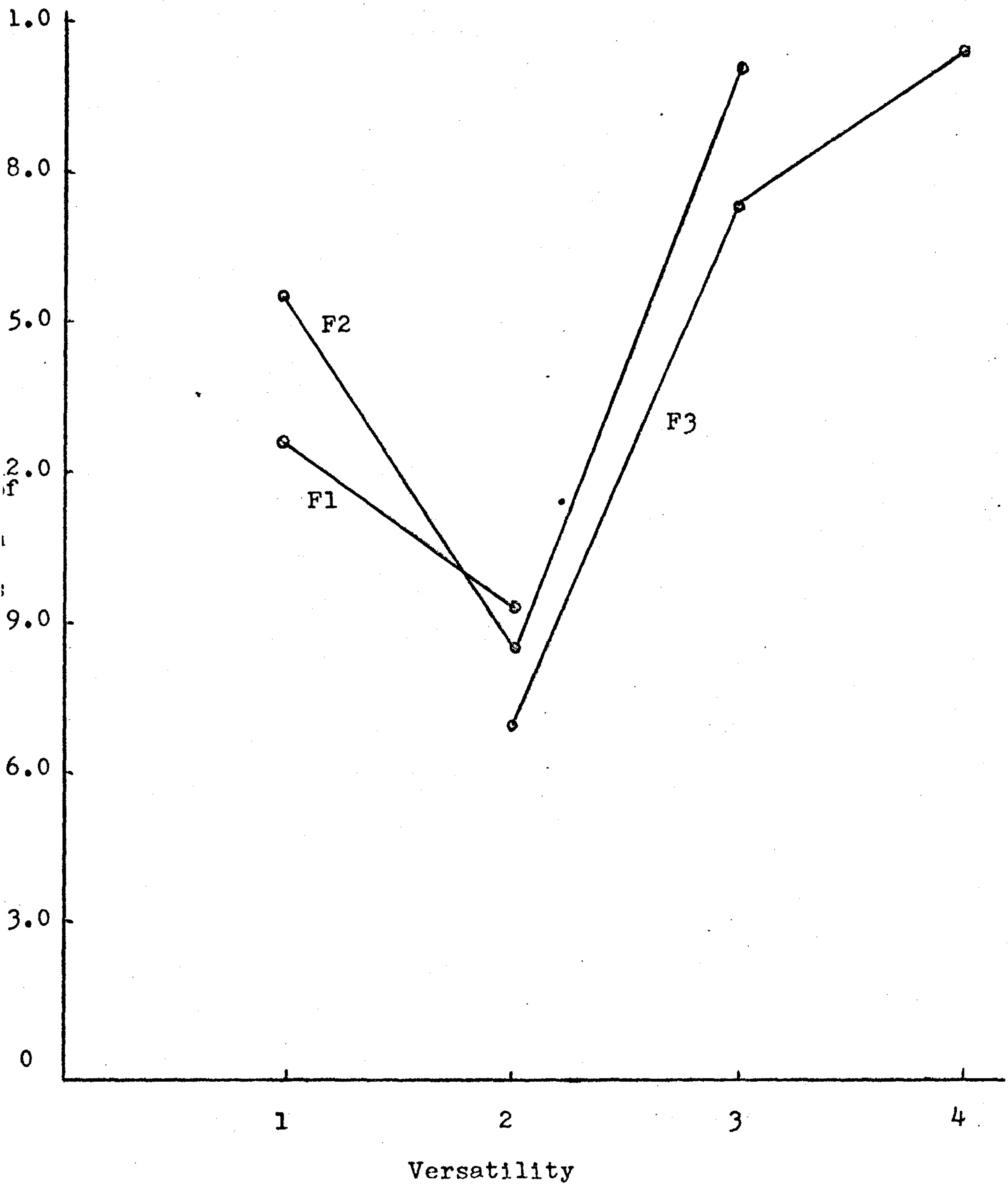

Fig. 2. Mean solution time scores as a function of versatility and frequency

Table 5

Mean of the Mean and Median times for all

Frequency (F) and Versatility (V) conditions used

(*= Low frequency sol. word times)

V		F 1	2	3	Mean across F
1	$\bar{X}$	14.5	15.1 16.2*		14.8 16.2*
	Mdn.	12.8	15.5 16.1*		14.2 16.1*
2	$\bar{X}$	13.6 15.2*	10.8	10.7 13.0*	11.7 14.1*
	Mdn.	9.4 14.1*	8.5	7.1 9.6*	8.3 11.8*
3	$\bar{X}$		17.0 16.0*	17.1	17.0 16.0*
	Mdn.		20.0 12.8*	17.3	18.7 12.8*
4	$\bar{X}$			17.7	17.7
	Mdn.			20.4	20.4
Mean across V	$\bar{X}$	14.0 15.2*	14.3 16.1*	15.2 13.0*	
	Mdn.	11.1 14.1*	14.7 14.5*	14.9 9.6*	

Table 6

Versatility counts of Position of Bigrams (B) in five-letter words

(1=pos. 1-2, 2=2-3, 3=3-4, 4=4-5; T=total, n= [illegible],964)

(AB-HU)

B	T	1	2	3	4												
AB	3	1	2	-	-	CL	7	6	-	1	-	ET	3	-	2	-	1
AC	5	-	1	4	-	CO	2	2	-	-	-	EV	3	-	3	-	-
AD	2	1	-	-	1	CR	6	6	-	-	-	EW	2	-	2	-	-
AF	1	1	-	-	-	CT	1	-	-	-	1	FA	1	1	-	-	-
AG	2	1	1	-	-	CU	3	1	1	1	-	FE	1	1	-	-	-
AI	8	-	5	3	-	DA	6	4	-	2	-	FF	3	-	-	-	3
AK	3	-	-	2	1	DE	9	5	-	-	4	FI	1	1	-	-	-
AL	10	-	4	4	2	DG	1	-	-	1	-	FL	6	6	-	-	-
AM	4	2	-	2	-	DI	2	2	-	-	-	FO	3	2	1	-	-
AN	15	3	4	7	1	DO	5	3	1	1	-	FR	1	1	-	-	-
AP	5	1	2	-	2	DR	7	6	-	1	-	FT	1	-	1	-	-
AR	14	2	5	6	1	DW	1	1	-	-	-	FU	1	1	-	-	-
AS	9	1	3	5	-	DY	3	1	-	-	2	FY	1	-	-	-	1
AT	6	-	2	2	2	EA	9	1	5	3	-	GA	1	-	1	-	-
AU	2	1	-	1	-	EB	2	-	2	-	-	GE	7	1	-	3	3
AV	5	-	3	2	-	EC	2	-	1	1	-	GG	1	-	-	1	-
AW	1	1	-	-	-	ED	2	-	-	1	1	GH	2	-	-	2	-
AY	3	-	1	-	2	EE	4	-	-	4	-	GI	2	2	-	-	-
BA	1	1	-	-	-	EG	3	-	2	1	-	GN	2	1	-	-	1
BE	9	5	-	3	1	EI	1	-	1	-	-	GO	2	-	-	1	1
BL	5	4	-	1	-	EJ	1	1	-	-	-	GR	5	4	-	1	-
BO	2	-	1	1	-	EK	2	-	-	-	2	GU	3	1	-	2	-
BR	3	2	-	1	-	EL	16	3	5	4	4	GY	2	-	-	-	2
BU	5	4	-	1	-	EM	1	-	-	-	1	HA	8	5	3	-	-
CA	4	3	1	-	-	EN	7	-	2	1	4	HE	6	3	2	1	-
CE	2	-	-	-	2	EP	2	-	2	-	-	HI	5	-	5	-	-
CH	6	4	-	-	2	EQ	1	1	-	-	-	HO	7	4	3	-	-
CI	2	-	1	1	-	ER	18	-	3	11	4	HT	2	-	-	-	2
CK	6	-	-	1	5	ES	8	-	-	4	4	HU	3	3	-	-	-

Note-only bigrams found at least once in a five-letter word are listed.

Table 6 (cont'd.)

Versatility counts of Position of Bigrams in five-letter words

(HY-PT)

B	T	1	2	3	4												
HY	1	1	-	-	-	LL	11	-	1	5	5	NT	8	-	-	1	7
IA	3	-	1	2	-	LM	2	-	1	1	-	NY	1	-	-	-	1
IC	6	-	-	3	3	LO	7	2	4	-	1	OA	2	-	1	1	-
ID	4	-	-	-	4	LP	3	-	-	1	2	OB	2	-	1	1	-
IE	3	-	1	2	-	LS	1	-	-	-	1	OC	1	-	1	-	-
IF	1	-	-	1	-	LT	3	-	-	1	2	OD	5	-	2	2	1
IG	3	-	2	1	-	LU	5	1	4	-	-	OF	1	1	-	-	-
IL	4	-	-	3	1	LV	1	-	-	1	-	OG	2	-	2	-	-
IM	4	-	4	-	-	LY	6	-	-	-	6	OI	4	-	3	1	-
IN	11	-	2	5	4	MA	4	1	1	-	2	OL	4	-	2	2	-
IO	3	-	-	3	-	MB	1	-	1	-	-	OM	3	-	2	1	-
IP	1	-	-	-	1	ME	3	-	1	1	1	ON	8	-	1	2	5
IR	4	-	2	1	1	MI	5	1	-	4	-	OO	5	-	2	3	-
IS	10	-	-	7	3	MM	2	-	-	2	-	OP	1	-	-	1	-
IT	4	-	-	1	3	MO	6	4	-	2	-	OR	13	-	3	1	9
IV	3	-	2	1	-	MU	2	-	1	1	-	OS	4	1	1	2	-
IX	1	-	1	-	-	MY	2	-	-	-	2	OT	8	1	2	2	3
JE	3	2	1	-	-	NA	3	2	1	-	-	OU	7	2	4	-	1
JI	1	1	-	-	-	NC	2	-	1	1	-	OV	1	-	-	1	-
JO	1	-	-	1	-	ND	1	-	-	-	1	OW	3	-	1	2	-
JU	1	1	-	-	-	NE	8	2	1	1	4	PA	4	1	2	1	-
KE	4	-	-	2	2	NG	6	-	2	-	4	PE	3	1	-	1	1
KN	1	1	-	-	-	NI	4	-	2	2	-	PH	1	-	-	-	1
KY	1	-	-	-	1	NJ	1	-	1	-	-	PI	1	-	-	1	-
LA	8	-	7	1	-	NK	3	-	-	-	3	PL	4	3	-	1	-
LD	1	-	-	-	1	NN	1	-	-	1	-	PO	2	1	-	1	-
LE	15	2	4	3	6	NO	6	3	-	3	-	PP	1	-	-	1	-
LI	8	3	3	2	-	NR	1	-	-	1	-	PR	3	3	-	-	-
LK	1	-	-	1	-	NS	2	-	-	-	2	PT	1	-	1	-	-

Table 6 (cont'd.)

Versatility counts of Position of Bigrams in five-letter words

(PU-ZY)

B	T	1	2	3	4
PU	1	1	-	-	-
PY	1	-	-	-	1
QU	3	3	-	-	-
RA	17	2	11	2	2
RC	1	-	-	1	-
RD	3	-	1	2	-
RE	15	3	6	2	4
RF	1	-	-	-	1
RG	2	-	-	2	-
RI	6	-	3	3	-
RK	1	-	-	-	1
RN	3	-	-	1	2
RO	14	4	7	1	2
RR	2	-	-	2	-
RS	3	-	-	3	-
RT	3	-	-	1	2
RU	3	-	3	-	-
RY	2	-	-	-	2
SA	4	4	-	-	-
SC	3	3	-	-	-
SE	7	1	-	-	6
SH	7	4	-	-	3
SI	4	2	1	1	-
SK	3	-	-	-	3
SL	2	2	-	-	-
SM	2	2	-	-	-
SN	2	-	-	2	-
SO	1	1	-	-	-
SP	4	2	1	-	1
SS	9	-	-	1	8
ST	11	6	-	2	3
SU	2	2	-	-	-
SW	3	3	-	-	-
SY	4	2	-	-	2
TA	8	5	1	1	1
TE	7	-	1	3	3
TH	6	2	1	-	3
TI	3	1	1	1	-
TL	1	-	-	1	-
TO	5	1	1	2	1
TR	7	4	2	1	-
TT	1	-	-	1	-
TU	6	5	-	1	-
TW	1	1	-	-	-
TY	4	-	-	-	4
UA	2	-	2	-	-
UB	1	-	1	-	-
UD	2	-	1	1	-
UE	1	-	-	-	1
UF	3	-	-	3	-
UG	2	-	2	-	-
UI	2	-	1	1	-
UL	6	-	4	2	-
UM	4	-	3	-	1
UN	7	3	1	2	1
UP	1	-	1	-	-
UR	7	1	5	-	1
US	7	-	2	4	1
UT	4	-	2	1	1
UX	1	-	-	-	1
VA	1	1	-	-	-
VE	12	1	-	6	5
VI	3	1	-	2	-
VO	2	2	-	-	-
WA	5	2	3	-	-
WE	3	-	3	-	-
WH	3	3	-	-	-
WI	1	-	-	1	-
WN	1	-	-	-	1
WR	1	1	-	-	-
WY	1	-	-	-	1
XO	1	-	-	1	-
YD	1	-	1	-	-
YE	1	-	-	1	-
YI	1	-	1	-	-
YR	1	-	1	-	-
ZE	1	1	-	-	-
ZY	1	-	-	-	1

APPROVAL SHEET

The Thesis submitted by Gene Edward Topper has been read and approved by members of the Department of Psychology.

The final copies have been examined by the director of the Thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the Thesis is now given final approval with reference to content and form.

The Thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Arts.

June 18, 1971
Date

Signature of Advisor