THE EFFECT OF COLOR CODING ON PERFORMANCE OF AN ALPHABETIC FILING TASK

by

BRUCE GARY KOE

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Approved by:

Dr. Stephen Kang

Major Professor

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INTRODUCTION

Office files are an accepted fact in over a million businesses in the United States and in several million more in the rest of the world. Typical files found in these businesses would contain information on correspondence, projects, sales accounts, cost accounts, employees, and servicing agents, just to name a few categories. The maintenance of these filing systems becomes a problem which grows in proportion to the information explosion that technology is producing. Hence, specialists, namely file clerks, have been called upon to retrieve, file, and in some cases, to logically classify information.

File clerks and secretaries, being human, make errors while filing. Usually these human errors are recognized by the absence of a file from its explicit location or by finding it in the wrong location. To help minimize these errors, Remington Office Systems has a Variadex (Color Keyed Variadex System, 1966) color coded filing system claimed to reduce finding time by as much as 80%. The Variadex System divides each letter of the alphabet into five color coded groups. For example, using the letter B, orange files are from Ba-Bd; yellow from Be-Bh; green from Bi-Bn; blue from Bo-Bq; violet from Br-Bz. In Variadex the index tabs are solid colors while the labels on the individual files are striped with the color key above and below the identifying name.

Still another Remington color based random filing system called Colorscan claims to decrease filing errors by 80% or more over conventional systems. In the Colorscan random filing system the alphabet may be broken up into several alphabetical sections per letter. For example, the letter B may contain tab cards B, Be, Bi, Bo, Br, and Bro. Files returned to the

system are filed at the front of the appropriate section found within the first letter groups. The item Blotter, Alfred E., is then filed just behind the Bi tab. Using this rule with all subsequent items to be filed between Bi and Bo, the more active files will be found near the front of each section while the entire section may have a random alphabetical appearance.

Smith (1963) found that, for five-colored lighted displays, average search times were considerably (14 to 34%) shorter when the color key was known in advance than when the color key was unknown. In a second study, on the redundancy of color coded displays, Smith again found color coding to reduce search times and found errors as much as 25% less using color code over no code conditions.

Research on color coding versus other types of coding indicate some characteristics common to color coding. Jones (1962) found research indicated that color codes are superior to other types of codes (ie: size, inclination, geometric shape, numeric form, and letters) for certain kinds of tasks. Visual search tasks seemed to demonstrate this generality best. These studies also suggest that limitations exist under conditions of limited time exposures and precise identification. In general, research suggests that tasks that involve scanning a group of visual objects in order to locate or count are performed better with color codes than with a variety of other codes (Jones, 1962).

Hitt et. al. (1960) and Ericksen and Hake (1954) suggest that search time varies inversely with the number of coding dimensions and/or with the number of stimulus categories. Hitt found that with two, four, and eight levels of color that performance decreased rapidly when the number of

stimulus categories exceeded two.

In short, there is evidence which suggests that color coding used for categorical type tasks (ie: partially redundant coding) stimulates more attention, hence improving performance in search tasks in general.

Chapanis and Halsey (1956) investigated the effect of luminous spectral hues, ranging from a series with 10 stimuli to one with 17, with four alphabet sizes. The smaller 10-hue series had the greatest accuracy (2% error) and the percentage of errors increased with the size of the series. Chapanis and Halseys' work was confirmed, for all practical purposes, by Conover (1959) who used 25 maximally saturated Munsell hues to determine that a normal observer can absolutely identify nine surface colors. These findings suggest that the number of categories of an effective color coding system should be quite small (for example, no more than ten different colors).

It is then reasoned that number of categories is a limiting factor in color coding. Therefore, the application of color coding compounded with a denser coding system (ie: numerical or alphabetical) improves search type tasks by using the gross categorization of color to speed rough area location and a rather high density code to provide discrete location within a particular hue.

PROBLEM

Even though the effect of color coding on the performance of filing systems seems relatively unexplored, the concept is widely accepted by many companies and institutions around the world. Certainly color coding must have some attributes which can be quantified by this experiment.

The first question that comes to mind is how does one define color coding? The conventional approach taken by many commercial color coding systems is to assign a particular color to certain letters or numbers. A problem, which will not be explored here but which may well deserve attention, is what contrasts should the color codes have and what number of colors should be used in any given system.

An even more basic problem is whether color coding significantly improves the performance of a filing task; and, how do you define performance? Certainly both speed and quality are important but may differ in weight with particular applications. In this experiment, performance was indicated by three indices; one of speed or rate, and two indicating quality. Speed was expressed as a rate of items filed per minute. The first quality index was the number of misfiled items; the second was the magnitude of each error, or more specifically, the number of items away from home position a misfiled item was placed.

The speed of performance, number of errors, magnitude of errors, and preference of users were the four criteria used in the investigation of three different alphabetic color coded filing systems.

Task

A population of 1875 color striped (a 1/4 inch band along the entire top edge) IBM cards were used for the alphabetical filing task. All the

cards in a box were key punched with a name and interpreted in the color stripe area of the cards. The cards, in alphabetical order, were then punched in columns 56-59 with a number from 1 to 1875 respectively. These punched numbers were used for detecting errors and to select the cards to be filed; the cards with a number ending in 3 or 9 (375 of the 1875 cards) were selected as the cards to be filed. A number was punched in column 50-52 of these 375 cards; the specific number for each card was assigned randomly. The 375 cards were then ordered on this random number; this permitted each subject to file the 375 cards in the same order.

No names beginning with the letter X were used in order to balance the distribution of letters equally at five letters per color. The names (last name first) for the 1875 cards were partially taken from the Kansas City, Kansas, telephone directory. Each letter grouping (A's, B's, C's, etc.) was preceded by a tab card indicating the first letter of the names that followed. Each letter category had 75 cards (75 cards x 25 letters = 1875 cards).

Three different color code systems were evaluated; each of the systems used the same names. The subjects filed the same 375 names each time to make a completed box of 1875 cards at the end of a condition.

The "no code" condition consisted of a box of solid manila (no color code) cards. The "first letter code" condition associated the first letter of the last names with the color key:

A-E	Blue
F-J	Red
K-O	Green
P-T	Manila
U-Z	Brown

The "second letter code" condition, similar to Remington's Variadex, associated the second letter of the last name with the color key. To equally balance the distribution of names within a letter in the second code, it was necessary to break down each group of 75 cards beginning with a common first letter into five groups of fifteen cards each coded on the second letter using the above color key. Therefore, for the letter B: Ba-Be, Blue; Bf-Bj, Red; Bk-Bo, Green; Bp-Bt, Manila; Bu-Bz, Brown. Hence: 15 cards/group x 5 groups/letter x 25 letters = 1875 cards.

Subjects

Twenty-four male undergraduate students attending Kansas State University served as subjects. All had admittedly good eye sight for close work and were not color blind. The average age was 18.5 years, median 18, with a range from 17 to 21. The average number of years of school was 12.7, median 12, with a range from 12 to 15.

Each of the four groups of six subjects came from an organized living group on campus; thus each person in the group knew the other five persons informally. The subjects received $6.00 base pay for the seven hour experiment (which the last three groups donated to their fraternity pledge treasuries) and could receive from nothing to $4.50 in bonus pay.

Apparatus

The file boxes were placed on a table 4' x 8' that was 40" from the floor of the Human Engineering Lab, Department of Industrial Engineering. The subjects sat on stools or, at their option, could work standing. Each subject had a decimal minute watch and five IBM cards of appropriate color designating the key to the color code. A block of wood 6" x 4" x 3" was given to each subject to place at the back of his box to keep the cards in

an upright position while searching and filing. The laboratory was quiet (approximately 55 db.) at about 75°F with low humidity and 60 foot candles of light at table height. The equipment used to generate, process, and validate the cards was an IBM model 029 key punch, a model 089 card sorter, and a model 1401 computer.

Procedure

Four groups of six subjects were used for the experiment. Each group performed the filing task from 5:00 P.M. until approximately 12:00 midnight on one of four nights in early October, 1967. The subjects, six to a group, were seated around a rectangular table. It was explained that the purpose of the experiment, which required filing IBM cards into boxes of IBM cards, was to determine performance with three different color codes. The first six subjects had three sets of 375 cards to file but the last three groups had the 375 cards in a set split in half so they had six sets which required approximately one hour each to file. The sequence each subject followed is given in Table 1. The bonus system was explained along with the fact that all the sets would be started at the same time. Each subject was familiarized with the use of his stop watch and how to time himself.

Social pressure and a bonus system were used as an incentive for the subjects to speed up their filing rate. The bonus system for the first six subjects gave a $1.00 bonus to the first man to finish one of the three sets, a $.50 bonus to both the second and third, and nothing to the last three to finish. The remaining 18 subjects received a bonus of $.75 for the first to finish one of the six sets, $.50 each for second and third, $.25 to fourth and fifth, and nothing for last place. The sequence was changed after six subjects to improve the sequence from three sets (A B C sequence) to six

Table 1. Experimental sequence per subject by color code conditions.

Subject	Sequence	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6
1	A	1	2	No			
2	B	No	1	2			
3	C	2	No	1			
4	D	No	2	1			
5	E	1	No	2			
6	F	2	1	No			
7	F	2	1	No	No	1	2
8	E	1	No	2	2	No	1
9	D	No	2	1	1	2	No
10	C	2	No	1	1	No	2
11	B	No	1	2	2	1	No
12	A	1	2	No	No	2	1
13	D	No	2	1	1	2	No
14	E	1	No	2	2	No	1
15	F	2	1	No	No	1	2
16	C	2	No	1	1	No	2
17	B	No	1	2	2	1	No
18	A	1	2	No	No	2	1
19	A	1	2	No	No	2	1
20	B	No	1	2	2	1	No
21	C	2	No	1	1	No	2
22	F	2	1	No	No	1	2
23	E	1	No	2	2	No	1
24	D	No	2	1	1	2	No

No = No code condition

1 = First letter code condition

2 = Second letter code condition

sets (A B C C B A sequence) with better balance for learning and fatigue. The bonus was increased to compensate more of the subjects in hope of increasing their overall chance to make a bonus.

Social pressure existed when some of the subjects had finished filing the required number of cards and were allowed to relax, leave the room, or comment to the others to hurry up so they could start the next set.

The first six subjects worked in only three periods and had three periods of rest, reward, and social pressure during the seven hour experiment. The remaining 18 subjects had six such periods. At the end of each set, times were recorded from the subjects' watches and bonus credits were given. After the last set, the subjects were asked which condition they preferred most and least. They were then paid and thanked for their help.

The 18 boxes of cards were taken to the 1401 computer where a printout of each box of cards was made showing the incorrectly inserted cards and the magnitude of the errors (Exhibit 1). The cards to be filed by the next subjects were removed and then sorted (columns 50-52) into the reproducible random order. Then the 375 cards were broken into two stacks of 188 and 187 cards. This separation was necessary since two sets were needed per condition to balance the effect of fatigue and learning.

Exhibit 1. Portion of typical computer printout.

Name	Random Number	Sequence Number	Error	Magnitude of Error
EBBERTS, MAX		308		
EBECK, CHAS	295	309		
EBELMESSER, L A		310		
ECKARD, HERBERT		312		
ECHOLS, LOUISE		311	INSERT ----------	DELTA = 1-
ECKHOFF, FOREST	705	313		
EDELBAUM, FANNIE		314		
EDWARDS, HAROLD		315		
EFFERTZ, FRED		316		
EFFIE, ROBERT		317		
EFT, ELIZABETH		318		
EGAN, JOHN	920	319		
EGBERT, ARTHUR		320		
EGELBERG, SALLY		321		
EGELHOFF, JIMMY		322		
EGERTON, THOMAS	632	323		
EHARHARDT, LINLEY		324		
EHERENMAN, CHAS		325		
EHLERS, ELMER		326		
EICHEM, L R		327		
EICHENBAUM, MAX		328		
EICHHOLZ, SID	449	329		
EIDSON, WILLIAM		330		
ELFFNER, ERNEST		331		
ELI, BRYAN		332		
ELLEDGE, WALTER		333		
EMERICK, ESTER		338	INSERT ----------	DELTA = 5
ELLIASON, MARTIN R		334		
ELLSBERRY, EDWIN		335		
EMANUEL, ELMER		336		
EMBERTON, HENRY		337		
EMMERT, DONALD	789	339		

RESULTS

The Dixon critera for rejecting outliers (Natrella, 1963) was used with a 10% risk to reject the data of subjects 4 and 21 as not being characteristic of the population. These two subjects' errors were 43 and 59% higher than the number of total errors for the next worst subject. All the following analyses consider only the remaining 22 subjects.

The times for filing the 375 cards are in Table 2. The average rate of performance for the subjects, averaged over all three conditions, was 4.0 cards per minute (cpm) with a range of 2.7 to 5.3 cpm. The average rate of performance for the no code was 3.9 cpm; for the first letter code 4.0 cpm; and for the second letter code 4.2 cpm. A series of Wilcoxon matched-pairs signed-ranks non-parametric tests (Natrella, 1963) where $\alpha = .05$ indicated that the 4.2 cpm for the second letter code was significantly faster than both the 3.9 cpm of the no code or the 4.0 cpm of the first letter code condition. However, there was no significant difference between the 3.9 cpm of the no code and the 4.0 cpm of the first letter code conditions.

The errors for filing 375 cards are in Table 3. The average number of errors was 32.1 per subject, ranging from 5 to 100. The average for the no code was 35.5 errors; for the first letter code 31.0 errors; and for the second letter code 29.8 errors. A series of Wilcoxon tests ($\alpha = .05$) indicated the 31.0 was significantly lower than the 35.5. The 29.8, however, was not significantly lower than the 35.5 (the critical value of T is 52 for $n = 20$ while the calculated T was 53.5).

If the reader wishes to accept an α risk of 6% then the difference is significant. This change from significance to non-significance seemed to be

Table 2. Minutes per condition.

Sequence	Subject	No Code	1st Letter Code	2nd Letter Code	Sum
A	1	89.4	87.5	70.5	247.4
A	12	115.7	136.1	115.3	367.1
A	18	97.2	100.4	87.6	285.2
A	19	89.6	106.2	97.1	292.9
B	2	129.5	89.9	126.7	346.1
B	11	117.6	116.6	111.3	345.5
B	17	83.4	75.2	71.2	229.8
B	20	99.1	95.3	85.7	280.1
C	3	96.7	95.3	97.9	289.9
C	10	92.8	90.6	94.7	278.1
C	16	101.3	97.4	102.1	300.8
C	21*	151.7*	141.7*	128.2*	421.6*
D	4*	125.8*	131.2*	100.7*	357.7*
D	9	112.5	93.1	94.3	299.9
D	13	123.9	104.1	101.6	329.6
D	24	109.3	107.2	101.2	317.7
E	5	89.1	113.9	90.1	293.1
E	8	97.4	109.8	85.5	292.7
E	14	120.3	129.8	99.9	350.0
E	23	88.5	91.7	80.0	260.2
F	6	130.8	102.1	144.0	376.9
F	7	104.0	116.6	106.2	326.8
F	15	87.0	89.5	86.9	263.4
F	22	117.8	111.8	116.1	345.7
Total		2292.9	2260.1	2165.9	6718.9

*Data eliminated.

Table 3. Errors per condition.

Sequence	Subject	No Code	1st Letter Code	2nd Letter Code	Sum
A	1	16	13	12	41
A	12	44	26	22	92
A	18	41	38	37	116
A	19	43	34	36	113
B	2	24	24	32	80
B	11	35	32	14	81
B	17	20	10	14	44
B	20	53	33	45	131
C	3	54	59	47	160
C	10	22	21	28	71
C	16	94	90	61	245
C	21*	139*	124*	112*	375*
D	4*	98*	158*	159*	415*
D	9	80	81	100	261
D	13	88	66	58	212
D	24	12	5	10	27
E	5	19	13	19	51
E	8	7	8	7	22
E	14	37	36	20	93
E	23	19	19	18	56
F	6	36	36	32	104
F	7	15	21	24	60
F	15	11	7	6	24
F	22	11	6	13	30
Total		781	678	655	2114

*Data eliminated.

the result of large differences for a few individuals. The 29.8 and the 31.0 were not significantly different.

The number of errors committed by subject, sequence, and condition are tabulated in Tables 4, 5, and 6.

When a card was inserted incorrectly in each condition, the average number of cards it was from its home position was tabulated in Table 7. A series of Wilcoxon tests, paired on subjects, (α = .05) indicated that the 15.6 positions per error was significantly less than either the 30.1 for the second letter code or the 30.9 for the no code. The second letter and no code conditions were not significantly different.

The magnitide of error for each misfiled card, Tables 8, 9, and 10, was defined as the sum of the absolute values of how far the misfiled cards were from their respective home positions. For example, a card in error found 25 places out of alphabetical order from its home position had a magnitude of 25. A card only 10 places from home position had a magnitude of 10. If these were the only two errors made, then the total magnitude of error would be 35. The sum of the magnitude of errors for the misfiled cards was used as a criterion of performance for the three conditions. The average summed magnitude of error per condition was 979 per subject. The average magnitude of error for the no code condition was 1095, for the first letter code was 485, and for the second letter code was 898. A series of Wilcoxon tests, paired on subjects, (α = .05) indicated the 485 of the first letter code was significantly better than both the 898 of the second letter code and the 1095 of the no code conditions. There was no statistical difference between the 898 of the no code and 1095 of the second letter code conditions (α = .05).

Chi-Square tests (Natrella, 1963), where $\alpha = .05$, on time, number of errors and magnitude of errors by sequence indicated there was no significant difference attributable to sequence for time or errors but there was a significant effect on magnitude of errors. The reason for this statistical difference could not be distinguished since sequence and subjects were confounded.

Table 11 illustrates the ranking of cards misfiled most often by first letter of last name and condition, as compared to Hodge's (1963) order of legibility for capital letters. There seemed to be no correlation between the results of this experiment and Hodge's.

A rather qualitative evaluation of the large deltas which contributed to the magnitude of error calculation indicated that subjects had difficulty in recognizing the difference between G and Q, and J and U.

The results of the subjects preferences for one condition over another, Table 12, were that the second letter code was the best liked and the no code condition was the least liked.

Table 4. Number of errors for no code condition.

Sequence	Subject	Letter A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	Y	Z	SUM
A	1	2	2	0	2	0	0	1	0	2	1	1	1	0	0	1	0	1	1	0	0	0	1	0	0	0	16
A	12	1	1	2	2	2	3	1	1	0	5	3	3	0	3	2	1	1	2	0	0	4	1	3	3	0	44
A	18	2	0	2	3	2	3	0	2	3	4	3	1	2	1	1	0	0	0	0	2	4	2	3	0	1	41
A	19	1	3	1	3	5	1	1	0	2	4	4	3	1	0	2	3	0	0	2	0	2	3	1	1	0	43
B	2	1	1	1	0	2	1	5	1	1	0	1	0	0	1	1	1	3	0	1	0	2	0	0	0	1	24
B	11	1	0	1	1	4	1	1	4	0	0	2	2	2	2	1	2	1	2	1	0	0	0	1	4	2	35
B	17	0	0	1	2	1	1	1	1	1	0	0	0	0	0	3	0	2	0	1	1	0	1	1	1	2	20
B	20	3	3	2	3	2	2	1	4	1	6	3	0	1	0	0	5	2	3	3	0	0	0	2	5	2	53
C	3	3	3	2	2	4	2	1	1	2	3	3	5	1	2	2	1	2	3	0	1	2	1	2	2	4	54
C	10	2	0	0	1	1	2	0	1	1	0	1	0	0	1	1	2	1	1	1	0	1	0	4	1	0	22
C	16	5	2	1	6	5	4	2	3	3	3	4	4	4	5	3	6	4	4	3	3	5	3	5	3	4	94
C	21																										
D	4																										
D	9	2	4	3	7	4	2	5	2	4	3	2	1	5	3	3	6	2	5	2	2	2	5	3	2	1	80
D	13	2	4	4	3	5	5	4	7	4	5	2	5	2	3	4	3	2	2	2	5	3	5	5	1	1	88
D	24	1	0	0	0	1	0	3	1	1	1	0	0	0	1	1	0	0	0	0	2	0	0	0	0	0	12
E	5	2	1	1	0	0	0	2	0	2	1	0	1	0	1	1	0	1	0	1	0	2	1	0	1	1	19
E	8	0	0	0	0	1	0	1	0	1	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	7
E	14	0	3	1	2	2	1	1	2	1	2	3	0	3	1	3	0	1	2	0	3	1	0	1	1	3	37
E	23	1	1	0	0	2	1	1	0	0	1	1	1	1	0	1	0	1	1	1	1	2	0	1	1	0	19
F	6	2	1	3	0	3	2	1	0	2	2	0	2	0	0	4	0	1	0	2	3	2	1	2	2	1	36
F	7	0	1	2	1	0	1	0	0	1	2	2	1	0	2	0	0	0	0	0	1	0	0	0	0	1	15
F	15	2	0	1	1	0	3	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	11
F	22	0	2	2	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	2	0	11
Total		33	32	30	39	46	36	32	30	33	43	37	31	23	27	36	31	25	26	21	24	32	24	35	31	24	781

Table 5. Number of errors for 1st letter code condition.

		Letter																								
Sequence	Subject	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	Y	Z	SUM
A	1	0	0	1	1	0	0	0	1	1	2	0	0	0	0	1	0	1	1	2	0	0	1	0	0	1	13
A	12	0	4	1	1	3	2	0	3	1	0	2	0	0	0	0	0	0	1	0	0	1	3	3	0	1	26
A	18	1	2	3	2	2	3	0	3	1	0	2	0	1	3	0	1	0	1	0	2	1	5	1	1	3	38
A	19	0	1	3	2	1	2	1	2	3	0	3	0	0	2	1	4	0	0	0	0	2	2	1	1	3	34
B	2	1	3	3	0	1	1	1	1	0	0	3	0	0	3	0	1	1	2	1	0	1	0	0	0	1	24
B	11	1	0	2	1	3	2	0	4	1	0	3	0	1	2	0	0	1	2	1	0	2	1	2	1	2	32
B	17	2	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1	1	10
B	20	3	0	2	2	2	0	1	2	1	2	1	1	1	1	0	0	3	1	0	2	1	2	2	2	1	33
C	3	2	4	4	0	0	3	4	2	3	2	5	0	3	2	0	0	2	3	0	2	3	0	2	2	11	59
C	10	1	2	2	0	3	0	1	0	0	1	0	1	1	1	1	0	1	0	1	0	0	1	0	4	0	21
C	16	5	3	7	2	4	6	3	1	1	6	4	3	2	2	3	3	5	5	4	3	4	1	1	6	6	90
C	21																										
D	4																										
D	9	6	4	3	5	6	5	1	3	4	1	3	2	3	5	2	3	5	3	3	2	5	2	2	0	3	81
D	13	3	1	4	2	3	4	1	4	4	2	3	0	6	2	4	1	3	2	0	1	2	2	3	8	1	66
D	24	0	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	5
E	5	2	2	1	0	1	0	0	1	1	0	0	0	1	0	1	0	1	0	0	0	1	0	1	0	0	13
E	8	0	0	1	0	1	0	1	0	1	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	8
E	14	3	3	2	0	4	1	2	2	2	1	1	1	1	0	1	1	1	1	0	1	1	3	2	0	2	36
E	23	1	2	1	0	2	0	1	0	2	0	1	0	1	1	0	0	3	0	0	1	1	0	1	0	1	19
F	6	3	0	2	2	1	2	0	0	2	2	2	2	2	0	3	1	1	0	2	1	0	4	1	1	2	36
F	7	2	2	1	0	2	0	0	1	1	1	1	0	1	0	2	1	0	0	0	1	1	0	0	2	2	21
F	15	0	0	1	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	1	1	7
F	22	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	6
Total		36	33	45	20	41	33	19	31	29	21	36	11	26	24	21	16	28	23	14	16	28	30	23	32	42	678

Table 6. Number of errors for 2nd letter code condition.

		Letter																								
Sequence	Subject	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	Y	Z	SUM
A	1	0	2	0	0	0	0	0	1	2	1	0	0	0	0	2	0	0	1	0	0	2	0	0	1	0	12
A	12	1	3	1	0	0	0	0	1	1	2	1	1	1	1	0	2	0	1	1	2	0	1	0	0	2	22
A	18	3	1	2	1	2	2	2	0	3	1	4	0	2	1	0	4	1	0	1	1	1	0	2	2	1	37
A	19	2	0	2	0	4	1	3	1	2	1	3	1	2	1	2	0	2	0	0	1	0	1	4	3	0	36
B	2	2	4	2	0	0	1	4	2	0	1	3	0	2	1	1	0	3	0	0	0	1	3	1	1	0	32
B	11	0	0	1	1	1	1	0	3	0	1	0	0	1	0	0	0	1	0	0	2	0	0	1	1	0	14
B	17	2	1	1	0	0	0	1	1	0	1	0	0	1	0	0	0	0	1	0	1	0	0	2	1	1	14
B	20	2	2	3	2	2	1	3	1	4	4	5	1	1	1	2	1	0	2	0	1	1	1	1	2	2	45
C	3	3	1	1	2	0	0	4	2	1	2	0	3	3	0	4	0	0	4	4	2	4	2	1	0	4	47
C	10	3	2	1	1	1	1	0	2	2	2	0	0	1	1	1	0	2	1	1	1	0	0	1	2	2	28
C	16	2	3	0	1	3	4	5	4	0	4	5	0	1	1	5	4	1	2	3	0	3	2	1	3	4	61
C	21																										
D	4																										
D	9	2	2	2	3	5	6	6	4	6	5	5	4	7	5	2	4	3	3	3	3	6	6	2	3	3	100
D	13	4	2	4	3	2	3	1	0	2	0	2	2	4	1	2	1	1	3	1	4	5	5	2	1	3	58
D	24	0	0	1	0	6	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	10
E	5	1	1	2	0	2	1	0	0	0	3	0	0	2	1	1	1	1	0	1	0	0	1	1	0	0	19
E	8	0	0	1	0	0	0	0	0	1	1	1	0	0	0	1	0	0	0	0	1	0	1	0	0	0	7
E	14	1	1	2	0	1	0	1	1	0	0	2	0	0	1	3	1	0	0	0	2	1	2	0	0	1	20
E	23	3	1	0	0	1	0	2	0	2	0	1	0	0	1	1	0	0	1	0	1	1	0	2	0	1	18
F	6	3	1	3	1	2	1	0	0	1	1	1	1	0	0	1	0	2	1	0	1	4	2	1	2	3	32
F	7	1	1	2	0	2	2	0	0	2	2	0	1	0	0	1	2	0	0	0	1	2	0	1	3	1	24
F	15	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	6
F	22	0	0	0	2	0	1	0	1	1	0	1	0	1	0	1	0	1	0	0	0	1	0	1	1	1	13
Total		36	28	31	18	34	25	32	24	30	35	34	14	30	17	30	21	19	20	15	24	32	27	24	26	29	655

Table 7. Average number of positions an error was from home position.

Sequence	Subject	No Code	1st Letter Code	2nd Letter Code
A	1	29.1	14.2	2.3
A	12	26.6	1.3	62.2
A	18	23.8	11.0	19.4
A	19	29.1	5.0	18.9
B	2	126.8	4.7	25.9
B	11	3.5	8.2	4.3
B	17	6.9	16.8	12.6
B	20	65.0	21.0	21.0
C	3	10.8	42.6	32.0
C	10	4.6	3.0	33.2
C	16	3.9	30.2	40.9
C	21*			
D	4*			
D	9	21.1	3.9	19.8
D	13	15.8	3.0	2.4
D	24	110.1	151.8	82.9
E	5	36.1	4.5	45.0
E	8	25.9	21.0	23.0
E	14	9.1	33.8	24.2
E	23	105.1	4.9	44.0
F	6	78.2	7.6	28.4
F	7	16.7	1.9	37.2
F	15	38.5	8.4	137.3
F	22	35.7	24.3	25.5

*Data eliminated.

Table 8. Magnitude of errors, "card positions from home", per letter, subject and sequence for no code condition.

		Letter												
Sequence	Subject	A	B	C	D	E	F	G	H	I	J	K	L	M
A	1	40	7	0	9	0	0	1	0	1	1	1	219	0
A	12	1	7	3	6	4	6	3	1	6	21	14	225	0
A	18	2	0	5	3	4	6	0	5	683	8	15	219	2
A	19	4	8	1	46	68	1	754	0	224	135	6	45	2
B	2	2	4	1	0	2	1	3021	1	1	0	1	0	0
B	11	1	0	4	1	21	3	1	16	0	0	4	37	3
B	17	0	0	4	10	46	3	23	1	1	0	0	0	0
B	20	4	6	2	1391	293	4	121	414	1	13	8	1	1
C	3	4	31	1	2	61	5	1	7	71	47	8	106	59
C	10	2	0	0	1	1	3	0	1	7	0	1	0	0
C	16	18	1	1	20	12	11	7	9	9	14	11	8	18
C	21													
D	4													
D	9	2	12	4	16	11	5	1506	3	16	7	4	1	7
D	13	10	12	24	11	42	13	757	24	26	47	41	35	14
D	24	1	0	0	0	1	0	2260	1	0	1	0	0	0
E	5	2	3	1	0	0	0	4	0	2	614	0	1	0
E	8	0	0	0	0	1	0	22	0	1	0	1	1	1
E	14	0	5	1	2	2	1	1	12	4	2	17	0	85
E	23	1	47	0	0	4	3	1507	0	0	1	306	1	2
F	6	2	4	5	0	3	2	754	220	827	0	0	2	0
F	7	0	3	4	9	0	1	0	0	1	8	1	219	0
F	15	35	0	1	8	0	4	0	0	223	0	0	0	0
F	22	0	4	3	0	0	1	0	0	0	0	1	0	0
Total		131	154	65	1535	576	73	10743	715	2104	819	440	1120	194

Table 8. Continued.....

Sequence	Subject	Letter N	O	P	Q	R	S	T	U	V	W	Y	Z	SUM
A	1	0	32	0	1	0	0	0	0	154	0	0	0	466
A	12	6	1	4	1	7	0	0	831	1	18	4	0	1170
A	18	1	3	0	0	0	0	5	3	2	8	0	2	976
A	19	1	0	9	1	0	0	2	4	5	35	1	0	1252
B	2	1	3	0	3	0	0	0	2	0	0	0	1	3044
B	11	0	2	1	2	4	0	0	0	0	14	4	3	121
B	17	0	6	0	2	0	1	1	0	1	1	1	37	138
B	20	0	0	187	4	4	30	895	0	0	17	35	20	3447
C	3	28	7	3	5	0	93	0	3	3	3	4	32	584
C	10	1	1	11	58	1	1	0	1	0	7	4	0	101
C	16	8	26	80	8	6	16	9	8	21	5	4	38	368
C	21													
D	4													
D	9	8	12	21	15	7	6	4	2	8	5	2	4	1688
D	13	82	62	21	8	42	4	68	5	23	19	1	1	1392
D	24	0	3	1	0	0	0	0	45	0	0	0	0	2313
E	5	50	1	0	1	0	0	0	2	0	1	3	1	686
E	8	0	154	0	0	0	0	0	0	0	0	0	0	181
E	14	17	34	0	2	41	0	44	1	0	1	1	65	338
E	23	1	0	0	42	1	4	1	41	0	33	1	0	1996
F	6	0	6	0	1	0	76	9	890	1	11	2	1	2816
F	7	2	0	0	0	0	0	1	0	0	0	0	1	250
F	15	1	151	0	0	0	0	0	0	0	0	1	0	424
F	22	0	0	1	0	0	1	0	0	0	3	45	334	393
Total		207	504	339	154	139	1097	144	1838	219	181	113	540	24144

Table 9. Magnitude of errors, "card positions from home", per letter, subject and sequence for first letter code.

Sequence	Subject	Letter A	B	C	D	E	F	G	H	I	J	K	L	M
A	1	0	5	1	1	0	0	0	2	5	5	0	4	0
A	12	0	3	1	1	6	3	0	3	1	0	2	0	0
A	18	1	4	8	3	2	7	4	0	1	0	4	0	1
A	19	0	14	10	11	1	3	2	4	4	0	5	0	0
B	2	2	8	6	0	1	1	1	2	1	0	59	4	0
B	11	3	0	2	6	5	5	0	4	1	0	5	0	1
B	17	2	0	0	0	3	1	0	1	0	0	0	0	0
B	20	39	2	0	20	4	36	1	1	2	311	28	0	4
C	3	7	8	15	0	0	63	9	1	46	6	7	72	3
C	10	1	1	2	0	11	0	3	0	0	1	1	1	1
C	16	15	16	10	6	47	9	766	1	1	90	6	7	3
C	21													
D	4													
D	9	8	5	4	14	16	16	1	8	8	1	21	2	6
D	13	22	0	4	2	3	14	1	6	11	5	3	0	6
D	24	0	0	0	0	1	0	754	0	0	0	3	0	0
E	5	4	7	1	0	1	0	0	1	2	0	0	4	1
E	8	0	5	1	0	1	0	4	1	0	0	0	3	1
E	14	3	9	28	0	6	16	776	2	16	3	1	3	1
E	23	1	1	1	0	4	0	1	0	2	0	6	0	1
F	6	21	5	8	9	1	4	0	0	9	7	14	3	1
F	7	2	8	1	0	2	0	0	1	2	2	0	4	1
F	15	0	0	3	0	1	0	0	0	0	0	1	0	0
F	22	0	0	1	0	0	0	1	0	0	3	0	0	0
Total		131	101	107	73	116	178	2324	38	112	434	166	107	31

Table 9. Continued.....

Sequence	Subject	Letter N	O	P	Q	R	S	T	U	V	W	Y	Z	SUM
A	1	0	150	0	2	4	2	0	0	1	0	0	2	184
A	12	0	0	0	0	3	0	0	1	7	3	0	1	35
A	18	52	0	2	0	2	0	52	10	164	1	1	99	418
A	19	5	3	14	0	0	0	44	6	5	1	6	33	171
B	2	3	0	0	2	14	5	0	2	0	0	0	1	112
B	11	46	0	0	8	16	63	0	4	1	77	3	12	262
B	17	0	0	0	0	1	0	0	2	1	0	156	1	168
B	20	67	0	0	65	20	0	1	31	40	7	11	2	692
C	3	2	12	0	0	3	28	0	16	0	148	37	2030	2513
C	10	1	28	0	0	0	1	0	0	0	0	11	0	63
C	16	10	462	425	61	18	202	14	4	1	2	308	231	2715
C	21													
D	4													
D	9	7	5	4	74	31	14	45	9	2	2	0	14	317
D	13	9	9	11	15	2	0	3	6	4	10	51	1	198
D	24	0	0	0	0	0	0	0	0	1	0	0	0	759
E	5	0	1	0	3	0	0	0	1	0	0	33	0	59
E	8	0	151	0	0	0	0	0	0	1	0	0	0	168
E	14	0	1	1	1	2	0	44	1	152	1	148	3	1218
E	23	1	1	0	49	0	0	1	1	0	22	0	1	93
F	6	0	158	1	2	0	2	1	0	7	1	12	8	274
F	7	2	0	1	1	0	0	1	3	0	0	6	3	40
F	15	0	2	0	0	0	0	0	48	0	0	3	1	59
F	22	0	0	0	56	0	0	0	0	0	0	85	0	146
Total		205	983	459	339	116	317	206	145	387	275	871	2443	10,664

Table 10. Magnitude of errors, "card positions from home", per letter, subject and sequence for second letter code.

Sequence	Subject	Letter A	B	C	D	E	F	G	H	I	J	K	L	M
A	1	6	0	0	0	0	0	0	3	4	1	0	4	0
A	12	1	217	1	0	0	0	0	1	1	2	5	1	1
A	18	9	1	3	1	4	6	299	0	5	2	6	0	2
A	19	4	0	1	1	11	1	10	1	5	4	4	3	2
B	2	2	9	2	0	0	1	756	0	1	9	16	4	2
B	11	0	0	1	1	1	2	0	24	0	4	0	0	0
B	17	6	4	1	0	0	0	1	1	1	3	0	0	1
B	20	4	1	3	4	14	4	758	7	18	4	6	1	3
C	3	12	1	3	2	0	2299	0	2	1	826	0	5	3
C	10	4	6	1	1	1	1	0	2	12	820	0	0	1
C	16	5	5	0	6	14	5	18	14	0	1655	13	0	2
C	21													
D	4													
D	9	2	3	1	5	7	17	761	7	10	840	7	12	10
D	13	8	5	4	3	2	3	1	0	3	4	3	0	4
D	24	0	0	1	0	0	0	0	0	0	826	0	0	1
E	5	1	6	2	0	2	2	0	0	1	827	0	4	2
E	8	0	0	1	0	0	0	0	0	1	0	1	0	0
E	14	1	1	5	0	1	0	1	1	0	0	80	0	0
E	23	3	0	0	0	4	0	761	0	3	0	1	0	1
F	6	3	6	3	8	2	1	0	0	2	828	1	6	0
F	7	1	1	3	0	2	2	0	0	9	826	0	6	0
F	15	1	0	0	1	0	0	0	0	0	819	0	0	0
F	22	0	0	0	2	0	1	0	4	2	0	1	4	1
Total		73	266	36	35	65	2345	3366	67	79	8300	144	50	36

Table 10. Continued.....

Sequence	Subject	Letter N	O	P	Q	R	S	T	U	V	W	Y	Z	SUM
A	1	0	3	0	1	1	0	0	2	0	0	3	0	28
A	12	1	0	2	0	1	1	0	3	1	0	0	1129	1368
A	18	50	0	312	1	0	2	1	1	0	7	6	1	719
A	19	1	447	1	8	0	0	2	0	1	12	160	0	679
B	2	1	3	0	8	0	0	0	1	9	3	1	0	828
B	11	4	0	0	1	0	0	10	0	0	9	3	0	60
B	17	0	0	0	0	146	0	2	0	0	2	8	1	177
B	20	1	6	1	2	1	0	6	3	82	3	3	10	945
C	3	0	152	0	0	2	0	0	2	8	3	0	4	3325
C	10	1	1	0	61	1	0	5	0	0	2	7	2	929
C	16	1	456	19	7	5	4	1	3	157	1	82	19	2492
C	21													
D	4													
D	9	11	2	8	7	3	8	6	39	160	2	7	44	1979
D	13	1	3	1	1	6	1	10	5	6	13	9	46	142
D	24	0	0	0	0	0	0	0	0	0	0	0	0	828
E	5	1	1	1	2	0	1	0	0	1	1	0	0	855
E	8	0	151	0	0	0	0	6	0	1	0	0	0	161
E	14	0	161	1	0	0	0	6	1	224	0	0	1	484
E	23	5	1	0	0	0	0	2	1	0	9	0	1	792
F	6	0	1	0	7	3	0	1	12	2	1	20	3	910
F	7	0	2	2	1	0	0	4	4	0	7	27	1	892
F	15	1	0	1	1	0	0	0	0	0	0	0	0	824
F	22	0	150	0	162	0	0	0	1	0	1	1	1	331
Total		79	1540	349	270	169	17	62	78	652	76	331	1263	19,748

Table 11. Ranking of most frequently misfiled cards by first letters.

No Code		1st Letter Code		2nd Letter Code		Hodge's Order	
Rank	Letter	Rank	Letter	Rank	Letter	Rank	Letter
1	E	1	C	1	A	1	Q
2	J	2	Z	3	C	2	H
3	D	3	E	3	J	3	G
4	K	4.5	A	3	K	4	O
5.5	F	4.5	K	5	G	5	B
5.5	O	6.5	B	6	E	6	Y
7	W	6.5	F	7.5	M	7	K
8.5	A	8	Y	7.5	Z	8	I
8.5	I	9	H	10	I	9	C
11	B	10	V	10	O	10	D
11	G	11	I	10	U	11	R
11	U	12.5	Q	12	W	12	W
14	L	12.5	U	13	B	13	F
14	P	14	M	14	Y	14	N
14	Y	15	N	15	V	15	V
16.5	C	16.5	R	16	F	16	M
16.5	H	16.5	W	17.5	H	17	S
18	N	18.5	J	17.5	T	18	P
19	R	18.5	O	19	P	19	E
20	Q	20	D	20.5	D	20	U
21	M	21	G	20.5	R	21	T
23	Z	22.5	P	22.5	N	22	Z
23	V	22.5	T	22.5	Q	23	J
23	T	24	S	24	L	24	A
25	S	25	L	25	S	25	L

Note Rank = 1 Most frequently misfiled
(Least legible for Hodge)

Table 12. Code preferences. Each subject picked best and least liked coding system.

Preference	No Code	1st Letter Code	2nd Letter Code
Best (Choice = +1)	+ 2	+ 4	+16
Least (Choice = -1)	-12	- 8	- 2
Total	-10	- 4	+14

DISCUSSION

The approach to choosing a filing system, like most problems, means resolving and evaluating many, often conflicting, objectives to produce a workable solution. One objective eminent in most production situations is productivity or speed. Often a second objective, quality, reduces this speed. Other objectives which enter into the problem of choosing a filing system could be employee preferences and economics.

From a rate of production standpoint, it was indicated by this experiment that the second letter code (4.2 cpm) was significantly faster than either the first letter code (4.0 cpm) or the no code (3.9 cpm). At the same time, there was no statistical difference between the first letter code and the no code condition. To put it another way, the second letter code was 7.7% faster than the no code, while the first letter code was only 2.6% faster than the no code.

It was interesting to note that the trend toward increasing productivity (no code < first code < second code) was the same as the subject's preferences. This could indicate that the natural barrier of resistance to change, often found in introducing new systems, could be overcome by the significant rise in production each worker could experience which could be seen as less work for the employee.

A second objective in choosing a filing system is quality, which, if overdone, can increase the overall cost of any system. This is where economics enters into the situation. If a coding system increases rate by 10% but also increases errors by 10%, one must evaluate the relative weights of quality and rate. For example, working with the filing of telephone numbers on cards may merit changes which increase rate since the inconvenience

cost of a misfiled telephone number, which can be found in any telephone book, may be quite small. Hence, rate of production may carry a greater emphasis than quality in this case. Conversely, in filing security certificates, one could find that quality, not quantity, is the important factor due to the high inconvenience cost associated with finding or replacing misfiled documents.

With errors as a criterion of performance and accepting a little larger α risk than conventional, there was no significant difference between the 29.8 errors per subject 2nd letter code and 31.0 errors per subject 1st letter code conditions but both of these were found significantly better than the 35.5 errors per subject average for the no code condition. In other words, the 1st and 2nd letter codes significantly reduced errors by 12.7 and 16.1%, respectively, over the no code. Hence, color coding had a significant effect.

Another index of quality would be the magnitude of errors committed. Taking the ratio of average magnitude of error to average number of errors within subjects and conditions yields the average magnitude of error for the error cards. This average distance a card in error was found from its home position was 30.9 positions for the no code, 30.1 for the second letter code, and 15.6 for the first letter code.

A series of Wilcoxon tests ($\alpha = .05$) indicated the 30.9 for the no code and the 30.1 for the second letter code were not significantly different, but the 15.6 for the 1st letter code was significantly better than either of the latter conditions. In other words, when a given error was made, the error for first letter code was approximately half the magnitude of the error for either the second letter or no code condition.

It was expected that the second letter code condition, which has the highest degree of division by color code, would have the lowest magnitude of

error, followed by the first letter code and then the no code, having increasing magnitudes of error respectively due to the decreasing degree of color code divisions. Another intuitive factor in favor of a higher degree of codification is the positive visual confirmation received when, for example, a red card, upon being filed, fits into a location with red cards before and after. Therefore, to a point, the higher the degree of color codification the better chance one has of avoiding coarse errors of high magnitude.

The results of the magnitude of errors for the no code correlated with with expectations but there was a statistically significant reversal in the first letter and second letter code conditions. The color coding in the first letter and second letter code conditions may have been sufficient to eliminate the coarse errors (high magnitude of error) which resulted in the no code. The higher degree of codification in the 2nd letter code was not as effective (as indicated by the tests on magnitudes of error) as the 1st letter code in screening out the fine errors. It may then follow that the optimum degree of color codification with magnitude of error as a criterion is the first letter code. Two studies by Hitt (1960) support such an interpretation. Hitt found that with a variety of different codes that performance decreased rapidly when the number of stimulus categories exceeded two.

The qualitative comparison of the cards misfiled by condition grouped on the basis of the first letter of the last name did not seem to correlate with Hodge's (1963) Order of Legibility which was based on a study of capital letters used in displays. In addition to ordering the alphabet from most to least legible, Hodge found that some letters were often confused (in

particular capital E's and F's). In this experiment it was noted that a large number of the gross errors were attributed to confusion of the letters G and Q, and J and U. There seemed to be little trouble with E's and F's.

In most practical applications of filing systems, the emphasis is placed on reduction of errors rather than rate of production due to the high inconvenience cost associated with locating misfiled items. Bearing this emphasis in mind along with the results of this experiment, one may conclude that a filing system based on a fundamentally simple color scheme like the 1st letter code may best achieve the objective of reducing number and magnitude of errors over a no color code system.

CONCLUSION

It must be stressed that there can be no panacea for the optimization of color codification in a filing task due to the relative weights put on rate and quality, which differ depending on the situation.

It was found in this experiment that the second letter code condition improved rate significantly over the first letter and no code conditions. The subjects' concensus also favored the second letter code over the first letter and no code conditions.

The number of errors was significantly less for the color coded conditions while the magnitude of error results indicated the first letter code was significantly better than the other two conditions. If a high inconvenience cost were associated with errors one could conclude, based on this experiment, that a 1st letter color coded filing system could significantly reduce both quantity and magnitude of errors over a no color code system.

It should be emphasized that the improvement in quality expected of a color coded filing system (10 - 15% less errors) is not as much as has been commercially claimed.

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THE EFFECT OF COLOR CODING ON PERFORMANCE OF AN ALPHABETIC FILING TASK

by

BRUCE GARY KOE

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ABSTRACT

Color coding in filing tasks has often been accepted as superior to no color coding. The purpose of this experiment was to explore the effect of filing names, typical of a telephone directory, color coded on the first letter and on the second letter of the last name using the key: Blue, A-E; Red, F-J; Green, K-O; Manila, P-T; Brown, U-Z. A no color code condition was used as a control. Rate of production, number and magnitude of errors, and user preference served as criteria.

Twenty-two subjects filed 375 appropriately color striped IBM cards into a box of IBM cards appropriately coded.

The rate of performance and subject preferences indicated that the 2nd letter code was better than the other two conditions.

Based on quantity of errors, the 1st and 2nd letter codes were significantly (α = .05) better than the no color code condition. Considering the magnitude of errors, the first letter code was significantly better than the two other codes. The results of this experiment suggest a color coded filing system based on a simple first letter scheme would significantly reduce the magnitude and quantity of high inconvenience cost errors over the conventional no color coded system.