No-FAT Multifactor Design of Experiments

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In my previous article "Trimming the FAT out of Experimental Methods" I presented arguments against one-factor-at-at-time (OFAT) in favor of multifactor design of experiments (DOE). Now I offer a case study that illustrates how a two-level factorial DOE can reveal a breakthrough interaction.

Imagine that the head of your corporate information technology (IT) department gains control of all the employees' video display terminals (VDTs). This IT tyrant decides to standardize the colors and typefaces for every display in a way that maximizes their readability. At random, three 'guinea pigs' are chosen from the population of the company's employees. Each subject is presented at random with all combinations of the following factors:

A. Foreground color – either black or yellow
B. Background color – white or cyan (a bluish color)
C. Typeface – Arial or Times New Roman (TNR), which represent two font types – san serif (a clean, modern look) versus serif (more elaborate, but old-fashioned).

The time they take to read 30 words (varied each time!) is provided in Table 1, with the randomized run order shown in superscripted parentheses after the time in seconds for each of the three people – P1, P2 and P3.

Table 1: Results from two-level factorial design on VDT

Std	A: Fore	B: Back	C: Type	P1 sec	P2 sec	P3 Sec
1	black	white	Arial	3.9$^{(7)}$	4.9$^{(13)}$	4.5$^{(22)}$
2	yellow	white	Arial	6.4$^{(2)}$	7.0$^{(9)}$	6.8$^{(24)}$
3	black	cyan	Arial	6.1$^{(4)}$	8.1$^{(16)}$	7.7$^{(20)}$
4	yellow	cyan	Arial	4.8$^{(3)}$	6.2$^{(15)}$	5.0$^{(19)}$
5	black	white	TNR	6.2$^{(8)}$	6.7$^{(12)}$	6.5$^{(23)}$
6	yellow	white	TNR	8.4$^{(6)}$	8.5$^{(10)}$	8.9$^{(21)}$
7	black	cyan	TNR	8.3$^{(5)}$	9.1$^{(14)}$	8.9$^{(17)}$
8	yellow	cyan	TNR	7.8$^{(1)}$	8.0$^{(11)}$	7.5$^{(18)}$

After blocking out the variation from person-to-persons, a statistical plot of effects (Figure 1) reveals that the following effects are significant:

- The main effect of typeface (factor C)
- An interaction of factors A (foreground) and B (background)

The other estimable effects (AC, BC and ABC) fall at the low end of the bottom effects axis, near zero, in line with the error (triangles) estimated by replicating each conditions for the three subjects.

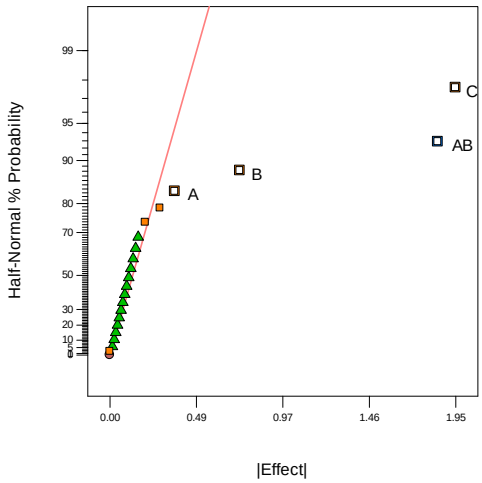

Figure 1: Plot of effects

Figure 2 shows the predicted time for an average employee (assume the three subjects were representative of the population) as a function of the three VDT parameters. Note at the lower, left front corner that the most readable screen (lowest time) is black foreground (A-) on white background (B-) with Arial typeface (C-).

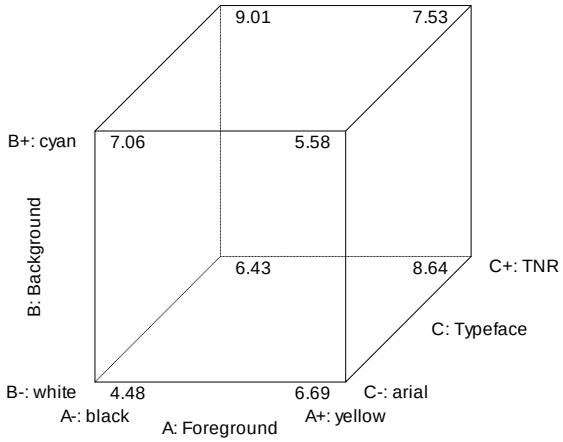

Figure 2: Cube plot of predicted times needed to read test on VDT

Figure 3 provides greater insights on the effects by illustrating the main effect of typeface (factor C) and the interaction of foreground and background (AB), which proves to be the key to understanding the readability of the VDT.

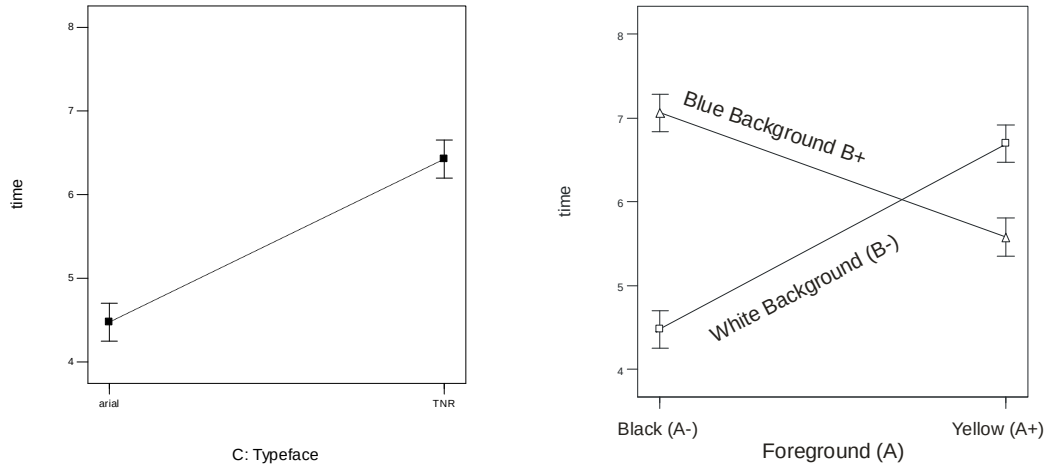

Figure 3: Main effect of typeface (left) and interaction of foreground vs background (right)

Now you can see that the effect of foreground color depends on the color chosen for the background. Black on white works best, but yellow on blue might be allowed by the IT tyrant if employees want some color on their VDT. However, this tyrant must not allow either black-on-blue or yellow-on-white, the two combinations at the upper end of readability time.

OFAT can never reveal even simple two-factor interactions of the sort illustrated here. By mastering the more sophisticated and efficient multifactor methods of DOE, scientists and engineers put themselves in position to quickly discover previously unknown combinations of variables that can lead to breakthrough improvements.

PS. Down with tyrants, IT or otherwise!