Section 3.

MARKETING RESEARCH

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THE RULES OF THE CREATION AND EXAMPLES OF THE APPLICATION OF FRACTIONAL EXPERIMENTS IN ASSESSING THE EFFECTIVENESS OF MARKETING COMMUNICATION

Abstract
The considerations in this paper are largely of methodological nature, as its purpose is to present construction rules and examples of application of Plackett-Burman designs and Latin square experiments. These measures despite some clear advantages over classic fractional experiments, remain relatively unpopular in research marketing.

Key words: *ssessing the effectiveness of marketing communication, marketing studies, Plackett-Burman designs, Latin square experiments*

1. Introduction

An experiment is research which provides reliable data on the effect of marketing activities (manipulated by the research) on an occurrence, person or a company being examined. The decision to apply the experimental method can be taken once three conditions are met: there is a probability of a cause-and-effect relationship (e.g. the researcher lifts a price to see to what extent demand will decrease), the correlation is sufficiently strong to be observed during the experiment, and it is possible to eliminate or control factors which, regardless of the researcher's activities, might trigger the analysed result. For instance, the researcher changes the price to find out how it will affect the demand and at the same time they are certain that the company is not waging any promotional campaigns that might boost demand [16, pp. 242-244].

An experiment is an attempt to fathom the examined occurrence, define its nature and the mechanisms that it is governed by. The experimental

method has the advantage of determining the cause-and-effect relationship of a given occurrence. Moreover, the experimental method makes it possible to determine the strength of this relationship, and so, for example, not only whether, but also to what extent a tested advertisement affects the shopping intentions of customers [27, p. 136]. According to Churchill [3, p. 205] an experiment may provide more convincing evidence of the existence of a causal relationship than exploratory or descriptive research.

There are many statistically specified experimental techniques which could be implemented to examine the effects of advertising or direct marketing [1, pp. 309-310]. Researchers have a wide range of laboratory or field experimental designs to choose from, which are often divided in two groups: simple models with one independent variable, and statistical models with two or more variables acting simultaneously [10, pp. 288-308].

An analysis of papers on market research published in Polish reveals that information on experimental design rules with multiple variables is relatively scarce. Special attention should be given to the publication edited by Rószkiewicz [17] following the Third Methodological Workshops devoted entirely to experimental methods, including a contribution by Mynarski [19, pp. 9-13] discussing factorial and fractional designs. Kaczmarczyk [10, pp. 300-303] also presents a description of experiments with multiple independent variables. Unfortunately, in those two cases, and also in other Polish publications on marketing research, there are very few references to the application of this type of experiment in research on advertising promotions, sales or e-mailings.

Experiments with two or more independent variables and their usage in marketing communication research are better represented in the literature in the English language. Non-serial studies devoted exclusively to the application of experiments in assessing marketing activities have been published and a part of the considerations therein addressed exclusively the research into the effects of marketing communication. The publication by Ledolter and Swersey [15] deserves particular attention as it outlines the rules and examples of factorial and fractional experiment designs, among other matters concerning research into the effectiveness of direct marketing.

Numerous examples of the application of experiments with multiple independent variables in marketing research (often conducted in cooperation with a business activity) can also be found in academic journals on marketing, such as the *Journal of Advertising*, *Journal of Interactive Marketing* and *Journal of Marketing Research*. For instance, Wilkinson

[26, pp. 72-86] used an experimental design to examine to what degree press advertising, price and display of products affects their sales in grocery shops.

It is worth noting that, in most cases, papers on the application of experiments in marketing research are of a practical nature. The experiments described therein are usually intended to solve a specific research problem. Their authors concentrate more on presenting the research results, and possibly their consequent managerial implications, rather than on laying out detailed research methodology. The article by Holland and Carvens [8] is one of the few exceptions where the basic rules for creating fractional designs are presented.

The purpose of this paper is to partially plug the methodological gap in the area of creating and applying experiments with two or more independent variables in marketing research, while giving special consideration to selected fractional designs – Plackett-Burman plans and Latin square.

2. Fractional experiments as an alternative to a factorial experiment

A factorial experiment sets out to test the effects of two or more independent variables (called factors) acting concurrently at least on two levels. The effects are assessed with the same precision as they would be in separate experiments with one independent variable [13, p. 431]. It needs to be stressed that testing the simultaneous effects of various factors on a dependent variable is, in many aspects, easier and usually less expensive, as it requires fewer rounds [15, p. 96; 6, p. 93]. For instance, presenting two factors through simple experiments (with one variable) takes at least 6 runs, whereas in a factorial experiment – 4. Moreover, in factorial experiments two types of effects can be analysed, which is a significant cognitive asset. Firstly, the effect of individual factors on dependent variables is analysed as the so-called main effect. Secondly, if the factors are not independent, the interactions between them are examined [24, p. 263; 13, p. 431].

Creating factorial experiment designs, i.e. those where all possible combinations are tested, is quite easy, as the number of analysed factors is low and their values are modified on two levels. In such situations 2^n combinations need to be tested, where n = number of factors. The number of required combinations rises as the researcher increases the number of analysed factors and/or levels on which they are distinguished. For instance, if

the test consists of two factors modified on two levels, two factors on three levels and one factor on four levels, then in the factorial experiment $2^2 \times 3^2 \times 4^1 = 144$ runs would be required.

The alternative solution is to apply the fractional experiment, that is, to test only a fraction (e.g. 1/2, 1/3, 1/4) of a combination. For instance, if a full factorial experiment involves analysing the effect of 4 independent variables (each modified on 3 levels), then $3^4 = 81$ different combinations need to be tested. In the fractional experiment it is sufficient to analyse only 1/3 i.e. 27 combinations [13, p. 803].

A fractional experiment is used when conducting a factorial experiment is time and/or capital intensive. It is particularly useful when the researcher tests a large number of factors with the basic purpose of identifying those that greatly affect the level of the dependent variable (so-called screening experiments). Kirk [13, p. 804] argues that in the first experiment a relatively large number of variables can be effectively tested, and in further experiments one should focus on the most significant variables and interactions to perform an in-depth result analysis. Decreasing the number of runs simplifies the process of designing and organising the research, bringing down its costs, but – what needs to be particularly kept in mind – also limits the amount of acquired information on interactions among independent variables. This information is carried in the resolution of the R design, whereby R=III means that main effects are confounded with two-factor interactions, R=IV – the main effects are confounded with three-factor interactions, and two-factor with other two-factor interactions, R=V – the main effects are confounded with four-factor interactions, and two-factor with three-factor interactions [15, p. 120].

The rules of designing a fractional experiment with variables modified on two different levels are presented in detail and accompanied by examples in marketing research by Ledolter and Swersey [15, pp. 111-149]. They also authored a paper in which they compare 2^7, 2^{7-1}, 2^{7-2}, 2^{7-3}, 2^{7-4} designs and then show an application of one of them (2^{7-3}) in the wording of the insert promoting a subscription to the Mother Jones magazine [14, pp. 469-475]. Creating fractional designs in which at least one of the factors is modified on three or more levels is a more complicated process. In such a research context, the optimal design is usually generated with specialised software.

Finney is believed to be the creator of the fractional experiment. In 1945, he introduced the ways of creating the 2^n and 3^n design (where n = the number of independent variables) and 1/2 of the 4×2^4 design, and showed their

possible applications in agriculture. In 1946, in turn, Plackett and Burman constructed designs which significantly reduced the number of combinations in experiments with n factors modified on 2-7 levels [4, p. 244].

3. Plackett-Burman designs

Plackett and Burman [21, pp. 305-325] created a concept of fractional designs with n runs where n is a multiple of 4. It was assumed in their paper that there may be 8, 12, 16, …, 96, 100 runs. Their approach, therefore, differs from the classic way of creating fractional experiments, where the number of tested combinations is a power of 2 (provided that each factor is tested on two levels).

Plankett-Burman designs can be used in screening experiments. They are also recommended for tests which analyse the effect of a relatively large number of independent variables, provided that the researcher focuses only on the analysis of the main effects (two-factor interactions are deemed insignificant). For instance, 7 factors can be tested in 8 runs, 11 in 12 or 99 in 100 runs [15, p. 150].

Constructing a Plankett-Burman design in screening experiments is relatively easy if the generators of the first row are known. Table 1 shows the value specifications for independent variables in the first row for experiments with 12, 20 and 24 runs. Creating the next rows consists in moving the signs one column to the right (Table 2). The sign '–' usually denotes the current level of an independent variable, e.g. the current price, while '+' refers to the new level of the analysed factor [23, p. 17]. According to another approach, a plus is a hypothetically better level of the variable under analysis (e.g. an e-mail enhancing the effectiveness of a promotional letter) and a minus – worse [15, p. 66].

Table 1

Examples of first row generators in Plackett-Burman designs

Number of runs	Number of factors	Distribution of values (levels) of factors in the first row
12	11	+ + – + + + – – – + –
20	19	+ + – – + + + + – + – + – – – – + + –
24	23	+ + + + + – + – + + – – + + – – + – + – – – –

Source: Own study based on [2, p. 284].

Table 2

Plackett-Burman design for 11 independent variables in 12 runs (combinations)

Run	Factors (independent variables)										
	A	B	C	D	E	F	G	H	I	J	K
1	+	+	–	+	+	+	–	–	–	+	–
2	–	+	+	–	+	+	+	–	–	–	+
3	+	–	+	+	–	+	+	+	–	–	–
4	–	+	–	+	+	–	+	+	+	–	–
5	–	–	+	–	+	+	–	+	+	+	–
6	–	–	–	+	–	+	+	–	+	+	+
7	+	–	–	–	+	–	+	+	–	+	+
8	+	+	–	–	–	+	–	+	+	–	+
9	+	+	+	–	–	–	+	–	+	+	–
10	–	+	+	+	–	–	–	+	–	+	+
11	+	–	+	+	+	–	–	–	+	–	+
12	–	–	–	–	–	–	–	–	–	–	–

Source: Own study based on [2, p. 284].

Plackett-Burman designs are rarely used in marketing research. Bell et al. [1, pp. 310-316] describe one of few cases of applying this type of experiment in assessing the effects of marketing communication, more precisely, in the field of direct mailing. They present a study involving marking 19 elements of a letter with a credit card offer (e.g. prepaid envelope vs. traditional stamp, additional graphic elements on the envelope vs. the lack thereof, customised vs. uniform content of the letter; low vs. high interest rate) in only 20 different combinations.

Even though Plackett and Burman's approach is usually associated with screening experiments, it is worth noting that researchers resort to this type of experiment plan when they assume the existence of significant two-factor integration. Seaver and Simpson [23, pp. 17-18] present general guidelines for the application of Plackett-Burman designs in exactly such a situation. They suggest creating a fold-over experimental plan, which in practical research means adding a new fraction to the design, exactly the same as the original one but with inverted signs (pluses are substituted by minuses and conversely).

Micheaux's research [18, pp. 45-66] is one of few examples of applying the Plackett-Burman design in the fold-over version to assess the ef-

fectiveness of promotional emails. In 16 runs it analyses the effect of 7 different features of the email on three occurrences: opening the email, clicking on the ad banner included in the email and unsubscribing. Table 3 shows a model of an experimental fold-over design applied by Micheaux. Runs 1-8 include a typical value distribution of independent variables (factors) in Plackett-Burman designs, runs 9-16 contain the new fraction created following the rules described above.[1]

Table 3

Example of the application of a Plackett-Burman design in assessing the effectiveness of emailing (7 independent variables, 16 runs)

	A Direct marketing gadget	B Sound	C Photos	D Sender	E Subject line	F Layout	G Colour
1	+	+	+	–	+	–	–
2	–	+	+	+	–	+	–
3	–	–	+	+	+	–	+
4	+	–	–	+	+	+	–
5	–	+	–	–	+	+	+
6	+	–	+	–	–	+	+
7	+	+	–	+	–	–	+
8	–	–	–	–	–	–	–
9	–	–	–	+	–	+	+
10	+	–	–	–	+	–	+
11	+	+	–	–	–	+	–
12	–	+	+	–	–	–	+
13	+	–	+	+	–	–	–
14	–	+	–	+	+	–	–
15	–	–	+	–	+	+	–
16	+	+	+	+	+	+	+

Source: Micheaux [18, p. 51].

[1] More information on examples of applications of Plackett-Burman designs in marketing research in: A. Kaniewska-Sęba, R. Nestorowicz, *Eksperymenty Plackett-Burman – zasady tworzenia i przykłady zastosowań w badaniach skuteczności komunikacji BTL (below-the-line)* /A. Kaniewska-Sęba, R. Nestorowicz // Marketing i Rynek – 2014. – № 4. – pp. 53-59.

4. Latin square design

The Latin square is a variation on the fractional experiment, which – according to Hamlin [7, p. 330] – should be used in marketing research. It is another way of reducing the cost and duration of research when analysing the effect of three variables (more precisely one independent variable and two extraneous variables) modified on several levels.

The main advantage of this design (similar to other fractional experiments) is the lower number of tested combinations than in the case of a factorial experiment. The Latin square includes n^2 observations which account for 1/n combinations in an n^3 factorial experiment where n – the number of analysed factors [8, p. 272]. For instance, in a factorial experiment when testing the effects of interaction among three variables (each on two levels) it is required to test $2^3 = 8$ combinations while in the Latin square: 4.

Table 4

Latin square design (4 x 4)

	B1	B2	B3	B4
A1	C1	C2	C3	C4
A2	C2	C3	C4	C1
A3	C3	C4	C1	C2
A4	C4	C1	C2	C3

Variables: A and B – extraneous variables, C – independent variable.

Source: Own study.

The core requirement when constructing an experimental design using the Latin square is to divide the extraneous variables into an equal number of groups, which means that each of the variables is modified on the same number of levels. The Latin square is a matrix whose rows represent the levels of one of the extraneous variables, while its columns represent levels of the other variable. Both variables build the 'square's sides' (Table 4). Another important aspect deals with the random distribution of various values of the independent variable in the first row and with the importance of the fact that the following rows cannot adopt the same values in any column or row [10, p. 300].

The literature in the field offers numerous examples of the application of the Latin square in marketing research, however – as pointed out by Hamlin [2005, p. 340] – most of them date back to the 1960s and '70s

[e.g. 5, pp. 63-67; 9, pp. 154-162; 22, pp. 23-33; 12, pp. 210-215; 25, pp. 431-434]. It is hard to find more current examples of its application. Firstly, the Latin square design allows testing only three variables, including one independent and two extraneous variables. Secondly, each variable needs to be divided into an equal number of levels, which practically is not always possible. Thirdly, there is no way of analysing interactions among the tested variables [20, pp. 94-98].

The last inconvenience could be eliminated by creating a double change-over design i.e. a design consisting of a combination of two Latin squares. The first of them would have a traditional form and the second one would represent an inverted value sequence of the independent variable. The rules of construction and model of application of this design in marketing research are described by Hoofnagle [9, pp. 157-158]. The aim of his experiment was to assess the promotional methods employed to date for lamb's meat and to test some alternative promotional tools. The independent variable was modified on three levels: A – promotional activity to date (advertising + merchandising); B – producer and retailer's joint advertisement (cofounded) and C – no promotional activity. The research was conducted in three periods (six weeks each) in six cities, two of which were located in an area of high lamb consumption, while the remaining three in an area of average consumption of this meat.

Table 5

A model of the application of the double change-over design

	Square 1. (region of high lamb's meat consumption)			**Square. (region of average lamb's meat consumption)**		
Stages of completion	City 1	City 2	City 3	City 4	City 5	City 6
September 6 – October 15	A	B	C	A	B	C
October 17 – November 26	B	C	A	C	A	B
January 2 – February 11*	C	A	B	B	C	A

* The period of Christmas and New Year's Eve was intentionally omitted.

Source: [9, p. 158]

Conclusion

The considerations in this paper are largely of methodological nature, as its purpose is to present construction rules and examples of application

of Plackett-Burman designs and Latin square experiments, which despite some clear advantages over classic fractional experiments (design of easy construction and fewer combinations of factors under analysis), remain relatively unpopular in research marketing.

It seems that the rare application of the Latin square design in current research projects in the field of marketing should mainly be put down to a series of limitations connected with its construction (e.g. the possibility to test only 3 variables). According to Holland and Carvens [8, p. 272], it seldom helps to solve a marketing problem as normally the research problem needs to be matched with the experimental plan, not the other way round.

In the case of Plackett-Burman designs, however, its rare application may to a large degree be attributed to a gap in the knowledge about the methodology. Plackett and Burman described their designs in an article that was published in the first half of the 20th century. Nevertheless, since then only a few non-serial publications on the topic of conducting research through experiment have presented the rules of creating this type of design (the book by Box et al. [2, pp. 281-294] is one example). The situation is similar for articles published in academic journals of marketing.

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Резюме

Размышления, высказанные в этой статье, носят методологический характер. Цель статьи – представить правила создания и примеры применения схем Плакетта-Бермана и экспериментов в виде латинского квадрата. Эти средства, несмотря на их существенное преимущество над "классическими" фракционными экспериментами, являются сравнительно мало популярны в маркетинговых исследованиях.

Ключевые слова: *оценка эффективности маркетинговой коммуникации, маркетинговые исследования, схемы Плакетта-Бермана, эксперименты в виде латинского квадрата*