

Tell Me What You Want: Conjoint Analysis Made Simple Using SAS®

Delali Agbenyegah, Alliance Data Systems, Columbus, Ohio

1. ABSTRACT

The measurement of factors influencing consumer purchasing decisions is of interest to all manufacturers of goods, retailers selling these goods, and consumers buying these goods. In the past decade, conjoint analysis has become one of the commonly used statistical techniques for analyzing the decisions or “trade-offs” consumers make when they purchase products. Although recent years have seen increased use of conjoint analysis and conjoint software, there is limited work that has spelled out a systematic procedure on how to do a conjoint analysis or use conjoint software. The goals of this paper are as follow: 1) Review basic conjoint analysis concepts, 2) Describe the mathematical and statistical framework on which conjoint analysis is built; 3) Introduce the TRANSREG and PHREG procedures, their syntaxes, and the output they generate using simplified real life data examples. This paper concludes by highlighting some of the substantive issues related to the application of conjoint analysis in a business environment and the available auto call macros in SAS/STAT®, SAS/IML® and SAS/QC® to handle more complex conjoint designs and analyses. The paper will benefit the basic SAS® user, statisticians and research analysts in every industry, especially in marketing and advertisement.

2. INTRODUCTION

Conjoint analysis is used to measure consumer preference and simulate their choice. Suppose a product is made up of several features (usually called attributes), conjoint analysis can help one quantify the importance of each attribute to the product preference and what combination of the different types of the attributes (usually called attribute levels) are mostly preferred by consumers.

Consider a computer having attributes such as brand, monitor size, processor speed, memory size and price. A consumer may prefer a Toshiba computer that has 15-inch monitor with 3GHz processor and 1 GB RAM at \$700 over a Lenovo computer that has 17-inch monitor with 3GHz processor and 1.5GB RAM at \$749. Conjoint analysis can help one quantify the importance of each attribute to the consumer's stated preference and identify what combination of attribute levels are most preferred. Depending on how one plans and designs the conjoint survey, one could identify which computer attributes consumers would be willing to trade off for lower prices and which attributes consumers would be willing to pay higher prices to have.

This method provides a way of understanding the underlying drivers compelling consumers to make decisions. Despite the complexity of human decision making, conjoint analysis has proven itself over the years to help marketers, engineers, psychologists and business managers to reduce the uncertainty they face in making consumer-centric decisions. Orme (2013).

For a full introduction to conjoint, please refer to Green and Wind (1975), Green and Srinivasan (1990).

3. THE CONJOINT DESIGN

The success of a conjoint survey and the usefulness of the results depend heavily on the conjoint design. Techniques and procedures from Design of Experiments are used to select which combination of attribute levels to be tested. In a conjoint survey, respondents are asked to state their preferences for products or services made up of different combinations of attribute levels. The two major types of conjoint design are explained below:

3.1 THE TRADITIONAL FULL PROFILE CONJOINT (TFPC) DESIGN

The Traditional Full Profile Conjoint displays full or complete product options made up of all possible combinations of all the attribute levels. The consumer is asked to rate his or her preference or likelihood of purchase using some rating system. Though this method ensures the study of many attributes and level combinations, it has a high potential of making the survey respondents weary. For example in a conjoint study of five attributes, each at three levels, there will be $3^5=243$ combinations for a full factorial design. It is almost impossible for respondents to rank all the possible combinations. Most researchers often use a fractional-factorial design which studies fewer runs. Though the fractional-factorial design has its own shortfalls such as confounding some effects, it has proven itself to work better in most conjoint studies. Below is an example of a typical Traditional Full Profile Conjoint survey of three attributes, each at two levels.

On a scale of 1 to 8, with 1 indicating low preference and 8 indicating high preference, rank your likelihood of purchase of the following computers.

<i>Product Features</i>	<i>Rank</i>
<i>Toshiba computer with 3GHz processor and 7-hour battery life at \$699</i>	
<i>Toshiba computer with 2GHz processor and 7-hour battery life at \$599</i>	
<i>Dell computer with 3GHz processor and 7-hour battery life at \$699</i>	
<i>Dell computer with 2GHz processor and 7-hour battery life at \$599</i>	
<i>Toshiba computer with 3GHz processor and 5-hour battery life at \$599</i>	
<i>Toshiba computer with 2GHz processor and 5-hour battery life at \$499</i>	
<i>Dell computer with 3GHz processor and 5-hour battery life at \$599</i>	
<i>Dell computer with 2GHz processor and 5-hour battery life \$499</i>	

3.2 CHOICE BASED CONJOINT (CBC) DESIGN

The most common conjoint design used today is the Choice Based Conjoint (CBC) design, where consumers are presented with different product options and asked to select the product they are most likely to purchase. This method has become more popular as it 'forces' the consumer to make a trade off and select just one option in the midst of many options. Typically in the market place, a consumer will end up choosing one product among others and hence CBC approximates real life situations than a Traditional Full Profile Conjoint design. Below is an example of a typical CBC questionnaire.

Which of the following laptop computers are you most likely to purchase?

<i>Brand</i>	<i>Toshiba</i>	<i>Dell</i>	<i>Toshiba</i>	<i>Dell</i>	<i>I will not own</i>
<i>Processor</i>					
<i>Speed</i>	<i>3GHz</i>	<i>2GHz</i>	<i>3GHz</i>	<i>3GHz</i>	<i>a laptop if</i>
<i>Battery Life</i>	<i>7-hours</i>	<i>7-hours</i>	<i>5-hours</i>	<i>5-hours</i>	<i>these were the</i>
<i>Price</i>	<i>\$699</i>	<i>\$599</i>	<i>\$499</i>	<i>\$499</i>	<i>only options</i>

In addition to the Traditional Full Profile Conjoint and the CBC, there are other methods such as the Adaptive Conjoint, Partial Profile Choice Based Conjoint, Adaptive Choice Based Conjoint and Menu Based Conjoint.

For a full review of conjoint design methods and how to choose which method to use under a specific condition, please refer to Bryan K. Orme, 2013, Getting Started with Conjoint Analysis and Warren F. Kuhfeld, Marketing Research Methods in SAS, October 2010, SAS 9.2 Edition.

There are a lot of factors to consider when designing and executing a conjoint survey including but not limited to choice of sample size, design efficiency, and orthogonality. While the focus of this paper is not to explain all the elements of the design of experiments that goes into planning and execution of conjoint analysis, it is important to note that SAS/QC can be used to generate orthogonal designs using the ADX menu system and SAS has also provided several auto call macros to handle different conjoint design situations. These options will be highlighted in section 9 of this paper.

4. TRADITIONAL FULL PROFILE CONJOINT (TFPC) ANALYSIS AND UTILITY ESTIMATION USING PROC TRANSREG

In a TFPC design, respondents are asked to rate their preference to different products or packages that are made of attribute level combinations. The conjoint analysis in this situation is based on the main effects ANOVA model where

The judgment data is decomposed into components based on the nominal attributes of the product. The parameter estimates from the conjoint ANOVA model are called utilities or part worth utilities which are measures of preferences of each attribute level. In SAS, the TRANSREG procedure is used to fit the conjoint model for each subject in one step. PROC TRANSREG was designed to handle conjoint studies along with other general linear models. It extends ordinary general linear models by providing optimal variable transformations and scaling methods that are iteratively derived using the method of alternating least squares. For more information about the methods and options available under PROC TRANSREG, please refer to the SAS help and documentation for PROC TRANSREG.

5. CHOICE BASED CONJOINT (CBC) ANALYSIS AND UTILITY ESTIMATION USING PROC PHREG

In CBC, respondents are asked to choose their preference for a product made up of different attributes. The Multinomial Logit Model is used in this case to model the aggregate choice data. The multinomial logit model assumes that the likelihood that an individual will choose one of the k alternatives, c_i from a set of possible alternatives, C is

$$P(c_i) = \frac{e^{X_i \beta}}{\sum_{j=1}^K e^{X_j \beta}} \quad (1)$$

where X_i is a vector of coded attributes and β is a vector of unknown attribute parameters. The utility for alternative c_i is $U(c_i) = X_i \beta$ which is a linear function of attributes. The probability that an individual will choose one of the k alternatives, c_i from a set of possible alternatives, C is the exponential of the utility of that alternative divided by the sum the exponentiated utilities of all the possible alternatives. The data set up in this choice experiment follows the form of a survival analysis, where the respondents chosen option is 'observed' or 'uncensored', and all the remaining alternatives not chosen by the respondents are 'censored'. In SAS/STAT®, you can fit the conjoint Multinomial Logit Model using the PHREG (Proportional Hazard Regression) procedure. The survival model fitted by the PHREG option has the same form as the conjoint Multinomial Logit Model.

6. MARKET SHARE SIMULATION

Most conjoint analysis has the primary goal of using the utilities generated from the conjoint analysis to estimate the proportion of times that particular product (with the attribute levels) will be purchased if the product were to be introduced to the market. This is popularly known as Market Share Simulation.

Suppose P_{ijk} is the probability of choosing the i th level of attribute A, j th level of attribute B, and k th level of attribute C in a 3-attribute product situation, and y_{ijk} is the corresponding estimated utility.

One way to do this market share simulation is the Maximum Utility Model which assumes that each subject will buy the product for which he or she has the maximum utility with probability of 1 as stated in the equation below.

$$P_{ijk} = 1 \text{ for } Y_{ijk} = \max(y_{ijk}), \text{ Otherwise, } P_{ijk} = 0 \quad (2)$$

To get the predicted market share, we average the probabilities across all the subjects.

Another method of market share simulation is the Logit Model which assumes that the probability of a subject purchasing a product is a logit function of utility as stated below:

$$P_{ijk} = \frac{e^{y_{ijk}}}{\sum e^{y_{ijk}}} \quad (3)$$

Market share can also be simulated using the Bradley-Terry-Lute (BTL) Model which assumes that the probability of a subject purchasing a product is a linear function of utility. Under that assumption,

$$P_{ijk} = \frac{y_{ijk}}{\sum y_{ijk}} \quad (4)$$

It is worth mentioning that each of these three methods has its advantages and disadvantages and it is strongly recommended that the researcher considers all of them before choosing one method over the other.

7. TRADITIONAL FULL PROFILE CONJOINT ANALYSIS EXAMPLE USING PROC TRANSREG

This example uses a simplified loyalty marketing survey data from an apparel retailer to illustrate conjoint analysis in SAS. For privacy reasons, the retailer will be referred to as 'Fibdel' in this paper. The goal of the study is to evaluate which benefit package attracts consumers to enroll in a loyalty program at Fibdel and become more engaged with Fibdel. The results of the study will be used to advise the management of Fibdel on which benefit package resonates more with their customers. For simplicity, we study only three factors, each at two levels as shown below:

Attributes	Attribute Levels
Point of Sale Offer	15% off your first Purchase , \$20 off your first purchase
Rewards	Spend \$300 and get \$15 coupon , Spend \$500 and get \$25 coupon
Birthday	\$20 off coupon on your birthday, 10% off coupon on your birthday

There are $2^3=8$ possible combinations of the attribute levels. The respondents were asked to rate their preference for the 8 different packages on a scale of 1 to 8, where 1 denotes the least preferred and 8 the most preferred. In this simple case, the data was collected through a customized online survey of 100 respondents, and results were compiled in an excel spreadsheet and later exported to SAS. Note that the data for a conjoint survey can be collected in many different ways based on the complexity of the survey.

The following table shows a snapshot of the survey data (SET1) set for the first 3 subjects.

	Options	Point of Sell Offer	Rewards	Birthday	subj1	subj2	subj3
1	Package1	*15% off yourfirst Purchase	Spend \$300 and get \$15 coupon	\$20 off coupon on your birthday	1	2	2
2	Package2	*15% off yourfirst Purchase	Spend \$500 and get \$30 coupon	\$20 off coupon on your birthday	3	3	1
3	Package3	\$20 off yourfirst purchase	Spend \$300 and get \$15 coupon	\$20 off coupon on your birthday	2	4	3
4	Package4	\$20 off yourfirst purchase	Spend \$500 and get \$30 coupon	\$20 off coupon on your birthday	7	5	6
5	Package5	*15% off yourfirst Purchase	Spend \$300 and get \$15 coupon	10% off coupon on your birthday	4	1	4
6	Package6	*15% off yourfirst Purchase	Spend \$500 and get \$30 coupon	10% off coupon on your birthday	5	8	5
7	Package7	\$20 off yourfirst purchase	Spend \$300 and get \$15 coupon	10% off coupon on your birthday	6	7	8
8	Package8	\$20 off yourfirst purchase	Spend \$500 and get \$30 coupon	10% off coupon on your birthday	8	6	7

Before running the conjoint analysis with the TRANSREG procedure, the following code customizes the output from the procedure to suit the conjoint analysis.

```
PROC TEMPLATE;
EDIT Stat.Transreg.ParentUtilities;
COLUMN Label Utility StdErr tValue Probt Importance Variable;
HEADER title;
DEFINE title; text 'Part-Worth Utilities'; space=1; end;
DEFINE Variable; print=off; end;
end;
run;
```

The next piece of SAS code invokes the TRANSREG procedure, which fits the conjoint model to a data set called SET1. The procedure fits the main effect ANOVA model for each of the 100 subjects. The MODEL statement specifies that an identity transformation will be used and the attributes are specified under the CLASS statement. The identity transformation specification under the MODEL statement ensures that the original ranking is not changed. The sum of the coefficients is restricted to sum up to zero. For more information about the MODEL statements and transformation options, please refer to the SAS help and documentation for PROC TRANSREG. The procedure below outputs the individual utilities for each subject in the UTILITY_SET data set.

```
ods exclude notes mvanova anova;
PROC TRANSREG data=SET1 utilities short separators=', '
METHOD=morals outtest=UTILITY_STATS;
title2 'Conjoint Analysis';
MODEL identity(subj: ) =
CLASS(Point_of_Sell_Offer Rewards Birthday / zero=sum);
output p ireplace out=UTILITY_SET coefficients;
run;
```

In the interest of space, the TRANSREG output for only one subject is shown below:

The TRANSREG Procedure Hypothesis Tests for Identity(subj3)

Root MSE	1.17260	R-Square	0.8690
Dependent Mean	4.50000	Adj R-Sq	0.7708
Coeff Var	26.05787		

Part-Worth Utilities			
	Utility	Standard Error	Importance (% Utility Range)
Intercept		0.41458	

Labe			
I			
4.5000			
Point of Sale Offer,\$20 off your first purchase	1.5000	0.41458	46.154
Point of Sale Offer,15% off your first Purchase	-1.5000	0.41458	
Rewards,Spend \$300 and get \$15 coupon	-0.2500	0.41458	7.692
Rewards,Spend \$500 and get \$30 coupon	0.2500	0.41458	
Birthday,\$20 off coupon on your birthday	-1.5000	0.41458	46.154
Birthday,10% off coupon on your birthday	1.5000	0.41458	

The output shows the part-worth utilities of each attribute level, as well as the importance of each attribute for subject 3. Clearly, this subject considered the point of sale and the birthday offers to be most important in enrolling in the loyalty program. From the part-worth utilities shown above, this subject likes \$20 off first purchase as the point of sale offer, spend \$500 and get \$30 as the rewards and 10% off coupon as the preferred birthday offer.

The output data set called UTILITY_SET has the utility information for all subjects and can be manipulated to find the most preferred packages across all subjects.

Below is the frequency output data set for the most preferred package.

	PACK	Frequency Count	Percent of Total Frequency
1	\$20 off your first purchase Spend \$300 and get \$15 coupon \$20 off coupon on your birthday	3	3
2	\$20 off your first purchase Spend \$300 and get \$15 coupon 10% off coupon on your birthday	9	9
3	\$20 off your first purchase Spend \$500 and get \$30 coupon \$20 off coupon on your birthday	23	23
4	\$20 off your first purchase Spend \$500 and get \$30 coupon 10% off coupon on your birthday	65	65

As shown in the table, 65% of the respondents chose \$20 off your first purchase, Spend \$500 and get \$30 and 10% off coupon on your birthday as their most preferred package and only 3% chose \$20 off your first purchase, Spend \$300 and get \$15 coupon and \$20 off coupon on your birthday as their most preferred benefits package.

The output data set named UTILITY_STATS under the TRANSREG procedure also has individual level statistics that can be manipulated to get aggregate level statistics if desired.

As mentioned in section 6, the goal of most conjoint analysis is to get the utilities of each attribute and use that to estimate the market share of each package or product. An example code is provided in the appendix that uses all the three market simulation methods described in section 6 to estimate the market share for all the packages. The market simulation results are shown in the table below:

	Point of Sell Offer	Rewards	Birthday	market_share_mum	market_share_blt	market_share_mnl
1	\$20 off your first purchase	Spend \$500 and get \$30 coupon	10% off coupon on your birthday	0.65	0.195972222	0.4688192896
2	\$20 off your first purchase	Spend \$500 and get \$30 coupon	\$20 off coupon on your birthday	0.23	0.1526388889	0.1913689982
3	\$20 off your first purchase	Spend \$300 and get \$15 coupon	10% off coupon on your birthday	0.09	0.165	0.1786540503
4	\$20 off your first purchase	Spend \$300 and get \$15 coupon	\$20 off coupon on your birthday	0.03	0.1216666667	0.0638831083
5	15% off your first Purchase	Spend \$500 and get \$30 coupon	10% off coupon on your birthday	0	0.1283333333	0.0476102945
6	15% off your first Purchase	Spend \$300 and get \$15 coupon	10% off coupon on your birthday	0	0.0973611111	0.0226151578
7	15% off your first Purchase	Spend \$500 and get \$30 coupon	\$20 off coupon on your birthday	0	0.085	0.019066207
8	15% off your first Purchase	Spend \$300 and get \$15 coupon	\$20 off coupon on your birthday	0	0.0540277778	0.0079828943

The above results can be used in conjunction with other factors that affect the choice of a package or product other than customer voice to make a final package recommendation to Fibdel.

8. CHOICE BASED CONJOINT ANALYSIS EXAMPLE USING PROC PHREG

This example illustrates CBC analysis using the PHREG procedure. Again, another group of 100 Fibdel customers were asked to choose which package alternative they preferred most among 8 possible alternatives. The attributes and attribute levels are the same as those tested in the above example in section 7. The key difference here is the customers were asked to choose which option they preferred most rather than ranking all the possible options. In most large scale conjoint studies, respondents may not see all possible options but SAS has provided auto call macros to ensure efficient survey designs that can help in the choice of possible attribute level combinations to test. These auto call macros are highlighted in section 9 of this paper.

Below is the question each subject was asked. The response expected from each subject is a one choice response in the range 1-8, indicating which of the 8 options they like most.

Which of the following options are you most likely to select as your preferred benefit option if you enroll in Fibdel Loyalty program?

	Point off Sale Offer	Rewards	Birthday
Option1	15% Off your first purchase	Spend \$300 and get \$15 coupon	\$20 Off coupon on your birthday
Option2	15% Off your first purchase	Spend \$500 and get \$30 coupon	\$20 Off coupon on your birthday
Option3	\$20 Off your first purchase	Spend \$300 and get \$15 coupon	\$20 Off coupon on your birthday
Option4	\$20 Off your first purchase	Spend \$500 and get \$30 coupon	\$20 Off coupon on your birthday
Option5	15% Off your first Purchase	Spend \$300 and get \$15 coupon	10% Off coupon on your birthday
Option6	15% Off your first Purchase	Spend \$500 and get \$30 coupon	10% Off coupon on your birthday
Option7	\$20 Off your first purchase	Spend \$300 and get \$15 coupon	10% Off coupon on your birthday
Option8	\$20 Off your first purchase	Spend \$500 and get \$30 coupon	10% Off coupon on your birthday

The data format needed for running a CBC using PROC PHREG is entirely different from what is needed to run a rank based conjoint analysis described in section 7. Below is the SAS dataset needed to fit the Multinomial Logit Model using the PROC PHREG for the first two subjects.

	Subj	Set	c	POS_15P	Rew_S300_G15	B_20D
1	1	1	2	1	1	1
2	1	1	2	1	0	1
3	1	1	2	0	1	1
4	1	1	2	0	0	1
5	1	1	2	1	1	0
6	1	1	2	1	0	0
7	1	1	1	0	1	0
8	1	1	2	0	0	0
9	2	1	2	1	1	1
10	2	1	2	1	0	1
11	2	1	2	0	1	1
12	2	1	2	0	0	1
13	2	1	2	1	1	0
14	2	1	1	1	0	0
15	2	1	2	0	1	0
16	2	1	2	0	0	0

The first column in the dataset shows the subject number, the second column shows the choice set, and the third column, labelled c shows which option is picked. The options picked have c=1 and all the remaining options have c=2. The remaining three columns denote the benefit options tested.

Before fitting the Multinomial Logit model, the **% phchoice** auto call macro is invoked to customize the PHREG output from a survival analysis output into a conjoint. More information regarding SAS auto call macros useful for conjoint analysis will be mentioned in the next section.

%phchoice(on)

```
PROC PHREG data=SURVEY_RESULTS outest=COEF;
strata subj set;
model c*c(2) = POS_15P Rew_S300_G15 B_20D / ties=breslow; label
POS_15P='15% off your first purchase' Rew_S300_G15='Spend
$300 and get $15 coupon' B_20D='$20 off coupon on your
birthday';
run;
```

%phchoice(off)

The next step is to use the coefficients of the Multinomial Logit Model (part-worth utilities) from the PHREG procedure stored in the outest=COEF data set to estimate the probability of choice or the market share for each package using the equation (1) mentioned in section 5. The result below shows the estimated probability of choice for each package.

	POS_15P	Rew_\$300_G15	B_20D	prob
1	\$20 off your first purchase	Spend \$300 and get \$15 coupon	10% off coupon on your birthday	0.1513679946
2	\$20 off your first purchase	Spend \$500 and get \$25 coupon	10% off coupon on your birthday	0.1454319948
3	15% off your first purchase	Spend \$300 and get \$15 coupon	10% off coupon on your birthday	0.1342319953
4	15% off your first purchase	Spend \$500 and get \$25 coupon	10% off coupon on your birthday	0.1289679955
5	\$20 off your first purchase	Spend \$300 and get \$15 coupon	\$20 off coupon on your birthday	0.1189320053
6	\$20 off your first purchase	Spend \$500 and get \$25 coupon	\$20 off coupon on your birthday	0.1142680051
7	15% off your first purchase	Spend \$300 and get \$15 coupon	\$20 off coupon on your birthday	0.1054680048
8	15% off your first purchase	Spend \$500 and get \$25 coupon	\$20 off coupon on your birthday	0.1013320046

The above results can be used in conjunction with other factors that affect the choice of a package or product other than customer voice to make a final package recommendation to Fibdel.

9. COMPLEX DESIGNS AND SAS® AUTO CALL MACROS

Most conjoint studies today are more complex than the examples described above. Even though the final conjoint data set to be analyzed in SAS, model fitting and the output generated follow similar form as the examples described above, the design of experiments, design evaluation, questionnaire creation, inputting and processing the raw data and getting the data in the right form for analysis in SAS can be very complicated and time consuming. The good news is that SAS has provided many auto call macros to aid all aspects of conjoint design and analysis, which are readily available for use, once one has the required SAS product. Below is the list of the auto call macros available for marketing research as published by SAS in 2010.

Macro	Required	Purpose
%ChoiceEff	STAT, IML	efficient choice design
%MktAllo		processes allocation data
%MktBal	QC	balanced main-effects designs
%MktBIBD	IML, QC	balanced incomplete block designs
%MktBlock	STAT, IML	block a linear or choice design
%MktBSize		sizes of balanced incomplete block designs
%MktDes	STAT, QC	efficient factorial design via candidate set search
%MktDups		identify duplicate choice sets or runs
%MktEval	STAT, IML	evaluate an experimental design
%MktEx	STAT, IML, QC	efficient factorial design
%MktKey		aid creation of the key= data set
%MktLab		relabel, rename and assign levels to design factors
%MktMDiff	STAT	MaxDiff (best-worst) analysis
%MktMerge		merges a choice design with choice data
%MktOrth		lists the orthogonal array catalog
%MktPPro	IML	partial profiles through BIB designs
%MktRoll		rolls a factorial design into a choice design
%MktRuns		selecting number of runs in an experimental design
%Paint		color interpolation
%PHChoice		customizes the output from a choice model
%PlotIt	STAT, GRAPH	graphical scatter plots of labeled points

Please go to <http://support.SAS®.com/techsup/technote/mr2010i.pdf> for a full review of the syntax and the usage of these macros. A few of the auto call macros are highlighted below to illustrate how they are used.

Suppose one wants to undertake a conjoint experiment to study four factors, each with three levels. The **%mktruns** macro can help one choose the number of choice sets if invoked as shown below with the output it generates:

%mktruns(3 3 3 3);

Saturated		= 9
Full Factorial = 81		
Some Reasonable		Cannot Be
Design Sizes	Violations	Divided By
9 *S	0	
18 *	0	
12	6	9
15	6	9
10	10	3 9
11	10	3 9
13	10	3 9
14	10	3 9
16	10	3 9
17	10	3 9
* - 100% Efficient design can be made with the MktEx macro. S		
- Saturated Design - The smallest design that can be made.		

n	Design	Reference
9	3 ** 4	Fractional-Factorial

n	Design	Reference
18	2 ** 1 3 ** 7	Orthogonal Array
18	3 ** 6 6 ** 1	Orthogonal Array

The output from this macro gives the saturated design, which is the smallest design that can be constructed to have a size of 9 and the full factorial design to be $3^4=81$. It goes on to list the possible designs with their violations as well as suggest orthogonal array designs, if they exist. It also suggests a 100% efficiency design can be generated using **%mktex** macro.

The next step will be to invoke the **%mktex** macro to generate the optimal design suggested.

The auto call macro below generates an optimal design with size 18 as suggested by the output generated from the **%mktruns** macro.

```
%mktex(3**4,n=18,seed=15);
```

Below is the output generated by the above code. It shows that the design has 100% D-efficiency (a measure of goodness of fit for the design, scaled from 0 to 100) and an average prediction standard error of 0.7071. The macro also generates a design data set that gives the attribute level combinations to be tested in the conjoint.

The OPTEX Procedure				
Class Level Information				
Class Levels Values				
x1	3	1 2 3		
x2	3	1 2 3		
x3	3	1 2 3		
x4	3	1 2 3		

Design n	D-	A-Efficiency	G-	Average Prediction Standard Error
1	100.0000	100.0000	100.0000	0.7071

The design data set generated is also shown below:

	x1	x2	x3	x4
1	1	1	1	1
2	1	1	2	2
3	1	2	1	3
4	1	2	3	1
5	1	3	2	3
6	1	3	3	2
7	2	1	1	3
8	2	1	3	1
9	2	2	2	2
10	2	2	3	3
11	2	3	1	2
12	2	3	2	1
13	3	1	2	3
14	3	1	3	2
15	3	2	1	2
16	3	2	2	1
17	3	3	1	1
18	3	3	3	3

It is also necessary to examine the design and perform efficiency checks before investing resources in the data collection, and the **%mkteval** macro can be used to carry out that exercise as shown below:

%mkteval(data=design)

The above examples were highlighted to provide exposure to some of the available auto call macros in SAS that are useful for conjoint analysis. These auto call macros provide a good starting point for conjoint design and analysis.

10. CONCLUSION

Conjoint analysis has gained a lot of popularity due to the recent shift to customer-centric decision making. The TRANSREG and PHREG procedures can be used to perform conjoint analysis in SAS as long as the data is prepared in the right format supported by SAS. There are complete auto call macros available in SAS STAT/IML/QC that make the design of conjoint experiment, questionnaire design, data collection, data processing, as well as the data analysis relatively easy.

REFERENCES

- Orme, Bryan K.(2005). *Getting Started with Conjoint Analysis. Strategies for Product Design and Pricing Research*. Third Edition, Glendale, CA: Research Publishers LLC
- Kuhfeld, Warren F. (2010).*Marketing Research Methods in SAS®. Experimental Design, Choice, Conjoint and Graphical Techniques*. SAS 9.2 Edition, MR-2010
- SAS Institute Inc, SAS® Technical Report r-109, *Conjoint Analysis Examples*, Cary, NC: SAS Institute Inc.
- Sawtooth Software(2013).*The CBC System for Choice Based Conjoint Analysis*, Version 8,Orem,UT; Sawtooth Software, Inc
- Green PE and Rao VR. (1971). *Conjoint measurement for quantifying judgmental data. Journal of Marketing Research*. doi:10.2307/3149575c.
- Green, P.E. and Wind, Y. (1975) *New Way to Measure Consumers Judgments*, Harvard Business Review, July-August
- Green, P.E., and Srinivasan, V. (1990), *Conjoint Analysis in Marketing: New Developments with Implications for Research and Practice*, Journal of Marketing

ACKNOWLEDGMENTS

The author would like to thank Yin Chen, Tim Sweeney, Alphonse Damas, Shannon Markiewicz, Brooke Biller and the entire Predictive Analytics team at Alliance Data Systems for their support.

CONTACT INFORMATION

Your comments and questions are valued and encouraged. Contact the author at:

Delali Agbenyegah
Alliance Data Systems
3100 Easton Square Place
Columbus, OH, 43219
delali.agbenyegah@alliancedata.com
www.delaliagbenyegah.com

SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc. in the USA and other countries. ® indicates USA registration.

Other brand and product names are trademarks of their respective companies.

APPENDIX

```

* ----- *
*   An Example Code for market simulation using Maximum Utility, *
*   Multinomial Logit and BTL Methods for the full profile rank *
*   based conjoint Analysis using the predicted utility output from *
* PROC TRANSREG *
*   Macro Variables are defined below: *
*   1)no_packs=Number of packages or products to be evaluated *
*   2)no_subjs=Number of subjects or respondents *
*   3)ind_vars=Names of the attributes tested *
*   4)util_set=The utility output dataset from PROC TRANSREG *
*   5)outdata=Name of your final output dataset that will have *
*       the market simulation *
* ----- *;
%macro market_share(no_packs,no_subjs,ind_vars,util_set,outdata);
data temp_data1;
    set &util_set.(where=(_type_ = 'SCORE'));
run;
/* construct a dataset of number of packages/subjects utilities*/
data temp_data2;
keep u1 - u&no_subjs v1 - v&no_subjs &ind_vars;
    array u[&no_subjs] u1 - u&no_subjs;
    array v[&no_subjs] v1 - v&no_subjs;
    do j = 1 to &no_packs;
        set temp_data1(keep=&ind_vars) point = j; /* get the independent
variables*/
        k = j; /*get the utilities*/
        do i = 1 to &no_subjs;
            set temp_data1(keep=p_depend_) point = k;
            u[i] = p_depend_;
            v[i] = exp(p_depend_);
            k = k + &no_packs;
        end;
        output;
    end;
stop;
run;
* compute utility sum for each subject;
proc means data=temp_data2 noprint;
var u1-u&no_subjs v1-v&no_subjs;
output out=temp_data1 sum=sumu1 - sumu&no_subjs sumv1-sumv&no_subjs;
run;
/* Calculate maximum utility for each subject*/
proc means data=temp_data2 noprint;
var u1-u&no_subjs;
output out=temp_data_m max=max1 - max&no_subjs;
run;
/* Compute expected market share using the BTL method and MNL method*/
data mark_share(keep=market_share_blt market_share_mnl &ind_vars);
if _n_ = 1 then set temp_data1(drop=_type_ _freq_);
    array u[&no_subjs] u1 - u&no_subjs;
    array m[&no_subjs] sumu1 - sumu&no_subjs;
    array v[&no_subjs] v1 - v&no_subjs;
    array n[&no_subjs] sumv1 - sumv&no_subjs;

```

```

set temp_data2;
do i = 1 to &no_subjs;
    u[i] = u[i] / m[i];
    v[i] = v[i] / n[i];
end;
market_share_blt = mean(of u1-u&no_subjs);
market_share_mnl = mean(of v1-v&no_subjs);
run;
/* identify the maximum utility*/
data temp_data3(keep=u1 - u&no_subjs &ind_vars);
if _n_ = 1 then set temp_data_m(drop=_type_ _freq_);
    array u[&no_subjs] u1 - u&no_subjs;
    array m[&no_subjs] max1-max&no_subjs;
set temp_data2;
do i = 1 to &no_subjs;
    u[i] = ((u[i] - m[i]) > -0.001); /* 0.001 is just a chosen number close
to zero*/
end;
run;
proc means data=temp_data3 noprint;
var u1-u&no_subjs;
output out=temp_data1_m sum=sum1 - sum&no_subjs;
run;
/* Compute expected market share using the Maximum utility method*/
data mark_share2(keep=market_share_mum &ind_vars);
if _n_ = 1 then set temp_data1_m(drop=_type_ _freq_);
    array u[&no_subjs] u1 - u&no_subjs;
    array m[&no_subjs] sum1 - sum&no_subjs;
set temp_data3;
do i = 1 to &no_subjs;
    u[i] = u[i] / m[i];
end;
market_share_mum = mean(of u1-u&no_subjs);
run;
Proc sort data=mark_share;
by &ind_vars;
run;
Proc sort data=mark_share2;
by &ind_vars;
run;
Data &outdata.;
merge mark_share2(in=a) mark_share(in=b);
by &ind_vars;
if a and b;
run;
Proc sort data=&outdata.;
by descending market_share_mnl;
run;
%mend market_share;
/* An example macro call based on the data used for illustration in this
paper*/
%market_share(8,100,Point_of_Sell_Offer Rewards
Birthday,utility_set,Market_simulation);

```