Paper CC184

IA_CTT: A SAS® Macro for Conducting Item Analysis Based on Classical Test Theory

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ABSTRACT

This paper provides a SAS® macro, called IA_CTT, for conducting item analysis using classical test theory (CTT). Item analysis from this macro yields information that includes test score statistics (e.g., mean, median, mode, Q1, Q3, standard deviation, skewness, kurtosis, alpha, standard error of measurement), individual item statistics (e.g., p-value, point-biserial correlation, corrected point-biserial correlation, reliability when item deleted, upper- and lower-group item discrimination), frequency distributions of individual options for each item based on overall samples and two different groups from top 25% (above Q3) and bottom 25% (below Q1) students (i.e., distractor analysis), and Mantel-Haenszel differential item functioning statistics. The macro reads in data from Microsoft Excel and exports outputs as Excel files. In addition to the macro for item analysis, this paper also provides interpretations of all the relevant statistics. Exemplary outputs are shown and interpreted at the end of the paper.

KEYWORDS: Item Analysis, Classical test theory, Distractor analysis

INTRODUCTION

Even though more advanced psychometric models, such as item response theory (IRT) or cognitive diagnostic models (CDM), have been widely applied, item analysis based on classical test theory (CTT) is still very often employed by researchers and practitioners for the purpose of test development (Yu & Wong, 2003). Item analysis helps identify problems with test items for test construction or the development of item banks that will be used continually. These problems can be corrected, resulting in a better test and a high-quality measurement (Lei & Wu, 2007). Item analysis is also a useful tool anytime when students complain about items in and out of classrooms.

This paper provides a SAS® macro, called IA_CTT, using base SAS for conducting item analysis using classical test theory. Item analysis from this macro yields information that includes test score statistics, individual item statistics, and distractor analysis (DA). Test score statistics include mean, median or 50 percentile, Q1 or 25 percentile, Q3 or 75 percentile, standard deviation, skewness, kurtosis, Cronbach's alpha, and standard error of measurement. Individual item statistics involve p-value, standard deviation for p-value, point-biserial correlation, corrected point-biserial correlation, test reliability, test reliability when item deleted, the correct number and percent in the upper group, the correct number and percentage in the lower group, and item discrimination between the upper and lower group. Distractor analysis statistics include frequency distributions of individual options for each item based on overall samples and two different groups from top 25% (i.e., above Q3; the upper group) and bottom 25% (i.e., below Q1; the lower group) students.

The macro reads in data from Microsoft Excel and exports outputs as Excel files. In addition to the macro for item analysis, this paper also demonstrates how to use this macro and presents the exemplary data format in excel and all the exemplary outputs at the paper.

THE IA_CTT MACRO

```
*----------------------------------------*
|MACRO FOR ITEM AND DISTRACTOR ANALYSES |
*----------------------------------------*;
options mprint;
%macro IA_CTT (nitems=, path=, dataname=, sheetname=);

/*EXTRACT THE DATA SET FROM MICROSOFT EXCEL;*/
PROC IMPORT OUT= WORK.tmp
            DATAFILE= "&path\&dataname"
            DBMS=xlsx
            REPLACE;
     SHEET="&sheetname";
     GETNAMES=YES;
```

```
Data tmp1;
 set work.tmp;
 keep id gender r1-r&nitems;
run;

/*EXPORT THE EXTRACTED DATA SET AS A TEXT FILE;*/
data tmp2;
 set tmp1;
 file "&path\tmp.txt";
 put id 1-5 gender 6-9 @11 (r1-r&nitems) ($1.);
 run;

/*CREAT THE KEY ARRAY, THE RESPONSE ARRAY, AND THE BINARY DATA ARRAY;*/
Data one;
 infile "&path\tmp.txt";
 array k[&nitems] $ 1 k1-k&nitems;
 array r[&nitems] $ 2 r1-r&nitems;
 array x[&nitems] 3. x1-x&nitems;
 retain k1-k&nitems;

if _N_ = 1 then
   input @11 (k1-k&nitems) ($1.);
   input @1 ID 1-5
         @6 gender 6-9
         @11 (r1-r&nitems) ($1.);

   do i = 1 to &nitems;
      if k[i] eq r[i] then do;
            x[i] = 1;
               substr(r[i],2,1) = '*';
         end;
         else x[i] = 0;
  end;
total = sum (of x1-x&nitems);
drop i;
run;


*EXPORT THE SCORE DISTRIBUTION TABLE;
ods excel file="&path\scodist.xlsx"
    style=pearl
    /*Sheet_interval of “none” means that each PROC won’t generate a
       new sheet automatically*/
    options(sheet_interval="none" sheet_name="scodist");

PROC FREQ data=one;
 Tables total / out=total;
Run;
ods excel close;


*EXPORT THE RESPONSE FREQUENCY TABLE FOR EACH ITEM;
Ods excel file="&path\respfreq.xlsx"
    Style=pearl
    options(sheet_interval="none" sheet_name="respfreq");

proc freq data=one;
 tables r1-r&nitems/list sparse nocum;
run;
ods excel close;
```

```
*++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*
 CONDUCT NECESSAY ANALYSES, SUCH AS CORRELATION, ALPHA,
 MEAN, TO OBTAIN THE STATISTICS WE WANT
*++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*;
PROC CORR DATA=one NOPRINT OUTP=PTBIS;
  VAR x1-x&nitems;
  WITH total;
RUN;
PROC CORR DATA=one NOCORR NOSIMPLE ALPHA noprint OUTP=alpha;
 VAR x1-x&nitems;
RUN;
PROC MEANS DATA=one N MEAN STD MIN Q1 MEDIAN Q3 MAX SKEWNESS KURTOSIS NOPRINT;
 OUTPUT OUT=test_stat1 N=total_N MEAN=total_MEAN STD=total_STD
        MIN=total_MIN Q1=total_Q1 MEDIAN=total_MEDIAN Q3=total_Q3
        MAX=total_MAX SKEWNESS=total_SK KURTOSIS=total_KUR;
 VAR total;
RUN;
*++++++++++++++++++++++++++++++++++++++++++++++++++*
  CREATE THE SUMMARY STATISTICS TABLE FOR TEH TEST
*++++++++++++++++++++++++++++++++++++++++++++++++++*;
data test_stat2;
 set test_stat1;
 RENAME _freq_= N;
 RENAME TOTAL_N = USED_N;
 RENAME total_MEAN = MEAN;
 RENAME TOTAL_STD = STD;
 RENAME TOTAL_MIN = MIN;
 RENAME TOTAL_Q1 = Q1;
 RENAME TOTAL_MEDIAN = MEDIAN;
 RENAME TOTAL_Q3 = Q3;
 RENAME TOTAL_MAX = MAX;
 RENAME TOTAL_SK = SKEWNESS;
 RENAME TOTAL_KUR = KURTOSIS;
 drop _type_;
data test_alpha;
 set alpha;
 if _type_='RAWALPHA';
 keep x1;
 RENAME X1 = ALPHA;
DATA test_stat3;
 MERGE test_stat2 test_alpha;
 SEM = STD*SQRT(1-ALPHA);
proc transpose data = test_stat3 out = test_dst1 PREFIX = VALUE;

DATA test_dst;
 SET test_dst1;
 RENAME _NAME_ = STATISTIC;
 RENAME VALUE1 = VALUE;
run;

/*EXPORT TEST STATISTICS;*/
ODS EXCEL file="&path\testsummary.xlsx"
    Style=pearl
    options(sheet_interval="none" sheet_name="test");

Proc print data=test_dst;
 format statistic $12.;
 title 'SUMMARY STATISTICS FOR THE TEST';
run;
ods excel close;

*++++++++++++++++++++++++++++++++++++++++++++++*
  EXTRACT EACH STATISTIC FOR ITEM SUMMARY
```

```
*++++++++++++++++++++++++++++++++++++++++++++++++++*;
data item_N;
 set PTBIS;
 if _type_='N';
 drop _type_ _name_;
proc transpose data=item_N out=item_N1 prefix=USED_N;
proc sort; by _name_; run;
data item_mean;
 set PTBIS;
 if _type_='MEAN';
 drop _type_ _name_;
proc transpose data=item_mean out=item_mean1 prefix=P_Value;
proc sort; by _name_; run;
data item_std;
 set PTBIS;
 if _type_='STD';
 drop _type_ _name_;
proc transpose data=item_std out=item_std1 prefix=P_STD;
proc sort; by _name_; run;
data item_corr;
 set PTBIS;
 if _type_='CORR';
 drop _type_ _name_;
proc transpose data=item_corr out=item_corr1 prefix=PBIS_CORR;
proc sort; by _name_; run;
data test_corr;
 SET alpha;
 IF _TYPE_ = 'RAWALPHA';
 DROP _TYPE_ _NAME_;
proc transpose data=test_corr out=test_corr1 prefix=TEST_ALPHA;
proc sort; by _name_; run;
data test_corr_deleted;
 SET alpha;
 IF _TYPE_ = 'RAWALDEL';
 DROP _TYPE_ _NAME_;
proc transpose data=test_corr_deleted out=test_corr_deleted1
prefix=TEST_ALPHA_DELETED;
proc sort; by _name_; run;
data corrected_item_corr;
 SET alpha;
 IF _TYPE_ = 'RAWCTDEL';
 DROP _TYPE_ _NAME_;
proc transpose data=corrected_item_corr out=corrected_item_corr1
prefix=CORRECTED_ITEM_corr;
proc sort; by _name_; run;

*++++++++++++++++++++++++++++++++++++++++++++++++++*
  CREATE THE SUMMARY STATISTICS TABLE FOR TEST ITEMS
*++++++++++++++++++++++++++++++++++++++++++++++++++*;
data item_dst;
merge item_N1 item_mean1 item_std1 item_corr1 CORRECTED_ITEM_CORR1 TEST_CORR1
TEST_CORR_DELETED1;
by _name_;
RENAME _NAME_=ITEM;
RENAME USED_N1 = USED_N;
RENAME P_VALUE1 = P_VALUE;
RENAME P_STD1 = P_STD;
RENAME PBIS_CORR1 = PBIS_CORR;
RENAME CORRECTED_ITEM_CORR1 = CORRECTED_PBIS_CORR;
RENAME TEST_ALPHA1 = TEST_ALPHA;
RENAME TEST_ALPHA_DELETED1 = TEST_ALPHA_DELETED;
q=input(compress(_name_,'x'),8.);
run;
```

```
*++++++++++++++++++++++++++++++++++++++++++++++++*
 Merge two datasets: raw and binary datasets
*++++++++++++++++++++++++++++++++++++++++++++++++*;
DATA two;
 set one;
if _N_ = 1 then set TEST_STAT3;
 drop USED_N STD MIN MAX SKEWNESS KURTOSIS ALPHA SEM;

*++++++++++++++++++++++++++++++++++++++++++++++++++++*
  CREATE THE grouping variables for distract analysis
*++++++++++++++++++++++++++++++++++++++++++++++++++++*;
data group;
 set two;
if total ge q3 then group = 2;
  else if total le q1 then group = 1;
  else group = .;

proc format;
   value group   1   ='lower group'
                 2   ='upper group'
                 .   ='missing';
run;

*++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*
 COMPUTE ITEM DISCRIMINATION: THE UPPER AND LOWER GROUPS APPROACH
*++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*;

*Create N: frequency and PCT: percent for two groups;
data long_form;
 set group;
 array r[*] $2 r1-r&nitems;
 do q = 1 to &nitems;
    choice = r[q];
    output;
 end;
 keep id group q choice;

data lower;
 set long_form;
if group=1;
proc tabulate data=lower;
 class q choice;
 table q*choice,
       n='n'*f=comma9.
       PCTN <choice>
       ;
 ods output table=aa;
 run;
data lower_group;
 set aa;
 if index (choice, '*');
 keep q choice N pctN_10;
 rename N = N_LOWER;
 rename pctN_10 = PCT_LOWER;

data upper;
 set long_form;
if group=2;
proc tabulate data=upper;
 class q choice;
```

```
 table q*choice,
       n='n'*f=comma9.
       PCTN <choice>
       ;
 ods output table=bb;
 run;
data upper_group;
 set bb;
 if index (choice, '*');
 keep q choice N pctN_10;
 rename N = N_UPPER;
 rename pctN_10 = PCT_UPPER;

proc sort data=item_dst; by q;
proc sort data=lower_group; by q;
proc sort data=upper_group; by q;

data item_dst;
 merge item_dst lower_group upper_group;
 by q;
 drop q choice;
 DISC_Q1Q3 = (PCT_UPPER - PCT_LOWER)/100;

*EXPORT THE DISTRACTOR ANALYSIS TABLE FOR EACH ITEM;
ODS EXCEL file="&path\distractor.xlsx"
    Style=pearl
    options(sheet_interval="none" sheet_name="distractor");

proc SORT data=GROUP;
BY group;
run;

proc freq DATA=GROUP;
 TABLE group*(r1-r&nitems)/SPARSE NOCOL NOPERCENT;
  FORMAT GROUP GROUP.;
run;
ods excel close;


*EXPORT THE SUMMARY TABLE OF ITEM STATISTICS;
Ods excel file="&path\itemstats.xlsx"
    Style=pearl
    options(sheet_interval="none" sheet_name="item");

Proc print data=ITEM_DST;
 title 'SUMMARY STATISTICS FOR TEST ITEMS';
 FORMAT _NUMERIC_ 7.3;
run;
ods excel close;
%mend;
```

INVOKING THE MACRO

To conduct item and distractor analyses using this macro, there is one element in the macro that needs to be modified in order to fit your datasets. In the section of “export the extracted dataset as a text file”, you may have more variables in your dataset, numeric or character. The variable names and location and length of the variables need to be specified as they are in the text data file. The dollar sign ($) needs to be added for the character variables. In the section of “create the key array, the response array, and the binary data array”, the locations of the key array and the response array should be consistent with those in the previous section.

```
/*EXPORT THE EXTRACTED DATASET AS A TXT FILE;*/
data tmp2;
 set tmp1;
 file 'c:\test2015.txt';
 put id 1-5 gender 6-9 @11 (r1-r&nitems) ($1.);
 run;

/*CREAT THE KEY ARRAY, THE RESPONSE ARRAY, AND THE BINARY DATA ARRAY;*/

if _N_ = 1 then
   input @11 (k1-k&nitems) ($1.);
   input @1 ID 1-5
         @6 gender 6-9
         @11 (r1-r&nitems) ($1.);
```

Below is the illustrating data file (Figure 1). The first row lists variables. The response variable names should be consistent with those in the macro. Here “r” is used, representing “response”. The second row has the keys. The students’ responses start in the third row.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	id	gender	r1	r2	r3	r4	r5	r6	r7	r8	r9	r10	r11	r12
2			D	B	D	E	E	B	B	B	B	C	B	C
3	1	1	B	B	C	D	C	A	B	B	E	A	A	A
4	2	0	D	B	-	-	-	D	-	-	D	E	-	-
5	3	0	E	E	D	D	B	C	B	D	-	D	E	-
6	4	1	A	C	A	E	B	D	C	B	C	A	A	B
7	5	1	B	B	D	E	B	A	C	B	A	A	B	C
8	6	1	B	B	C	D	E	B	D	B	A	A	B	B
9	7	1	A	D	C	E	B	D	-	C	B	D	AE	-
10	8	0	A	D	D	B	B	B	A	B	C	A	B	D
11	9	0	A	B	C	E	B	B	C	A	A	A	B	D
12	10	0	A	B	D	B	C	A	B	A	C	D	D	C
13	11	0	A	B	C	C	C	B	C	B	A	B	B	C
14	12	0	D	A	C	E	E	A	C	B	B	A	B	C
15	13	1	A	C	C	E	B	B	C	B	B	C	B	C
16	14	1	B	B	C	E	E	A	B	B	B	B	A	E
17	15	1	-	-	D	E	C	B	-	A	D	-	B	D
18	16	0	C	B	C	E	A	B	B	D	B	C	B	A
19	17	0	A	B	C	D	B	A	B	B	A	B	C	C
20	18	1	D	B	A	D	B	A	B	B	D	A	B	C
21	19	0	D	D	C	C	A	B	E	B	A	A	B	E
22	20	0	D	D	C	B	B	C	B	C	C	D	B	A
23	21	1	D	D	A	C	B	A	C	B	B	D	E	D
24	22	1	A	B	A	E	D	A	B	B	A	B	A	D
25	23	0	E	B	B	B	C	C	-	B	C	B	B	A

Sheet1 Sheet2 Sheet3

Figure 1. The Illustrating Data for the Macro.

The arguments used for this macro are shown below. The arguments indicate that there are 12 items (nitems=12). The data are located in the C drive (path=c:\) and the data file name is called “test2015.xlsx” (dataname=test2015.xlsx). The worksheet name for the data is called “sheet1” (sheetname=sheet1).

```
%IA_CTT (nitems=12, path=C:\, dataname=test2015.xlsx, sheetname=sheet1);
```

OUTPUT EXAMPLES FROM THE MACRO

As mentioned earlier, this macro is able to yield a series of useful tables, including the test summary table (Figure 2), the score distribution table (Figure 3), individual item summary table (Figure 4), the response frequency table for each item (e.g., Figure 5),

Obs	STATISTIC	VALUE
1	N	249
2	USED_N	249
3	MEAN	5.49
4	STD	1.888
5	LOWEST	1
6	Q1	4
7	MEDIAN	6
8	Q3	7
9	HIGHEST	10
10	TOTAL_SKEWNE	-0.015
11	TOTAL_KURTOS	-0.695
12	ALPHA	0.342
13	SEM	1.532

Figure 2. The Test Summary Table

total	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	2	0.8	2	0.8
2	9	3.61	11	4.42
3	33	13.25	44	17.67
4	37	14.86	81	32.53
5	42	16.87	123	49.4
6	44	17.67	167	67.07
7	42	16.87	209	83.94
8	31	12.45	240	96.39
9	6	2.41	246	98.8
10	3	1.2	249	100

Figure 3. The Score Distribution Table

Obs	ITEM	USED_N	P_VALUE	P_STD	PBIS_CORR	CORRECTED_ PBIS_CORR	TEST_ALPHA	TEST_ALPHA_ DELETED	N_LOWER	PCT_LOWER	N_UPPER	PCT_UPPER	DISC_QQ
1	x1	249	0.667	0.472	0.442	0.209	0.342	0.284	33	40.741	72	87.805	0.471
2	x2	249	0.703	0.458	0.477	0.258	0.342	0.266	35	43.21	76	92.683	0.495
3	x3	249	0.454	0.499	0.499	0.262	0.342	0.258	13	16.049	61	74.39	0.583
4	x4	249	0.044	0.206	0.1	-0.009	0.342	0.35	2	2.469	6	7.317	0.048
5	x5	249	0.482	0.501	0.5	0.262	0.342	0.258	10	12.346	63	76.829	0.645
6	x6	249	0.482	0.501	0.41	0.157	0.342	0.305	19	23.457	57	69.512	0.461
7	x7	249	0.394	0.49	0.283	0.025	0.342	0.36	22	27.16	51	62.195	0.35
8	x8	249	0.739	0.44	0.203	-0.031	0.342	0.375	54	66.667	70	85.366	0.187
9	x9	249	0.253	0.436	0.437	0.223	0.342	0.282	7	8.642	42	51.22	0.426
10	x10	249	0.458	0.499	0.172	-0.094	0.342	0.407	30	37.037	43	52.439	0.154
11	x11	249	0.667	0.472	0.423	0.188	0.342	0.293	30	37.037	70	85.366	0.483
12	x12	249	0.149	0.356	0.089	-0.1	0.342	0.385	12	14.815	15	18.293	0.035

Figure 4. The Individual Item Summary Table

r1	Frequency	Percent
A	17	6.83
B	47	18.88
C	19	7.63
D*	166	66.67

Figure 5. The Response Frequency Table for Item One

		r1				
group		A	B	C	D*	Total
LOWER GROUP		12	29	7	33	81
		14.81	35.80	8.64	40.74	
UPPER GROUP		1	6	3	72	82
		1.22	7.32	3.66	87.80	
Total		13	35	10	105	163
Frequency Missing = 86						

Figure 6. The Distractor Analysis Table for Item One

CONCLUSION

The first author has worked several projects with school districts in terms of conducting item and distractor analyses as well as interpreting students' performance based on their test scores. It is found that there is a need to create a friendly-used macro for item analysis. Lei and Wu (2007) indicate some limitations of the currently existing software so they created a SAS macro for item analysis using SAS/IML. However, not all SAS users have access to IML. This paper introduces a macro that is developed using Base SAS. This macro imports data from Excel and exports outputs to Excel, which is the most commonly used software by practitioners (e.g., psychometricians at school

districts). This macro yields all the necessary outputs for test analysis and item and distractor analyses which are produced by commercial software such as ITEMAN (Assessment Systems Corporation, 1989).

ACKNOWLEDGMENT

This project was financially supported by the Osceola County School District who offered the contract to the first author. The initial macro was developed by the first author for conducting item analysis for the School District of Osceola County, Florida. The final macro was modified by the authors.

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