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# Examining Cronbach Alpha, Theta, Omega Reliability Coefficients According to the Sample Size

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Differentiations according to the sample size of different reliability coefficients are examined. It is concluded that the estimates obtained by Cronbach alpha and teta coefficients are not related with the sample size, even the estimates obtained from the small samples can represent the population parameter. However, the Omega coefficient requires large sample sizes.

Key words: Cronbach alpha, theta, omega, reliability, scale, sample size.

#### Introduction

A scale is needed to measure and that scale must be reliable and valid. The scale's reliability does not matter in the case of measuring the concrete characteristics. But, it is an important problem in the case of measuring the abstract characteristics. So, it is necessary to analyze the reliability of the scales using some statistical

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methods. In making a reliability analysis, the reliability coefficients that are suitable in obtaining the reliability of the scale and the structure of the empirical study must be examined. Sample size is also important to determine the reliability level of the scale. Thus, one of the dimensions that must be examined is the changes in Cronbach alpha, theta, and omega coefficients according to the sample size.

### Reliability

The scale, used to get some information on a defined subject, must have some properties. Reliability, a property that a scale must have, is an indicator of consistency of measurement values obtained from the measurements repeated under the same circumstances (Gay, 1985; Carmines & Zeller, 1982; Arkin & Colton, 1970; O'Connor, 1993; Carey, 1988).

The reliability of the scale can be examined by different ways. The reliability of the scale can be examined by applying the scale once, applying the scale twice or applying the equivalent scales once. In case of applying the scale once, the reliability of internal consistency is examined. The reliability coefficient ranges between 0 and 1.

Methods of Internal Consistency

If the reliability can be estimated by applying the scale once, the error in reliability estimation will be less than the other reliability estimation methods. In this kind of reliability estimation, wrong management, scoring, temporary changes in personal performance affect the internal consistency, the leading affect will be the content sampling (O'Connor, 1993).

Another method, split-half, denotes the homogeneity indices of the items in the scales. It pertains to the relationship level between the responses of the items and the total scale score (Oncu, 1994). An increase in homogeneity in the set of items increases this reliability estimate (O'Connor, 1993). The idea that the internal consistency methods depend upon is that every measurement tool is constructed to realize an objective and those have known equal weights (Karasar, 2000). The internal consistency methods are preferred because they are economical and easy to apply (Oncu, 1994).

#### Cronbach Alpha

The Alpha coefficient method (Cronbach, 1951), is a suitable method that can be used for likert scale items (e.g., 1-3, 1-4, 1-5). Thus, it is not limited to the true-false or correct-incorrect format (Oncu, 1994).

Cronbach alpha coefficient is weighted standard variations mean, obtained by dividing the total of the k items in the scale, to the general variance (Thorndike et al., 1991).

$$\alpha = \frac{n}{(n-1)} \left[ 1 - \frac{\sum_{i=1}^{n} \sigma_{Y_i}^2}{\sigma_x^2} \right]$$

n: Number of the items

 $\sigma_{Y_i}$ : i<sup>th</sup> item's standard deviation

 $\sigma_{V}$ : General standard deviation

(2.1)

If the items are standardized, coefficient is calculated by using the items' correlation mean or variance-covariances' mean (Carmines & Zeller, 1982; Ozdamar, 1999a; SPSS, 1991; SPSS, 1999).

Calculation of alpha coefficient due to the correlation mean,

$$\alpha = \frac{n \overline{\rho}}{1 + (n-1)\overline{\rho}}$$
(2.2)

Calculation of alpha coefficient due to the variance-covariance mean,

$$\alpha = \frac{n \overline{\sigma_{XX}} / \overline{\sigma_X}}{1 + (n - 1)\overline{\sigma_{XX}} / \overline{\sigma_X}}$$
(2.3)

When the formula for calculating Cronbach alpha using the correlation means between items is examined, it can be seen that it is proportionally related with the number of the items and the mean of the correlation between items (Carmines & Zeller, 1982). If the correlation between the items is negative, alpha coefficient will also be negative. Because this situation will spoil the scale's additive property, it also causes a spoil in the reliability model and the scale is no more additive (Ozdamar, 1999a). The coefficient is equal to the mean of all probable coefficients using split-half method (Carmines & Zeller, 1982; Gursakal, 2001).

### Theta Coefficient

The Theta coefficient depends on the principal components analysis. In principal components analysis, the components are in descending order due to the variances of (2ch)of the constructions (Carmines & Zeller, 1982). The first component is the linear component with the maximum variance. The second component is the linear component with the second maximum variance. Components can be explained by the component variances defined by the percentage values to explain the variance of the original data set in order (Ozdamar, 1999b). Theta coefficient depends on that property. The Theta coefficient, takes into account the eigenvalue that maximum explains the event, is calculated as follows:

$$\theta = (N/N-1)(1-1/\lambda_i)$$

N: Number of items

 $\lambda_i$ : The largest eigenvalue (the first eigenvalue)

(2.4)

Omega Coefficient

Another coefficient for linear dependencies is the Omega coefficient proposed by Heise and Bohrnstedt (1970). It depends on the factor analysis model. Omega coefficient is modeled on factor analysis. In this type of modeling, in calculating the coefficient, before factoring "1" values on diagonal in the correlation matrix are replaced with the communality values. The Omega coefficient can be calculated with two ways, using variance-covariance matrix and correlation matrix (Carmines & Zeller, 1982).

When studied with variance-covariance matrix,

$$\Omega = 1 - \left( \sum \sigma_i^2 - \sum \sigma_i^2 h_i^2 \right) / \left( \sum \sum \sigma_{x_i x_j} \right)$$

$$h_{\rm i}^{\rm 2}$$
 : Communality of the  $i^{\text{th}}$  item 
$$\eqno(2.5)$$

When studied with correlation matrix,

$$\Omega = 1 - \left( a - \sum_{i} h_{i}^{2} \right) / (a + 2b)$$

a: Number of items

b: Sum of the correlations among items

(2.6)

There are some differences between the Theta and Omega coefficients. They depend on different factor-analytic models. The Theta coefficient depends on principal components model, whereas the Omega coefficient depends on factor analysis model. Therefore, in calculating the eigenvalues for Theta coefficients, the diagonal 1.0 values are used, but in calculating the Omega coefficients,

communality values that are not related with 1.0 values are used (Carmines & Zeller, 1982).

There is a relationship between Alpha, Theta, and Omega coefficients. If the items take parallel values, three coefficients are equal each other and will be 1.0. Otherwise, the relationship of magnitude for the coefficients will be  $\alpha < \theta < \Omega$ . Among these internal consistency coefficients,  $\alpha$  gives the lower bound of the reliability coefficient and  $\Omega$  gives the upper bound of the reliability coefficient (Carmines & Zeller, 1982).

#### Methodology

To compare the Alpha, Theta and Omega coefficients, a data set has been used from an instrument developed by Ercan et al. (2004) to measure patient satisfaction in the secondary health-care units. To obtain the effects of different number of items and different sample sizes, 3 different scales are constructed with 39, 34, and 30 items by subtracting some items from the scale with 43 items. Because all the subjects did not answer all the items, the subject numbers in the scales are also different. There are 170 subjects answered all of the 43 items, 240 subjects answered all of the 39 items, 230 subjects answered all of the 34 items, and 320 subjects answered all of the 30 items.

After giving a number to each of the subjects, samples are constructed by producing random numbers using MINITAB 13.2 beginning from 10 and increasing 10 units each of those random numbers. The same procedure was repeated 10 times and for each of the samples Cronbach alpha, Theta and Omega reliability coefficients are calculated.

SPSS 13.0 was used for these analyses. Statistical comparisons are performed in order to determine if alpha, theta and omega coefficients change or not according to the sample size and in order to determine the sample size that the reliability coefficients begin to get stable. Before the between group comparisons, the homogeneity of variances is tested using the Levene statistic. If the variances are found to be homogeneous, then analysis of variance

	1 able-4.1. The homogeneity test results for the scale with 30 hems											
		Levene Statistic	Degree of	Degree of	Significance							
			Freedom 1	Freedom 2	level (p)							
·	α	5.631	31	288	< 0.001							
	θ	5.578	31	288	< 0.001							
	Ω	1.531	31	288	0.040							

Table-4.1: The homogeneity test results for the scale with 30 items

Table-4.2: Significance level in comparison of  $\alpha$ ,  $\theta$  and  $\Omega$  reliability coefficients according to different sample sizes using Kruskal-Wallis test for the scale with 30 items

	α	θ	Ω
$\chi^2$	23.706	46.720	259.636
Degree of freedom	31	31	31
Significance level (p)	0.822	0.035	< 0.001

Bonferroni correction: 
$$\alpha^* = 1 - (1 - \alpha)^{1/k}$$

$$\alpha^* = 1 - (1 - 0.05)^{1/32} = 0.0016$$

and Tukey HSD post-hoc comparison test are applied. If the variances are heterogeneous, Kruskal-Wallis and Mann-Withney U tests are applied to make reliability comparisons according to sample size. The level of significance in multiple comparisons is determined after Bonferrroni correction  $(\alpha^* = 1 - (1 - \alpha)^{1/k})$  k: number of groups).

#### Results

The results of comparisons  $\alpha$ ,  $\theta$  and  $\Omega$  coefficients according to different sample sizes are given in Table 4.1, 4.2, 4.3, 4.4 for the scale with 30 items.

Table-4.3: Significance level (p values  $\times$  10<sup>-3</sup>) in comparison of  $\theta$  reliability coefficients according to different sample sizes using Mann-Whitney U test for the scale with 30 items ( $\alpha$ \*=0.0016).

n	10 20	30 40 5	0 60	70	80 9	90	100 1	10 120	130	140	150 1	60 17	0 18	0 190	200	210	220	230	240 2	50 26	30 2	70 28	80 29	00 300	310	320
10	631	315 315 3	15 280	353	393	393	353 3	353 393	3 393	353	315 3	53 31	5 35	3 353	315	315	315	353	353 3	53 39	93 3	15 3°	15 31	5 436	436	436
20		912 684 7	96 52	9 579	100	529	631 5	29 529	529	631	353 3	15 19	0 16	5 089	123	190	123	123	105 0	89 16	65 O	52 07	75 07	'5 123	075	063
30		315 3	93 21	8 315	529	247	218 2	218 190	190	190	165 1	43 10	5 10	5 089	105	123	075	089	089 1	05 12	23 0	63 07	75 07	5 075	105	089
40		8	53 68	4 912	796	579	853 4	81 529	353	280	218 1	43 12	3 12	3 123	123	123	089	143	123 1	23 12	23 0	89 06	63 07	'5 123	123	123
50			52	9 971	853	436 (	684 3	353 529	9 190	165	247 1	43 05	2 03	4 052	075	105	105	105	035 0	52 07	75 O	75 O	52 03	5 023	023	023
60				796	353	971 !	912 9	12 100	912	912	796 7	39 52	9 43	6 247	315	481	436	436	218 2	18 39	93 1	90 19	90 24	7 353	165	123
70					739	739	9126	31 796	393	436	529 2	47 16	5 14	3 089	190	143	165	105	105 1	65 21	18 1	43 10	05 06	3 075	075	089
80					;	315	529 2	247 280	105	089	123 0	52 01	1 00	4 009	011	023	019	019	004 0	05 00	9 0	09 00	05 00	5 002	002	002
90							971 7	'96 97	1 739	796	5793	53 28	0 24	7 218	353	280	165	165	123 1	90 31	150	89 08	89 10	5 105	143	218
100							7	39 79	3 481	481	315 3	15 21	8 19	0 165	190	218	143	165	218 1	43 24	17 1	23 14	43 10	5 218	190	143
110								97	1 796	853	529 4	81 31	5 31	5 247	247	280	165	190	247 1	65 28	30 1	05 14	43 14	3 165	165	143
120									579	684	739 3	15 19	0 10	5 105	315	190	315	075	063 1	43 24	17 0	89 08	89 03	35 035	052	075
130													_											7 165		
140											853 7	39 48	31 31	5 143	143	247	353	247	052 0	75 12	23 1	23 10	05 07	75 023	043	023
150											5										_			<b>'</b> 5 075		
160												52										_		5 075		
170													63				_							86 280		_
180														393										3 353		
190																								6 853		
200																								2 796		
210																					_			9 579		
220																					_			1 579		
230																								1 912		
240																			7		_			3 912		
250																				52				6 971		
260																					3			8 280		
270																						7		9 9 1 2		
280																							97	'1 971		
290																								9/1	912	
300 310																									912	481
320																										401
320																										

Table-4.4: Significance level (p values×  $10^{-3}$ ) in comparison of  $\Omega$  reliability coefficients according to different sample sizes using Mann-Whitney U test for the scale with 30 items ( $\alpha$ \*=0.0016).

n	10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320
10	$000\ 000\ 000\ 000\ 000\ 000\ 000\ 000$
20	052002000000000000000000000000
30	$023\ 002\ 001\ 000\ 000\ 000\ 000\ 000\ 000$
40	08900900700000000000000000000000
50	123105011000000000000000000000000
60	$853\ 123\ 011\ 001\ 000\ 000\ 000\ 000\ 000\ 00$
70	$280\ 023\ 005\ 003\ \overline{001}\ 000\ 000\ 000\ 000\ 000\ 000\ 000\$
80	218 019 015 005 000 000 000 000 000 000 000 000
90	353247089009005001001000000000000000000000
100	853 481 075 035 007 004 001 001 000 000 000 000 000 000 000
110	579 075 063 009 005 000 001 000 000 000 000 000 000 000
120	165 165 019 011 005 004 000 000 000 000 000 000 000 000
130	912 315 247 105 052 009 005 005 004 001 000 002 002 000 000 000 000 000 000
140	353 190 052 029 007 004 004 003 001 001 001 002 000 000 000 000 000 000
150	684 190 143 052 015 015 009 004 005 004 007 000 000 000 000 000 000
160	436 218 075 035 035 019 007 004 009 007 001 000 000 000 000
170	247 123 165 105 123 043 023 075 052 007 004 004 002 003 003
180	436 393 393 315 123 123 247 218 063 035 007 019 023 023
190	739 853 971 579 393 579 579 315 143 075 105 123 123
200	971 912 739 853 684 684 280 190 143 143 029 029
210	971 796 631 912 739 315 165 190 143 075 063
220	631 684 100 912 436 190 165 123 123 123
230	971 912 912 529 247 143 063 043 105
240	100 971 481 165 105 075 035 075
250	100 218 165 052 035 011 029
260	353 165 105 105 052 07 <del>5</del>
270	393 280 280 353 481
280	631 853 739 100
290	971 912 971
300	853 100
310	912
320	

The results of comparisons  $\alpha$ ,  $\theta$  and  $\Omega$  coefficients according to different sample sizes

are given in Table 4.5, 4.6, 4.7 for the scale with 34 items.

Table-4.5: The homogeneity test results for the scale with 34 items

	Levene	Degree of	Degree of	Significance level
	Statistic	freedom 1	freedom 2	(p)
α	11.003	22	207	< 0.001
θ	10.477	22	207	< 0.001
Ω	3.238	22	207	< 0.001

Table-4.6: Significance level in comparison of  $\alpha$ ,  $\theta$  and  $\Omega$  reliability coefficients according to different sample sizes using Kruskal-Wallis test for the scale with 34 items

Bample Bizes asing Taras	onar vvaring test for t	ne beare with 5 i i	COTTIO
	α	θ	Ω
$\chi^2$	6.329	8.960	176.741
Degree of freedom	22	22	22
Significance level (p)	1.000	0.994	< 0.001

Bonferroni correction: 
$$\alpha^* = 1 - (1 - \alpha)^{1/k}$$

$$\alpha^* = 1 - (1 - 0.05)^{1/23} = 0.0022$$

Table-4.7: Significance level (p values×  $10^{-3}$ ) in comparison of Ω reliability coefficients according to different sample sizes using Mann-Whitney U test for the scale with 34 items ( $\alpha$ \*=0.0022)

t	o ai	ffere	nt sa	amp	le si	zes ı	ısınş	g Ma	ann-	Whi	tney	U te	est fo	or th	e sca	ale v	vith	<i>34</i> 1	tems	(α1	·=0.0	JU22	<u>2)                                    </u>
n	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230
10		000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000
20			004	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000
30				280	043	007	001	001	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000
40					247	043	009	004	002	000	000	000	000	000	000	000	000	000	000	000	000	000	000
50						481	143	063	023	003	000	000	000	000	000	000	000	000	000	000	000	000	000
60							280	143	052	009	001	000	000	000	000	000	000	000	000	000	000	000	000
70								853	353	143									000				
80									579	247	075	089	043	029	004	011	001	002	000	000	000	000	000
90										739	315	247	123	123	023	015	007	005	002	001	002	001	002
100											684	739	247	218	075	052	043	009	005	003	002	001	002
110												971	579	315	052	105	035	011	005	003	002	001	002
120													436	280	063	075	023	011	002	001	002	001	015
130														912	218	190	075	035	005	003	003	002	015
140															247	123	043	019	002	001	002	001	002
150																971	315	218	015	003	009	003	015
160																	218	280	011	004	005	002	002
170																		912	280	075	052	019	019
180																			280	123	089	052	105
190																				436	353	218	796
200																					912	631	684
210																						631	280
220																							165
230																							

The results of comparisons  $\alpha$ ,  $\theta$  and  $\Omega$ coefficients according to different sample sizes

are given in Table 4.8, 4.9, 4.10, 4.11 for the scale with 39 items.

Table-4.8: The homogeneity test results for the scale with 39 items

	Levene Statistic	Degree of freedom 1	Degree of freedom 2	Significance level
α	10.692	23	216	(p) <0.001
θ	12.048	23	216	<0.001
Ω	1.418	23	216	0.104

Table-4.9: Significance level in comparison of  $\alpha$  and  $\theta$  reliability coefficients according to different sample sizes using Kruskal-Wallis test for the scale with 39 items

	α	θ
$\chi^2$	7.206	8.702
Degree of freedom	23	23
Significance level (p)	0.999	0.997

Table-4.10: Significance level in comparison of  $\Omega$  reliability coefficients according to different sample

sizes by analysis of variance for the scale with 39 items

	Sum of	Degrees of	Sum of	F	Significance
	Squares	freedom	Squares		level (p)
Between groups	0.00536	23	0.0002329		
Within groups	0.000352	216	0.00000163	142.881	< 0.001
Total	0.00571	239			

Bonferroni correction: 
$$\alpha^* = 1 - (1 - \alpha)^{1/k}$$

$$\alpha^* = 1 - (1 - 0.05)^{1/24} = 0.0021$$

Table-4.11: Significance level (p values  $\times$  10<sup>-3</sup>) in comparison of  $\Omega$  reliability coefficients according to different sample sizes using Tukey's HSD post-hoc comparison test for the scale with 39 items ( $\alpha$ \*=0.0021).

n	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	2	102	2023	30 24	0
10		000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	00	0 00	00 00	00 00	0
20			002	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	00	000	00 00	00 00	0
30				031	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	00	0 00	00 00	00 00	0
40					729	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	00	0 00	00 00	00 00	0
50						899	003	000	000	000	000	000	000	000	000	000	000	000	000	000	00	0 00	00 00	00000	0
60							781	000	000	000	000	000	000	000	000	000	000	000	000	000	00	0 00	00 00	00000	0
70								100	972	322	2029	000	000	000	000	000	000	000	000	000	00	0 00	00 00	00000	0
80									100	986	561	035	005	002	000	000	000	000	000	000	00	0 00	00 00	00000	0
90										100	947	227	051	021	004	000	000	000	000	000	00	0 00	00 00	00 00	0
100											100	934	617	411	159	021	001	000	000	000	00	0 00	00 00	00 00	0
110												100	991	953	749	264	035	001	000	000	00	0 00	00 00	00 00	0
120													100	100	100	963	558	086	011	003	00	0 80	00 00	00 00	0
130														100	100	100	908	330	069	020	05	550	01 00	1000	0
140															100	100	977	525	147	049	11	190	02 00	200	0
150																100	999	836	388	170	33	350	1201	000	1
160																	100	996	863	610	82	211	04 09	1018	8
170																		100	999	975	99	975	14 47	'9 17	1
180																			100	100	10	009	75 96	3775	0
190																				100	) 10	001	00 10	00 984	4
200																					10	001	00 10	00 999	9
210																						1	00 10	0099	1
220																							10	00 100	0
230																								100	0
240																									
-																									_

The results of comparisons  $\alpha$ ,  $\theta$  and  $\Omega$  coefficients according to different sample sizes

are given in Table 4.12, 4.13, 4.14 for the scale with 43 items.

Table-4.12: The homogeneity test results for the scale with 43 items

	Levene	Degree of	Degree of	Significance level
	Statistic	freedom 1	freedom 2	(p)
α	6.313	16	153	< 0.001
θ	7.654	16	153	< 0.001
Ω	2.463	16	153	0.002

Table-4.13: Significance level in comparison of  $\alpha$ ,  $\theta$  and  $\Omega$  reliability coefficients according to different sample sizes using Kruskal-Wallis test for the scale with 43 items

	α	θ	Ω
$\chi^2$	11.248	7.026	141.750
Degree of freedom	16	16	16
Significance level (p)	0.794	0.973	< 0.001

Bonferroni correction: 
$$\alpha^* = 1 - (1 - \alpha)^{1/k}$$

$$\alpha^* = 1 - (1 - 0.05)^{1/17} = 0.003$$

n	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
10		000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000
20			000	000	000	000	000	000	000	000	000	000	000	000	000	000	000
30				143	000	000	000	000	000	000	000	000	000	000	000	000	000
40					001	000	000	000	000	000	000	000	000	000	000	000	000
50						353	015	002	000	000	000	000	000	000	000	000	000
60							123	011	003	000	000	000	000	000	000	000	000
70								218	089	009	003	000	000	000	000	000	000
80									353	105	105	005	001	000	000	000	000
90										393	315	035	015	009	002	001	002
100											912	280	190	089	035	029	023
110												280	165	105	035	029	009
120													631	481	190	075	023
130														912	579	123	043
140															436	218	063
150																481	165
160																	481
170																	

Table-4.14: Significance level (p values×  $10^{-3}$ ) in comparison of Ω reliability coefficients according to different sample sizes using Mann-Whitney U test for the scale with 39 items ( $\alpha$ \*=0.003)

#### Conclusion

The answer to the question of sample size in this context is important. The accuracy of reliability coefficients changes according to the sample size. There is high positive correlation between number of items and reliability coefficient as mentioned in Carmines and Zeller (1982). Also, the difference in number of items must be taken into account.

Significant differences are not observed due to the sample size in the commonly used Cronbach Alpha, and with the Theta coefficient which is based on principal components. However, with the Omega coefficient, based on factor analysis, large differences were observed due to the sample size. With an increase in item numbers, however, the Omega coefficient is stabilized even for smaller sample sizes.

Ozdamar (1999a) mentioned that the sample size should be more than 50 in reliability

analysis applications. According to the results of this study, that sample size is not important for the Cronbach alpha or theta coefficients, and is stable even for a small number of items (although of course an increase in the number of items will increase the magnitude.) However, in order to estimate the population parameter with Omega coefficient, the item number is important. With an increase in item number, either the consistency of estimation or the reliability level increases.

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