LI Analysis Training Series

Reliability: Calculating Cronbach's Alpha (α)

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Purpose: The primary purpose of Cronbach's alpha (α) is to provide an indicator of the internal reliability or consistency of items in a multiple item scale or index (Vogt, 1999). The output from the SPSS Reliability command that produces alpha can also be used to determine whether an item or scale is free from measurement error, to identify inconsistent items and to view the means and standard deviations of and correlation between items in the index. While the SPSS Reliability command provides multiple options and models, this memo presents the typical format for obtaining and using Cronbach's alpha and other statistics to assess a scale and its component items.

For scales, higher levels of a reliability coefficient (Cronbach's alpha) are associated with lower random error and greater measurement of the true score. Since it is based on the number of items included in the scale, reliability will increase as the number of items increases. Reliability coefficient values greater than (or equal to) 0.7 are generally accepted as indicative of a reliable scale, while those less than 0.7 are generally not considered a reliable scale. In GAIN analyses, a classical scale is calculated as rnd(mean.3(scale items)*K)[1]. Be aware that some items can be combined in summative indices that have low alphas but are still highly predictive of key outcomes in your study (e.g. sources of stress may not be related, but the more there are, the greater the likelihood of a significant consequence).

Background:

Cronbach's alpha (Cronbach, 1951) is a measure of internal consistency. More specifically, alpha is a lower bound for the true reliability of the scale. Mathematically, reliability is defined as the proportion of the variability in the responses to the survey that is the result of differences in the respondents. That is, answers to a reliable survey will

[1] Where K=the number of items in the scale. This formula requires at least 3 valid responses, and in effect replaces any missing items with the mean of the remaining items. Multiplying by the number of items and rounding the result returns the scale to the same metric as the individual items.

differ because respondents have different opinions, not because the survey is confusing or has multiple interpretations. The computation of Cronbach's alpha is based on the number of items on the survey (k) and the ratio of the average inter-item covariance to the average item variance.

$$\alpha = \frac{k(cov/var)}{1 + (k - 1)(cov/var)}$$

Under the assumption that the item variances are all equal, this ratio simplifies to the average inter-item correlation, and the result is known as the Standardized item alpha (or Spearman-Brown stepped-up reliability coefficient). (SPSS 14.0.2 Tutorial, 2006)

$$\alpha = \frac{kr}{1 + (k - 1)r}$$

Data Requirements:

Reliability requires only numeric variables. It is also assumed that the items are believed to be related to each other to create an interval scale.

Procedure:

There can only be one /VARIABLES and one /SCALE subcommand per Reliability command with a maximum of 500 variables listed on each command. System Missing values can impact results as RELIABILITY deletes cases from analysis if they have a missing value for any variable named on the VARIABLES subcommand. Thus, if more variables are specified in the /VARIABLES subcommand than are given in the /SCALE subcommand, Reliability will drop records from the /SCALE analysis if they do not have valid responses on all items in the /VARIABLES subcommand. The command will not run if variables on the /SCALE list are not also listed on the /VARIABLES list. Use the /MISSING=Include subcommand to include user-missing values. System-missing values are always excluded.

The following syntax provides examples of Reliability commands for 2 of the main GAIN scales. The first command was used to create the results reported in this document.

```
*Substance Frequency Scale (SFS).
RELIABILITY
   /VARIABLES= s2s1p to s2ot1p
   /scale(SFS8) = s2s1p to s2ot1p
   /FORMAT=LABELS
   /MODEL=ALPHA
   /STATISTICS=DESCRIPTIVE SCALE CORR COV
   /SUMMARY=TOTAL MEANS VARIANCE CORR .

*Current Withdrawal Scale (CWS).
RELIABILITY
   /VARIABLES= s3c1 to s3c99
   /scale(CWS22) = s3c1 to s3c99
```

```
  /FORMAT=LABELS
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE CORR COV
  /SUMMARY=TOTAL MEANS VARIANCE CORR .
```

Reliability can also be used to obtain the Intra-class Correlation. It can be used to estimate the stability of measure over time (test-retest reliability if a short enough time) and/or to partial-out systematic variation from other sources (e.g., variations in raters, context) that would otherwise be included in the error in a Pearson Product Moment Correlation (Funk & Dennis, 1999). The output from the syntax below includes the Case Summary, Reliability Statistics and the "Intraclass Correlation Coefficient" table provided below. The ICC value from this output is used in the Table 1 example under "Describing these Procedures". Please note that this syntax uses a 'horizontal' file where there is only one row per client and the wave is indicated in the variable name for each scale or variable. In the syntax below, sfs8p_0 is the SFS value from the GAIN-I for the client, sfs8p_12 is the SFS value from the 12 month M90.

```
RELIABILITY
  /VARIABLES=sfs8p_0  sfs8p_3 sfs8p_6 sfs8p_9 sfs8p_12
  /SCALE('SFS8p')  ALL/MODEL=ALPHA
  /ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0 .
```

Output: (using SPSS 14.0.2) Our comments in the boxes below do not appear in actual output.

Reliability

The Note below (shown in the output file under the label "Active Dataset") identifies the dataset used for the analysis. This is a key feature in SPSS 14 and higher where multiple datasets can be opened at the same time.

```
[DataSet1] G:\EAT\All\GI4_022806_Analytic.sav
```

Warnings

This warning means that at least one item is predictable from other items in the scale. See the Inter-Item Correlation table and the Item-Total Statistics tables below for further discussion of this warning.

The determinant of the covariance matrix is zero or approximately zero. Statistics based on its inverse matrix cannot be computed and they are displayed as system missing values.

Scale: SFS8

Name of the scale (as assigned in the syntax "/scale(SFS8)…").

Case Processing Summary

	N	%

Number of cases included in the analysis. Be careful if the N excluded is high (we generally look for no more than 5% excluded).

Cases	Valid	4446	97.1
	Excluded(a)	135	2.9
	Total	4581	100.0

a Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.759	.742	8

Cronbach's Alpha!
Use this information in reporting scale reliability. If the items used in the scale are on different metrics, report the Alpha based on standardized items.

The output below is due to the command: /STATISTICS=DESCRIPTIVE.
It shows the basic statistics for each item in the scale.

Item Statistics

	Mean	Std. Deviation	N
s2s1p Proportional (/90) Days used AOD	.3356	.34178	4446
s2s2p Proportional (/90) Days drunk/high most of day	.1372	.24638	4446
s2s3p Proportional (/90) Days prob meeting responsibilities	.0483	.14778	4446
s2ab1p Proportional (/90) Days used Alcohol/Intoxicated	.0992	.18783	4446
s2c1p Proportional (/90) Days used Marijuana	.2360	.31115	4446
s2de1p Proportional (/90) Max days of Cocaine or Crack Use	.0082	.05787	4446
s2gj1p Proportional (/90) Max days of Heroin, Methadone or Opioid Use	.0091	.05961	4446
s2ot1p Proportional (/90) Max days of Other Drug use	.0216	.09574	4446

The table below is due to the syntax command /STATISTICS=CORR.
It shows which items are most strongly correlated with each other. High values indicate the presence of groups of respondents who commonly endorse both items suggesting that the one of the items may be unnecessary for the scale. Low values may indicate an item that doesn't fit well in the scale. The highlighted cell is the highest correlation between items and is most likely the reason for the zero (or near zero) determinant of the covariance matrix warning. This is not surprising since the data set includes only adolescents whose most common substance of abuse/dependence is marijuana.

Inter-Item Correlation Matrix

	s2s1p Proportional (/90) Days used AOD	s2s2p Proportional (/90) Days drunk/high most of day	s2s3p Proportional (/90) Days prob meeting responsibilities	s2ab1p Proportional (/90) Days used Alcohol/Intoxicated	s2c1p Proportional (/90) Days used Marijuana	s2de1p Proportional (/90) Max days of Cocaine or Crack Use	s2gj1p Proportional (/90) Max days of Heroin, Methadone or Opioid Use	s2ot1p Proportional (/90) Max days of Other Drug use
s2s1p Proportional (/90) Days used AOD	1.000	.612	.331	.416	.820	.173	.183	.258
s2s2p Proportional (/90) Days drunk/high most of day	.612	1.000	.346	.294	.659	.160	.167	.213
s2s3p Proportional (/90) Days prob meeting responsibilities	.331	.346	1.000	.182	.313	.111	.117	.230
s2ab1p Proportional (/90) Days used Alcohol/Intoxicated	.416	.294	.182	1.000	.279	.163	.162	.178
s2c1p Proportional (/90) Days used Marijuana	.820	.659	.313	.279	1.000	.094	.110	.134
s2de1p Proportional (/90) Max days of Cocaine or Crack Use	.173	.160	.111	.163	.094	1.000	.155	.214
s2gj1p Proportional (/90) Max days of Heroin, Methadone or Opioid Use	.183	.167	.117	.162	.110	.155	1.000	.321
s2ot1p Proportional (/90) Max days of Other Drug use	.258	.213	.230	.178	.134	.214	.321	1.000

The table below is due to the syntax command /STATISTICS=COV.

Inter-Item Covariance Matrix

	s2s1p Proportional (/90) Days used AOD	s2s2p Proportional (/90) Days drunk/high most of day	s2s3p Proportional (/90) Days prob meeting responsibilities	s2ab1p Proportional (/90) Days used Alcohol/Intoxicated	s2c1p Proportional (/90) Days used Marijuana	s2de1p Proportional (/90) Max days of Cocaine or Crack Use	s2gj1p Proportional (/90) Max days of Heroin, Methadone or Opioid Use	s2ot1p Proportional (/90) Max days of Other Drug use
s2s1p Proportional (/90) Days used AOD	.117	.052	.017	.027	.087	.003	.004	.008
s2s2p Proportional (/90) Days drunk/high most of day	.052	.061	.013	.014	.050	.002	.002	.005
s2s3p Proportional (/90) Days prob meeting responsibilities	.017	.013	.022	.005	.014	.001	.001	.003
s2ab1p Proportional (/90) Days used Alcohol/Intoxicated	.027	.014	.005	.035	.016	.002	.002	.003
s2c1p Proportional (/90) Days used Marijuana	.087	.050	.014	.016	.097	.002	.002	.004
s2de1p Proportional (/90) Max days of Cocaine or Crack Use	.003	.002	.001	.002	.002	.003	.001	.001
s2gj1p Proportional (/90) Max days of Heroin, Methadone or Opioid Use	.004	.002	.001	.002	.002	.001	.004	.002
s2ot1p Proportional (/90) Max days of Other Drug use	.008	.005	.003	.003	.004	.001	.002	.009

The table below is the result of the command /SUMMARY=MEANS VARIANCE CORR.

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	.112	.008	.336	.327	40.963	.014	8
Item Variances	.043	.003	.117	.113	34.883	.002	8
Inter-Item Correlations	.264	.094	.820	.725	8.682	.030	8

The table below is the result of the command /SUMMARY=TOTAL. It provides information about the statistics for the scale and the alpha if an item were excluded. This can assist in the process of scale development. For example, the highlighted cell value is closest to 1 and may be related to the zero (or near zero) determinant of the covariance matrix warning.

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
s2s1p Proportional (/90) Days used AOD	.5596	.522	.801	.	.651
s2s2p Proportional (/90) Days drunk/high most of day	.7580	.697	.670	.	.687
s2s3p Proportional (/90) Days prob meeting responsibilities	.8469	.904	.384	.	.746
s2ab1p Proportional (/90) Days used Alcohol/Intoxicated	.7960	.862	.393	.	.744
s2c1p Proportional (/90) Days used Marijuana	.6592	.585	.740	.	.667
s2de1p Proportional (/90) Max days of Cocaine or Crack Use	.8870	1.007	.204	.	.768
s2gj1p Proportional (/90) Max days of Heroin, Methadone or Opioid Use	.8861	1.003	.225	.	.767
s2ot1p Proportional (/90) Max days of Other Drug use	.8736	.971	.285	.	.760

The table below is due to the command `/STATISTICS=SCALE`
It provides information about the scale AS CALCULATED using the records with valid responses to all of the items listed in the RELIABILITY command. This may be different from the mean of the scale calculated with our syntax that uses all records with at least 3 valid responses

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
.8952	1.034	1.01680	8

The table below is due to the command (from syntax example #3):
`/ICC=MODEL(RANDOM) TYPE(CONSISTENCY) CIN=95 TESTVAL=0`

If you have requested the ICC statistic, you will see a table similar to this one. The ICC Single Measure (.337) is reported in Table 1 below. The Single measure is used since we are looking at a single measure and its ICC over time. The ICC provides a measure of the percentage of variance attributable to stability among participants= responses. If most of the variance among responses is due to differences between participants (as opposed to differences within participants), then the ICC will be near 1. If, on the other hand, there is high variability within participants across time, then the ICC will be much less than 1.

Intraclass Correlation Coefficient

		95% Confidence Interval		F Test with True Value 0			
	Intraclass Correlation(a)	Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.337(b)	.314	.360	3.540	1761	7044	.000
Average Measures	.718	.696	.738	3.540	1761	7044	.000

Two-way random effects model where both people effects and measures effects are random.
a Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.
b The estimator is the same, whether the interaction effect is present or not.

Comments

You can find information about the SPSS reliability algorithm by selecting this option from the RELIABILITY command Overview or see the full details in the SPSS documentation available where your SPSS program has been installed, commonly at (bold indicates the portion of the path that is subject to change):

C:\Program Files\SPSS14\Help\algorithms\reliability.pdf

Describing These Procedures. These procedures would normally be described in brief text format

> *The **Substance Problem Scale** (SPS; 16 items, alpha of 0.90 with adolescents and .92 with adults) is a count of past-year symptoms related to any alcohol or drug use disorders, including abuse, dependence, substance induced health and psychiatric problems; it is based on the DSM-IV-TR (APA)[2] and is associated with increased odds of internalizing and externalizing disorders.[3]*

For reporting alpha for multiple scales, a table format is often used. This can be done in several ways. Table 1 below presents an example from the beginning of the Adolescent Norms table as one example. Table 2 below presents another format from Lennox, Dennis, Ives, & White; (2006) that is often used in articles or proposals.

[2] American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR)*. 4th - text revision ed. Washington, DC: American Psychiatric Association;
[3] Chan YF, Dennis ML, Funk RR. (in press). Prevalence and comorbidity of major mental disorders among adolescents and adults presenting to substance abuse treatment. *Journal of Substance Abuse Treatment*.

Table 1. Baseline and Follow-up Psychometrics of GAIN Scales
CSAT_2006_ACYEASTD

GAIN Question	Variable	GAIN Scale Name/Subscale name (Time Period)	Measure-ment Model	Baseline N 5+% Missing 15+ % Missing	Observations 5+% Missing 15+ % Missing	K items	Baseline Mean	Baseline St. Dev.	Baseline Alpha	Across Waves Alpha (FU)	Across Waves ICC
A2	CIS	Cognitive Impairment Screen (current)\b,c	Summative	11926	18772	6	3.51	3.23	**NA**	**NA**	0.34
Background											
B4	TxPI	Treatment Pressure Index (current)\b	Summative	***3937***	***3563***	8	1.16	0.99	**NA**	**NA**	0.20
Substance Use											
S2	SFS8p	Substance Frequency Scale (past 90 days)	Classical	11928	18852	8	0.12	0.15	**0.80**	**0.79**	0.34
S3	CWS	Current Withdrawal Scale (past week)\d	Classical	11903	18826	22	1.43	3.23	**0.92**	**0.92**	0.18
S8a	SES	Self-efficacy Scale (current)	Classical	11895	***3784***	5	4.23	1.21	**0.71**	**0.78**	0.38
S8c	POS	Problem Orientation Scale (current)	Classical	11871	***4325***	5	0.94	1.67	**0.92**	**0.92**	0.31
S8d	TMI	Treatment Motivation Index (current) \b	Summative	**11416**	***3532***	5	1.90	1.34	**NA**	**NA**	0.44
S8e	TRI	Treatment Resistance Index (current)\b,e	Summative	11768	***3587***	4	1.01	1.00	**NA**	**NA**	0.40
S9	SPSL	Substance Problem Scale (Lifetime)	Classical	11911	18819	16	7.80	4.74	**0.90**	**0.92**	**0.72**
S9c-h	*SIIL*	*SPS-Substance Issues Index (Lifetime)\b,f*	Summative	11827	18689	5	2.85	1.42	**NA**	**NA**	0.60
S9h-u	*SUDSL*	*SPS-Substance Use Disorder Scale (Lifetime)\d,f*	Classical	11879	18817	11	4.95	3.61	**0.88**	**0.91**	0.69
S9h-m	*SAIL*	*SPS-SUDS- Substance Abuse Index (Lifetime)\d*	Classical	11585	18752	4	1.93	1.43	0.70	**0.77**	0.58
S9n-u	*SDSL*	*SPS-SUDS-Substance Dependence Scale (Lifetime)\d,f*	Classical	11835	18811	7	3.01	2.46	**0.85**	**0.88**	0.68
S9	SPSY	Substance Problem Scale (Past Year)	Classical	11911	18819	16	6.75	4.72	**0.90**	**0.93**	0.57
S9c-h	*SIIY*	*SPS-Substance Issues Index (Past Year)\b,f*	Summative	11827	18689	5	2.50	1.49	**NA**	**NA**	0.50
S9h-u	*SUDSY*	*SPS-Substance Use Disorder Scale (Past Year)\d,f*	Classical	11879	18817	11	4.24	3.53	**0.88**	**0.92**	0.55
S9h-m	*SAIY*	*SPS-SUDS- Substance Abuse Index (Past Year)\d*	Classical	11585	18752	4	1.66	1.41	0.70	**0.79**	0.49

Table 2. Definition of Measures[\a]

SELF REPORTED MEASURES OF SUBSTANCE USE

Past Month Use. Yes (1) or No (0) for self reported use in the past month of any (including alcohol and other drugs) substance. (Recoded from recency below).

Recency of Use. Recency of last use of any substance rated as 6: past 48 hours, 5: 3 to 7 days ago, 4: 1 to 4 weeks ago, 3: 1 to 3 months ago, 2: 4-12 months ago, 1: 1+ Years ago. 0: never.

Peak Quantity of Use. During the past 90 days, the peak amount consumed of any substance where marijuana: standard joint, calculated as ounce=25-30 joints; dime=4-5 joints; nickel=2-3 joints; 1 blunt=2-6 joints; 1 gram=1-2 joints; 1 bowl=1 joint; 10 1-hit pipes=1 joint; cocaine in standard rocks, calculated 8 ball= 32 rocks; teen = 16 rocks; gram = 10 rocks; quarter gram=2.5 rocks; dime = 1 rock; nickel = 1 hit = 1/2 rock; opioids in standard dime bags, calculated as 1 grams=10 dime bags; or any drug (using max of above or standard drinks, calculated as 1 standard drink =1 beer=1 glass wine=1 mixed drink=1 shot; 40 ounces beer=3 drinks; Fifth= up to 26 drinks.

Frequency of Use. During the past 90 days, how many days they reported any (including alcohol and other drugs) substance.

Substance Frequency Scale (SFS; alpha=.74). The GAIN's SFS is a multiple item measure that averages percent of days reported of any AOD use, days of heavy AOD use, days of problem from AOD use, days of alcohol, marijuana, crack/cocaine and heroin/opioid use.

OTHER MEASURES FOR CONSTRUCT VALIDATION

Substance Problems Scale (SPS; alpha=.90). The GAIN's SPS is a count of past month symptoms of substance abuse, dependence, or substance induced disorders and is based on DSM-IV.[24,25]

Social Risk Index (SRI). The GAIN's SRI is a sum of items indicating how many people the respondent hangs out with socially are involved in school, training, illegal activities, substance use or treatment, (in Version 5, also includes are in recovery).

Recovery Environmental Risk Index (RERI12p). The GAIN's RERI is an average of items (divided by their range) for the days (during the past 90 days) of alcohol in the home, drug use in the home, fighting, victimization, being homeless, and structured activities that involved substance use and the inverse (90-answer) percent of days going to self-help meetings, and involvement in structured substance-free activities.

Illegal Activities Scale (IAS; alpha=.74). The GAIN's IAS is an average of items (divided by their range) for the recency of illegal activity, and days (during the past 90 days) of any illegal activity and supporting oneself financially with illegal activity.

Emotional Problems Scale (EPS; alpha=.84). The GAIN's EPS is an average of items (divided by their range) for recency of mental health problems, memory problems, and behavioral problems and the days (during the past 90 days) of being bothered by mental problems, memory problems and behavioral problems, and the days they problems kept participant from responsibilities.

\a Definitions from the GAIN,[15] Cronbach's alphas from this sample at first assessment; alpha not applicable to summative indices, but justified based on demonstrated predictive validity.[18]

Annotated Bibliography

Cronbach, L. J. 1951. Coefficient alpha and the internal structure of tests. Psychometrika, 16:3, 297-334.

Funk, R.R., & Dennis, M.L. (1998). Intraclass correlation for test-retest reliability and/or stability (Lighthouse Institute Analysis Training Series). Bloomington, IL: Chestnut Health Systems. Retrieved from http://www.chestnut.org/li/downloads

Lennox, R., Dennis, M., Ives, M., & White, M. K. (2006). The construct and predictive validity of different approaches to combining urine and self-reported drug use measures among adolescents in substance abuse treatment. American Journal on Addictions, 15(Suppl. 1), 92-101.

Statistical Program for the Social Sciences (SPSS 1999). SPSS Base 10.0 User's Guide. Chicago, IL: Author (www.spss.com).
This is the most recent non-electronic SPSS manual describing the procedures for running Reliability. For the most part, the syntax has not changed from earlier versions.

Statistical Program for the Social Sciences version 14.0.2 (SPSS 2006). SPSS Tutorial "Measures of Reliability in Scale Problems > Using Reliability Measures to Analyze Survey Items>Cronbach's Alpha."