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Research and Development Division

Professional DynaMetric Programs, Inc.

ProScan Confirmatory Factor Analysis

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Background Information

Instruments that are used to assess traits, such as the ProScan Survey, require rigorous testing of their psychometric properties, such as reliability and validity. Reliability is the extent to which random sources of measurement error are minimized and refers to how dependably or consistently a test measures a characteristic (Henson, 2001). Validity is defined as the extent to which an instrument measures what it is intended to measure (Messick, 1989). Initially, validity is tested through a procedure known as exploratory factor analysis (EFA). EFA is based on the idea that each item or group of items effectively describes a construct, such as the five constructs that comprise the ProScan—Dominance, Extroversion, Pace, Conformity, and Logic. EFA assessment is complex but rigorous, which is ideal when determining whether scores from an instrument are valid. To further demonstrate evidence of validity following an EFA, in an even more rigorous manner, a technique called confirmatory factor analysis (CFA) can be performed. CFA examines the "fit" of the hypothesized factor structure to the observed data. CFA provides evidence of construct validity and confirms the relationship of hypothesized items to latent variables.

Long-Term Psychometric Assessment Plan

A long-term research plan was developed to consistently and continually assess the ProScan instrument psychometrically. Throughout this process, areas of improvement were identified, allowing for the integration of new words as societal language has evolved over time. In order to determine potential areas of improvement and test the effectiveness of new words, a series of EFAs were initially performed. Through EFA, potential new words were tested, and the words that performed the best were selected for testing in a confirmatory factor analysis (CFA). A CFA allows researchers to test whether the hypothesized factor structure of the ProScan (traits and corresponding words/items) is effective. CFA is generally used to test a theory, model, or hypothesis that is formulated a priori (in advance) (Frey, 2018; Schreiber, Nora, Stage, Barlow, & King, 2006). In this case, the CFA was used to test the theory that various new items (words) performed more effectively than the previous words used for each trait (factor/latent construct).

Study Purpose

Recently, a CFA was conducted to test the psychometric properties of the ProScan Survey, including the testing of new words. The purpose of this study was to confirm that the newly proposed model (ProScan traits with corresponding new words) had psychometric properties superior to those of the previous ProScan model.

Methods

To conduct the CFA, a theory-based hypothesis (the structure of the traits and each item/word) was constructed since CFA is driven by theory. Then each latent construct (trait/factor) and each indicator (word/item) that comprises the latent construct had to be defined. The model could then be specified, and a metric for the latent variables could be set. The number of parameters to be estimated was then determined to obtain an over-identified model. Global and component fit indices were compared in terms of model fit. Where these were not acceptable, post-hoc model specifications could be made by consulting modification indices along with expert experience. Hypotheses were then assessed to determine to what extent they were supported by the study results and best model fit. Acceptable fit was considered evidence of validity.

The analysis included 6951 individuals. Initially, all latent constructs were tested for validity using a single-factor model for each trait. Once all the single-factor models had been tested and assessed for fit through CFA (five individual 1-factor models for each latent construct), a full 4-factor model and a 1-factor model were tested through CFA. For models that contain more than one factor, each individual factor is often tested first to assess any issues within the factor itself before assessing the larger, more complex model. The a priori hypothesized factor analysis was expected to contain four correlated factors including Dominance, Extroversion, Pace and Conformity. Logic was not included in the 4-factor model but was tested individually due to the nature of the constructs and relationship between the other factors. The theory concerning the relationships among the four factors (Dominance, Extroversion, Pace, and Conformity), with Logic as a standalone factor, was originally described in the initial development of the ProScan and is clearly illustrated in the design of PDP's Data Sheet graphs. A CFA was performed in the first sample to assess psychometric properties and the fit of the new model (4-factor and 1-factor). Then two additional CFAs were performed for the purpose of confirming the results and reproducibility of the initial CFA models (4-factor and 1-factor). CFA is a large sample procedure that requires a minimum of n = 200; therefore, each sample had significantly more than the minimum sample required for each analysis (Table 1). Reproducibility of a model is extremely important to ensure that results can be replicated and confirm that the proposed model is measuring what it purports to measure consistently every time. Mplus (version 8.4; Muthén & Muthén, 2012) was used to conduct all CFAs.

Table 1. CFA Sample Sizes (n)	
CFA 1	1579
CFA 2	1623
CFA 3	3749

Reliability was also assessed for each sample in this study. Cronbach's α is a measure of reliability, with acceptable levels commonly defined as .70 and above (Cronbach, 1951). Higher reliability coefficients indicate more repeatable or more reliable instrument scores.

Fit Assessment

Assessment of the CFA was based both on global fit indices and on item diagnostic statistics, including standardized factor loadings, modification indices, and the squared multiple correlation. The global fit indices were used to determine appropriate model fit. Tests and fit indices that were used included the χ^2 test based on the weighted least squares mean variance estimator (WLSMV; Muthén, 1998–2004), the Comparative Fit Index (CFI; Bentler, 1990), Tucker Lewis Fit Index (TLI; Tucker & Lewis, 1973), Root Mean Square Error Approximation (RMSEA; Browne & Cudeck, 1992; Steiger, 2007), and the Weighted Root Mean Squared Residual (WRMR; Muthén, 1998–2004). Due to sample size, which can inflate significance with extremely large samples, χ^2 tests were not evaluated. The suggested cutoff level for an appropriate fitting model is to have a CFI ≥ .95 or TLI ≥ .95, and RMSEA < 0.06 with a goal of having .05 within the 90% confidence interval (Hu & Bentler, 1999; Browne & Cudeck, 1992; Steiger, 2007). Modifications were made one at a time, and model fit was reassessed after each modification was made.

Results

Reliability

Reliability was considered excellent for all three samples, with all coefficients far above the acceptable threshold of .70 (Table 2).

Table 2. Chronbach's α Reliability	
CFA 1	.88
CFA 2	.87
CFA 3	.88

Cronbach's alpha, which is a measure of reliability between zero and one, revealed that reliability of trait scores was high (α = .88). This coefficient of .88 means that 88% of the variance explained is due to true score and 12% is due to measurement error. The 88% is excellent and well above the acceptable criteria of 70%, indicating that the scores are in fact reliable and consistent. This means that the ProScan is a trustworthy instrument that can be used confidently.

Validity

Individual latent constructs (factors) for all five factors were first assessed. Global fit indices revealed excellent fit for each individual trait. The initial 4-factor (Dominance, Extroversion, Pace, Conformity) and 1-factor (Logic) CFAs (CFA 1) were performed and assessed for fit. Excellent fit was achieved for each model, as can be seen in Tables 3 and 4.

Table 3. 4-Factor CFA 1 (D, E, P, C) Global Fit Indices	
CFI	0.953
TLI	0.946
RMSEA	0.058
SRMR	0.047
Chi-Square	p < .001

Table 4. 1-Factor CFA 1 (L) Global Fit Indices	
CFI	0.981
TLI	0.968
RMSEA	0.069
SRMR	0.013
Chi-Square	p < .001

The second CFA (CFA 2) was performed for replication purposes and yielded similar results in a different sample. However, global fit statistics indicated the need for slight modifications to achieve excellent fit. Therefore, two modifications were made to the hypothesized model to allow two items to crossload onto other factors. All crossloadings were considered weak, and therefore were considered to be minor modifications. The 4-factor and 1-factor models for CFA 2 are shown in Tables 5 and 6.

Table 5. 4-Factor CFA 2 (D, E, P, C) Global Fit Indices	
CFI	0.940
TLI	0.932
RMSEA	0.062
SRMR	0.053
Chi-Square	p < .001

Table 6. 1-Factor CFA 2 (L) Global Fit Indices	
CFI	0.972
TLI	0.953
RMSEA	0.090
SRMR	0.023
Chi-Square	p < .001

To confirm the reproducibility of the two modifications, a third CFA (CFA 3) was conducted in a different sample. A very large sample size was utilized (more than twice the size of the samples for CFA 1 and CFA 2) to provide additional evidence and support that the hypothesized model was reproduced in a larger, general population. The 4-factor and 1-factor models for CFA 3 can be seen in Tables 7 and 8.

Table 7. 4-Factor CFA 3 (D, E, P, C) Global Fit Indices	
CFI	0.938
TLI	0.930
RMSEA	0.064
SRMR	0.053
Chi-Square	p < .001

Table 8. 1-Factor CFA 3 (L) Global Fit Indices	
CFI	0.975
TLI	0.958
RMSEA	0.083
SRMR	0.021
Chi-Square	p < .001

Conclusions

The results of this study provide evidence of excellent reliability and validity for the ProScan scores that included updated items. CFA results heavily support the original researchers' rationale that Dominance, Extroversion, Pace, and Conformity comprise a 4-factor model and that Logic is best interpreted individually as a single factor. The models (correlated latent constructs with items) were also replicated in large samples with minimal post-hoc modifications. Replication in large samples provides very strong evidence of validity, especially since this level of rigor is not typical due to the high cost and large samples that are required. Replication of analyses in large samples is generally expensive and doubles or triples the length of the study; however, this study utilized triplicate replication in very large samples in order to provide stronger validity evidence. Overall, the changes that were made to the ProScan provided an updated version of the instrument that produced reliable and valid scores, which were—most importantly—reproducible. This study has confirmed the proposed model structure, which should instill confidence in the updated ProScan's use and score interpretation.

References

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin*, 107(2), 238.

Browne, M. W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. Bollen & J. Long (Eds.), *Testing structural equation models* (pp. 136–162). Newbury Park, CA: Sage.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16, 297–334.

Frey, B. (2018). *The SAGE encyclopedia of educational research, measurement, and evaluation* (Vols. 1–4). Thousand Oaks, CA: SAGE Publications, Inc.

Henson, R. K. (2001). Understanding internal consistency reliability estimates: A conceptual primer on coefficient alpha. *Measurement and Evaluation in Counseling and Development*, 34(3), 177.

Messick, S. (1989). Validity. In R. L. Linn, (Ed.), *Educational measurement*. (3rd ed.) New York: Macmillan.

Muthén, B. O. (1998–2004). *Mplus technical appendices*. Los Angeles: Muthén & Muthén.

Steiger, J. H. (2007). Understanding the limitations of global fit assessment in structural equation modeling. *Personality and Individual Differences*, 42(5), 893–898.

Tucker, L. R., & Lewis, C. (1973). A reliability coefficient for maximum likelihood factor analysis. *Psychometrika*, 38(1), 1–10.