Included Analyses

- CFA with 9 variables and 3 constructs

Results

Confirmatory Factor Analysis (CFA)

Introduction

A CFA model was conducted to determine whether the latent variables (Visual, textual, and speed) adequately describe the data. Bootstrapping was performed using a maximum of 100 iterations to determine the standard errors for the parameter estimates.

Assumptions

Multivariate Outliers. Influential points were identified in the data by calculating Mahalanobis distances and comparing them with the quantiles of a χ^2 distribution (Newton & Rudestam, 2012). An outlier was defined as any Mahalanobis distance that exceeds 27.88, the .999 quantile of a χ^2 distribution with 9 degrees of freedom (Kline, 2015). There were 2 observations detected as outliers.

Multicollinearity. Although variables should be correlated with one another to be considered suitable for factorization, variables that are too highly correlated can cause problems in CFA. To assess multicollinearity, the squared multiple correlations were inspected and the determinant of the correlation matrix was calculated. Any variable with an $R^2 > .90$ can contribute to multicollinearity in the CFA model (Kline, 2015). Variables that exhibit high multicollinearity should either be removed from the analysis or combined as a composite variable. There were no variables that had an $R^2 > .90$. Another assessment for multicollinearity is to assess the determinant of the data's correlation matrix. A determinant that is ≤ 0.00001 indicates that multicollinearity exists in the data (Field, 2017). The value of the determinant for the correlation matrix was 0.05, indicating that there was no multicollinearity in the data.

Results

First, the reliability of the analysis was tested based on the sample size used to construct the model. Next, the results were evaluated using the Chi-square goodness of fit test and fit indices. Lastly, the squared multiple correlations (R^2) for each endogenous variable were examined. The results of the CFA model are presented in Table 1. The correlations between the latent variables are presented in Table 2. The node diagram is shown in Figure 1.

Table 1

Unstandardized Loadings (Standard Errors), Standardized Loadings, and Significance Levels for Each Parameter in the CFA Model (N = 301)

Parameter Estimate	Unstandardized	Standardized	*p*
Loadings			
Visual → visual_1	1.00(0.00)	0.62	--
Visual → visual_2	0.78(0.15)	0.48	< .001
Visual → visual_3	1.11(0.24)	0.71	< .001
textual → textual_1	1.00(0.00)	0.85	--
textual → textual_2	1.13(0.07)	0.87	< .001
textual → textual_3	0.92(0.05)	0.83	< .001
speed → speed_1	1.00(0.00)	0.61	--
speed → speed_2	1.23(0.19)	0.80	< .001
speed → speed_3	0.85(0.12)	0.56	< .001
Errors			
Error in visual_1	0.83(0.13)	0.61	< .001
Error in visual_3	0.63(0.13)	0.50	< .001
Error in visual_2	1.06(0.11)	0.77	< .001
Error in Visual	0.52(0.15)	1.00	< .001
Error in textual_1	0.38(0.05)	0.28	< .001
Error in textual_2	0.42(0.05)	0.25	< .001
Error in textual_3	0.37(0.05)	0.31	< .001
Error in speed_1	0.75(0.08)	0.63	< .001
Error in speed_2	0.37(0.10)	0.36	< .001
Error in speed_3	0.70(0.08)	0.69	< .001
Error in speed	0.44(0.09)	1.00	< .001
Error in textual	0.97(0.13)	1.00	< .001

Note. $\chi^2(27) = 153.53$, $p < .001$; -- indicates the statistic was not calculated due to parameter

constraint.

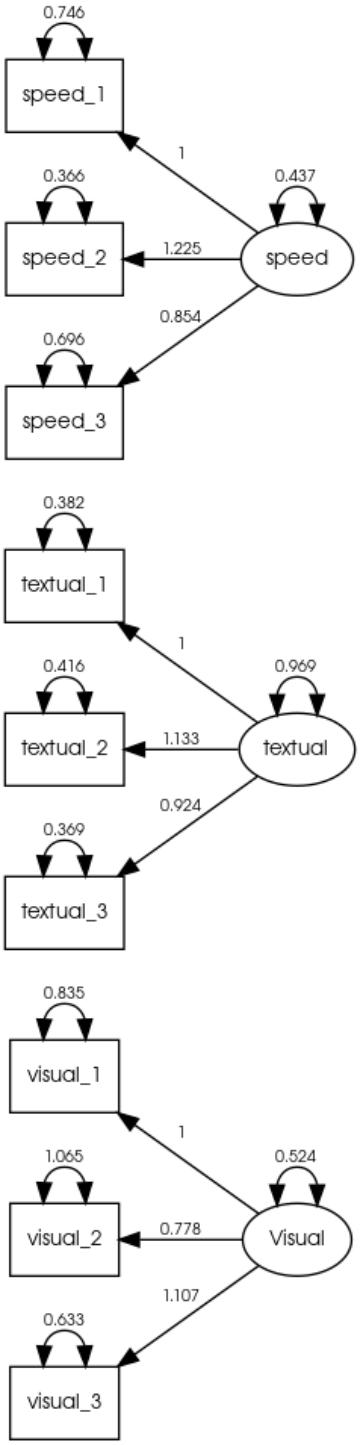
Table 2

Correlation Table for the Latent Variables

Variable	Visual	textual	speed
Visual	1.00	--	--
textual	0.00	1.00	--
speed	0.00	0.00	1.00

Figure 1

Node diagram for the CFA model



Evaluating sample size. Factor analysis requires a large sample size to construct repeatable and reliable factors. A variety of authors suggest different benchmarks to determine sufficient sample size for CFA. Some authors use benchmarks based on overall sample size. A common rule of thumb for determining sufficient sample size is 300 observations (Tabachnick &

Fidell, 2013; Comrey & Lee, 2013). Other authors use the ratio (*N:q*) of overall sample size to the number of free parameter estimates (latent variable, indicator, variance, covariance or any regression estimates) included in the model. Kline (2015) recommends that the *N:q* ratio should be about 20 to 1. Schreiber et al. (2006) suggest that the consensus for a sufficient *N:q* ratio is 10:1. On the lower end of the ratio, Bentler and Chou (1987) suggest that an acceptable *N:q* ratio is 5:1. The participant to item ratio for this analysis was approximately 16 to 1, where sample size was 301 and the number of variables included was 18. According to the *N:q* ratio rule-of-thumb, the given sample size is sufficient to produce reliable results.

Model fit. There are a variety of ways to measure if the CFA model adequately describes the data. The Chi-square statistic is the most popular statistic used to measure model fit. Besides the Chi-square statistic, fit indices are also used to help researchers determine if the factor analysis model fits the data properly. Along with the Chi-square goodness of fit test, the following fit indices were used to assess the model fit: root mean square error of aproximation (RMSEA), comparative fit index (CFI), Tucker-Lewis index (TLI) and standardized root mean square residual (SRMR).

Fit indices. The TLI was less than .95, TLI = 0.81, which is indicative of a poor model fit (Hooper et al., 2008). The CFI was less than .90, CFI = 0.86, suggesting that the model is indicative of a poor model fit (Hooper et al., 2008). The RMSEA index was greater than .10, RMSEA = 0.12, 90% CI = [0.11, 0.14], which is indicative of a poor model fit (Hooper et al., 2008). The SRMR was greater than .08, SRMR = 0.16, which implies that the model fits the data poorly (Hooper et al., 2008). The fit indices are presented in Table 3.

Goodness of fit test. A Chi-square goodness of fit test was conducted to determine if the CFA model fits the data adequately. It is standard practice for CFA to include the Chi-square test. However, this test is sensitive to sample size, which causes the test to almost always reject the null hypothesis and indicate a poor model fit when the sample size is large (Hooper et al.,

2008). The results of the Chi-square goodness of fit test were significant, $\chi^2(27) = 153.53$, $p < .001$, suggesting that the model did not adequately fit the data.

Table 3

Fit Indices for the CFA model

NFI	TLI	CFI	RMSEA	SRMR
0.83	0.81	0.86	0.12	0.16

Note. RMSEA 90% CI = [0.11, 0.14]; -- indicates that the statistic could not be calculated.

Squared multiple correlations. The individual relationship between each indicator variable and latent variable can be assessed by the observed variable's R^2 value. The R^2 value identifies how much of the indicator variable's variance explains the factor. An R^2 value $\leq .20$ suggests that the observed variable does not adequately describe the factor and should be considered for removal from the model (Hooper et al., 2008). There were no observed variables with R^2 values $\leq .20$. The R^2 values, along with the error variances for each observed variable are presented in Table 4.

Table 4

Estimated Error Variances and R^2 Values for Each Indicator Variable - Latent Variable Relationship in the CFA model.

Endogenous Variable	Standard Error	R^2
visual_1	0.83	.39
visual_3	0.63	.50
visual_2	1.06	.23
textual_1	0.38	.72
textual_2	0.42	.75
textual_3	0.37	.69
speed_1	0.75	.37
speed_2	0.37	.64
speed_3	0.70	.31

Note. -- indicates the statistic could not be calculated.

References

Bentler, P. M., & Chou, C. P. (1987). Practical issues in structural modeling. *Sociological Methods & Research, 16*(1), 78-117. https://doi.org/10.1177/0049124187016001004

Comrey, A. L., & Lee, H. B. (2013). *A first course in factor analysis*. Psychology Press. https://doi.org/10.4324/9781315827506

Field, A. (2017). *Discovering statistics using IBM SPSS statistics: North American edition.* Sage Publications

Hooper, D., Coughlan, J., & Mullen, M. (2008). Structural equation modelling: Guidelines for determining model fit. *Electronic Journal of Business Research Methods, 6*(1), 53-60.

Intellectus Statistics [Online computer software]. (2023). Intellectus Statistics. https://statistics.intellectus360.com

Kline, R. B. (2015). *Principles and practice of structural equation modeling*. Guilford Publications.

Newton, R. R., & Rudestam, K. E. (2012). *Your statistical consultant.* Sage Publications.

Schreiber, J. B., Nora, A., Stage, F. K., Barlow, E. A., & King, J. (2006). Reporting structural equation modeling and confirmatory factor analysis results: A review. *The Journal of educational research, 99*(6), 323-338.

Tabachnick, B. G. & Fidell, L. S., (2019). *Using multivariate statistics.* Pearson Education.

Glossaries

Confirmatory Factor Analysis

Confirmatory factor analysis (CFA) is a multivariate statistical technique to assess how well a specified number of scale variables represent the given constructs. CFA is similar to exploratory factor analysis, but in CFA one specifies which scale variables load onto a certain construct. CFA assesses whether the hypothesized underlying constructs fit the data well.

Adjusted Goodness-of-Fit Index (AGFI): An absolute fit index used for CFA to assess model fit. Values greater than .90 indicate a good fit and values less than .90 indicate a poor fit. This fit index is not recommended to be used on its own.

Chi-Squared Statistic (χ^2): A test statistic based on the χ^2 distribution. Used with the *df* to calculate a *p*-value.

Comparative Fit Index (CFI): A relative fit index used for CFA to assess model fit. Values

greater than .95 indicate a good fit, values between .90 and .95 indicate an acceptable fit, and values less than .90 indicate a poor fit.

Covariance: A measurement that indicates the degree that two variables are linearly related to one another. Used in CFA and SEM model specifications to imply if two latent variables or indicator variables are correlated with each other.

Degrees of Freedom (*df*): Refers to the number of values used to compute a statistic; used in conjunction with a test-statistic to calculate the *p*-value.

Determinant: A value calculated from a square (n × n) matrix with useful mathematical properties.

Error Variance: Indicates how much variance of a given parameter that does not contribute to the latent variable. Also referred to as the residual variance.

Fit Index: A value that is a measure of how well factor analysis model fits the data. The most common are: root mean square error of approximation, standardized root mean square residual (RMSEA), comparative fit index (CFI), and the Tucker-Lewis index (TLI).

Goodness-of-Fit Index (GFI): An absolute fit index used for CFA to assess model fit. Values greater than .95 indicate a good fit, values between .90 and .95 indicate an acceptable fit, and values less than .90 indicate a poor fit. This fit is not recommended to assess model fit.

Indicator Variable: A variable used to predict or create a latent variable. Also referred to as the observed variable.

Latent Variable: A set of observed scale variables that have strong relationships with one another or have a similar pattern. Also referred to as a factor.

Modification Indices: A value that estimates the decrease in the Chi-square statistic for an improved model fit. Commonly used with CFA and SEM to re-specify the model.

Multicollinearity: A state of very high intercorrelations or inter-associations among a set of variables.

Non-Normed Fit Index (TLI): A relative fit index used for CFA to assess model fit. Values greater than .95 indicate a good fit and values less than .95 indicate a poor fit, although .80 has been used as a cut off to indicate adequate fit.

Normed-Fit Index (Bentler and Bonnet Index or NFI): A relative fit index used for CFA to assess model fit. Values greater than .95 indicate a good fit, values between .90 and .95 indicate an adequate fit, and values less than .90 indicate a poor fit.

Probability Value (*p*): The probability of observing the test statistic under the null hypothesis.

Root Mean Square Error of Approximation (RMSEA): An absolute fit index for CFA to assess model fit. Values less than .08 indicate a good fit, values between .08 and .10 indicate an acceptable fit, and values greater than .10 indicate a poor fit.

Squared Multiple Correlations (R^2): Used in CFA to estimate each variable's communality. Also, referred to as R^2 in multiple linear regression. A value from 0 to 1 that shows the fraction of variance explained.

Standard Error of Loading: How much the unstandardized loading is expected to vary.

Standardized Loading: Ranges from -1 to 1, gives the strength of the relationship between the indicator variable and latent variable. Interpreted like a correlation.

Standardized Root Mean Square Residual (SRMR): An absolute fit index for CFA to assess model fit. Values less than .05 indicate a good fit, values between .05 and .08 indicate an acceptable fit, and values greater than .08 indicate a poor fit.

Unstandardized Loading: The slope of the indicator variable with the latent variable. Treated like a Beta coefficient in regression.

Raw Output

Confirmatory Factor Analysis

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Included Variables:
visual_1, visual_2, visual_3, textual_1, textual_2, textual_3, speed_1, speed_2, and
speed_3

Sample Size (Complete Cases):
N = 301

Multivariate Outliers:
Mahalanobis distances vs. .999 quantile of χ² distribution (χ²(9) = 27.877)

Outliers (Row Number in Data Set):
164

Multicollinearity:
Determinant of the Correlation Matrix 0.0472

Squared Multiple Correlations (R²):
```

Variable	R^2
visual_1	0.358
visual_2	0.173
visual_3	0.282
textual_1	0.629
textual_2	0.635
textual_3	0.602
speed_1	0.309
speed_2	0.346
speed_3	0.349

Modification Indices:

Parameter	Modification Indices	Parameter Change
Visual ↔ textual	26.552	0.277
Visual ↔ speed	22.633	0.188
visual_1 ↔ speed_3	14.396	0.200
textual ↔ speed	12.152	0.162
textual_1 ↔ speed_1	7.095	0.106
visual_1 ↔ textual_1	6.547	0.111
visual_2 ↔ speed_1	6.279	-0.148
visual_3 ↔ speed_3	4.651	0.109

visual_3 ↔ textual_2	4.487	-0.0954
textual_1 ↔ speed_2	2.934	-0.0600

Estimated Error Variances and R^2 Values for Each Endogenous Variable:

Endogenous Variable	Standard Error	R^2
visual_1	0.835	0.386
visual_3	0.633	0.504
visual_2	1.065	0.229
textual_1	0.382	0.717
textual_2	0.416	0.749
textual_3	0.369	0.692
speed_1	0.746	0.369
speed_2	0.366	0.642
speed_3	0.696	0.314

Note: -- indicates the statistic could not be calculated.

Model Fit Indices:

GFI	AGFI	NFI	TLI	CFI	RMSEA	SRMR
0.901	0.835	0.833	0.809	0.857	0.125	0.161

Chi-square Goodness of Fit Test: $\chi^2(27) = 153.527$, $p < .001$; RMSEA 90% CI = [0.106, 0.144]

Unstandardized Loadings (Standard Errors), Standardized Loadings, and Significance Levels for Each Parameter in the CFA Model (N = 301):

Parameter Estimate	Unstandardized	Standardized	p
Loadings			
Visual → visual_1	1.000(0.00000)	0.621	--
Visual → visual_2	0.778(0.149)	0.479	1.796×10^{-07}
Visual → visual_3	1.107(0.241)	0.710	4.236×10^{-06}
textual → textual_1	1.000(0.00000)	0.847	--
textual → textual_2	1.133(0.0699)	0.866	0.00000
textual → textual_3	0.924(0.0549)	0.832	0.00000
speed → speed_1	1.000(0.00000)	0.608	--
speed → speed_2	1.225(0.194)	0.801	2.528×10^{-10}
speed → speed_3	0.854(0.116)	0.561	2.023×10^{-13}
Errors			
Error in visual_1	0.835(0.127)	0.614	4.804×10^{-11}
Error in visual_3	0.633(0.126)	0.496	5.304×10^{-07}
Error in visual_2	1.065(0.111)	0.771	0.00000
Error in Visual	0.524(0.151)	1.000	5.099×10^{-04}
Error in textual_1	0.382(0.0514)	0.283	1.144×10^{-13}
Error in textual_2	0.416(0.0547)	0.251	2.731×10^{-14}
Error in textual_3	0.369(0.0471)	0.308	4.663×10^{-15}
Error in speed_1	0.746(0.0841)	0.631	0.00000

Error in speed_2	0.366(0.0972)	0.358	1.638×10^{-04}
Error in speed_3	0.696(0.0797)	0.686	0.00000
Error in speed	0.437(0.0909)	1.000	1.528×10^{-06}
Error in textual	0.969(0.130)	1.000	1.028×10^{-13}

Note: -- indicates the statistic was not calculated due to parameter constraint.