Validity of Processing Speed Ability Test based on Internal Structure

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Abstract: This study constructed a new intelligence tests based on Cattel Horn Carrol theory (CHC theory). The aim is to test some broad ability of the newly developed tests, namely processing speed ability, consisting of three narrow abilities. In accordance with Cattel Horn Carrol theory, processing speed ability is one of the broad abilities that contribute in shaping general intelligence. There are three narrow abilities of processing speed ability, namely perceptual speed, number facility and rate of test taking. These abilities were studied through 299 items and were piloted on 135 subjects. Through confirmatory factor analysis using the JASP 0.9 program, the model was found as a good fit (χ^2 = 0.341, p=0.559 (greater than 0.05), df =1, RMSEA = 0.000 (90% CI [0.000 - 0.0191], and those three factors (perceptual speed, number facility and rate of test taking) were consistent with factors measured in processing speed ability tests. Based on the model accuracy index, it shows that the proposed model is capable of describing the narrow ability of processing speed ability.

1 INTRODUCTION

Cognitive ability has become an important subject in psychology because it shows one of the individual differences of concern by psychologists. Cognitive ability can take the form of intellectual potential, logical thinking ability, comprehension, analytical ability, numerical ability, verbal ability and intelligence etc. Scientists consider that intelligence plays an important role in determining human behavior. Intelligence is considered capable of predicting individual success in careers (Gottfredson, 2009; Kaufman et al., 2012), study (Lohman and Gambrell, 2012; Lohman et al., 2008; Naglieri et al., 2003; Vanderwood et al., 2001) and survival (Vanderwood et al., 2001).

Based on its very important role, assessing (i.e. knowing or measuring) the capacity of intelligence in a person is important. Assessing someone's intelligence is related to assessment activities that ultimately relate to intelligence tests. A psychological assessment activity is an attempt to evaluate the individual who is facing the problem; this activity explains that the information obtained from the assessment that can be used to solve the problem (Marnat, 2003). The assessment will be related to the measurement activity which is a systematic procedure for observing someone's behavior and describing it with the help of a numerical scale or categorization system. Meanwhile, the test is one of the means of collecting data on measurement activities. The test activity is an objective and standard measurement of a behavioral sample (Anastasi and Urbina, 1997). Tests play an important role in psychological decision-making regarding the fate of individuals, groups and the wider community. However, decision-making becomes less precise when the available data is less accurate. Finally, the accuracy of the data indicates the quality of assessment activities that are influenced by the quality of a test kit. While the quality of a test tool can be seen from the evaluation that should be done before using the test tool. One of the evaluations that can be done is on the validity aspects of the test. This article discusses the validity of the Speed Processing Ability test as part of a common intelligence developed based on the Cattel Horn Carrol theory (CHC theory).

The Cattel Horn Carrol theory is the theory of intelligence which is the integration of Gf-Gc theory

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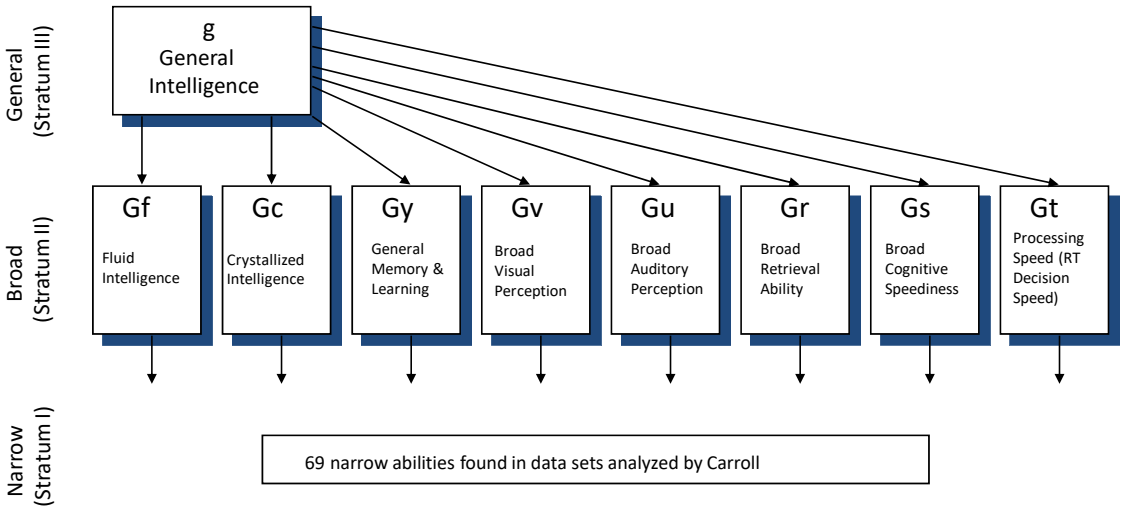

Figure 1: Carroll's Three-Stratum Theory of Cognitive Abilities (1993) (Mcgrew and Flanagan, 1998).

from Cattel-Horn and three stratum theory from Carroll (Beaujean, 2015; Furnham and Mansi, 2014). Raymond Cattell (1941, 1971). It has argued that intelligence consists of two factors (g and s) further developed by John Horn, who is also a student of Cattell (1968, 1994). Then Carroll, in 1993, conducted a review and analysis of a number of thousands of intelligence test databases and produced three stratum models of human intelligence and cognitive abilities (Carroll, 1993). These models are considered capable of describing the human cognitive structure as it uses a strong empirical base. These opinions are integrated into Cattell-Horn and Carroll theories (eventually referred to as CHC). According to CHC theory, intelligence consists of pervasive, broad and narrow capabilities that are arranged hierarchically. Carrol suggests there are at least 69 narrow abilities, as shown in Figure 1. While McGrew conducted a study again and found 59 narrow abilities (Floyd et al., 2009; Mcgrew, 2009).

The CHC theory has broad implications for the measurement of intelligence (McGrew, 1997, in Gregory, 2011; McGrew in (Flanagan and Harrison, 2005b; Mcgrew, 2009). At present, CHC theory has a major influence on the development of intelligence tests, especially revised versions of previously developed tests. Alfonso, Flanagan and Radwan (Flanagan and Harrison, 2005b) have summarized several tests whose development is influenced by the CHC theory. For example, KABC, Kaufman Assessment Battery for Children (1983) was revised into KABC-II in 2004 through a measurement of five broad abilities of CHC; SB-IV, Stanford–Binet Intelligence Scales, Fourth Edition (1986) was revised to SB5 in 2003 to which Working Memory was added. In addition, WAIS-R, Wechsler Adult Intelligence Scale - Revised (1981) developed into WAIS-III in 1997 by comprehending Fluid Reasoning and Working Memory. Whereas WPPSI-R, Wechsler Preschool and Primary Scale of Intelligence-Revised (1989) was revised to WPPSI-III in 2002 by comprehending Processing Speed and Fluid Reasoning. Another example is the revision of WJ-R, Woodcock–Johnson Psycho-Educational Battery-Revised (1989) to WJ III in 2001 through the blueprint preparation. Quite major revision was done to WISC-III, Wechsler Intelligence Scale for Children - Third Edition (1991) which was revised to WISC-IV in 2003 and that affected several subtests, including: (1) elimination of Verbal and Performance, (2) replacement of Freedom from Distractibility Index to Working Memory Index, (3) replacement of Perceptual Organization Index to Perceptual Reasoning Index, and (4) comprehending Fluid Reasoning and Processing Speed. Moreover, development of new tests, namely RIAS, Reynolds Intellectual Assessment Scales (2003), WRIT, Wide Range Intelligence Test (2002), and KAIT, Kaufman Adolescent and Adult Intelligence Test (1993) has also been affected by the CHC theory.

On one hand, unfortunately, the tests mentioned above have not been adopted in Indonesia. Meanwhile, the adaptation process requires a long

and complicated procedure, psychometric criteria that must be fulfilled, high cost due to the long procedure, and surely the permission of the publisher and test developer. In addition, most of these tests are administered individually. Therefore, from a practical point of view, test administration that demands speed or which can be administered in a classical manner is still less favorable.

On the other hand, practically, in accordance with the experience of researchers as psychology practitioners for several years, there are many problems to be faced, especially in connection with the intelligence assessment. Such issues may affect the quality of the assessment itself, so that assessors need to pay attention to this. These problems include 1) The availability of varied assessment tools is still limited; 2) The most widely available assessment tools are an external adaptation conducted in the 1960-1970s. At that time the method of adapting the measuring instrument was not as advanced as it is now, so it is likely that the adaptation is simply translating; 3) The number of limited intelligence tests means that the frequency of use becomes very high. This makes the content of the test known to the participants. In these conditions the assessment result does not reflect the individual, so there is the possibility that a psychological practitioner will gain unreliable data. Finally, 4) Most of the existing test kits are for individual administration, while group administration tests are still indispensable.

This article is part of a larger research work that includes developing intelligence tests based on the CHC theory that is currently at the point of preparing the items for each narrow ability (there are 4 broad abilities consisting of 12 narrow abilities). This article specifically discusses the validity test of cognitive speediness (some authors call it cognitive speed processing or speed processing abilities) which is one of the broad abilities of CHC theory. According to McGrew, processing speed abilities consist of three narrow abilities, Perceptual Speed, Number Facility and Rate of Test Taking (Flanagan & Harrison, 2005), which will be the basis for the preparation of blueprint tests in this study. The test to measure speed processing ability is interesting to be developed because in addition to being an important part of intelligence, this test also has a role in other aspects of ability such as memory and fluid intelligence. McGrew (Flanagan & Harrison, 2005) summarizes some studies that show the role of speed processing abilities against working memory and fluid intelligence, i.e, research conducted by Fry and Hale (2000); Conway, Cowan, Bunting, Therriault and Minkof (2002), and Sub, Oberaurer, Wittmann, Wilhelm and Schulze (2002).

As mentioned earlier, Cognitive Processing Speed (Gs) refers to the speed of continuous learning or automatic cognitive processes, especially when high-level attention and concentration are required. For example, the ability to perform simple counts quickly demonstrates the ability of high speed processing abilities. The ability to distinguish two words also demonstrates the ability of high processing speed ability. According to CHC theory, as the broad ability, speed processing ability has three narrow abilities, namely Perceptual Speed, Number Facility and Rate of Test Taking. The researcher hypothesizes that these three narrow abilities consisting of Perceptual Speed, Number Facility and Rate of Test Taking are substantially appropriate to measure processing speed ability. In addition, the researcher tries to involve gender variables to see if there is a gender effect on the processing speed ability.

2 METHOD

Research Design. The design of this study applies a quantitative approach. In quantitative research, the positivism paradigm becomes the basis for determining the variables and hypotheses in explaining the research and testing the hypotheses associated with causal explanations in general (Neuman, 2014). The technique of data collection in this research is by using a survey. According to Neuman (2014), data collecting methods using survey techniques are conducted by asking people who become the subject of research to fill in a written questionnaire (paper based).

Participant. Participants in this study were those who were involved in the selection of prospective mentors of children prone to drop out of school organized by the Social Office of Surabaya City Government. The program is part of a campus social responsibility involving students from several universities in the city of Surabaya. There were 135 participants in this study consisting of 105 (78%) women and 30 (22%) men from several universities in Surabaya. Average and standard deviations of P (Perceptual Speed), N (Number Facility) and R9 (Rate of Test Taking) are listed in the following table.

Table 1: Descriptive Statistic Men and Women Participant.

		P	N	R9
Men	Mean	31.46	19.86	28.52
	SD	6.86	6.09	11.48
Women	Mean	30.70	20.92	32.66
	SD	5.46	5.51	11.31

Instruments. The instrument that became the object of this research is a new instrument to measure processing speed ability or cognitive processing speed (Gs) consisting of three sub-tests. The tests are compiled based on CHC theory. According to McGrew (Flanagan and Harrison, 2005a; Mcgrew, 2009), the definition of processing speed ability is the ability to automatically and fluently perform relatively easy or overlearned cognitive tasks, especially when high mental efficiency (i.e. attention and focused concentration) is required. This is the speed of executing relatively overlearned or automatized elementary cognitive processes. Gs consists of three narrow abilities, which are Perceptual speed (P), Number facility (N) and Rate of test taking (R9).

Perceptual speed (P): Ability to rapidly and accurately search, compare (for visual similarities or differences) and identify visual elements presented side by side or separated in a visual field. Recent research (Ackerman, Beier & Boyle, 2002; Ackerman & Cianciolo, 2000; Ackerman & Kanfer, 1993), suggests that P may be an intermediate-stratum ability defined by four narrow sub-abilities: Pattern recognition, Scanning, Memory, and Complex. Item form: there are a pair of combination of letters and numbers. Participants are asked to determine whether the pair is the same or not. There are 100 items. Alpha reliability of 0.769. Work time is 5 minutes.

Number facility (N): Ability to rapidly perform basic arithmetic (i.e. add, subtract, multiply, divide) and accurately manipulate numbers quickly. N does not involve understanding or organizing mathematical problems and is not a major component of mathematical/quantitative reasoning or higher mathematical skills.

Rate of test taking (R9): Ability to rapidly perform tests that are relatively easy or overlearned (require very simple decisions). This ability is not associated with any particular type of test content or stimuli. Item form: there is a pair of words, participants are asked to cross out the same letter. There are 99 items. The coefficient of alpha reliability is 0.923. Work time is 5 minutes. Examples of items for each narrow ability are in the Appendix.

Data analysis. A first-order confirmatory factor analysis was performed to test the hypothesis. To test validity based on internal structure, confirmatory factor analysis was conducted using JASP 0.9 (JASP Team, 2018).

3 RESULT

The parameters used to test the accuracy of the model were Chi Square (χ2), significance level (p), CFI and root mean square error of approximation (RMSEA). The result of data analysis showed Chi-square (χ^2) = 0.341 (9, N = 135), p = 0.559; CFI = 1. 000; SRMR = 0.017; RMSEA = 0.000 (90% CI [0.000 - 0.0191]. The RMSEA described the residuals contained in the model, so the expected value was very small, under 0.08. In the arranged model, the obtained RMSEA value was 0.000 which proved that the arranged model was fit, just like any other parameter which indicated that the accurate index was fit. Full results are listed in Table 2.

Table 2 : Model Fit Parameter.

Parameter	Model
χ^2	0.341
Degrees of freedom	1
p	0.559
SRMR	0.017
RMSEA	0.0000
90 Percent Confidence Interval	0.000 – 0.191
p-value RMSEA <= 0.05	0.620

Table 3 : Parameter Estimate.

Label	Est	p
Gs =~ P	1. 000	-
Gs =~ N	0.602	0.195
Gs =~ R	1.204	0.182
Gender ~ Gs	-0.030	0.135

4 DISCUSSION

This study aims to test the validity of the test processing speed ability consisting of three narrow abilities, namely Perceptual Speed, Number Facility and Rate of Test Taking. Based on the result of confirmatory factor analysis, the study shows that

the three mentioned factors prove to form a constraint processing speed ability. It is indicated by the parameters showing that the model is fit.

The parameters for the model accuracy test also show that the model can explain the roles of all three factors. RMSEA value of 0.000 proves that the model is very fit. Similarly, the value of Chi Square (χ^2) whose magnitude is 0.341 with a significance level (p) of 0.559 (greater than 0.05) indicates that the index of accuracy meets the criteria. This means that the model can describe a well-measured factor. Thus, based on a trial that aims to estimate the validity of internal structure, the research shows that the prepared processing speed ability test has good internal validity. This is evidenced from the index of model accuracy that all meet the expected range of values.

The researcher wanted to know why the temporary model fit of the parameter estimate was not significant. To answer this question, the researcher did post hoc to know the magnitude of statistical power. With a sample size of 135, RMSEA of 0.000, alpha of 0.05 and df equal to 1, the statistical power obtained was 5%. This statistical power was very small, and this result at once answered the question why the temporary model fit parameter of each narrow ability was not significant. With a sample size of 135, RMSEA of 0.000, alpha of 0.05 and df equal to 1, the statistical power obtained was 5%. This statistical power was very small, and this result at once answered the question why the model was suitable while the parameters of each narrow ability was not significant. Simulation was also done to prove that to obtain statistical power of 80% the required sample was at least 78,490 people. Meanwhile, due to the gender effect on processing speed ability, the result showed that there was no difference between men and women. This could be seen from the level of significance (p) gender for processing speed ability of 0.135 (see Table 1.3). This fact showed that there was no influence or different ability of a person in terms of processing speed ability if viewed from the aspect of gender.

Results of the validity test found that all three factors have a fit model in measuring speed processing ability. However, some weaknesses are identified, e.g. the statistical power which is weak (only about 5% due to insufficient sample size). As mentioned earlier, to obtain a stronger statistical power (about 80%) the required sample was at least 78,490 people. To test a theoretical model, it should include all indicators/sub-tests/narrow abilities as the larger project of the study. Research on the planned intelligence test has 12 sub-tests, so the degree of freedom is 78. If assuming RMSEA is 0.04, and wanting to obtain 80% statistical power, then the required sample is 293.

Moreover, for test developers interested in the same field, it is recommended to conduct further research to enrich the validity of this test through different validity sources, such as validity based on criteria with other variables. And for practitioners, this test can be used to measure speed processing abilities. However, it is necessary to be careful in interpreting the test results, as these tests are new so there is little evidence available regarding the validity of this test. Another future challenge is to develop norms from larger groups that could be used to interpret test results more accurately. The related norms to interpretation are required for diagnostic purposes, so that the existence of norms becomes absolute if the test is to be used in a practical field.

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APPENDIX

Appendix 1: Sample Item

NARROW ABILITY	SAMPLE ITEM	OPTION
Perceptual Speed (P)	5+7=12 10- 9=19	R W R W
Number Facility (N)	Aab ..... Aab cdOp cd0p	= ≠ = ≠
Rate of Test Taking (R9)	pagi --- puli denah--- parik	cross the same letters between the left and right word.