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# 12 Etiology of Factor Structure in the Kaufman Assessment Battery for Children

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## Introduction

The Kaufman Assessment Battery for Children (K-ABC) is an individually administered test designed to assess intelligence based on a model of sequential and simultaneous processing (Kaufman & Kaufman, 1983). Simultaneous processing refers to a child's mental ability to integrate inputs simultaneously to solve a problem correctly, whereas sequential processing refers to the arrangement of stimuli in a sequential or serial order for successful problem solving (Kamphaus & Reynolds, 1984). The Simultaneous and Sequential scales, which measure the two types of processing, combine to form the Mental Processing Composite (MPC). The K-ABC also has a third component, the achievement scale, which measures abilities that complement those measured by the MPC. The test creators made the assumption that the three factors underlying the K-ABC's scales were uncorrelated or only moderately correlated with one another (Kaufman & Kaufman, 1983). They argued that the orthogonal or uncorrelated factor structure of the K-ABC is supported by various studies using factor analyses (e.g., Kaufman & Kamphaus, 1984; Willson, Reynolds, Chatman, & Kaufman, 1985), including a study with Japanese participants (Matsubara, Fujita, Maekawa, & Ishiguma, 1993).

Unfortunately, however, the distinct structure of the three factors (simultaneous, sequential, and achievement) has not been supported because earlier studies using factor analysis did not examine the oblique structure due to the K-ABC's theoretical basis (e.g., Kaufman & Kamphaus, 1984; Japanese sample: Matsubara et al., 1983); some earlier studies failed to support the independent three-factor structure of the K-ABC (Willson et al., 1985); and interpretations of the results of the confirmatory factor analysis were not statistically appropriate (e.g., Kaufman & Kaufman, 1983; Willson et al., 1985; see Strommen, 1988). Indeed, substantial and significant inter-factor correlations have been reported (Keith, 1985; Strommen, 1988). Furthermore, an alternative model, in which a general intellectual factor, or g, was presumed to reflect three factors (verbal memory, nonverbal reasoning, and verbal reasoning) showed a fairly good fit to the data, suggesting an alternative interpretation of the K-ABC scales (Keith & Dunbar, 1984).

We have reported elsewhere (Fujisawa & Ando, 2008) that K-ABC data collected at 42 months generally supported the K-ABC factor structure, but we did not test the data using confirmatory factor analysis. Furthermore, we did not examine how genetic and environmental influences underlie the structure.

In the present report, we investigated whether the factor structure assumed by the K-ABC would be confirmed by confirmatory factor analysis in a sample of 60-month-old twins. Furthermore, we also investigated the etiology of the factor structure.

## Method

### Participants

The sample consisted of 136 sets of twins living in the Tokyo area. The mean age of the children was 5.23 years old (SD = 0.15). The twins included 31 male MZ twin pairs, 35 male DZ twin pairs, 37 female MZ pairs, and 33 female DZ twin pairs. We excluded three male-male MZ pairs and one female-female MZ pair from the subsequent analyses because they had developmental disabilities or their first language was not Japanese.

### Measures

*Kaufman Assessment Battery for Children (K-ABC)*

Trained testers administered the K-ABC in a laboratory setting according to the K-ABC Administration and Scoring Manual for individuals 60 months of age (Matsubara et al., 1993). Different testers administered the K-ABC to each twin to avoid tester bias.

The scales included the following:

**Sequential scale:** Hand Movements, Digit Recall, and Word Order.

**Simultaneous scale:** Gestalt Closure, Triangles, Matrix Analogies, and Spatial Memory.

**Achievement scale:** Faces and Places, Math, Riddles, and Reading/Decoding.

### Analysis

We reported the descriptive statistics for each task and tested whether scores differed by sex or by zygosity. We also assessed the phenotypic correlations among tasks to begin to understand the factor structure of tasks. Confirmatory factor analyses for an orthogonal model in which the three factors of K-ABC (sequential, simultaneous, and achievement processing) were uncorrelated and for an oblique model in which the three factors were correlated with one another were conducted. Because a twin and a co-twin can be interchangeable, we conducted the confirmatory factor analyses based on double-entered data and then adjusted the degrees of freedom following Olsen & Kenny (2006). Using the adjusted degrees of freedom, we compared the fits of the two models using chi-square values, root mean square errors of approximation (RMSEA), and Akaiki's Information Criterion (AIC). Based on the results of the confirmatory factor analyses, we tested the common pathway with correlated factors model (see Neale, Boker, Xie, & Maes, 2003, for details) to clarify the etiology of the factor structure.

## Results

### Descriptive statistics

Descriptive statistics for the scores on each task are presented in Table 1. With the exception of the significant difference by sex on Matrix Analogies

Table 1. *Means of tasks (standard deviations are in parenthesis) by sex and by zygosity.*

| | Male | | Female | | t | df | p | MZ | | DZ | | t | df | p |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hand Movements | 10.73 | (3.54) | 10.74 | (3.04) | –0.03 | 261 | ns | 10.88 | (3.64) | 10.60 | (2.90) | 0.68 | 261 | ns |
| Digit Recall | 11.09 | (3.12) | 10.75 | (2.99) | 0.89 | 261 | ns | 11.18 | (2.89) | 10.66 | (3.19) | 1.39 | 261 | ns |
| Word Order | 10.69 | (3.15) | 10.84 | (3.14) | –0.39 | 261 | ns | 10.85 | (3.24) | 10.69 | (3.05) | 0.42 | 261 | ns |
| Gestalt Closure | 10.42 | (3.21) | 10.30 | (3.08) | 0.29 | 261 | ns | 10.05 | (3.06) | 10.64 | (3.20) | –1.53 | 261 | ns |
| Triangles | 11.44 | (3.70) | 11.06 | (2.55) | 0.98 | 261 | ns | 11.29 | (3.06) | 11.19 | (3.23) | 0.25 | 261 | ns |
| Matrix Analogies | 9.94 | (3.03) | 10.86 | (3.11) | –2.42 | 260 | < .05 | 10.50 | (3.17) | 10.36 | (3.04) | 0.37 | 260 | ns |
| Spatial Memory | 10.74 | (2.91) | 10.46 | (2.50) | 0.85 | 260 | ns | 10.41 | (2.81) | 10.77 | (2.59) | –1.09 | 260 | ns |
| Math | 108.59 | (16.63) | 107.37 | (14.80) | 0.63 | 260 | ns | 107.85 | (16.86) | 108.04 | (14.52) | –0.10 | 260 | ns |
| Riddles | 99.64 | (16.19) | 100.44 | (13.59) | –0.44 | 260 | ns | 97.82 | (14.21) | 102.20 | (15.20) | –2.41 | 260 | < .05 |
| Reading | 101.19 | (19.03) | 103.99 | (14.42) | –1.35 | 260 | ns | 102.41 | (16.61) | 102.90 | (17.01) | –0.24 | 260 | ns |

Table 2. *Phenotypic correlations among tasks.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 Hand movements | 1 | | | | | | | | | |
| 2 Digit recall | .282** | 1 | | | | | | | | |
| 3 Word order | .323** | .507** | 1 | | | | | | | |
| 4 Gestalt closure | .122* | .068 | .121* | 1 | | | | | | |
| 5 Triangle | .286** | .165** | .219** | .121* | 1 | | | | | |
| 6 Matrix analogies | .246** | .194** | .206** | .124* | .385** | 1 | | | | |
| 7 Spatial memory | .337** | .074 | .230** | .064 | .422** | .274** | 1 | | | |
| 8 Math | .396** | .316** | .390** | .074 | .320** | .322** | .371** | 1 | | |
| 9 Riddle | .177** | .251** | .256** | .370** | .152* | .186** | .138* | .304** | 1 | |
| 10 Reading | .303** | .362** | .319** | .097 | .286** | .294** | .256** | .520** | .240** | 1 |

*Note.* *: $p < .05$, **: $p < .01$

and a difference by zygosity on Riddles, scores on most tasks did not differ significantly by sex or zygosity. Based on these results, we adjusted the scores by sex and then standardized them within zygosity for the subsequent analyses.

## Phenotypic correlations among tasks

Phenotypic correlations among tasks are shown in Table 2. Most tasks were significantly correlated with one another; the exceptions to this trend were the nonsignificant correlations between Digit Recall and Gestalt Closure, between Digit Recall and Spatial Memory, between Gestalt Closure and Spatial Memory, between Gestalt Closure and Math, and between Gestalt Closure and Reading. These results suggest the existence of a correlated factor structure underlying the tasks included in the K-ABC.

## Phenotypic confirmatory factor analyses

The data indicated that an orthogonal model in which the three factors (sequential, simultaneous, and achievement) were not correlated with one another produced a higher chi-square value and a significantly poorer model fit ($\chi^2$ = 227.88, adjusted df = 77, p < .05, RMSEA = .15, AIC = –146.120) compared with an oblique model in which the three factors were correlated with one another ($\chi^2$ = 108.59, adjusted df = 71, p = .99, RMSEA = .11, AIC = –253.380). The three factors were strongly correlated with one another in the oblique model (sequential and simultaneous: .54, sequential and achievement: .75, simultaneous and achievement: .71). Although even the oblique model did not provide a sufficiently good model fit, we applied a common pathway with correlated factors model in the following behavioral genetic analysis.

## Common pathway with correlated factors model

The results of the common pathway with correlated factors model are presented in Figure 1 ($\chi^2$ = 475.82, p = .99, AIC = –248.18, RMSEA = .10). As shown in Figure 1, the effects of the genetic and shared environmental influences on the three factors (sequential processing, simultaneous processing, and achievement) of the K-ABC were significant. The genetic influences had a substantial impact on sequential and simultaneous processing, whereas shared environmental influences had a substantial effect on achievement. Nonshared environmental influences did not substantially affect the three factors, although the nonshared environmental influence on simultaneous was significant. As shown in Table 3, the genetic correlations among the three factors were very strong (greater than .91). Additionally, the shared environmental correlations between sequential processing and achievement, and between simultaneous processing and achievement, were substantial (greater than .91). However, the shared environmental correlation between sequential and simultaneous processing was not significant. The nonshared environmental correlations among the three factors were not significant. None of the genetic and shared environmental influences that were unique to each task was significant, except for the significant genetic influences on Gestalt and Reading and the significant shared enviromental influence on Riddles. Only the nonshared environmental influences that were unique to each task were significant. Note that they include measurement errors.

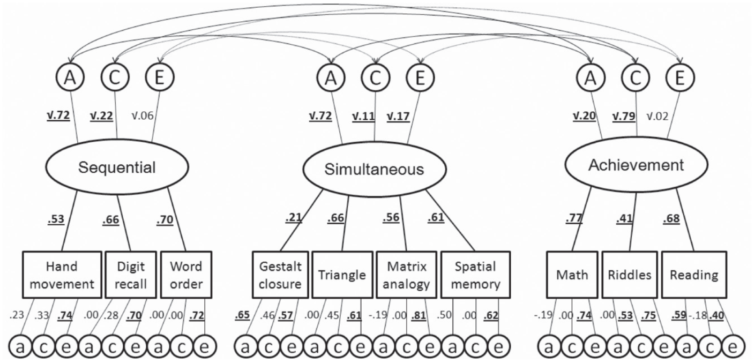


Figure 1. *Standardized path estimates of the common pathway with the correlated factors model.* Path estimates shown in bold type and underlined did not include 0 in their 95% confidence intervals. Estimates of the genetic and environmental correlations among factors were omitted from the figure. However, the estimates of the correlations shown by dark-gray curved arrows did not include 0 in their 95% confidence intervals, whereas the estimates of the correlations shown by pale-gray curved arrows did. A: Genetic influence. C: Shared environmental influence. E: Non-shared environmental influence. a, c, e: genetic, shared, and nonshared environmental influences unique to each task.

Table 3. *Genetic and environmental correlations among three factors.*

| | A | | | C | | | E | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1 Sequential | 1 | | | 1 | | | 1 | | |
| 2 Simultaneous | **0.91** | 1 | | –0.45 | 1 | | 0 | 1 | |
| 3 Achievement | **1** | **0.95** | 1 | **0.91** | **1** | 1 | 0.59 | 1 | 1 |

*Note.* A: Genetic correlations. C: Shared environmental correlations. E: Nonshared environmental correlations. Correlation coefficients in bold type with underline did not include 0 in their 95% confidence intervals.

# Discussion

The creators of the Kaufman Assessment Battery for Children assumed that its three factors, sequential, simultaneous, and achievement, were uncorrelated or at least correlated only modestly with one another (Kaufman & Kaufman, 1983). However, the findings reported here suggest that the factor structure of the K-ABC does not support this assumption. The confirmatory factor analyses showed that the orthogonal structure model in which the factors were uncorrelated produced a significantly poorer fit to the data compared with the oblique structure model in which the factors were correlated. Additionally, the three factors were substantially correlated with one another. Our findings are consistent with those of previous studies (e.g., Keith, 1985; Strommen, 1988). Given that even the oblique structure model did not show a sufficiently good fit, it is likely that an alternative model may be able to explain data more accurately (e.g., Keith & Dunbar, 1984).

The genetic correlations among the three factors were substantial. Given that the genetic correlations were greater than .91, it is likely that almost the same genes affect sequential processing, simultaneous processing, and achievement. This finding can be interpreted in two ways. First, it may be that the three factors are not phenotypically distinct cognitive processes or genetically distinct cognitive processes but are simply a single form of general cognitive processing. Second, it may be that the three factors measure distinct aspects of cognitive processing but the same genes affect their operation. This latter interpretation is consistent with the "generalist genes" hypothesis, which suggests that the same genes affect diverse cognitive abilities and disabilities (Plomin & Kovas, 2005; Kovas & Plomin, 2006). The second interpretation is more likely to apply, given the interesting result concerning the shared environmental correlations among the three factors. That is, the shared environmental correlations between sequential processing and achievement and between simultaneous processing and achievement were substantial, whereas the shared environmental correlation between sequential and simultaneous processing was not significant. It is likely that, as implied by the results of the phenotypic analysis, the prediction derived from an orthogonal factor structure proposed by the creators of the K-ABC would be unable to explain the etiology of the factor structure accurately and that an alternative factor structure would be more accurate in this regard. Future research should explore this issue.

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