Relationships among cognitive processes, intellectual abilities, and everyday task performance

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Running head: INTELLECTUAL ABILITIES AND EVERYDAY TASK PERFORMANCE

Abstract

Some previous studies have suggested that observed individual differences in cognition and intellectual ability may be a function of adult age differences in working memory and speed of processing (e.g., Hertzog, 1989; Salthouse, 1990, 1991; Tomer & Cunningham, 1989). Other researchers have suggested that individuals' repertoires of cognitive processes and intellectual ability may be an important underlying component of everyday problem-solving capabilities (e.g., Berry & Irvine, 1986; Willis, 1991). The present study attempted to integrate these perspectives.

A sample of 111 older adults (44 M, 67 F) from a Florida retirement community was recrutited. Subjects had a mean age of 76.8 years (SD = 5.64), and a mean of 15.2 years of education (SD = 2.43). Participants received a broad test battery which included measures of basic cognitive processes (speed, working memory), and intellectual abilities (fluid reasoning and crystallized knowledge). Subjects also received the *The Everyday Problems Test [EPT]*.

There were three main study findings. First, four broad second-order dimensions of ability were identified (General Memory, General Speed, Fluid Intelligence and Crystallized Intelligence). Second, these four ability dimensions were significantly correlated with our measure of everyday problem-solving. Finally, a structural equation analysis revealed that General Memory and Speed had only indirect effects on everyday problem-solving, mediated through Fluid and Crystallized Intelligence. Fluid and Crystallized Intelligence were the only significant direct predictors of EPT performance.

Discussion focused on the role of cognitive variables as components of real-life task performance.

everyday tasks were examined as predictors of ability performance seven years later) suggested that abilities were a better predictor of subsequent everyday task performance.

Other research laboratories have reported similar findings. Using different operational definitions of everyday problems, Cornelius and Caspi (1987) and Camp, Doherty, Moody-Thomas, and Denney (1989) reported significant relationships between measures of fluid and crystallized intelligence and everyday problem-solving. In our recent work with a new measure of everyday problem-solving, called the Everyday Problems Test (EPT) (Willis, Note 1) measures of fluid and crystallized intelligence again emerged as the principal predictors of EPT performance (e.g., Willis, Marsiske & Diehl, 1991). As in the earlier research with the Test of Basic Skills (ETS, 1977), fluid intelligence measures had principal salience for the prediction of everyday problem-solving performance, followed by crystallized intelligence.

The present study constitutes an extension of these prior research findings. Measures of memory and speed, which we have included in our measurement batteries, have not emerged as significant predictors of everyday problem-solving performance when included in regression analyses with fluid and crystallized intelligence. This is surprising, in light of the substantial research effort (as in this Cognitive Aging Conference) that has been expended on the study of age differences and age changes in memory and speed performance. Drawing from the work of Salthouse (1990, 1991) and Hertzog (1989), among others, we hypothesize that memory and speed may not exert direct predictive influences on everyday task performance when examined in combination with fluid and crystallized intelligence, but may exert their effects indirectly through fluid and crystallized intelligence. This

represents an expansion of our hierarchical view: memory and speed are seen as basic cognitive processes which are employed in higher order psychometric abilities, such as fluid (Gf) and crystallized (Gc) intelligence. Measures of Gf and Gc, in turn, are seen as relatively basic and content-free assessments of complex skill performance. Everyday problem-solving draws on these basic but complex skills.

The present research addresses three questions:

1. Can second-order dimensions of memory, speed, and fluid and crystallized intelligence be derived from a broad battery of cognitive measures?

2. What is the correlational pattern of relationships between these second-order dimensions of cognition and a measure of everyday problem-solving (EPT)?

3. Can a tertiary model be used to represent the relationship between basic cognitive processes, higher-order intellectual abilities, and complex everyday skills?

Method

Subjects

The sample comprised 111 individuals from a Florida retirement community, 44 males and 67 females. The mean educational level of this sample at Time One was 15.22 years (S.D. = 2.43 years, range = 7 - 22 years). The mean age of the subjects was 77.78 years (S.D. = 5.64 years, range = 68-94 years). Subjects rated their general health, vision, and hearing on a 6-point Likert-type scale (1 = very good, 6 = very poor). The mean health self-rating was 1.80 (S.D. = 0.88), the mean vision self-rating was 2.22 (S.D. = 1.09), and the mean hearing self-rating was 2.30 (S.D. = 1.14). Average annual income of this group was between $26,000 and $28,000, ranging from $4,000 to over $50,000.

The participants had been a part of a larger study, begun in 1990, that included 202 residents of the retirement community. To determine whether attrition effects were a potential source of bias, t-test comparisons were made between the returning sample and the total original sample. Using this approach, only one variable showed a significant difference between the returning sample and the original sample, and this was the EPI total score. Returning subjects had a Time One mean of 52.47 (in T-score metric) on the EPI, with an S.D. of 8.5 standardized score points. The original sample of 202 subjects had a mean of 50, with an S.D. of 10. The performance of the returning subjects was significantly higher ($p < .05$) than that of the original sample. While this difference reached significance, it reflects only two-tenths of a standard deviation difference between the original and returning sample.

Measures

Three categories of measures were relevant to this study: personal, demographic, and health measures, cognitive and intellectual ability measures, and everyday problem-solving measures.

Personal and demographic measures

Subjects received a Personal Data questionnaire as part of a homework packet. Questions include subject age, marital status, educational level, gender, life satisfaction, income, subjects' household composition, time spent reading, recent life events, work history and job complexity.

Health measures

The Personal Data questionnaire also includes self-evaluations of health, hearing, and vision. Subjects also report the number of physician and hospital visits in the past year.

In addition to these health questions subjects were asked to bring all their current prescription medicines to a testing session. The names, dosage, ordered frequency, and duration of administration for each prescription drug were recorded. Drug data were subsequently coded according to American Hospital Formulary Service (AHFS, 1991) codes, and categorized according to therapeutic class.

Prior factor analyses of these health data, and similar data from another sample (Willis et al., 1990; Willis and Marsiske, 1991b; Willis, Marsiske & Diehl, 1991) had suggested that health variables could be factored into four dimensions: General Health, Hearing Impairment, Vision Impairment, and Cardiovascular Impairment. For each of these factors, higher scores meant higher degrees of impairment.

Cognitive and intellectual ability measures

Subjects received an intellectual ability battery of 19 tests which prior studies indicated were relatively pure markers of particular primary mental ability factors (Baltes et al., 1980; Cattell, 1971; Horn & Cattell, 196[illegible], Schaie, 1979, 1983).

Table 1 summarizes the measures of intellectual and cognitive abilities, included in this study, and their hypothesized primary and second-order [illegible] structure. Prior work with these measures suggested that they all had adequate test-retest and internal consistency reliabilities (Baltes et al., 1980; Schaie et al., 1989). The tests were administered under standardized conditions. Below, a brief description of the measures representing each primary mental ability is provided.

Verbal ability. Measures of Verbal Ability are multiple-choice tests which assess recognition vocabulary. Subjects must compare target words to possible synonyms, and identify which words are closest in meaning. Subject score was the number of correctly identified synonyms.

Figural Relations. Subjects must examine novel arrays of figural stimuli and identify patterns in these stimuli. Tasks include identifying which figure might come next in a series, which figure would best complete an incomplete matrix, and which figure would enable the subject to place an object in relation to other objects in a fashion similar to a target stimulus. Subject score was the number of correctly identified stimuli.

Inductive Reasoning. The Letter Series test requires subjects to examine a series of letters and decide, from five alternatives, which letter would come next in the series. The Word Series test has an analogous design, requiring subjects to identify which calendar month would come next in a series of months. Subject score was the number of correctly identified next stimuli.

Spatial Orientation. Measures of this primary ability present subjects with sequences of two-dimensional line drawings and ask subjects to identify which, from among six choice stimuli, are similar to a target stimulus but rotated on a 360^o plane, and which are rotated and mirror images of the original stimulus. The Figure Rotation test uses abstract line drawings, while the Object Rotation uses drawings of common objects. Subject score was the number of correctly identified rotations, minus the number of incorrectly identified mirror images.

Memory Span. The Visual Number Span test presents subjects with sequences of four to nine digits on a flip chart. Duration of exposure (study time) for the digit sequence is a linear function of the number of digits. Subjects must recall all digits in the exact order in which they were presented. Similarly, the Word Span test presents subjects with three to eight word sequences, and requires that they remember all words in exact sequence. Time to mark one's response is also a linear function of the number of digits or words presented. Subject score was the number of perfectly recalled spans, weighted by the number of words or digits in each span.

Perceptual Speed. Measures of this primary ability assess the speed with which subjects can make simple visual discriminations among figural and digital stimuli. Subject score was the number of correctly performed visual discriminations recorded during the time allowed.

Numerical Facility. Thurstone's (1962) Number Addition test was divided into odd-even split halfs at the time of data analysis. Subjects receive triplets of one- and two-digit numbers and are told to sum them as quickly and accurately as they can. Subject score is the number of correctly-added sums.

Verbal Fluency. Subjects receive five minutes to write as many unique words (no series or proper nouns were allowed) beginning with a target letter. Word Fluency I requires subjects to write words beginning with "S"; Word Fluency II requires words to begin with a "C". Subject score is the number of words written, minus all duplicate words, words-in-series, and proper names.

Working memory. Given the arguments of Daneman and Carpenter (1980) and Salthouse (1990, 1991) that working memory is an important component of adult age differences in cognition, two measures of working memory were included.

Furthermore, although Spatial Orientation is not commonly discussed as a marker of fluid intelligence, measures of this primary ability had their highest correlations with fluid markers in this sample Thus, Spatial Orientation was treated as a fluid marker. Number Addition was initially treated as a marker of Crystallized Intelligence. Examination of this initial model revealed several difficulties. The Number Addition factor did not have a high loading on the Crystallized factor. In fact, the highest modification index produced by LISREL VI (Joreskog & Sorbom, 1986) in this initial analysis was for the Number Addition factor on the second-order General Speed factor. The Verbal Fluency had a high loading on the Crystallized factor, but a non-significant loading on the Speed factor. The Memory Span and Working Memory factors were highly related to one another, although they are theoretically distinct aspects of memory (e.g., Daneman and Carpenter, 1980). In addition, a number of very high modification indices was found in the <u>theta</u>, or residual, matrix, suggesting the presence of significantly correlated residuals. Since several correlated residuals made conceptual and theoretical sense it was decided to freely estimate the three highest correlated residuals although this adds the danger of producing a very sample-specific factor solution, . The three correlated residuals were between Figural Relations and Working Memory, Perceptual Speed and Memory Span, and Spatial Orientation and Perceptual Speed. The correlated residuals involving Speed seem to reflect the speeded nature of each task. The Figural Relations tasks involve a number of dimensions which subjects must hold in active memory, suggesting a relationship with the Working Memory tasks.

Modifying the second-order factor structure in accordance with the findings from this initial run, the revised second-order factor model that was

accepted is presented in Table 2. Inspection of the <u>lambda</u> factor loading matrix reveals that all loadings were moderate-to-high. The relatively high factor intercorrelations in Table 2 are suggestive of the presence of a strong general factor at a third-order level. The three estimated correlated residuals were all significantly greater than zero ($p < .05$). The fit of this second-order model was excellent ($\chi^2(20) = 33.15$, $p < .05$; <u>GFI</u> = 0.941, <u>RMSR</u> = 0.037).

<u>Correlations among cognitive and everyday problem-solving variables</u>

Table 3 presents the Pearson Product-Moment correlation coefficients among standardized (<u>M</u> = 50, <u>SD</u> = 10) cognitive and everyday problem-solving scores. Inspection of this correlation matrix reveals several interesting findings. First, correlations among cognitive and problem-solving variables were uniformly high and positive, suggesting substantial shared variance among cognitive variables, and between these cognitive variables and the <u>EPI</u>. Second, speed was more highly correlated with fluid and crystallized factors than with the <u>EPI</u> total score. Similarly, memory was more highly correlated with fluid intelligence than with the <u>EPI</u> total. Finally, fluid and crystallized factors were more highly correlated with the <u>EPI</u> than they were with memory and speed variables. This lent preliminary support to the hypothesized structural equation system that is discussed below.

Structural equation models

A set of models examined the pattern of relationships among cognitive process variables (memory, speed), intellectual ability variables (fluid and crystallized intelligence) and performance on the EPI. In addition, the pattern of relationships among these variables was examined controlling for subject age, education, and health and sensory status. These demographic and health variables were treated as exogenous variables in the model, with the remaining variables treated as endogenous. Path (beta) coefficients were estimated using LISREL VI (Joreskog & Sorbom, 1986). Only LISREL's beta matrix was used, simultaneous specifying exogenous-endogenous and within-endogenous relationships; the gamma matrix was not estimated in these analyses.

The first model tested was the null model and it examined an hypothesized system in which exogenous variables were allowed to be correlated with one another, but there were no relationships among exogenous and endogenous variables, or among endogenous variables. As expected, the fit of this model was poor ($\chi^2[46] = 339.77$, $p < .0001$, GFI = 0.563, RMSR = 0.259).

The second model estimated was a fully recursive model (Figure 1). In this model, all exogenous variables were estimated as predictors of all endogenous variables. In addition, Memory and Speed were estimated as predictors of Fluid and Crystallized intelligence, as well as EPI performance. Finally, Fluid and Crystallized factors were estimated as predictors of performance on the EPI. Using the χ^2 criterion, the fit of this model was significantly better than the null model ($\chi^2[8] = 30.96$, $p < .0001$, GFI = .954, RMSR = 0.064). The improvement in fit was substantial and significant (improvement $\chi^2[38] = 308.81$, $p < .0001$).

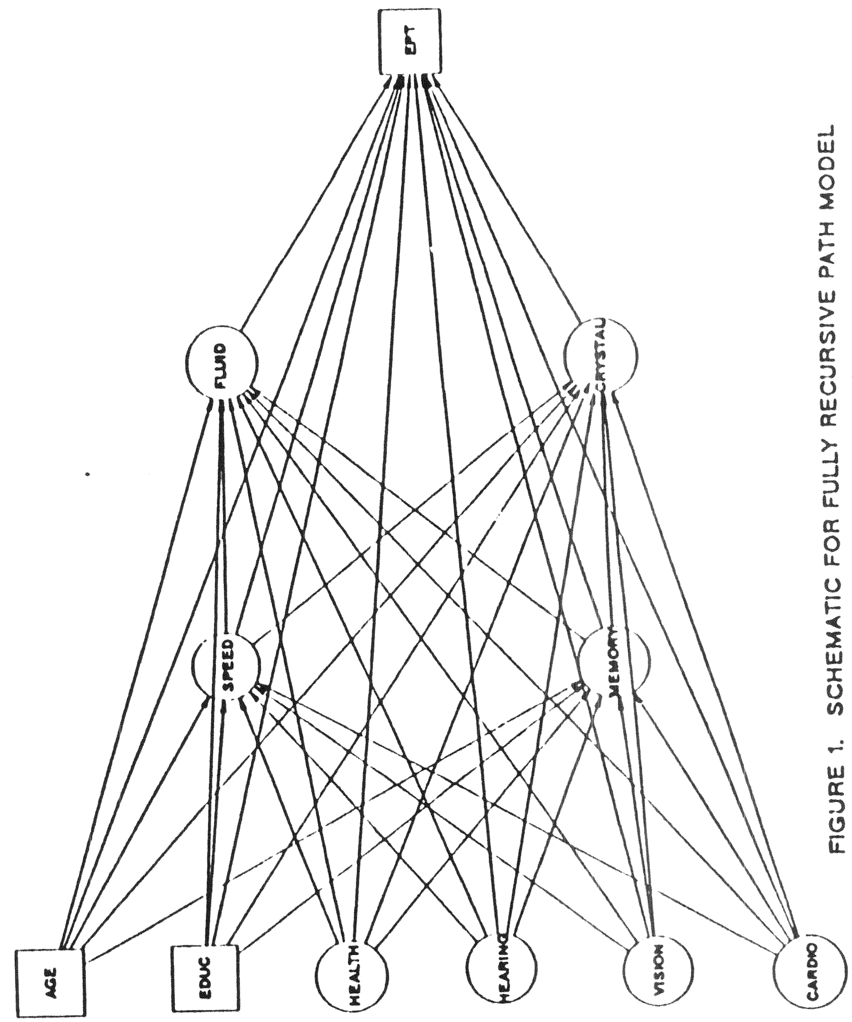

FIGURE 1. SCHEMATIC FOR FULLY RECURSIVE PATH MODEL

Discussion

This study examined three issues. First, the structure of a broad battery of cognitive and intellectual ability measures was examined, to see if the measures could be dimensionalized into broad second-order factors which represented basic cognitive processes (e.g., memory and speed) or more complex intellectual abilities (e.g., fluid and crystallized intelligence). Second, the pattern of correlation between these process and ability variables and a measure of everyday problem-solving capability, the EPI, was assessed. Finally, a structural equation analysis of the variables was undertaken, to see whether the influence of memory and speed on everyday problem-solving is direct or indirect, mediated through the more complex abilities of fluid and crystallized intelligence.

With regard to the first issue, a measurement model was identified that seemed to suggest that certain measures represented more basic cognitive processes, while other measures represented more complex fluid and crystallized factors. The primary ability factors of Perceptual Speed and Number Addition were taken as markers of a General Speed factor. A General Memory factor was marked by the primary abilities of Memory Span and Working Memory. The Fluid Intelligence factor was marked by the primary abilities of Figural Relations, Inductive Reasoning, and (in this sample) Spatial Orientation. (Not surprisingly, Spatial Orientation was the weakest marker of Fluid Intelligence, since it is commonly seen as a relatively pure marker of a General Visualization factor). Primary abilities of Verbal Ability and Verbal Fluency were taken as markers of Crystallized Intelligence.

Examining the patterns of correlation among these abilities lent support to an hierarchical conception of the relationships among cognitive processes, intellectual abilities, and everyday problem-solving. Memory and Speed were more highly related to Fluid and Crystallized Intelligence than they were to everyday problem-solving. Fluid and Crystallized intelligence, on the other hand, were most highly related to the everyday problem-solving variable.

The structural equation analyses lent additional support to this hypothesized system of influences. Memory and Speed had direct effects only on Fluid and Crystallized Intelligence, while the only significant predictors of EPI performance were Fluid and Crystallized Intelligence.

It is important, however, to underscore that these models were conducted on <u>concurrently</u> collected data. That is, there was no temporal lag between the collection of ability and EPI data, or between collection of process and ability variables. This is important, because it points out that strong causal inferences cannot be drawn from the data above. Rather, the results are suggestive of an hierarchical system of influences that has received much theoretical discussion in the empirical literature (e.g., Berg and Sternberg, 1985; Hertzog, 1989; Salthouse, 1990, 1991), and which has been, in part, found in other empirical investigations (e.g., Camp et al., 1989; Cornelius & Caspi, 1987; Willis et al., 1992; Willis & Schaie, 1986).

It is also important to emphasize that this study represents, as all empirical investigations, a <u>selection</u> of variables of each domain of interest, and does not claim to include a comprehensive representation of cognitive process, psychometric ability, or everyday problem solving variables. Future studies replicating and extending these findings are necessary.

Future research must examine the temporally-lagged relationships among cognitive process, intellectual ability, and everyday problem-solving variables. This is necessary to strengthen our notions about the causal

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