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# Environmental factors as a conceptual framework for examining cognitive performance in Chinese adults

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Cognitive abilities were examined across the lifespan for a Chinese sample, taking into consideration gender, education, and environmental factors. Participants were tested on the five subtests of the Primary Mental Abilities (PMA), a psychometric instrument measuring cognitive abilities. Environmental factors were assessed with a measure known as the Life Complexity Inventory (LCI), which provides information on the many aspects of the participants' micro-environment. A MANOVA was used to examine patterns of cohort and gender differences in intellectual performance, and significant main effects for cohort were found. Polynomial trend analyses confirmed that age was linearly related to most mental abilities. Of the seven environmental factors, only the Intellectual Environment factor was significantly associated with all ability scores with positive correlations ranging from $r = .20$ to .32. Positive correlations indicate that a particular environmental factor is associated with higher ability or greater flexibility.

## Introduction

Over the years, a literature is beginning to emerge on understanding differences in cognitive abilities across cultures (Chan, 1996; Gottfredson, 1986; Mayes & Jahoda, 1988; Schmidt & Hunter, 1981; Schneider & Schmitt, 1992; Tulviste, 1991; Vernon, 1987). Although many of these studies have examined racial differences in cognitive abilities, little attention has been paid to understanding the relationship between systematic micro-environmental dimensions, such as work and intellectual environments, and abilities. Previous cross-cultural research that has investigated contextual effects on intellectual development has focused predominantly on children and adolescents (Ceci & Roazzi, 1984; Chodzko-Zajko, 1991; Cole & Scribner, 1974; Ghuman, 1975; Goodnow, 1986; Laosa, 1980; Munroe & Munroe, 1985). Only a few extended their concern to study the interaction between environmental factors and cognitive abilities past young adulthood (Gribbin, Schaie, & Parham, 1980; Labouvie-Vief & Chandler, 1978; O'Hanlon, 1993; Schooler, 1984, 1990).

Similar to lifespan research on the relationship between intellectual performance and environmental influences, there has also been little attention to how adults from non-Western cultures may differ in terms of cognitive abilities at different ages. Hence, this study examined cohort and gender differences, and age trends in cognitive abilities in Chinese adults, as well as the relationship between intellectual performance and environmental factors.

### *Age differences on intellectual performance*

Lifespan research has recognised the existence and the magnitude of age-related intellectual change and the description of patterns of cohort differences (Baltes, Staudinger, & Lindenberger, 1999; Hultsch, Hammer, & Small, 1993; Murphy, 1989; Salthouse, 1992; Schaie, 1996). However, it is generally accepted that age relations vary dramatically across different cognitive tests (Salthouse, 1991; Schaie, 1996). For instance, research has found that age-related declines in cognitive performance is most likely to occur in tasks requiring working memory or effortful processing, such as free recall (Craik, Byrd, & Swanson, 1987; Just, Carpenter, & Keller, 1996; Park, Puglisi, & Smith, 1986). In contrast, smaller age effects are frequently observed on tasks with low processing demands, such as cued recall, recognition memory, and verbal ability (Baltes & Lindenberger, 1997; Craik & McDowd, 1987; Park et al., 1996; Schaie, 1996).

Craik and colleagues (1987) have suggested that ageing is associated with a reduction in working memory, which refers to the amount of processing resource available to simultaneously store new information and to perform mental tasks on either incoming or recently accessed information (for a review, see Baddeley, 1986; Park et al., 1996). Because high resource-demanding tasks, such as free recall, are largely dependent on the availability of sufficient processing resources for their successful completion, older adults generally perform poorer on these tasks due to a limited working memory capacity. Conversely, less resource-demanding tasks, such as cued recall,

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recognition memory, and verbal ability, are largely performed with little conscious attention and thus show smaller age-related performance decrements.

Although research generally found evidence for some aspects of cognitive abilities declining with age among Western societies (Salthouse, 1988; Schaie, 1996), only a few cross-cultural studies have inspected patterns of adult cognitive performance (Avolio & Waldman, 1994; Geary, Salthouse, Chen, & Fan, 1996; Park, Nisbett, & Hedden, 1999). There is little research on this topic, but what has been examined provides considerable support for declines in cognitive functioning that occur with age that appear to be neurobiologically based (Baltes & Lindenberger, 1997; Baltes & Smith, 1997) and that would be observed in other cultures (Avolio & Waldman, 1990, 1994; Geary et al., 1996; Park et al., 1999). Recently, Park and colleagues (1999) examined subjects from Beijing and the United States to study cultural differences on a picture-fragment completion task. Participants were required to generate images of the missing features in order to identify the item. Young Americans outperformed young Chinese, however, older adults from both cultures approached the tasks similarly and performed at the same level. In addition, subjects were asked to compare two figures and make quick decisions about the similarity or dissimilarity of the two patterns. Age differences were found, with young adults performing at a faster level than older adults, and older Asians and Americans performing at the same speed. These findings are consistent with the results of Geary et al. (1996), who found that older adults from different cultures performed processing tasks at the same speed.

Avolio and Waldman (1990, 1994) examined age differences in perceptual, psychomotor, and cognitive abilities for White, Black, and Hispanic male and female participants employed in comparable occupations. The finding of greatest interest to the present discussion was the observation that differences in these abilities across age groups were relatively small until at least age 65. That is, across these three cultural groups, there is more evidence for significant age effects at the upper end of the lifespan.

Extensive efforts have been directed at increasing our understanding of the neurobiological processes that mediate a substantial amount of age-related declines in high resource-demanding cognitive tasks (Baltes & Lindenberger, 1997; Baltes & Smith, 1997; Baltes et al., 1999), and it is possible that these neurobiological declines are culturally universal (Park et al., 1999). However, the extent to which a similar decline can be identified for older adults in other cultures is less clear as research in this area is lacking.

### *Gender differences on cognitive functioning*

Results of studies examining diverse cognitive skills have illustrated that the structure of mental abilities is not identical across gender. Studies of sex differences among White samples have arrived at a general conclusion that men outscore women on spatial orientation and mathematical skills, whereas women excel on certain tests of verbal skills (Schaie, 1983). For example, in a meta-analysis of male-female differences in cognitive abilities, Hyde (1981) found median gender differences of 0.45 SDs for verbal, 0.43 SDs for quantitative, and 0.45 SDs for spatial ability.

Although the aforementioned conclusion may generally hold for Western cultures, it is suspect as to how universal this conclusion is. A number of studies, conducted outside of the USA, have concluded that females performed significantly better on word fluency tests, whereas males achieved significantly higher scores on spatial tests (Lynn, 1992; Mann, Sasanuma, Sakuma, & Masaki, 1990). However, other studies have different conclusions. With regard to the female advantage on verbal skills, a study of Japanese adults did not reveal sex differences on a word fluency test (Sasanuma et al., 1985). Similarly, no sex differences on word fluency performance were found among Hawaiian individuals (Wilson et al., 1975).

Feingold (1994) did a cross-cultural quantitative review of findings of gender differences in verbal, mathematical, and spatial abilities. His review indicated that males were not consistently more variable than females in mathematical and spatial abilities. Rather, males outperformed females in some nations and females outperformed males in other nations.

The literature reviewed thus far includes inconsistent findings of gender differences in variability in verbal, mathematical, and spatial skills among groups outside Western cultures. Although findings of greater male variability in mathematical and spatial abilities were evident in the USA, they were not always found across other non-Western cultures. The sparse data regarding sex differences among individuals from non-Western cultures does not always replicate the prevalent Western findings. Thus, gender differences in cognitive abilities should be considered as part of cross-cultural intelligence studies.

### *Research on cognitive abilities and environmental factors*

Although a substantial number of sensory, motor, and cognitive abilities have been reported to decline with age, differences between individuals may be observed in terms of the rate and the extent of this decline. In recent years, researchers have been focused on the identification of environmental factors (e.g., health lifestyles, nutrition, fitness activities) that may mediate the rate and extent of cognitive ageing, and that may account for individual differences in cognition and development. For example, Sharma (1971) and Ghuman (1975) suggested that intellectual performance was low in India compared to immigrant Indians attending British schools, partly because of inadequate health provisions and nutrition.

Gribbin et al. (1980), Labouvie-Vief and Chandler (1978), Schaie (1996), Schooler (1984, 1990), and others have called for a "contextualist" theoretical framework. They have focused on the complex environmental variables that affect the maintenance of adult cognitive performance. For example, macrovariables, such as social class and sociohistorical context, have been identified as possible predictors of cognitive performance. This framework presumes that we learn to think about and solve problems in our everyday lives through the appropriation, use, and adaptation of practices, artefacts, and values developed by our culture over time (Baltes et al., 1999; Gauvain, 1993). Research conducted by Munroe and Munroe (1985) has indicated that directed distance from home, that is, travel undertaken while participating in activities (i.e., herding, weeding crops, running errands), and not free-time distance from home (i.e., playing) contributes to spatial skills on several spatial tasks.

Vernon (1987) contrasted two main types of cultures, namely hunting-gathering people (West Indies) and sedentary-agriculture people (Indian). Hunter-gatherers tend to engage in cultural practices that stress independence and resourcefulness in rearing their children. Vernon found that such practices were linked to their higher scores on visuospatial tests than the compared group that emphasised conformity and strict socialisation.

The influence of numerous environmental factors on cognitive competencies has also been investigated at a microlevel. Variables, such as occupational types, lifestyles, and physical activities, have been linked to intellectual differences across individuals. Cognitive performance has been shown to vary as a function of an individual's occupational type and work environment. Fozard and Nuttall (1972) found that individuals with higher status occupations performed better on cognitive abilities than those with lower status occupations. Avolio and Waldman (1990, 1994) reported that occupational types moderated the relationship between age and cognitive test performance across different racial groups. Occupations, such as manufacturing, clerical, machinery construction and repair, agriculture and forestry, and professional technical positions, were found to account for increases in variance for verbal, numerical, and motor coordination skills.

Miller, Slomczynski, and Kohn (1987) found evidence regarding the relationship between complex work environments and intellectual abilities. Job conditions that were complex, involving closeness of supervision and limited routinisation, were related to cognitive flexibility. Subjects who were identified with intellectual decrements were found to engage in a less substantively complex work environment.

Lehr and Olbrich (1976) found that individuals from larger households and social networks performed better on intelligence tests than the comparison group. Analyses from the Seattle Longitudinal Study revealed that individuals with distinct lifestyles, such as homemakers, the disengaged, and the semi-engaged (e.g., high in both number of friends and home-related activities), were differentiated by the level of their intellectual performance (Gribbin et al., 1980; Schaie, 1983). Although the homemakers and the semi-engaged cluster did not show a striking relationship with the ability scores, the disengaged cluster was negatively correlated with all ability test scores. Similarly, O'Hanlon (1993) examined patterns of correlation between micro-environmental dimensions and cognitive abilities. Variables associated with dimensions, such as prestige, social status, intellectual environment, and work complexity, were generally found to have stronger positive correlations with verbal meaning, reasoning, and word fluency tests. These positive relationships were interpreted as indicating that a particular dimension was associated with higher ability or greater flexibility.

The literature reviewed thus far emphasised the importance of studying contextual and environmental influences on intelligence in adulthood. Despite the recognition of the importance of environment, little cross-cultural research has examined which features of the environment facilitate cognitive competence and which features may obstruct it (Ceci & Roazzi, 1984). Hence, cross-cultural studies are needed to test the generality of Western theories regarding the interaction of systematic environmental factors with cognitive abilities.

The purpose of the current investigation was to extend earlier work reported by O'Hanlon (1993) by examining cognitive abilities across cohorts for Chinese males and females. The present study was also concerned with investigating the following research questions:

1. To what extent will patterns of age differences in ability levels be similar or different for a Chinese sample as compared to the results generally found in Western samples?
2. To what extent will the generalisability of Western findings that: (a) males excel in mathematical and spatial abilities; and (b) females excel in verbal ability hold for a Chinese sample?
3. What is the relationship between intellectual performance and environmental factors, such as Physical Environment, Prestige, Work Complexity, Social Status, Mobility, Social Network, and Intellectual Environment?

## Method

The design of the present study was based on the model of the Seattle Longitudinal Study (SLS: Schaie, 1996). Subjects for the China Primary Mental Abilities (PMA) Study were 121 Chinese adults (56 women and 65 men) aged 20 to 80 years who were selected from Tianjin, a large metropolitan area in China. The educational distribution of this area was determined from the municipal statistical manual for each age decade. Subjects included employees from two large factories (manual, clerical and managerial personnel, retirees), teachers in public schools, and nonfaculty employees of Nankai University. With the exception of the oldest cohort, approximately 20 subjects were recruited for each age decade matching the within-decade age distribution of the Tianjin population. The investigators were unable to obtain the intended cell size of the oldest group when data collection was ended subsequent to the Tian Men Square incident. A total of six age-cohorts were analysed for this study. Age and education levels by cohort and gender are provided in Table 1.

**Table 1**
*Summary of demographic information for the sample*

| | | | | *Cell size* | |
|---|---|---|---|---|---|
| *Age-cohort* | *Mean* | *(SD)* | *Range* | *M* | *F* |
| Cohort 1: 1908–17 | | | | 6 | 6 |
| Age | 75.00 | (2.45) | 71–79 | | |
| Education | 7.33 | (4.16) | 2–16 | | |
| Cohort 2: 1918–27 | | | | 13 | 9 |
| Age | 65.23 | (3.64) | 61–70 | | |
| Education | 6.23 | (4.25) | 1–17 | | |
| Cohort 3: 1928–37 | | | | 14 | 10 |
| Age | 55.38 | (3.33) | 51–60 | | |
| Education | 7.67 | (2.99) | 3.15 | | |
| Cohort 4: 1938–47 | | | | 12 | 7 |
| Age | 44.79 | (2.72) | 41–50 | | |
| Education | 8.63 | (2.65) | 6–13 | | |
| Cohort 5: 1948–57 | | | | 9 | 13 |
| Age | 36.36 | (2.66) | 32–40 | | |
| Education | 8.59 | (2.97) | 5–16 | | |
| Cohort 6: 1958–68 | | | | 11 | 11 |
| Age | 23.95 | (3.44) | 20–30 | | |
| Education | 10.09 | (2.96) | 5–15 | | |

## Measures

*Intelligence measure.* The five tests used to measure mental abilities of the Chinese subjects were Inductive Reasoning, Number, Space, Verbal Meaning, and Word Fluency (Thurstone, 1958).

*Verbal meaning.* This 50-item test measured the ability to comprehend words through the person's evidence of understanding verbal ideas and recognising words. This test was adapted to the Chinese language by choosing words of varying difficulty levels from the Chinese middle-school dictionary.

*Word fluency.* The intention of this measure was to test the speed and articulation of words that are used in speaking and writing. It measured a person's active vocabulary and the fluency with which words are retrieved from long-term memory using the lexical rule. In the adaptation of the Word Fluency test the lexical rule was modified. Instead of generating words starting with the same letter, such as the letter "s" used in the Seattle Longitudinal Study, here the subjects were asked to generate multiple Chinese words/characters that start with the most common radical (上). This radical, which means "up or above", served as a root from which other words were generated.

*Inductive reasoning.* This measure referred to the ability to identify regularities and to infer principles or rules. This ability was assessed by performance on a Number Series test involving induction of a rule in a series of numbers in order to pick the next number.

*Number.* This ability was assessed by performance on addition problems as quickly and accurately as possible. It required the subject to add and subtract to verify if the solution provided on the test was correct.

*Space.* In this test, subjects had to compare each abstract figure provided to them with multiple responses and select the figures that would match the stimulus figure on mental rotation. The tests for Reasoning, Numerical, and Spatial abilities do not require a verbal response and have been used widely in different cultures. We therefore only translated the instructions for these tests into Chinese. The five mental abilities were measured under accelerated conditions as specified in the original Thurstone tests using the same protocol as in the Seattle Longitudinal Study.

To ensure that the PMA tests have separate and characteristic abilities, the intercorrelations among the abilities were computed and are presented in Table 2. The low correlations provide substantial evidence for the distinctiveness of the abilities. In addition, internal consistency estimates for the tests were satisfactory, with .91 for Verbal, .95 for Number, .92 for Space, and .81 for Reasoning. The reliability for Word Fluency was not computed as the intention of the test was to measure the total number of words that could be generated under accelerated conditions.

**Table 2**
*Intercorrelations among PMA tests for the Chinese and US groups*

| *Ability* | *Verbal* | *Reasoning* | *Number* | *Space* |
|---|---|---|---|---|
| *Chinese group* | | | | |
| Verbal | | | | |
| Reasoning | .45 | | | |
| Number | .48 | .35 | | |
| Space | .40 | .47 | .33 | |
| Word fluency | .34 | .27 | .19 | .20 |
| *US group* | | | | |
| Verbal | | | | |
| Reasoning | .33 | | | |
| Number | .35 | .22 | | |
| Space | .39 | .36 | .24 | |
| Word fluency | .50 | .26 | .32 | .33 |

$p < .05$

*Environmental measure.* The Life Complexity Inventory (LCI; Gribbin et al., 1980) examines a broad range of adult activities and interests and includes data on interpersonal, work, social, structural, and cultural aspects of the participants' environment. These variables include basic demographic information, home environment questions, characteristics of the work or home-making environment, neighbourhood composition, travel, mobility, reading activities, continued educational pursuits and social network data (see Gribbin et al., 1980 and Schaie, 1996, for greater detail). The LCI also includes data on the frequency of leisure activities based on the work of Lowenthal and associates (Lowenthal et al., 1975).

The LCI used in the Seattle Longitudinal Study (SLS) was translated into Chinese and adapted to obtain comparable information on variables that make up the micro-environment of the adults in the Chinese sample. The measure was adapted in close consultation between the Chinese and American investigators, and the Chinese testers were trained to administer the LCI inventory following the same protocol as used in the SLS.

Because the sample size of the present study was inadequate, SLS data were examined to develop environmental and leisure dimensions that summarise the Life Complexity Inventory (O'Hanlon, 1993). To define the LCI dimensions, the total sample ($n = 1376$) was randomly split into two halves to provide a specification sample and a verification sample to test replicability of solutions found within the SLS sample. Exploratory factor analyses and model development were conducted using the first half of the sample. The fit indices for the seven factor model were: $\chi^2 = 1565$, $df = 373$, $p < .001$, GFI = .928, RMSR = .048. The resulting seven factor structure was cross-validated on the second sample using confirmatory factor analyses (LISREL 8 statistical software). Results showed no significant differences between the two samples in terms of age, $t(1366) = .35$, n.s., or gender, $\chi^2(1, N = 1368) = .05$, n.s., indicating that the two groups were comparable. The seven factors were labelled: (1) Work Complexity; (2) Social Status; (3) Prestige; (4) Physical Environment; (5) Social Network; (6) Mobility; and (7) Intellectual Environment. Table 3 lists items defining these dimensions. The final accepted structure of factor loadings and factor intercorrelations are presented in Table 4.

In addition, six leisure factors were developed from the list of leisure activities in the LCI. These factors were labelled: (8) Household; (9) Social Activity; (10) Educational/Cultural; (11) Fitness; (12) Solitary; and (13) Communication. The fit indices for this six factor model were: $\chi^2 = 225$, $df = 200$, $p < .001$, GFI = .981, RMSR = .027. Table 5 lists items defining these activity domains. Table 6 presents the final accepted structure of factor loadings and factor intercorrelations.

**Table 3**
*Life complexity variables included in factor analysis for the SLS sample*

| *Variable description* | *Variable label* |
|---|---|
| Marital status (married or unmarried) | Marriage |
| Occupation | Occupation |
| Income | Income |
| Educational level | Education |
| Changes in households during the last 5 years | Household |
| Changes in jobs during the last 5 years | Job |
| Changes in profession during the last 5 years | Profession |
| Number of neighbours you confide in | Neighbour |
| Number of visits to people not in your neighbourhood | Visit |
| Number of meetings you attended in the last month | Meeting |
| Own a home | Own home |
| Amount of art objects in home | Art |
| Number of books in the home | Book |
| Number of rooms in home | Room |
| Quality of air in the neighbourhood | Air |
| Number of trees in neighbourhood | Tree |
| Noise level in the neighbourhood | Noise |
| Number of magazines read in the last month | Magazine |
| Number of educational courses taken | Courses |
| Work status (coded as working vs. not working) | Worknow |
| Percentage of work hours spent reading | HourRead |
| Working with people | Employee |
| Working under time pressure | Pressure |
| Place where work occurs | WorkWhere |

*Modification and derivation of the Chinese version of the LCI.* Two demographic variables of the LCI were modified to take into account cultural differences. The variable occupational status was recoded to conform better with the Chinese culture's status hierarchy as persons holding occupational roles that involve comparable tasks in the USA and China may earn different incomes on a relative as well as absolute basis, and may represent quite different levels of occupational prestige. Occupational status was recoded following the guidelines presented in Che-Alford (1990). Total Family Income was also adjusted in accordance with China's currency value and typical income ranges.

Factor solutions obtained from the LCI in the SLS sample (O'Hanlon, 1993) were used in computing factor scores for the Chinese sample. To permit comparison across the various micro-environment dimensions, raw scores of LCI items were standardised into *T*-score form ($M = 50$, $SD = 10$) based on the total Chinese sample means and standard deviations. Then an unweighted composite of *T*-scores was calculated to obtain factor scores.

## Results

### *Differences in cognitive abilities*

Raw ability across were standardised into *T*-scores ($M = 50$, $SD = 10$) based on the total means and standard deviations. Table 7 presents the means, standard deviations, and range by age and gender on each of the cognitive abilities. Because the five Primary Mental Abilities are known to be moderately correlated, a Multivariate Analysis of Variance (MANOVA) was used. The five mental abilities were the dependent variables, and age was the independent variable.

**Table 4**
*LISREL maximum likelihood estimates for the final LCI model*

| *Variable* | *I* | *II* | *III* | *IV* | *V* | *VI* | *VII* | *U/var* |
|---|---|---|---|---|---|---|---|---|
| Education | .770 | | | | | | | .390 |
| Occupation | .758 | | | | | | | .426 |
| Marital status | | .538 | | | | | | .765 |
| Own home | | .535 | | | | | | .782 |
| Income | | .549 | | | | | | .362 |
| Room | | .711 | | | | | | .608 |
| Air | | | .690 | | | | | .516 |
| Tree | | | .694 | | | | | .526 |
| Noise | | | −.371 | | | | | .861 |
| Job | | | | .777 | | | | .447 |
| Household | | | | .588 | | | | .659 |
| Profession | | | | .377 | | | | .774 |
| Book | | | | | .546 | | | .704 |
| Art | | | | | .495 | | | .758 |
| Magazine | | | | | .358 | | | .871 |
| Courses | | | | | .383 | | | .852 |
| Neighbour | | | | | | .384 | | .857 |
| Meeting | | | | | | .523 | | .726 |
| Visit | | | | | | .367 | | .860 |
| HourRead | | | | | | | .488 | .761 |
| Worknow | | | | | | | .831 | .342 |
| Pressure | | | | | | | .536 | .707 |
| WorkWhere | | | | | | | −.698 | .470 |
| Employee | | | | | | | .395 | .834 |

| *Factor int* | *I* | *II* | *III* | *IV* | *V* | *VI* |
|---|---|---|---|---|---|---|
| I Prestige | | | | | | |
| II S/Status | .299 | | | | | |
| III Phy Env | .359 | .351 | | | | |
| IV Mobility | .093 | −.179 | −.081 | | | |
| V Int Env | .594 | .411 | .366 | −.028 | | |
| VI S/Net | .019 | −.048 | .111 | −.312 | .173 | |
| VII Work/C | .492 | .330 | .140 | .177 | .320 | −.355 |

*Notes*: From O'Hanlon (1993). U/var = Unique variance; Factor int = Factor intercorrelations; S/Status = Social Status; Phy Env = Physical Environment; Int Env = Intellectual Environment; S/Net = Social Network; Work C = Work Complexity.

**Table 5**
*Leisure activity list*

| *Activity* | *Variable label* |
|---|---|
| Participant sports | Sport |
| Outdoor hobbies | Outdoor |
| Participant in educational activities | Educ |
| Cultural activities | Cult |
| Visiting | Visit |
| Social life and parties | Social |
| Shopping | Shop |
| Handicrafts | Craft |
| Solitary games or hobbies | Alone |
| Daydreaming and reminiscing | Dream |
| Writing/correspondence | Write |
| Cooking | Cook |
| Household chores | Chore |

*Cohort and gender differences.* A significant multivariate main effect was detected for birth cohort ($p < .001$; Wilk's lambda). Univariate analyses for each of the five abilities were examined. Bonferroni analyses with adjusted alpha levels indicated that

**Table 6**
*LISREL maximum likelihood estimates for the final activity model for the SLS sample*

| *Variable* | *H/h* | *S/Act* | *Ed/Cul* | *Fit* | *Sol* | *Comm* | *U/var* |
|---|---|---|---|---|---|---|---|
| Cook | .807 | | | | | | .348 |
| Chore | .733 | | | | | | .463 |
| Shop | .427 | | | | | | .654 |
| Visit | | .696 | | | | | .516 |
| Social | | .363 | | | | | .701 |
| Educ | | | .625 | | | | .609 |
| Cult | | | .565 | | | | .681 |
| Sport | | | | .386 | | | .851 |
| Outdoor | | | | .301 | | | .848 |
| Alone | | | | | .487 | | .763 |
| Craft | | | | | .603 | | .637 |
| Dream | | | | | | .533 | .715 |
| Write | | | | | | .356 | .710 |
| *Factor int* | *H/h* | *S/Act* | *Ed/Cul* | *Fit* | *Sol* | | |
| H/h | | | | | | | |
| S/Act | .431 | | | | | | |
| Ed/Cul | .199 | .400 | | | | | |
| Fit | −.022 | .375 | .485 | | | | |
| Sol | .406 | .478 | .300 | .200 | | | |
| Comm | .360 | .709 | .588 | .452 | .380 | | |

*Notes*: From O'Hanlon (1993). H/h = Household; S/Act = Social Activity; Ed/Cul = Educational/Cultural; Fit = Fitness; Sol = Solitary; Comm = Communication; U/var = Unique variance; Factor int = Factor intercorrelations.

**Table 7**
*Mean ability scores by age and gender*

| *Cohort* | *Verbal* | *Space* | *Reason* | *Number* | *Wd fluency* |
|---|---|---|---|---|---|
| Cohort 1 | | | | | |
| Mean | 47.92 | 44.50 | 47.08 | 46.33 | 41.67 |
| (SD) | (10.08) | (5.55) | (7.04) | (7.15) | (9.33) |
| Range | 29–64 | 38–59 | 36–57 | 33–58 | 31–55 |
| Cohort 2 | | | | | |
| Mean | 45.43 | 43.44 | 43.48 | 43.63 | 44.97 |
| (SD) | (10.24) | (5.76) | (4.45) | (6.81) | (7.38) |
| Range | 26–60 | 33–56 | 36–53 | 32–56 | 34–63 |
| Cohort 3 | | | | | |
| Mean | 46.87 | 49.89 | 46.37 | 47.70 | 51.72 |
| (SD) | (7.35) | (10.17) | (7.11) | (10.22) | (9.88) |
| Range | 30–62 | 35–75 | 36–70 | 32–75 | 35–75 |
| Cohort 4 | | | | | |
| Mean | 52.58 | 53.79 | 51.75 | 52.69 | 51.75 |
| (SD) | (10.70) | (10.56) | (11.33) | (9.24) | (6.36) |
| Range | 28–70 | 36–75 | 36–70 | 39–75 | 35–60 |
| Cohort 5 | | | | | |
| Mean | 51.77 | 52.84 | 50.85 | 53.10 | 55.06 |
| (SD) | (10.59) | (8.36) | (8.81) | (8.69) | (9.31) |
| Range | 31–73 | 39–66 | 36–75 | 36–75 | 35–75 |
| Cohort 6 | | | | | |
| Mean | 55.64 | 53.68 | 57.59 | 52.59 | 54.77 |
| (SD) | (8.12) | (11.03) | (10.98) | (7.22) | (5.18) |
| Range | 41–74 | 32–72 | 36–75 | 39–66 | 42–65 |
| *Gender* | | | | | |
| Males | | | | | |
| Mean | 50.62 | 51.31 | 50.21 | 49.79 | 49.75 |
| (SD) | (10.12) | (9.86) | (10.11) | (9.78) | (8.53) |
| Range | 26–74 | 35–72 | 36–75 | 32–75 | 35–75 |
| Females | | | | | |
| Mean | 49.45 | 48.07 | 48.84 | 48.89 | 48.83 |
| (SD) | (9.96) | (9.76) | (9.29) | (8.47) | (9.99) |
| Range | 29–73 | 32–75 | 36–75 | 33–75 | 31–75 |

on all abilities, cohorts 1, 2, and 3 (50-, 60-, and 70-year-old persons) performed significantly lower than the younger three cohorts. A significant main effect for gender was found for Spatial ability with men obtaining a higher average performance than women, $F(1, 109) = 4.01$, $p < .05$. Table 8 lists the summary of univariate analyses for each ability that revealed significant cohort and gender differences.

*Nonlinear effects.* The patterns of cohort differences presented in Figure 1 suggest that the association between age and cognitive performance may be nonlinear. To observe the nature and form of the nonlinear association between age and cognitive performance, Age was entered into a multiple regression equation as a set of coefficients of orthogonal polynominal terms. Such a procedure can be used to test the linearity and nonlinearity of the relation between age and cognitive performance. The following variables were entered in a hierarchical fashion beginning with Age, $Age^2$, $Age^3$, Gender, Age × Gender, $Age^2$ × Gender, $Age^3$ × Gender, and Education. If nonlinearity is present in the relationship between age and cognitive performance, the cumulative $R^2$ that is due to the addition of the quadratic variable to the equation should be significant (Cohen & Cohen, 1983).

As presented in Table 9, there was an instance where age had a nonlinear relationship with mental abilities. The only component of Age that accounted for trivial amounts of additional variance was the cubic effect on the Number ability. $Age^2$ × Gender was the only interaction term that contributed a small increment of variance to the prediction of Space ability.

*Gender effect.* The addition of gender to the equation resulted in nonsignificant changes in $R^2$ (see Table 9). Thus, gender was not significant in terms of predicting cognitive abilities in this sample.

*Education.* As education has been found to be moderately correlated with mental abilities, the effect of education on cognitive performance was also added to the equation. For the regression of education on the five abilities, the $R^2$ change was .07 ($p < .05$) for Verbal ability only (see Table 9). Education did not significantly increase the prediction of other abilities.

## *Environmental dimensions and cognitive performance*

The relationship between environmental factors and mental ability scores was next examined. In Table 10, the zero-order correlations between environmental factors and ability scores are presented. Positive correlations suggest that a high score on a given environmental factor is associated with higher ability. Of the seven dimensions, Intellectual Environment was the

**Table 8**
*Summary of univariate effects for cohort and gender differences on cognitive abilities*

| *Ability* | *Cohort*[a] (*F*) | *Sex*[b] (*F*) |
|---|---|---|
| Verbal | 3.53** | 0.42 |
| Space | 5.45** | 4.01* |
| Reason | 6.88** | 0.68 |
| Number | 4.48** | 0.31 |
| Word fluency | 7.78** | 0.35 |

[a]*df*(5,109); [b]*df*(1,109); * $p < .05$; ** $p < .01$.

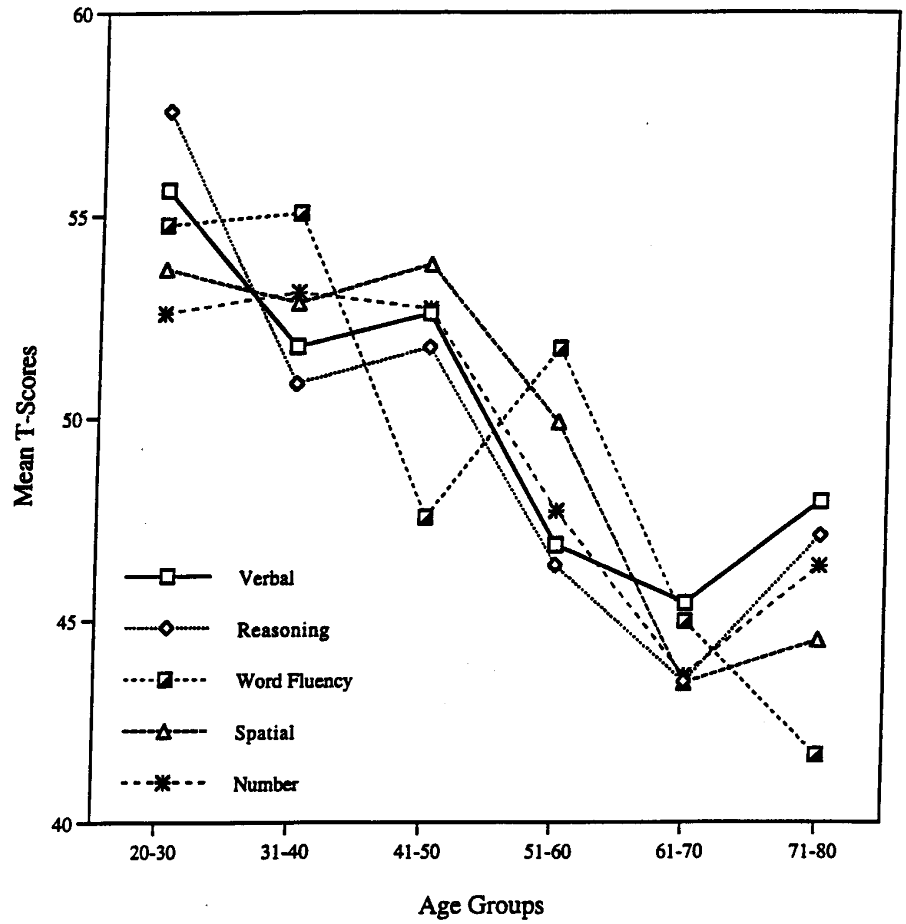


**Figure 1.** Cohort differences on levels of cognitive abilities.

only factor that was significantly associated with all ability scores with correlations ranging from $r = .20$ to .32.

The Prestige factor had a positive correlation with Verbal ability ($r = .26, p < .05$). Although the Work factor revealed a pattern of negative correlations with all ability scores, this relationship was significant only with Word Fluency ($r = -.26$, $p < .01$), Inductive Reasoning ($r = -.22$, $p < .05$), and Number ($r = -.23, p < .01$). A pattern of negative correlations was also detected for the Physical Environment and Social Network factors, but was significant only for Number ($r = -.22$, $p < .05$), and Verbal ability and Word Fluency ($r = -.21$, $r = -.17$, $p < .05$), respectively. Whereas positive correlations may indicate that a particular factor (e.g., Intellectual, Prestige, Education/Culture) enriches cognitive competence, negative correlations (e.g., Work Complexity and Physical Environment) are associated with less flexibility in intellectual functioning.

*Activity dimensions and cognitive functioning.* The activity levels were also correlated with the PMA ability scores (see

**Table 9**
*Hierarchical regression results testing for nonlinearity in the age-cognitive performance relationship*

| | *Verbal* | | *Space* | | *Reason* | | *Number* | | *Wd fluency* | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Effect* | $R^2$ | $\Delta R^2$ | $R^2$ | $\Delta R^2$ | $R^2$ | $\Delta R^2$ | $R^2$ | $\Delta R^2$ | $R^2$ | $\Delta R^2$ |
| Age | .11* | | .14* | | .18* | | .13* | | .20* | |
| Age$^2$ | .12 | .01 | .15 | .01 | .20 | .02 | .13 | .00 | .20 | .00 |
| Age$^3$ | .12 | .00 | .16 | .01 | .20 | .00 | .17 | .04* | .20 | .00 |
| Gender | .13 | .01 | .18 | .02 | .21 | .01 | .17 | .00 | .20 | .00 |
| Age × Gender | .14 | .01 | .20 | .02 | .22 | .01 | .17 | .00 | .20 | .00 |
| Age$^2$ × Gender | .15 | .01 | .23 | .03* | .23 | .01 | .17 | .00 | .21 | .01 |
| Age$^3$ × Gender | .15 | .01 | .25 | .02 | .23 | .00 | .18 | .01 | .21 | .01 |
| Education | .22 | .07* | .25 | .00 | .24 | .01 | .19 | .01 | .22 | .01 |

*$p < .05$.

**Table 10**
*Correlations between environmental and leisure factors with cognitive measures*

| | *Verbal* | *Space* | *Reason* | *Number* | *Wd fluency* |
|---|---|---|---|---|---|
| *Env factors* | | | | | |
| Work C | −.11 | −.16 | −.22* | −.23** | −.26** |
| S/Status | .00 | −.16 | −.04 | .03 | .06 |
| Prestige | .26** | .02 | .05 | .05 | .16 |
| Phy Env | −.16 | −.04 | −.08 | −.22* | −.10 |
| S/Net | −.21* | −.05 | −.05 | −.07 | −.17* |
| Mobility | .11 | .08 | .11 | .11 | .14 |
| Int Env | .28** | .20* | .25** | .22* | .19* |
| *Act factors* | | | | | |
| H/h | −.09 | −.00 | −.05 | −.09 | .02 |
| S/Act | .10 | .10 | .09 | .11 | −.03 |
| Ed/Cul | .18* | .03 | .03 | .06 | .13 |
| Fit | .03 | .09 | .13 | −.04 | −.18* |
| Sol | −.03 | −.04 | −.08 | −.03 | .08 |
| Comm | −.03 | .07 | .05 | −.06 | −.06 |

$^*p < .05$; $^{**}p < .01$. Env factors = Environmental factors; Work C = Work Complexity; S/Status = Social Status; Phy Env = Physical Environment; S/Net = Social Network; Int Env = Intellectual Environment; Act factors = Activity factors; H/h = Household; S/Act = Social Activity; Ed/Cul = Educational/Cultural; Fit = Fitness; Sol = Solitary; Comm = Communication.

Table 10 for summarised results). However, only Fitness was found to have a significant negative correlation with the Word Fluency ability ($r = -.18$, $p < .05$) and Educational/Cultural was positively correlated with Verbal ability ($r = .18$, $p < .05$).

Partial correlation analysis was carried out to examine the interrelationships between cognitive abilities and environmental factors. The correlation between Prestige and Verbal ability remained highly significant when gender and age trends were controlled (partial correlation coefficient, $r = .27$, $p < .01$). Similarly, controlling for gender and age trends also resulted in a significant correlation between Fitness and Word Fluency (partial correlation coefficient, $r = .20$, $p < .05$). The remaining correlations were not significant when gender and age trends were introduced to the equation.

Although these relationships were significant, they were generally of low magnitude and were relatively inconsistent. Thus, these results should be interpreted with caution, and these findings should be replicated with larger samples before attempting further inferences.

## Discussion

A primary goal of this study was to examine patterns of cohort and gender differences in intellectual performance in Chinese adults. Regarding this goal, results indicated that older subjects, on average, performed lower on all of the primary mental ability tests. Across all abilities, the average performance of the 20- to 30-year-olds was significantly higher than that of those over 60 years old. This finding falls in line with previous research. Prior studies on age-test performance have found evidence for significant age effects at the upper end of the lifespan (Avolio & Waldman, 1994; Salthouse, 1991; Schaie, 1990). These results confirm and provide consistency in the lifespan literature that focuses on cognitive abilities and test performance across different age groups.

With the exception of Word Fluency, the performance level seemed to be significantly lower after age 60 as observed in the data. Confirming prior research (Avolio & Waldman, 1994; Hultsch et al., 1993; Schaie, 1983), results from the present study indicate that differences in intellectual performance across age groups were relatively small until at least age 65.

In terms of predicting cognitive performance, age was found to be linearly related to mental abilities. This conclusion is evident in the regression analyses testing for age trend effects. Thus, as supported from some of the literature on cognitive ageing, there is evidence of linear age differences with older groups generally having lower scores than young groups (Chodzko-Zajko, 1991; Cockburn & Smith, 1991; Salthouse, 1991, 1992; Schaie, 1996).

The age differences found from the current study and other published studies may provide qualified support for the hypothesis proposed by Baltes and Lindenberger (1997) and Baltes and Smith (1997). That is, because of the levelling effects of neurobiological processes on cognition, older adults tend to perform less well on abilities such as reasoning, spatial cognition, and fluid intelligence (Mayr & Kliegl, 1993; Salthouse, 1991, 1992; Schaie, 1996). Alternatively, the declines in cognitive functioning could also occur due to cohort effects (Park et al., 1999; Schaie, 1996). For example, Geary et al. (1996) found that although older Chinese and Americans performed at the same level on mathematical skills, young Chinese and Americans were different. Perhaps there was a lesser focus on mathematics education for the two older cohorts as compared to a stronger emphasis on mathematical skills in China in recent years.

The evidence regarding gender differences in this study was less consistent with earlier studies. Contrary to prior research which generally found males to excel in mathematical and spatial abilities and females to excel in verbal ability (Benbow, 1988; Gentile, 1993, Harris, 1978; Jacklin, 1989; Lynn, 1992; Maccoby & Jacklin, 1974; Schaie, 1996), the current study did not find such a pattern. However, it is consistent with other studies that have arrived at the same conclusion (Feingold, 1994; Mayes & Jahoda, 1988; Sasanuma et al., 1985). That is, although findings of greater male variability in mathematical and spatial abilities were evident in the USA, they were not always found in other non-Western cultures.

Perhaps it is difficult to reconcile the literature on sex differences because data do not often replicate each other. Even though the findings in this study agree with a number of related studies, they fail to replicate others (Caplan, MacPherson, & Tobin, 1985; Sasanuma et al., 1985; Schaie, 1996). This inconsistency may be attributed to the use of different tests and different test procedures, in addition to the focus on different points in development. All of these factors must be considered for systematic comparisons to occur and for universal statements to be viable.

Seven dimensions of the environment that were labelled Prestige, Social Status, Physical Environment, Mobility, Intellectual Environment, Social Network, and Work Environment were correlated with the five mental abilities. A major finding in this study was that across all abilities, Intellectual Environment was significantly correlated with all mental abilities. This finding is expected as this factor appears to measure aspects of the environment (e.g., number of books and art objects in home, number of educational courses taken, number of magazines read) that are related to cognitive performance. However, the relationship between Intellectual

Environment and cognitive performance disappeared after age was entered into the equation.

Overall, the pattern of correlations between the LCI factors and the five mental abilities was found to be generally low compared to previous research (Arbuckle, Gold, & Andres, 1986; Arbuckle, Gold, Andres, Schwartzman, & Chaikelson, 1992; Avolio & Waldman, 1990; Boxtel, Langerak, Houx, & Jolles, 1996; Chase-Lansdale & Gordon, 1996; Fozard & Nuttall, 1972; O'Hanlon, 1993; Phillip, 1991). These results do not necessarily imply that there is no evidence of association between environmental factors and cognitive performance among Chinese adults. Indeed, they may simply suggest that the meaning of environment in Western cultures is different from that in non-Western societies. Because the Life Complexity Inventory questionnaire was initially developed in the USA, it is reasonable to suspect that not all items are equally meaningful in China. In addition, it should be noted that data on the LCI questionnaire were collected as a replication of existing research (the Seattle Longitudinal Study). No efforts were made to develop new indicators for the Chinese environment. The present study's objectives were examined within this framework.

### *Limitations and future research*

Because the data used in this study were cross-sectional, test patterns across cohorts may be attributed to ageing, as well as time of measurement and cohort effects (Schaie, 1996). Therefore, the results are limited in terms of describing issues related to intra-individual changes in abilities with age. This study offered the possibility to examine whether and to what extent hypotheses tested and confirmed in Western samples hold for a non-Western culture. When research is extended in a cross-cultural direction, we are faced with the issue of comparability or equivalent of cross-cultural data (Hui & Triandis, 1985). Therefore, the results found in this study should be interpreted with caution for several reasons. The present study was hampered by the lack of a representative taxonomy explicitly developed to describe the environment in a Chinese population. The LCI dimensions analysed in this study were quantified by factor analytic methods using data from the SLS sample. The measurement precision is limited due to the assumption that the LCI dimensions are equivalent in both cultures. This assumption remains to be tested.

In terms of ability performance, there is a paucity of data regarding gender differences among individuals from non-Western countries. Results from the current study indicated that age and environmental factors were more important than gender, although gender differences were found for spatial ability. Yet any male-female differences may be influenced by cohort-effects, as evident in the SLS data regarding gender-specific cohort differences (Schaie, 1990). Given that men generally averaged higher scores on certain portions of intelligence tests, it is still not possible from the data to explain why this difference occurred. More research is needed to probe the biologically based accounts of individual differences or other sociological and cultural factors that may be important to identify gender differences (Alazarov-Por, 1983; Benbow, 1988; Geschwind & Galaburda, 1987; Lieblich, 1985). Because there is relatively little research regarding gender differences, studies such as this one may point to areas where future research might focus to clarify the inconsistencies found in the current literature. In addition, because the LCI questionnaire was essentially a replication of the Seattle Longitudinal Study, future research could define and operationalise items specific to dimensions characteristic of the culture being examined.

The environments may play an important role in the prediction of cognitive abilities, but they may have stronger implications for other areas of life, such as personality, life and work satisfaction, and health. To do so there would need to be much better documentation of the extent and type of environment that describes the complexities of the relationships among environmental factors and other aspects of personal functioning. This study represents only an initial step toward the analysis of cognitive functioning as related to environmental factors. These findings lay important groundwork for additional research. Future studies may take many different directions. However, one possible direction is to replicate the LCI dimensions obtained from the SLS data and extend them to countries other than the USA and China. Hence, confirming and increasing and culture-general nature of the LCI environmental dimensions.

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