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This is the accepted version of a paper published in *Journal of Cross-Cultural Gerontology*. This paper has been peer-reviewed but does not include the final publisher proof-corrections or journal pagination.

Citation for the original published paper (version of record):

Sternäng, O., Lövdén, M., Kabir, Z N., Hamadani, J D., Wahlin, Å. (2016)
Different context but similar cognitive structures: Older adults in rural Bangladesh.
Journal of Cross-Cultural Gerontology, 31(2): 143-156
<https://doi.org/10.1007/s10823-016-9284-2>

Access to the published version may require subscription.

N.B. When citing this work, cite the original published paper.

Permanent link to this version:

<http://urn.kb.se/resolve?urn=urn:nbn:se:hj:diva-29395>

Different context but similar cognitive structures: Older adults in rural

Bangladesh

Ola Sternäng^{1,2}, Martin Lövdén³, Zarina N. Kabir⁴, Jena D. Hamadani⁵, & Åke

Wahlin^{1,3,6,7}

¹Institute of Gerontology, School of Health Sciences, Jönköping University, Sweden,

²Stockholm Brain Institute, Sweden, ³Aging Research Center, Karolinska Institutet,

Sweden, ⁴Department of Neurobiology, Care Sciences and Society, Karolinska

Institutet, Sweden, ⁵International Centre for Diarrhoeal Disease Research, Dhaka,

Bangladesh, ⁶Department of Psychology, Stockholm University, Sweden, ⁷School of

Medicine, University of Queensland, Brisbane, Australia

Address for correspondence: Ola Sternäng, Institute of Gerontology, School of Health

Sciences, Jönköping University, Box 1026, SE-551 11 Jönköping, Sweden

Phone: +46 (36) 101328, Email: ola.sternang@hhj.hj.se

Abstract

Most research in cognitive aging is based on literate participants from high-income and Western populations. The extent to which findings generalize to low-income and illiterate populations is unknown. The main aim was to examine the structure of between-person differences in cognitive functions among elderly from rural Bangladesh. We used data from the Poverty and Health in Aging (PHA) project in Bangladesh. The participants ($n = 452$) were in the age range 60-92 years. Structural equation modeling was used to estimate the fit of a five-factor model (episodic recall, episodic recognition, verbal fluency, semantic knowledge, processing speed) and to examine whether the model generalized across age, sex, and literacy. This study demonstrates that an established model of cognition is valid also among older persons from rural Bangladesh. The model demonstrated strong (or scalar) invariance for age, and partial strong invariance for sex and literacy. Semantic knowledge and processing speed showed weak (or metric) sex invariance, and semantic knowledge demonstrated also sensitivity to illiteracy. In general, women performed poorer on all abilities. The structure of individual cognitive differences established in Western populations also fits a population in rural Bangladesh well. This is an important prerequisite for comparisons of cognitive functioning (e.g. declarative memory) across cultures. It is also worth noting that absolute sex differences in cognitive performance among rural elderly in Bangladesh differ from those usually found in Western samples.

Key words: cognitive sex differences, cognitive structure, individual differences, literacy, low-income countries

Word count (main text incl. references): 6,253

Introduction

Most studies on cognition and cognitive aging have been conducted in developed countries, and mainly on Western populations (Park & Gutchess, 2006). Our knowledge is limited about how the structure of individual differences in cognitive functions is organized in other cultures, or in developing countries. The present study is unique in that we used data from the Poverty and Health in Aging (PHA) project (Kabir et al., 2006) in Bangladesh (a low-income country) to study the structure of individual differences in cognition, mainly long-term declarative memory. At present, the dominant view is that our memory is organized in different forms, interacting with one another, but with separate features (e.g., Eichenbaum & Cohen, 2001; Schacter, Wagner, & Buckner, 2000; Squire, Stark, & Clark, 2004). The view proposed by Schacter and Tulving (1994) includes five memory systems: working memory, procedural memory, the perceptual representation system, episodic memory, and semantic memory. Episodic and semantic memory constitutes long-term declarative memory. These two memory forms are interrelated and also correlate highly with for example processing speed (Verhaeghen & Salthouse, 1997). Nyberg et al. (2003) have shown that both episodic and semantic memory can be further divided into sub-forms, such as recall and recognition for episodic memory, and verbal fluency and semantic knowledge for semantic memory.

To be able to study cognitive functions cross-culturally, the structure of individual differences in cognition needs to be the same in the studied cultures (i.e. measurement equivalence across cultural groups is required; see e.g., Meredith, 1993). The main aim of the present study was to examine the structure of individual differences between persons in cognition (recall, recognition, verbal fluency, semantic knowledge, and processing speed) in older people (≥ 60 years) from rural Bangladesh. To the best of our knowledge, no study has yet examined the structure of these cognitive abilities in adults in Bangladesh (or in other low-income countries). There are, however, a few studies that have examined the structure of other

abilities in low-income countries (e.g., Ghorbani, Watson, & Hargis, 2008 [emotional intelligence]) and in other Asian countries (e.g., H. Chen, Keith, Weiss, Zhu, & Li, 2010 [intelligence for children]; Fukuda, Saklofske, Tamaoka, & Lim, 2012 [emotional intelligence]). These few studies indicate that the structures of the examined abilities are rather similar to those found in the West. Our hypothesis was, therefore, that a model of the cognitive structure that is established on Western populations (c.f. Laukka et al., 2013; Nyberg, et al., 2003) also fit the Bangladesh data well, and that these cognitive abilities can be seen as separate entities also in Bangladesh. A second aim of the present study was to examine how some important demographic factors, such as age and sex, are related to cognitive performance and the structure of cognitive abilities. We were also interested in illiteracy, a low prevalence factor in Western research, while highly prevalent in the developing countries. Age was chosen because of our focus on cognitive aging. There is probably a selection effect before 60 years of age because of great pressure from socio-economic situations and living conditions (see Sternäng, Kabir, Hamadani, & Wahlin, 2012), which may have an impact on the outcomes.

Our sample is, therefore, interesting to study and probably not representative for the younger part of the population in Bangladesh. Sex was chosen because sex differences in Bangladesh are much different to those typically found in the West (e.g., Herlitz & Kabir, 2006). Until recently, men have lived longer than women in Bangladesh, which is contrary to all western societies. Also, there are profound sex differences in literacy, which was also found in our sample. Literacy is an education variable, and the structure of individual differences in cognition might be education-related (see Whitfield, Allaire, Gamaldo, & Bichsel, 2010). Literacy is important in this context because it is closely associated with cognitive performance (e.g., Herlitz & Kabir, 2006; Sternäng, et al., 2012), and illiteracy is highly prevalent in the elderly adult population of Bangladesh.

The present study is important for future studies that aim to compare cognitive data from Bangladesh (representing low-income countries) with data from high-income countries. The present study also investigates measurement equivalence (e.g., Bontempo & Hofer, 2007; Meredith, 1993) across age, sex, and literacy, which is crucial for comparisons of cognitive abilities between different age groups, between women and men, and between illiterates and literates within Bangladesh. In the present study, measurement invariance was examined up to weak (or metric) and strong (or scalar) invariance levels (Blankson & McArdle, 2013; Bontempo & Hofer, 2007; Meredith, 1993). In a weak invariance model, factor loadings are equal across groups, and in a strong invariance model, both factor loadings and intercepts of the manifest indicators are constrained to be equal across groups.

Methods

Participants

Focus of the PHA project (Kabir, et al., 2006) is to study aging in rural Bangladesh in relation to biological, environmental, and societal factors. The participants lived in Matlab, a rural area in Bangladesh situated about 60 kilometers southeast of the capital Dhaka. The research organization International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) has systematically built up a register since 1966, which comprised about 220 000 persons from 142 villages in this area in 2003. A random sample of 850 persons who were 60 years of age or older was drawn from the register. Towards the end of 2003, after obtaining consent from the participants, they were interviewed in their home, and then brought to a nearby health station for clinical and cognitive examinations. Of the total selected sample of 850 persons, 625 underwent interviews. The reasons behind these dropouts were mainly because people had migrated or could not be reached (104), had died before the start of data collection (63), or were registered twice in the database (11). Only 38 declined to participate. Four-hundred-and-seventy-one finished both interviews and examinations (for dropouts in

PHA, see Kabir, et al., 2006). The participants that did not undergo examinations were mainly women, were older and had poorer socioeconomic status than the participants that completed both interviews and examinations, but their health status was similar (Ferdous, Cederholm, Kabir, Hamadani, & Wahlin, 2010). Dementia screening was made by geriatricians based on criteria according to DSM-IV (American Psychiatric Association, 1994). Exclusion of participants diagnosed with dementia and multivariate outliers (using Mahalanobis distance) resulted in a final sample of 452 persons (249 women and 203 men) who were between 60 and 92 years of age at the time of examination (Mean age 69.3, SD 6.8). For characteristics of the final sample, see Table 1.

 Insert Table 1 about here

Cognitive variables

In the cognitive test battery, we replaced, where relevant, verbal stimulus materials with pictures. This was done in order to be able to assess illiterate participants who comprised more than 60% of the final sample. Also, the test material in PHA was adapted to the Bengali culture and all tasks were subjected to a series of pilot testing before the start of the study, where each instrument was evaluated at the item level to secure its properties to assess both literate and illiterate participants. The focus of the present study was on five cognitive variables. Four of them, recall, recognition, verbal fluency and semantic knowledge are often regarded as long-term declarative memory (Nyberg et al., 2003), Verbal fluency may, however, also be considered as an aspect of executive control (Shao, Janse, Visser, & Meyer, 2014). The fifth studied cognitive ability, processing speed, is a measure of cognitive processing efficiency.

The cognitive tests were as follows (two in each cognitive domain):

Recall. In the first recall test, the investigator read aloud 12 words. The presentation interval was 5 s for each word during which the words were presented. In the second test of 12 pictures of objects, the investigator termed and showed the pictures simultaneously (5 s per object). In both tests, 2 min were allotted for verbal recall and the number of correctly recalled words or objects constituted the test scores.

Recognition. One test was a free-choice (yes/no) recognition test of 12 words (same words as in recall test 1) together with 12 distractors. The other test was a recognition test of 12 pictures of objects (same pictures of objects as in recall test 2) together with 12 distractors. The test scores in both tests were the number of hits minus false alarms.

Verbal fluency. In the first verbal fluency test, the participant was instructed to say as many different animal names as possible in one minute, and in the second test, the participant was asked to say as many different exemplars of food as possible in one minute. In both tests, the test score was the number of correct words.

Semantic knowledge. The first knowledge test concerned the meaning (synonyms) of 20 words. There were three alternatives for each target word and the score was the number of correct alternative choices. Of the two distractors, one word was semantically nearly related to the presented word, and the other one was totally different from the presented word. The second test was a culture-adapted version of WAIS-R Information test and contained 20 semantic knowledge questions. These questions varied from concrete (e.g. which color is included in the Bangladeshi flag?) to abstract (e.g. why do humans stop growing at a certain age?). The test score was the number of correct answers.

Processing speed. In the first processing speed test, the participant was instructed to fill in the missing line in as many boxes, with a missing side, as possible during 1 min, and in the second test, to cross as many balls among several other symbols as possible during 30

seconds. The test scores were the number of boxes completed and the number of crossed balls, respectively.

Demographic variables

Age, sex, and literacy were included in the present study to represent demographic variables. The participants' age was double-checked with questions in relation to biological and historical events, since many people in rural Bangladesh do not know their exact age, and there was no formal birth registration system in earlier days. Determining age this way in low-income countries is well established (e.g., Allain et al., 1997). Literacy was a dichotomous variable (illiterate or literate) and a participant was classified as literate if the participant had reported that he or she could read and write Bangla.

Statistical Analyses

On the basis of previous findings from Western samples (e.g., Laukka, et al., 2013; Nyberg, et al., 2003), a five-factor cognitive model was tested through confirmatory factor analysis (CFA; see Figure 1) in order to examine if this cognitive model was effectual also for older people in rural Bangladesh.

Insert Figure 1 about here

The five latent cognitive variables (recall, recognition, verbal fluency, semantic knowledge, and processing speed) in the model were based on two observed cognitive indicators each. The indicators were: 1. Recall of random words, 2. Recall of objects, 3. Recognition of random words, 4. Recognition of objects, 5. Verbal fluency: animals, 6. Verbal fluency: food, 7. Meaning of words, 8. Factual knowledge, 9. Processing speed: boxes, 10. Processing speed: cross symbols. Since the recall and recognition tests were based on the

same stimuli, the error terms (between recall and recognition of random words, and between recall and recognition of objects) were allowed to correlate in the model.

Structural equation modeling was performed with IBM SPSS AMOS version 20 (Arbuckle, 2011) using maximum likelihood estimation. Alpha levels were set at $p < .05$. The absolute fit index used was the root mean squared error of approximation (RMSEA; Steiger, 1990), which can vary between 0 and 1. RMSEA values below .06 indicate good fit (Hu & Bentler, 1999).

The χ^2 difference (χ^2_{diff}) and the comparative fit index (CFI; Bentler, 1990) constituted comparative fit indices. The χ^2_{diff} can be used for comparing nested models (see Kelloway, 1998), and a better fitting model has a lower χ^2 value and a significant χ^2_{diff} compared to the other models. CFI values range between 0 and 1, and values above .95 indicate good comparative fit (Hu & Bentler, 1999). The difference in CFI, ΔCFI , has turned out to be a good indicator when testing for measurement invariance (Cheung & Rensvold, 2002), where a ΔCFI value greater than -.01 indicates non-invariance (Cheung & Rensvold, 2002). For sample sizes smaller than 300 participants, Chen (2007) suggests instead to use -.005 as cutoff.

To be able to compare results from different subpopulations, the tests used should show measurement equivalence (see Meredith, 1993) across the studied groups (e.g., women and men). If the structure of individual cognitive differences is not the same across groups, it makes it problematic to draw conclusions about group differences in those cognitive dimensions. We tested the five-factor cognitive model for measurement equivalence across age (two age groups: 60-70 years of age, $n = 287$ and 71-92 years of age, $n = 165$), sex (women, $n = 249$ and men, $n = 203$), and literacy (illiterates, $n = 274$ and literates, $n = 178$). The cutoff for the two age groups was a compromise between having identical group sizes and having a split in the middle of the age range. Measurement equivalence was tested

through multigroup CFA and included tests of weak (or metric) invariance (i.e. the factor loadings were the same across groups) (e.g., Horn & McArdle, 1992) and strong (or scalar) invariance, where also the intercepts were the same across groups (Bontempo & Hofer, 2007). A model where the parameters were allowed to differ between the two groups (the free model) was compared with a model where the factor loadings were constrained to be the same in both groups (the weak invariance model). The χ^2_{diff} and the ΔCFI were used as indicators where a non-significant χ^2_{diff} or a $\Delta\text{CFI} \leq -.005$ supported weak invariance. If the χ^2_{diff} instead was significant ΔCFI was greater than $-.005$, there was a difference in model fit between the free and the constrained model and at least one parameter was not invariant. In those cases, follow-up calculations with univariate tests of measurement equivalence were performed to examine for which variables the factor loadings differed. After testing for weak invariance, the fit of a strong invariance model (where both factor loadings and intercepts were constrained to be equal in both groups) was compared with the weak invariance model. To estimate the means for the factors, we set one of the intercepts to zero in both groups, for the same tests as we used for setting the factor loadings to 1 (see Figure 1). The intercept of the other test thus reflected the mean difference between the tests of an ability, and was in the free and weak invariance models allowed to differ between groups. In the model assuming strong invariance, this intercept parameter was fixed to equal across groups. If the indicators, χ^2_{diff} and ΔCFI , did not support strong invariance, then follow-up calculations with univariate tests were done in the same way as for test of weak invariance described above.

After testing for measurement equivalence, relationships among the three demographic factors (age, sex, and literacy) and the five latent cognitive variables were examined. The demographic factors were considered as exogenous variables (i.e. independent variables not predicted by the model) and the cognitive abilities as endogenous variables (i.e. dependent variables predicted by the model). First, the correlations between the demographic factors and

the latent cognitive variables were calculated. Next, a multiple regression model with age, sex, and literacy as independent variables was constructed. The two models made it possible to first observe the raw correlations, and then, in the multiple regression model, study the unique effects, for example, if sex has an effect on cognition when age and literacy have been covaried out.

Results

Structure of individual differences in cognitive abilities – confirmatory factor analysis

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Insert Table 2 about here

The fit indices of the five-factor model are listed in Table 2. The model demonstrated very good fit according to all indices (e.g. RMSEA = .027). Factor loadings and correlations of the standardized five-factor model can be seen in Figure 1. All factor loadings and correlations were significant.

Test of measurement equivalence for the demographic factors

We continued to examine if the five-factor model was sensitive to variations in age, sex or literacy. Our fit indicators supported both weak age invariance and strong age invariance (see Table 2). The ΔCFI values were smaller than -.005 and the χ^2_{diff} values were non-significant. Thus, the tested five-factor model was strongly age invariant for the tested age range, 60-92 years of age.

The five-factor model demonstrated also weak sex invariance, but when testing for strong sex invariance, the χ^2_{diff} value was significant and the ΔCFI value was above -.005. We continued, therefore, with univariate tests, which indicated strong sex invariance for recall,

recognition and verbal fluency, but not for semantic knowledge ($\chi^2_{\text{diff}} = 7.21$, $\text{df}_{\text{diff}} = 1$, $p = 0.007$) and processing speed ($\chi^2_{\text{diff}} = 9.92$, $\text{df}_{\text{diff}} = 1$, $p = 0.002$). To examine this partial strong sex invariance further, we examined the raw correlations between sex and knowledge and processing speed. The sex differences were larger in factual knowledge ($r = -.72$) than what they were in meaning of words ($r = -.48$) and men performed on a higher level on both. The sex differences were also larger in the speed test of crossing balls ($r = -0.61$) than in the test of completing boxes ($r = -.47$).

When testing for weak literacy invariance of the five-factor model, the ΔCFI value was within the border of $-.005$, but the χ^2_{diff} value was significant. According to the ΔCFI value, the full weak invariance should not be rejected, but to be cautious, we continued with univariate calculations. These comparisons revealed that recall ($\chi^2_{\text{diff}} = 2.92$, $\text{df}_{\text{diff}} = 1$, n.s.), recognition ($\chi^2_{\text{diff}} = 0.56$, $\text{df}_{\text{diff}} = 1$, n.s.), verbal fluency ($\chi^2_{\text{diff}} = 0.21$, $\text{df}_{\text{diff}} = 1$, n.s.), and processing speed ($\chi^2_{\text{diff}} = 0.02$, $\text{df}_{\text{diff}} = 1$, n.s.) were invariant for literacy, but that semantic knowledge was not ($\chi^2_{\text{diff}} = 8.93$, $\text{df}_{\text{diff}} = 1$, $p = 0.003$). This result remained even after controlling for age ($\chi^2_{\text{diff}} = 8.93$, $\text{df}_{\text{diff}} = 1$, $p = 0.003$). Since the ΔCFI value was $-.005$, we also tested for strong literacy invariance, and the indices supported strong literacy invariance of the model (see Table 2).

Relationships between Demographic and Cognitive Variables

The model for the relationships between demographic and cognitive variables is presented in Figure 2. Since semantic knowledge was not invariant for literacy, we refrained from analyzing effects of literacy on semantic knowledge.

The fit indices of the demographic-cognitive model demonstrated very good fit to the data (see Table 2). The model fit was identical for both the correlation and the multiple regression models below.

Insert Figure 2 about here

Correlation model. All correlations between the demographic and latent cognitive variables were significant (see Figure 2). The highest age correlation detected was that between age and recall ($r = -.38$) and the lowest was that between age and semantic knowledge ($r = -.11$). Two correlations within the demographic variables in the model were not significant and close to zero: the correlations between age and sex, and between age and literacy.

The correlations between sex and the latent cognitive variables showed that, in general, women performed poorer than men across all cognitive variables. The highest correlations were those between sex and semantic knowledge, and between sex and processing speed ($r = -.77$ and $r = -.63$, respectively), whereas the lowest correlations were those between sex and recall, and between sex and recognition ($r = -.17$ and $r = -.20$, respectively). All correlations are shown in the results in Figure 2, but note that semantic knowledge and processing speed did not show strong sex invariance. The raw correlations for the four semantic knowledge and processing speed tests were, however, also higher than for all the other cognitive tests.

Literacy showed strongest associations with verbal fluency and processing speed, and weakest associations with recall and recognition. Sex and literacy had a rather strong association: more women were illiterates (see Figure 2).

Insert Figure 3 about here

Multiple regression model. Since age was not correlated with sex or literacy, the associations between age and the five latent cognitive variables remained at the same levels in the multiple regression model (see Figure 3).

The relationships between sex and the latent cognitive variables decreased, in general, by approximately .10 (because of the associations of sex with literacy). The correlation pattern remained the same, but at a lower level. The relationship between sex and recall was no longer significant.

The correlations between literacy and the five latent cognitive variables were at a more similar level across the cognitive variables (range $r = .19 - r = .34$) in the multiple regression model.

Discussion

The main aim of the present study was to examine the structure of individual differences in cognitive functions, mainly long-term declarative memory, in older persons in rural Bangladesh. It was of great interest to examine if the structure documented in previous research, and conducted on Western populations, could be replicated at the conceptual level based on data from a population that differs greatly, at least culturally, demographically, and economically, from most Western populations. The perhaps most striking difference between this study and previous comparable work is the inclusion of sixty percent illiterates. We think that an important reason for performing studies of, for example, the structure of cognitive functions in very different (compared to Europe or USA) cultures is that the relative importance of background variables may vary (e.g., Sternäng, et al., 2012), representing the possibility of different causal mechanisms across cultures and/or effects due to inherent differences in the variables at focus (Zsembik & Peek, 2001). The present study shows that such variations are however not exerting a major impact on a very fundamental prerequisite in cognitive aging research: The structure of long-term declarative memory.

Our findings suggest that the structure of long-term declarative memory obtained in studies based on samples from high-income countries (e.g., Nyberg, et al., 2003) also fit well to individual differences in Bangladesh, although there is no literature using the identical set of cognitive abilities. This is in line with our first hypothesis. The five-factor model was rather stable and demonstrated both age (strong invariance) and sex invariance (partial strong invariance). Nyberg and colleagues also found age invariance (Nyberg, et al., 2003) and sex invariance (Maitland, Herlitz, Nyberg, Bäckman, & Nilsson, 2004) for their model including recall, recognition, verbal fluency, and semantic knowledge in samples with participants in the age range of 35-85 years of age. The partial strong sex invariance in the present study suggests that the five cognitive factors mean the same thing for both women and men, but caution should be taken when examining sex differences in means for latent factors for semantic knowledge and processing speed. Sex differences in semantic knowledge and processing speed need to be studied in a more nuanced manner since the mean differences are probably larger or smaller in certain aspects of semantic knowledge and in certain aspects of processing speed. These results indicate that men are relatively better than women in tests of factual knowledge than in tests of meaning of words. This may indicate a difference between direct knowledge versus more verbal ability and vocabulary and it is possible that women are relatively better in verbal ability. This is in line with findings that men, on average, perform about half a standard deviation higher on tests of general knowledge than women (Lynn & Irwing, 2002), which is nearly as strong as the male advantage in certain spatial tasks. In the tests of processing speed, men turned out to be relatively better than women in crossing balls than in drawing lines. These two are different type of speed tests, and maybe that can reflect slightly different aspects of processing speed. A review by Roivainen (2011) about sex differences in processing speed supports also the notion that processing speed may be divided into separate abilities.

However, our model also extended the findings by Nyberg and colleagues (Maitland, et al., 2004; Nyberg, et al., 2003) showing limited invariance for literacy. The χ^2_{diff} was significant when we tested for weak literacy invariance, but the ΔCFI value was, however, within its range, and the five-factor model demonstrated also strong literacy invariance with good values of the indices. We think, however, that caution should be made when using semantic knowledge in comparing illiterate and literate participants until this have been examined further. Importantly, it was only the dimension semantic knowledge that seems to mean different things (i.e. did not represent the same theoretical construct) for literates and illiterates. This might be reasonable in the light of that illiterates lack formal education. A well-established finding in studies of Western populations is that years of education are very important for cognitive test scores in old age (Bäckman, Small, Wahlin, & Larsson, 2000). Furthermore, years of education have normally, at least in the West, stronger impact on crystallized abilities, such as general knowledge and vocabulary, than on fluid abilities (e.g., Anstey & Christensen, 2000; Kramer, Bherer, Colcombe, Dong, & Greenough, 2004).

Another aim of the study was to examine if other demographic factors than in developed countries (e.g. literacy) would influence cognitive abilities. Our results from tests of the five-factor model and the demographic-cognitive model suggest that literacy is a very important demographic factor in Bangladesh, and perhaps in other developing countries. It appears in general to have a strong impact on absolute levels of cognitive performance, which has been demonstrated also in other studies (c.f. Sternäng, et al., 2012). The correlation between age and literacy was, however, close to zero.

The relationships between age and the cognitive variables seem to be in line with previous findings from Western samples (e.g., Nyberg, et al., 2003; Rönnlund, Nyberg, Bäckman, & Nilsson, 2005). Similar to such studies, semantic knowledge was the least age sensitive and recall was the most age sensitive. The most striking result was that sex did not

show the same relationships with these cognitive variables that we normally observe in Western samples. We would have expected a pattern such that women were better in verbal fluency, recall, and recognition, but that the sex differences would not be as large in semantic knowledge and processing speed (e.g., see Halpern, 2000). In the present study, it was instead men that performed, on average, at a higher level in all cognitive measures with the largest differences found in tests of semantic knowledge and processing speed. Women performed worse on all cognitive variables, but this difference was less pronounced in verbal fluency, recognition and especially recall (a difference which was not significant when considering literacy in the multiple regression model). Thus, it seems that the pattern of the relative cognitive sex differences among Bangladeshi older persons is similar to that usually found in Western samples, but that women overall perform at lower levels than those of men. One important factor behind women's poorer overall cognitive performance is probably the notable differences in lifestyle between women and men in Bangladesh (see Herlitz & Kabir, 2006; Sternäng, et al., 2012). Older men and women have in general lived very different lives in Bangladesh. Herlitz and Kabir (2006) described this with the terms private and public sphere. In rural Bangladesh, most of the women have to stay in the private sphere, which constitutes of the "bari" – some houses around a common courtyard, while the public sphere is open for men. The exposure to the complexities of the public sphere enables men to exercise and elaborate on their cognitive abilities. Women, on the other hand, do not have the same opportunities in rural Bangladesh. The cognitive tests applied in the present study are traditionally used in the West, and are designed with the basic assumption of a certain level of education. Had we used tests of the same cognitive abilities applying the kind of everyday life-education that these persons have in order to manage their livelihood and daily lives, we might not have ended up in a different structure, but certainly different levels of cognitive

ability. The formal education situation is improving in Bangladesh, but when our elderly participants were young, very few girls received formal education.

Even if the results are clear, there are some methodological limitations. First, the relationships between the demographic and cognitive variables were only analyzed within a cross-sectional design. Longitudinal studies are needed to avoid cohort effects and to analyze aspects of causality (Nilsson, Sternäng, Rönnlund, & Nyberg, 2009; Sternäng, Wahlin, & Nilsson, 2008). Second, only two indicators for each cognitive dimension were available. Three or more indicators per cognitive dimension would have been preferred. Third, PHA used adapted versions of already developed test materials from developed countries. If tests and methods had been developed in Bangladesh, and not just integrated with the Bengali culture with respect to stimulus material, such tools might have potentially revealed important features of the culture that likely cannot be explored with the present test instruments (see Greenfield, 1997).

Conclusions

This study demonstrated that recall, recognition, verbal fluency, semantic knowledge, and processing speed form separable abilities also among older persons in rural Bangladesh. The cognitive structure in our sample was found to be stable and the model demonstrated strong invariance for age and partial strong invariance for sex and literacy. Partial strong sex invariance suggests that caution should be taken when comparing mean differences between men and women in the latent factors semantic knowledge and processing speed since these sex differences might be different in different types of tests within these factors. The model was partially strongly invariant for literacy, since semantic knowledge (as the only cognitive ability) was sensitive to illiteracy. The findings are important since they indicate that it is possible to compare results from cognitive studies between Bangladesh and other countries,

and also between cognitive studies within Bangladesh for different age groups (≥ 60 years), for men and women, and for illiterates and literates (excluding semantic knowledge).

Literacy was in general a strong predictor of cognitive performance. It is worth noting that cognitive sex differences in Bangladesh differed from those usually found in Western samples. Women performed in general worse on all assessed cognitive abilities, with the smallest sex differences found in recall, recognition, and verbal fluency. Future research will determine what might be the cause of these cognitive sex differences.

Acknowledgements

This work was supported by Swedish Council for Research in the Humanities and Social Sciences (Dnr 421-2011-1621). The Poverty and Health in Ageing (PHA) was funded by Department for International Development (DfID), UK; Swedish Agency for Research Cooperation / Swedish International Development Agency; and the Swedish Research Council. We acknowledge the contribution of the staff in the PHA project.

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This manuscript includes 2 tables and 3 figures.

Table 1. Descriptive data for the final sample ($n = 452$)

Table 2. Fit statistics for the tested models

Figure 1. The five-factor model (standardized correlations and factor loadings, all p values below .001)

Figure 2. The demographic-cognitive correlation model (standardized correlations)

Figure 3. The demographic-cognitive multiple regression model (standardized regression weights)

Table 1. Descriptive Data for the Final Sample (n = 452)

Variables	Mean (SD)	Skewness	Kurtosis
Demographic			
Age	69.3 (6.8)	.89	.37
Women (%)	55		
Illiterate (%)	61		
Cognitive test scores			
Recall test 1	3.69 (1.44)	.27	.04
Recall test 2	5.12 (1.52)	-.27	.15
Recognition test 1	5.60 (2.51)	-.66	-.01
Recognition test 2	7.60 (2.72)	-1.50	1.47
Verbal fluency test 1	10.59 (3.81)	.35	-.21
Verbal fluency test 2	12.13 (3.58)	.16	-.04
Knowledge test 1	12.40 (3.43)	-.01	-.26
Knowledge test 2	11.11 (3.55)	.01	-.75
Processing speed test 1	25.64 (11.05)	.55	-.22
Processing speed test 2	9.72 (5.06)	.91	.26

Table 2. Fit Statistics for the Tested Models

Model	df	χ^2	RMSEA	CFI	Model	Δ df	χ^2 diff	Δ CFI
The five-factor model	23	30.58	.027	.996				
Test of age invariance:								
Free baseline model	46	79.53	.040	.981				
Weak invariance model	51	89.05	.041	.978	Weak vs. free	5	9.52 (n.s.)	-.003
Strong invariance model	56	98.26	.041	.976	Strong vs. weak	5	9.21 (n.s.)	-.002
Test of sex invariance:								
Free baseline model	46	57.26	.023	.992				
Weak invariance model	51	63.84	.024	.990	Weak vs. free	5	6.58 (n.s.)	-.002
Strong invariance model	56	84.76	.034	.979	Strong vs. weak	5	20.92 ($p = .001$)	-.011
Test of literacy invariance:								
Free baseline model	46	46.15	.003	1.000				
Weak invariance model	51	57.91	.017	.995	Weak vs. free	5	12.43 ($p = .029$)	-.005
Strong invariance model	56	61.30	.015	.996	Strong vs. weak	5	3.39 (n.s.)	.001

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The demographic – cognitive model	38	74.30	.046	.985				

Note. For tests of measurement invariance, the total sample ($n = 452$) was dichotomously divided into (a) young ($n = 287$) and old ($n = 165$), (b) men ($n = 203$) and women ($n = 249$), and (c) illiterates ($n = 274$) and literates ($n = 178$).

Figure 1. The five-factor model (standardized correlations and factor loadings, all p values below .001)

Note. Factor loadings were set to 1 for Recall test 1 (words), Recognition test 1 (words), Fluency test 1 (animals), Knowledge test 1 (synonyms), and Processing speed test 1 (boxes).

Figure 2. The demographic-cognitive correlation model (standardized correlations)

Note. Since the measurement model already has been tested, the figures relating to those associations are not included in the figure above.

* $p < .05$ (two-tailed), ** $p < .01$ (two-tailed), *** $p < .001$ (two-tailed)

Figure 3. The demographic-cognitive multiple regression model (standardized regression weights)

Note. Since the measurement model already has been tested, the figures relating to those associations are not included in the figure above.

* $p < .05$ (two-tailed), ** $p < .01$ (two-tailed), *** $p < .001$ (two-tailed)