Intelligence 40 (2012) 260–268

Contents lists available at SciVerse ScienceDirect

Intelligence

journal homepage:

Two thirds of the age-based changes in fluid and crystallized intelligence, perceptual speed, and memory in adulthood are shared

Paolo Ghisletta [a,b,*], Patrick Rabbitt [c,d], Mary Lunn [e], Ulman Lindenberger [f]

[a] Faculty of Psychology and Educational Sciences, University of Geneva, Boulevard du Pont d'Arve 40, 1211 Geneva, Switzerland
[b] Distance Learning University, Switzerland
[c] Department of Experimental Psychology, University of Oxford, 9 South Parks Road, Oxford, OX1 3UD, U.K.
[d] University of Western Australia, Perth, Australia
[e] Department of Statistics and St. Hughs' College, University of Oxford, 1 South Parks Road, Oxford, OX1 3TG, U.K.
[f] Center for Lifespan Development, Max Planck Institute for Human Development, Lentzeallee 94, 14195 Berlin, Germany

ARTICLE INFO

Article history:
Received 1 September 2010
Received in revised form 15 February 2012
Accepted 22 February 2012
Available online 16 March 2012

Keywords:
Cognition
Aging
Shared change
Longitudinal data
Multivariate multilevel model

ABSTRACT

Many aspects of cognition decline from middle to late adulthood, but the dimensionality and generality of this decline have rarely been examined. We analyzed 20-year longitudinal data of 6203 middle-aged to very old adults from Greater Manchester and Newcastle-upon-Tyne, UK. Participants were assessed up to eight times on 20 tasks of fluid intelligence, perceptual speed, memory, and vocabulary. We controlled for potential effects due to retest, city, sex, and socio-economic class. Average performance in all tasks declined with age, and individual differences in decline were present for all but one memory and two vocabulary tasks. Half of the variance in level of performance was shared across tasks. This proportion increased to 66% for individual differences in change. General level of performance and change therein correlated positively. We conclude that cognitive decline is heterogeneous across individuals and rather general at the within-individual level.

The dimensionality of cognitive change has long been the subject of cognitive aging research (Rabbitt, 1993). In particular, the question of the degree of generality in the rates of within-person changes within and across cognitive domains remains. The question "Is individual cognitive decline a general process, or is it differentially manifested across different domains?", albeit quite old, remains current.

The generality of adult cognitive decline can be investigated across and within persons. *Across persons*, the generality question can be phrased as, "Do all individuals eventually experience cognitive decline?" or "Is decline normative for the adult population?" *Within persons*, the question can be phrased as, "Does it all go together when it goes?" (Rabbitt, 1993) or "Does decline within a person tend to occur simultaneously across different cognitive abilities?" The across-person question corresponds to the identification of interindividual differences in change (i.e., variance in change), and the within-person question corresponds to the analysis of interrelations in within-person change (covariances in change). Either question requires the analysis of longitudinal data to directly estimate within-person change, and between-person differences therein (Baltes & Nesselroade, 1979).

Most recent analyses of longitudinal data indicate heterogeneity in rates of change and moderate to strong positive associations in such rates across different cognitive abilities (e.g., Anstey, Hofer, & Luszcz, 2003; de Frias, Lövdén, Lindenberger, & Nilsson, 2007; Ghisletta & Lindenberger, 2003; Habib, Nyberg, & Nilsson, 2007; Lindenberger & Ghisletta, 2009; Tucker-Drob, 2011; Wilson et al., 2002). Individuals do not change uniformly; while some experience marked decline, others decline less, or may even stay stable (Habib et al., 2007). At the same time, the within-person patterns of change display some regularity across different

* Corresponding author. Tel.: +41 22 379 91 31; fax: +41 22 379 91 60.
E-mail addresses: paolo.ghisletta@unige.ch (P. Ghisletta), patrick.rabbitt@psy.ox.ac.uk (P. Rabbitt), mary.lunn@st-hughs.ox.ac.uk (M. Lunn), lindenberger@mpib-berlin.mpg.de (U. Lindenberger).

0160-2896/$ – see front matter © 2012 Elsevier Inc. All rights reserved.
doi:10.1016/j.intell.2012.02.008

cognitive domains. Typically, little to no intraindividual change is detected in crystallized abilities, while much within-person change in fluid abilities, speed, and memory exists. It is across this latter group of abilities that some associations in rates of change appear. For instance, Anstey et al. (2003) found relatively strong correlations among eight-year rates of change in speed and memory tasks ($r = .52$) after statistically controlling for age, gender, education, depressive symptoms, general physical health, and medical condition. Wilson et al. (2002) analyzed six-year longitudinal behavioral data on episodic and semantic memory, working memory, perceptual speed, and visuospatial abilities tasks. They found that the rates of change in all domains correlated moderately to strongly, even when controlling for practice effects (from $r = .37$ to $r = .78$). Moreover, a principal component analyses revealed that the first component of the rates of change accounted for 61.8% of their variance. Lindenberger and Ghisletta (2009) found strong to very strong correlations across rates of change over 13 years in perceptual speed, memory, and verbal fluency tasks after control for age, time to death, and risk of dementia (from $r = .51$ to $r = 1.00$, mean $r = .81$). Furthermore, an exploratory factor analysis revealed that 65% of the variance in these rates of change was accounted for by a common change factor. Finally, Tucker-Drob (2011) analyzed two-occasion data, assessed over up to seven years, on abstract reasoning, spatial visualization, episodic memory, and processing speed tasks, where each domain was assessed by three tasks. The author found that the latent change components of the four cognitive domains correlated moderately to strongly (from $r = .24$ to $r = .76$) and loaded substantively and positively on a common change factor. Moreover, the author concluded that change in the 12 cognitive tasks was on the average partially common (39%), partially domain-specific (33%), and partially task-specific (28%). Also, it was found that the evidence for common change did not differ reliably between the young (18–49 years), middle aged (50–69 years), and older (70–95 years) subsamples.

The reviewed recent longitudinal studies all applied the same type of statistical analysis, namely multilevel modeling (MLM) for longitudinal data (Laird & Ware, 1982), which closely resembles the Latent Growth Model in the structural equation modeling literature (McArdle, 1986). The MLM contains two main components: the Intercept, which stands for general level of performance, and the Slope, representing change in performance. Intercept and Slope estimates describe both the average sample trajectory as well as the individuals' deviations from this trajectory.

The multivariate MLM, which is used here (see also Lindenberger & Ghisletta, 2009) offers the additional advantage over multiple univariate MLMs of estimating the amount of interrelationships among the Intercepts and Slopes of all variables considered. In the present application, we are particularly interested in the correlations among all Slopes estimated in the multivariate MLM, which operationalize the associations in rates of change in cognitive performance.

The studies discussed above applied the MLM to study change as a function of occasions of measurement or participation time in the study. Age was simply considered as a focal covariate, which may modify the associations among rates of change. To study the dimensionality of cognitive aging, however, it is preferable to define change over chronological age (McArdle, 1988). This further augments the interpretability of the results in terms of developmental change, rather than mere passing of time, in cognitive performance during adulthood and advanced age, in accordance with lifespan theories of cognition (for a review see Lindenberger, 2001). Furthermore, given that the data are sparser when the time basis is chronological age rather than time in study or occasions of measurement, variances in slope often are not detected in the former situation. In other words, the statistical power to detect interindividual differences in intraindividual change is greater when change is described as a function of time in study or occasions of measurement than when change is described as a function chronological age. This also influences the power to detect slope covariances. Thus, inferences about associations among rates of change based on chronological age are more robust than when time in study or occasions of measurement are used as the time basis. This approach requires samples of aging individuals of considerable size that are measured over periods of time sufficiently long to exhibit change. An alternative and rather popular approach consists in estimating age effects on intraindividual change by comparing change gradients, defined over time in study or occasions of measurement, across different age groups.

Here, we analyze cognitive data from the University of Manchester Longitudinal Study (Rabbitt et al., 2004), a large-scale 20-year longitudinal examination of cognitive performance in over 6000 healthy individuals initially aged 42 to 96 years. Some of the variables we considered have been analyzed in previous reports (e.g., Rabbitt, Lunn, Ibrahim, Cobain, & McInnes, 2008a; Rabbitt, Lunn, Wong, & Cobain, 2008b; Rabbitt, Lunn, Wong, & Cobain, 2008c; Rabbitt et al., 2004). Those reports, however, did not focus on the multivariate relationships among the cognitive tasks, whereas those relationships are the focal interest in this paper. We investigate the amount of shared variance in cognitive change by applying the MLM statistical model to multiple markers of fluid and crystallized intelligence, perceptual speed, and memory. The large sample size, its broad coverage of age, and the breadth of the cognitive assessment allowed us studying cognitive change as a function of chronological age (instead of time of testing or occasions of measurement) over a range of different cognitive domains. We statistically controlled for various factors that often hamper the validity of age-based results in longitudinal studies, notably retest effects, and for variables potentially associated to cognitive performance (socio-economic status, sex, and place of residence).

1. Method

1.1. Participants

The analyses include a total of 6203 volunteering participants (4379 or 70.6% women), 2819 (45.4%) of whom from Greater Manchester (UK) and 3384 from Newcastle-upon-Tyne (UK). The sample did not include individuals with severe visual or auditory handicaps. Participants with mild, correctable sensory handicaps were assessed with corrective devices. Socio-economic status was categorized according to the Registrar General's Scale of Occupational Categories (Office-of-Population-Censuses-and-Surveys, 1980) into six