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Ageing and Skills

A REVIEW AND ANALYSIS OF SKILL GAIN AND SKILL LOSS OVER THE LIFESPAN AND OVER TIME

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AGEING AND SKILLS: A REVIEW AND ANALYSIS OF SKILL GAIN AND SKILL LOSS OVER THE LIFESPAN AND OVER TIME

OECD Working Paper No. 72

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ABSTRACT

The relationship between ageing and skills is becoming an important policy issue, not least in the context of population ageing. Data from the Programme for the International Assessment of Adult Competencies (PIAAC) will potentially add considerably to the understanding of the relationship between ageing and foundation skills. In particular, the fact that data from the 1994-1998 International Adult Literacy Survey (IALS) and the 2003-2007 Adult Literacy and Lifeskills Survey (ALL) will be linked with PIAAC offers a unique opportunity to examine trends over time at the cohort level for a wide range of countries. Specifically, repeated measures will enable an analysis of whether there is skill gain and skill loss over the lifespan of cohorts and overtime between cohorts. This is especially important because age-skill profiles observed on the basis of a single cross-section are difficult to interpret. With this as a backdrop, this paper has sought to provide an overview of what is known about age-skill profiles and to conduct an analysis that demonstrates how trend data based on repeated cross-sectional observations of direct measures of skill at the cohort level can be used to estimate skill gain and skill loss over the lifespan and over time.

RÉSUMÉ

La relation entre l’âge et les compétences constitue une problématique de plus en plus importante pour les pouvoirs publics, surtout dans le contexte du vieillissement de la population. Les données collectées dans le cadre du Programme international d’évaluation des compétences des adultes (PIAAC) permettront certainement de mieux comprendre le lien qui existe entre l’âge et les savoirs fondamentaux. Ainsi, le recoupement des résultats de l’Enquête internationale sur la littératie des adultes (IALS) de 1994-1998 et de l’Enquête sur la littératie et les compétences des adultes (ALLS) de 2003-2007 avec ceux du PIAAC permettra de procéder à une analyse chronologique des tendances observées au niveau des cohortes, dans un large éventail de pays. En l’occurrence, des mesures régulières permettront de déterminer si les compétences augmentent ou diminuent tout au long de la vie des cohortes et dans le temps entre les cohortes. Il s’agit d’une avancée capitale dans la mesure où les profils de compétences établis en fonction de l’âge à partir d’une seule coupe transversale sont difficiles à interpréter. Avec ces éléments en toile de fond, le présent document s’efforce de faire le bilan des connaissances actuelles sur les profils de compétences en fonction de l’âge et de mener une analyse qui montre comment les données tendancielles fondées sur des observations transversales régulières de mesures directes des compétences au niveau des cohortes peuvent être utilisées pour évaluer l’acquisition et la perte de compétences tout au long de la vie et dans le temps.

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INTRODUCTION

1. Steep drops in fertility combined with an increase in longevity are prompting many OECD governments to view ageing as a major dimension of policy[1]. Not least, the relationship between ageing and skills is becoming an important policy issue. Understanding better the causes and consequences of skill gain and skill loss over the lifespan as well as over time matters for at least four inter-related reasons.

2. First, it matters in the context of policies that seek to maintain the attachment of older workers to the labour market. Demographic shifts are leading to a sharp rise in the ratio of older inactive persons per worker – the ratio is expected to nearly double from about 38% in the OECD area in 2000 to over 70% in 2050 (OECD, 2006). Accordingly, a debate has emerged on whether working life should be extended beyond the “traditional” retirement age to finance the negative implications of this shift, for example on public pensions and health expenditures. Understanding better the links between ageing and skills is an important aspect to this debate.

3. Second, it matters in the context of an ageing workforce. A drop in fertility and increased rates of labour force participation among older adults over 55 are together leading to a rise in the average age of working adults[2]. The stock of skills available to the labour market is thus becoming more dependent on the up-skilling and/or re-skilling of the existing workforce than on people leaving the initial education system. Understanding better the processes and factors involved in skill gain and skill loss thus take on added significance. Skills are not fixed after the qualification point. What people do as they age matters for developing, maintaining or for losing their skills. While skills can continue to increase as a function of work experience, they may also depreciate due to a lack of use. Some of this relates directly to education and training supply into old age. Otherwise, much of what happens to skills is dependent on what people do in their every day including at work. Insights on work related factors which may influence the development of skills and whether these are relevant for policy are thus becoming more important.

4. Third, it matters because skill loss poses a risk to the value of educational investments. While several factors may be responsible for skill loss, theory and evidence suggests that skill underutilization may be a particularly important factor that needs to be understood better for policy purposes. Skill loss and skill underutilisation may not only be two factors that can adversely affect opportunities for productivity and growth, but one may cause the other. Indeed, there is growing policy interest in whether increased rates of educational attainment across the OECD are being put to productive use or whether they are slowly deteriorating due to a lack of use. This follows from the “use it or lose it” (Statistics Canada & OECD, 1995) and “intellectual challenge” hypotheses (Staff *et al.*, 2004; Pazy, 2004; de Grip *et al.*, 2008). Both propositions suggest that skills are like muscles that develop if you use them in a challenging way, otherwise they can stagnate or be lost. Recent evidence suggests that skill underutilization is a widespread phenomenon (see Krahn & Lowe, 1998; Boothby, 1999; Statistics Canada & OECD, 2005; Statistics Canada & OECD, 2011). A key concern is to ensure that work practices are flexible and technologies are adopted in a way that not only makes effective use of workers’ skills so as to limit skill atrophy and wasted opportunities to increase productivity, but also to optimize skill formation over the entire career span of workers.

[1] By 2050, about 33% or more of the population in Italy, Japan, and the Republic of Korea and about 20% or less in Mexico, Turkey, and the United States is projected to be age 65 or older (OECD, 2006). The U.S. Census Bureau estimates that already by 2030, about 20% of the U.S. population (71.5 million Americans) will be 65 or older compared to about 12% percent in 2000 (see Report of the Taskforce on the Aging of the American Workforce, 2008).

[2] The *Report of the Taskforce on the Aging of the American Workforce* (2008) estimated that between 2004 and 2014, the labour force participation rate in the US is projected to increase by 42.3% for people aged 55 to 64, and by 74% for people aged 65 and older.

5. Fourth, it matters because increases in life expectancy which are not accompanied by the maintenance and use of certain skills may have negative consequences on people's health, quality of life and personal well being. This is linked to the continued contribution of older adults to social, civic, political and cultural life. A sense of feeling that one has something to offer is a critical component of *successful ageing*, and may be related to the maintenance and use of certain skills into old age.

6. The availability of data from the Programme for International Assessment of Adult Competencies (PIAAC) will potentially add considerably to the understanding of the relationship between ageing and skills. It will provide an information base that will help to identify whether countries are experiencing net skill gains or losses over time and as their populations age. In limited ways, it will also provide some scope to understand better the wider processes implicated in skill gain and loss. Up to 17 countries that are participating in PIAAC will have two or three observations of a repeated measure of a key foundation skill for adults aged 16 to 65 spanning a 9 to 18 year period. In view of the forthcoming data from PIAAC, this paper aims to provide:

- A brief conceptual and theoretical background to ageing and skills as well as a brief discussion on methodological approaches to studying skill gain and skill loss over the lifespan
- An overview of what is known about age-skill profiles
- An extended empirical overview of age-skill profiles using data from the 1994-1998 International Adult Literacy Survey (IALS) and the 2003-2007 Adult Literacy and Lifeskills Survey (ALL)
- An overview of what is known about the factors influencing skill gain and skill loss

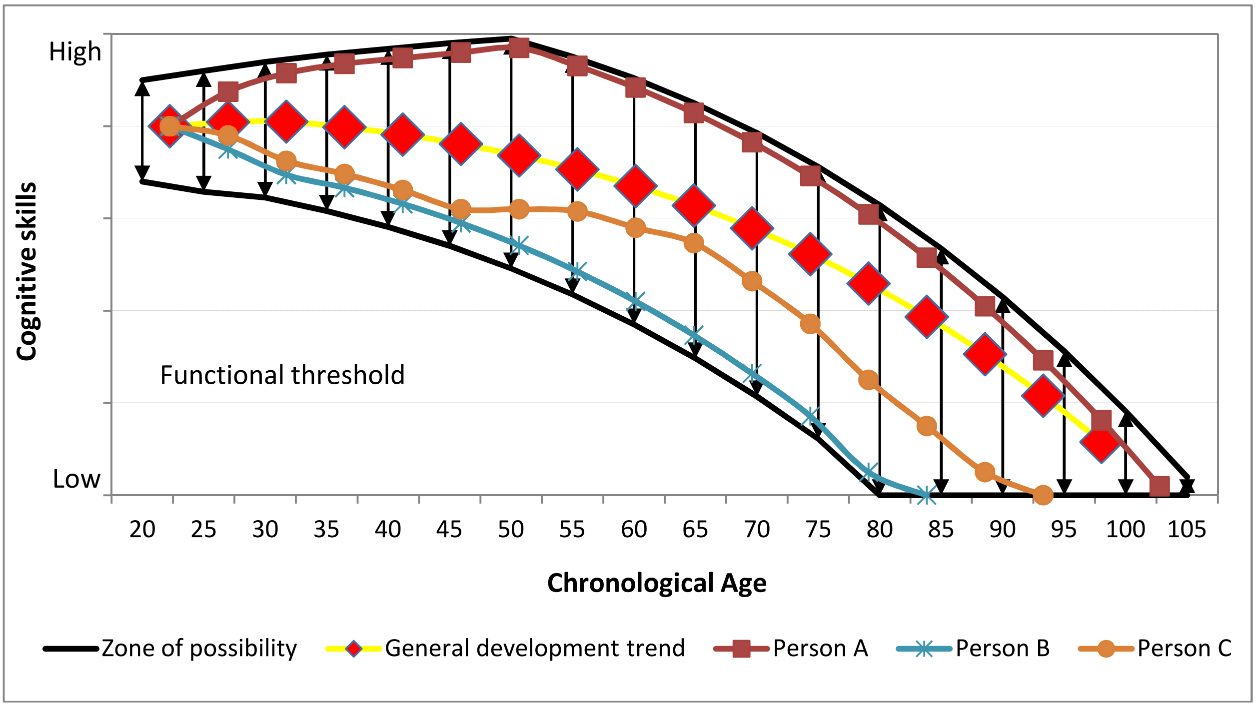
AGE-SKILL PROFILES: A CONCEPTUAL AND THEORETICAL BACKGROUND

7. Several studies have found a tendency for cognitive skills to rise in the early years and then eventually decline as adults age. Scholars from different disciplinary perspectives have attempted to provide a better understanding of the phenomena underlying this observed relationship. To be sure, ageing and skills is not a straightforward relationship to disentangle. In an attempt to grasp the complexity of various underlying phenomena, this section highlights some of the main conceptual and theoretical background by focusing on the essential channels that link ageing and skills.

Theoretical description of age-skill profiles over the lifespan

8. Although not uniform across cognitive domains and may depend on a variety of factors, *normal ageing* is a concept described in the cognitive ageing literature as being accompanied by overall declines in cognitive functioning. This is supported by evidence of a general downward development trend (see section providing an overview of the evidence on age-skill profiles). Hertzog *et al.* (2009) depicted normal age decline as a zone of possible cognitive development across adult life for a given individual (see Figure 1). The general development trend for an individual under 'typical' circumstances suggests that declines in cognitive functioning can begin as early as age 20 and continue into old age, accelerating particularly after the age of 50. Decline is often observed to accelerate in old age, especially in the case of dementia.

Figure 1. Depiction of the zone of possible cognitive development across adult life for a given individual



Source: Adapted from Hertzog *et al.* (2009) with permission from Sage Publications.

9. Figure 1 depicts a zone of possibility according to Hertzog *et al.*'s (2009) interpretation of observed trends, which is delineated by optimal and suboptimal boundaries. This zone of possibility suggests that neurological changes which come with ageing constrain cognitive functioning, but not all individuals need follow the general trend. Depending on biological, behavioural, environmental and social influences, individuals' trajectories may vary within this zone. Most importantly, research on the brain's plasticity over the individual's lifecycle suggests that people can learn anew into late adulthood (OECD, 2007). Persons A, B and C, in Figure 1, for example, are shown to have very different trajectories. At some point, individuals' cognitive abilities may fall below a functional threshold as depicted in Figure 1 where goal-directed functioning in the ecology may be compromised.

10. Cognitive decline may, therefore, be possible to delay or avoid altogether. There is indeed a substantial share of adults aged 100 who do not show signs of cognitive impairment (Kliegel, Moor & Rott, 2004). Barnes *et al.* (2007) and Yaffe *et al.* (2009) reported that about 9-30% of the elderly maintain good cognitive functioning, while about 53-58% experience minor declines, and about 16-33% experience major declines or dementia. Schaie (1984) found that even at 81, less than half of observed individuals showed a reliable decline in skills over the preceding 7 years.

11. Depp and Jeste (2006) suggested that about one third of the elderly can be considered 'successful agers'. While there are no consistent definitions of the concept of 'successful ageing' (Rowe & Kahn 1987; Depp & Jeste, 2006), three components are commonly included (see Fiocco & Yaffe, 2010): the absence of disease; an active engagement in life; and, the maintenance of cognitive and physical functioning. An important issue is, therefore, to identify the factors and conditions which may lead to *successful ageing* (see discussion on *behavioural and practice effects*).

12. Not all cognitive skills, however, appear to follow the same overall pattern. In the early years, up to about the age of 18 to 20, cognitive skills of all kinds are expected to increase, but thereafter, development patterns are expected to diverge depending on the type of skill. Some skills may thus begin to

decline already in early adulthood, while others may continue to rise slightly, then stagnate, and only then eventually decline.

13. Figure 2 displays Cattell's (1987) theoretical portrait of the lifespan curves of two concepts relating to different types of cognitive functioning, namely *fluid* vs *crystallized intelligence*, or alternatively *cognitive mechanics* vs *pragmatics*.

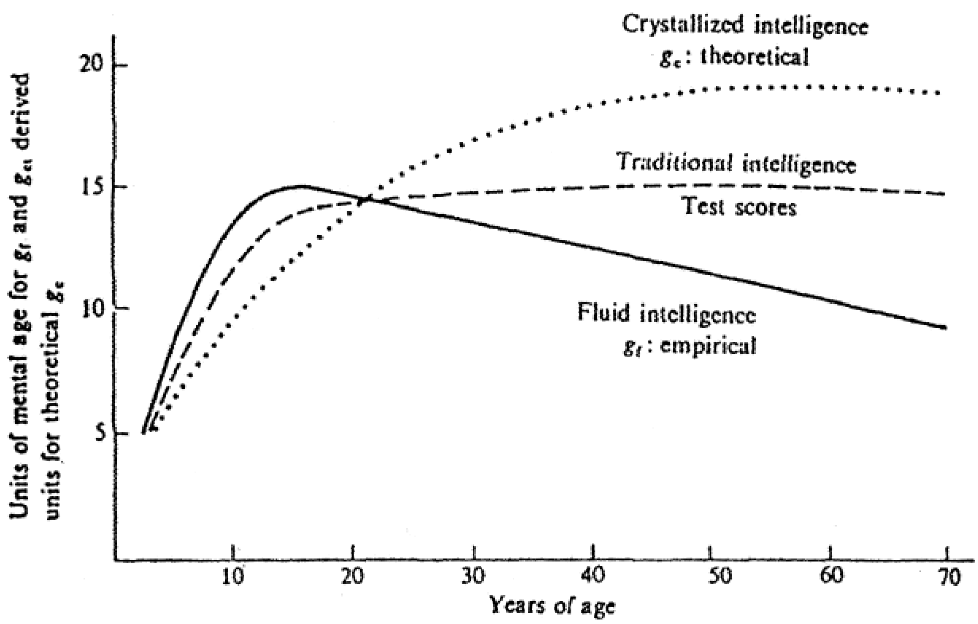
14. Important elements of cognitive functioning such as attentional capacity, processing speed, reasoning, working memory capacity and spatial ability are in the cognitive ageing literature referred to as *cognitive mechanics* – a concept that is comparable to *fluid intelligence* (Gf) (Cattell, 1971), which is meant to refer to the ability to learn or understand things independent of prior knowledge (Baltes, 1993). These types of skills are argued to be primarily genetically and biologically controlled (see Baltes, 1993; Toga & Thompson, 2005). In contrast, other elements of cognitive functioning such as knowledge, skills and wisdom are referred to as *cognitive pragmatics* – a concept that is comparable to *crystallized intelligence* (Gc) (Cattell, 1971), which is meant to refer to abilities that are acquired or learned (Baltes, 1993). These types of skills are argued to be primarily socially and culturally determined (Baltes, 1993).

15. The concept of *traditional* or *general intelligence* (*G*) comprises elements of both *fluid (Gf) and crystallized (Gc) intelligence*, which effectively averages the two trajectories and is thus seemingly stable over the lifespan. Evidence suggests that a 'general' factor does not adequately describe the complexity of cognitive ageing, primarily because of diverging sub types (i.e., *Gf* and *Gc*).

16. So called *Gf-Gc theory* suggests that in early phase of the lifespan, Gc is expected to rise together with Gf, but then in early adulthood, Gc may rise further while Gf levels off and rapidly declines in later adulthood (McArdle *et al.*, 2000). Evidence from a wide range of studies including both cross-sectional and longitudinal designs supports these predictions (see section providing an overview of the evidence on age-skill profiles).

17. Thus *fluid intelligence* is expected to decline already in early adulthood. Adults may nevertheless offset the general development pattern by compensating with increases in *crystallized intelligence*, for example via continued learning and experience (Baltes, 1987). Indeed, studies suggest that experience can lead to an accumulation of knowledge and skills (i.e., pragmatics) until an advanced age, when they may level off (Horn & Hofer, 1992; Schaie, 1994; Marsiske & Smith, 1998).

Figure 2. A theoretical description of lifespan curves of intellectual abilities



Source: Cattell (1987). Reproduced in McArdle *et al.* (2002) with permission from Elsevier Science.

Life course and structuration theory

18. Life course theory (Elder, 1998) is useful for thinking about the multiple trajectories of individuals and their developmental implications. A variety of historical, social, cultural and economic forces help to shape the trajectories of early childhood development, education, work and family formation which in turn influence experiences, behaviours and the development of an individual over the lifespan. The focus here is on the development of skills.

19. Ageing is a key factor influencing the development of skills, but the relationship is difficult to disentangle because age acts as a marker for multiple sources of accumulated change which has occurred as time has passed. In summary, at least four distinct types of changes, which are relevant for understanding age-skill profiles, may occur as people age. First, age reflects the accumulation of change over the lifespan within individuals. Second, it reflects changes over the lifespan in the types of contexts that individuals engage in as they age, and the extent to which they do so. Third, it reflects changes over time within those contexts. Fourth, it reflects changes over time to the social and cultural conditions that regulate the interaction between individuals and various contexts. As used here, contexts are meant to refer not only to the physical environment, but also the elements of structure that surround the social and cultural conditions embedded within contexts, such as the constraints that individuals face in acting independently and making their own choices.

20. In considering the various sources of change that may affect skill development either within individuals or between individuals over time, it is useful to make a distinction between factors related to individual change and those related to social (or contextual) change. The two interact at different points in the lifespan to effectively define individual trajectories, experiences, behaviours and ultimately skill development. Some life transition points are strongly influenced by social structures (e.g., entry into first grade, conditions of access to higher education), while some are mainly driven by individual choice (e.g., getting married, having children, reading habits), but most depend on an interaction of the two (e.g., deciding to attend post-secondary education, occupational choice).

21. The distinction between individual and social factors which influence skill development can be situated in the context of Giddens' (1984) *theory of structuration*. The central notion is that individuals are recognized as agents who make choices and decisions which affect their behaviours and opportunities relating to their skill development. But while many individuals in modern societies have the benefit of exercising their agency and are able to select paths to follow, their choices are always contingent on the opportunities and constraints of culture and social structures. As an example, a different set of forces are operating to moderate the career choices and career mobility of women compared to men, and these are changing over time. Another example includes early selection of students into academic vs vocational pathways. Yet another includes shocks to wider social and economic conditions such as growing up during the Great Depression. These types of factors and how they evolve either over the lifespan of individuals or over time between individuals can be linked to different types of effects known as *age*, *cohort*, and *period effects*, which will be discussed in more detail.

Individual factors affecting skill gain and skill loss

22. Changes within the individual over the lifespan are further confounded by two types of maturation effects, namely *neurological* and *behavioural maturation*. A distinction is thus made between ageing effects in the biological or neurological sense with regard to physical elements of the brain – this is referred to as *ageing cum neurological maturation effects*; and, ageing effects in the behavioural sense with regard to the social and cultural elements of behaviour and practices – this is referred to *ageing cum behavioural and practice effects*. These two types of maturation effects are not necessarily independent of one another but may nevertheless be subject to different trajectories of development and influenced by different factors in different stages of life. For example, the two types of maturation effects can be linked to diverging changes over time in fluid and crystallized intelligences, respectively. The following discusses *neurological maturation effects* and *behavioural and practice effects* in more detail, as well as the potential role of *genetics* and age as a more general marker of the stage of the lifespan which interacts with both types of maturation effects.

Genetic effects

23. There is little doubt that both *nature* and *nurture* interact to play a decisive role in influencing the level, growth and decline of cognitive skills over the lifespan of each individual (Neisser *et al.* 1996; Reynolds *et al.* 2005). Conclusive evidence on the role of nature vs nurture however, remains elusive. Today, most researchers acknowledge that it is too difficult, if not impossible to differentiate satisfactorily the effects of nature and nurture. Epigenetic research for example, has revealed complex inter-linkages between biological, behavioural, environmental and social factors (Cunha & Heckman 2007; 2008). Nevertheless, genetics and perhaps more broadly, the evolution-based neurophysiological architecture of the mind is expected to play some role.

24. Evidence indeed suggests that the intergenerational correlation of skills is positive. This measure however, is subject to both genetic factors (nature) and parental investment (nurture). Twin and adoption studies have been a popular method for nearly a century in attempting to disentangle the two, enabling the comparison of different sibling-parental groups. Bouchard and McGue (1981) review 111 studies about the correlation of cognitive abilities between different sibling groups (See Table 1).

Table 1. Correlation of cognitive abilities between different sibling groups

Siblings	No. of correlations	No. of pairings	Weighted average
Monozygotic twins reared together	34	4672	.86
Monozygotic twins reared apart	3	65	.72
Dizygotic twins reared together	41	5546	.60
Siblings reared together	69	26,473	.47
Siblings reared apart	2	203	.24

Source: Bouchard and McGue (1981)

25. The comparison of twins either reared together or apart has provided some evidence about the role of nature vs nurture in the development of cognitive functioning. For example, in a Swedish twin and adoption study, Björklund, Lindahl and Plug (2006) found a high intergenerational correlation between combinations of parental/environmental characteristics for both biological and adoptive parents and their children's educational success as well as income. These findings support the notion that nature and nurture both play a role. In another study, Turkheimer *et al.* (2003) showed that the growth rate of IQ scores for adopted children depend considerably on the socio-economic status of the adopting parents.

26. Similar research has found that *monozygotic twins* (i.e., genetically identical siblings) share more similar characteristics of cognitive functioning than *dizygotic twins* (Devlin, Daniels & Roeder, 1997), providing some evidence that genetic factors matter in determining cognitive functioning. Otherwise, research supports the notion that genetics have a significant influence on differences in IQ scores, explaining about half the difference among adults (Davies *et al.*, 2011).

27. The influence of genes on IQ appears to grow from childhood to adulthood. While environmental factors are found to exert strong influence on IQ in early life, Bouchard (2004) showed with twin and adoption data that the influence of genetic factors increases with age while the influence of their shared environment in the early years decreases. This suggests that diverging experiences in later life matter but that this is conditioned by genetic factors. Haworth *et al.* (2010) replicated Bouchard's finding in a sample with 11,000 twins from four countries. They showed that the heritability of general cognitive ability increases significantly and linearly during the schooling years from the age of 9 to 17.

28. Underpinning the complexity of the linkages however, differences in IQ, as with height, can only be attributed to an overall effect of many genes, each with only a tiny influence (Davies *et al.*, 2011). As important as genes may appear to be in explaining intelligence, they do not operate in isolation and the role of experiences cannot be ignored.

29. Furthermore, some types of cognitive skills may be more relevant to genetics than others. For example, *cognitive mechanics*, or alternatively, *fluid intelligence* such as attentional capacity, processing speed, reasoning, working memory capacity and spatial ability are seen as being primarily associated with genetic factors and to follow a pattern of development that is largely dependent on the *neurological maturation of the brain*.

30. Nevertheless, *fluid intelligence* may need to be nurtured to its full potential especially in the early stages of *neurological maturation* (e.g., development of sensory perception, motor skills and memory). Motivation to learn, interest, effort and goodness of teaching thus remain critical aspects in the building up of *fluid intelligence* (Cattell, 1987, p. 139).

31. Moreover, fluid and crystallized intelligence are not independent. In his *investment theory*, Cattell (1987) proposed that the ability to learn and reason, especially in situations demanding insight into complex relations, depend on fluid intelligence. Thus the building up of crystallized intelligence is at least partly dependent on fluid intelligence. Cattell's theory implies a dynamic relationship, suggesting that *investment* in the development of both fluid and crystallized intelligence in early childhood in the context of educationally relevant settings influences the further acquisition of crystallized intelligence over the entire lifespan, and may explain individual differences in this respect. There is some evidence to support this notion. For example, Gow *et al.* (2011) and Deary *et al.* (2000) found that cognitive skills in childhood are by far the most important predictor of cognitive abilities in later life.

Ageing cum stage of life effects

32. Indirectly, age is an important factor because it is a marker reflecting a particular point or stage in the lifespan of an individual, each of which may be more closely associated with one or more contexts relevant for learning and nurturing cognitive functioning. For example, in early childhood, the home context plays a predominant role in the development of a child. While this persists well into the schooling years and even into adulthood, the schooling context begins to take on a larger role as time passes. Similarly, in adulthood, work becomes an increasingly relevant context, while schooling contexts can be replaced with intermittent spurts of adult education and training. The kinds of work contexts encountered and the extent of continued learning however, begin to diverge markedly beyond the stage of initial schooling. Thus the extent to which individuals continue to interact and engage in nurturing contexts at various lifespan points (for example, at work), and how those contexts are structured may, therefore, have important impacts on cognitive development over time.

33. By extension, the longer one has been away from nurturing contexts (e.g., initial schooling) he/she may experience reduced cognitive functioning, including declines in attentional capacity, processing speed, reasoning, working memory capacity and spatial ability. Younger adults for example, may have the benefit of more recent schooling. This implies a *recency effect*, suggesting that the further in time one is from a nurturing experience, the less relevant it may become as a factor influencing skills, and skills may even decline from the level they once were. For example, from what it may have been at the time initial schooling was completed.

34. The stage of life of an individual can be seen as a proxy of aspects relating to both biological and behavioural maturation. These two types of maturation however, can diverge in their impact on cognitive skills. Age is thus a general marker reflecting a certain stage of the biological ageing process as well as a certain pattern of behaviour that is more typical for that corresponding stage of life. The following subsections take a closer look at neurological and behavioural maturation and consider their potentially distinct influences on the development of skills.

Ageing cum neurological maturation effects

35. A major reason provided for observed declines in cognitive functioning is age-related neurological changes which may constrain cognitive performance (Hertzog *et al*., 2009). Research from the field of cognitive ageing, which is multidisciplinary and includes findings from research in neuroscience,

neuroimageing and neuropsychology, has found that normal ageing is accompanied by both structural and functional changes in the brain (see Drag & Bieliauskas, 2009)[3].

36. *Structural changes* to the brain include declines in brain volume, particularly in the frontal cortex, an area critical for working memory capacity. The frontal cortex also includes the most dopamine sensitive neurons, which is important because the dopamine system is associated with attention capacity, short-term memory, planning and drive. Both gray (neurons) and white matter (myelin sheath that insulates neurons, enabling them to respond to stimulus more rapidly) are susceptible to decline with age. The breakdown of white matter, as in the case of Parkinsons Disease, increases noise and inefficiency in responding to stimulus. Reduced volume is also found in the hippocampus area, an area involved in memory processes, but this is not nearly as much as in the case of Alzheimer's disease. These types of structural changes are consistent with the *general memory loss* hypothesis and *general slowing* hypothesis.

37. *Functional changes* to the brain include altered patterns of neuronal activation compared to younger adults when completing the same tasks. Shifts in neuronal activation patterns have been demonstrated for various cognitive functions including attention, memory and visuospatial processing (Davis *et al.*, 2008). Activation patterns also tend to be less specific as adults age, suggesting reduced neural specialization, which in turn may lead to less accurate information transmission, higher levels of distortion, and less distinct mental representation of information (Li, Lindenberger & Sikström, 2001).

38. Attempts to explain observed *functional changes* have led to the *compensating scaffolding hypothesis* (Park & Reuter-Lorenz, 2009), which suggests that in confronting challenges including in situations of neural decline, the brain recruits other brain regions to compensate for structures that are inadequate or have become inefficient. Successful compensation is not guaranteed and may depend on acculturation and prior levels of cognitive functioning.

39. Many of these structural and functional changes do not follow a linear curve. The rates of change are slow in young and middle-age adulthood and accelerate in later life.

40. *Cognitive reserve* may play a particularly important role. The theory underlying this concept (Stern, 2002; 2009; Satz, 1993; Katzman, 1993) suggests that some individual characteristics such as persistence or experiences including prior knowledge and skills may allow individuals to cope better than others with physical damages to the brain. Individuals with similar brain damages have been found to demonstrate different levels of cognitive impairment which may be attributed to different levels of cognitive reserve.

Ageing cum behavioural and practice effects

41. People gain experience as they age and learn how to deal with cognitive demands over time via *behavioural and practice effects*. The outcome of the interaction between *cognitive mechanics* and *pragmatics* invariably depends on the extent and nature of experiences accumulated in multiple contexts over the entire lifespan, as well as other factors such as the genetic and biological ones discussed above.

42. *Practice engagement theory* (Reder, 1994) proposed that engaging in activities on a recurring basis reinforces and develops the skills required to perform those activities. In this sense, cognitive and other skills can be maintained and even increased. By extension, a lack of exposure may lead to a deterioration of skills. This is closely related to the '*use it or lose it*' hypothesis (Mincer & Ofek, 1982; Krahn & Lowe, 1998). In short, those who continuously engage their skills continue to develop their

[3] Research designs include: using specialized tools such Magnetic Resonance Imageing (MRI) or Positron Emission Tomography (PET) (see Daffner, 2010); animal studies to give insights into neurological aspects of ageing. The transferability of the results to humans is often unclear but these studies allow to control highly the conditions and interventions.

potential, but those who do not risk losing them. Similarly, the '*intellectual challenge'* hypothesis (Staff *et al.*, 2004; Pazy, 2004; de Grip *et al.*, 2008) suggests that continued engagement in simple and less challenging tasks than individuals are otherwise capable may lead to a loss of the skills underpinning those capabilities, especially as they age. Both the 'use it or lose it' and 'intellectual challenge' hypotheses suggest that skills are like muscles that develop if you use them, otherwise they can be lost.

Nurturing effects of the home and family background, schooling and other educative contexts

43. The building up of cognitive functioning, including both fluid and crystallized intelligence begins with a nurturing home and family environment. While this continues well into the schooling years and beyond (Bloom, 1964; Kreppner & Lerner, 1989), especially with respect crystallized intelligence, the educative climate of the home may exert most of its influence in the early years of childhood (Bloom, 1964: 121). The home is not only a learning environment for the child, however, it also plays an important role in shaping one's affective state (i.e., motivation, interest) in other learning environments, including schools and other contexts (Hess & Holloway, 1984). It may also influence opportunity and access to nurturing environments, which facilitate the development of skills. This may be either reinforced or compensated by schooling.

44. Beyond the early adult years, not everyone goes on to further education (i.e., higher education) and trajectories of *behaviour and practice* among adults from the same cohort begin to diverge substantially. This is exacerbated by the fact there are clear tendencies for those who already have the highest levels of education to continue taking up adult learning opportunities over the entire adult lifespan (Desjardins, Rubenson & Milana, 2006).

Nurturing effects of practices at work and in other contexts

45. Depending on labour force and occupational status as well as a variety of other factors, individuals engage in practices at work and in other contexts which vary in frequency, variety, criticality and intensity. Such practices may influence the maintenance, gain or even loss of certain skills. For example, those who engage more in practices requiring cognitive application, such as reading and writing, both at work and at home, may enhance their prospects of gaining or maintaining their skills that are relevant to those activities (e.g., literacy skills).

46. Increased variability of the trajectories of what people do in the everyday both a work and at home, may help to explain why some adults are observed to maintain their skills as they age while others lose them. Indeed, Morse (1993) showed – albeit with cross-sectional data – that the variability of cognitive (and physical) functioning among individuals increases with age, including for measures of perceptual speed, reaction time and memory.

Social factors affecting skill gain and skill loss

47. Individuals come into contact with a variety of contexts such as the home both in childhood and in adulthood; schools, other education or training both in childhood and in adulthood; and, community contexts and work contexts. These contexts – including their physical environments as well as the social, cultural and technological conditions under which individuals come to experience them – are subject to change over time, not only in themselves but also in the extent and nature to which individuals engage in those contexts. Such changes bring about the potential for both *cohort* and *period effects* to skill development. While changes of this nature are outside the control of any given individual, they may nevertheless affect the skill development trajectories of the individuals in question by influencing their choices and behaviours which in turn affect the extent of their interaction with various contexts and what they do in those contexts.

48. The potential for cohort and period effects implies that adults who are aged 60 today may not be entirely comparable to adults who will be aged 60 in ten years from now. Thus age-differences in cognitive skills that are observed on the basis of cross-sectional data are not easy to interpret with certainty because they confound *ageing effects*, whether driven by *neurological* or *behavioural maturation*, with *cohort* and *period* effects.

Cohort effects

49. Definitions of cohort effects vary considerably in the scholarly literature, so it is useful to elaborate on how this concept is viewed in this study. Some authors have reserved the term *cohort* to refer to potentially enduring effects of early life experiences. However, this can be generalized to any unique combination of age and period. For example, growing up as a child during the Great Depression can have as enduring an influence on behaviours or skills as is the case for an adult in mid-life who experienced the same circumstances. Moreover, the extent and nature of the influence may be very different and lead to distinct cohort effects.

50. *Cohort effects* as interpreted in this study thus refer to observed variations in characteristics or relationships over time which can be linked to a group of individuals who are defined by some shared temporal experience or common life experience, such as year of birth, or year of exposure to particular phenomena. More specifically, in this study a *cohort effect* is said to occur when between-generation heterogeneity in experiences is greater than within-generation heterogeneity in experiences. The source of heterogeneity however, is further distinguished between cohort effects that are unique to particular combinations of age and period, and cohort effects that reflect systematic change.

Cohort effects unique to a particular combination of age and period

51. Age cohorts can be influenced by single events which affect all individuals at a certain time, such as epidemics, famines, wars or major cultural changes. These are not necessarily generation-specific in the sense that they affect all cohorts, but how they affect the cohorts may still be generation-specific. They are also not necessarily orderly or progressive. Some events may have a positive influence on the development of cognitive skills (e.g., mass dissemination of newspapers) while others may exert a negative influence (e.g., environmental disasters).

Cohort effects reflecting systematic change

52. Other types of contextual influences may reflect more systematic change that has either positive or negative implications with respect to skill development. They refer to historical phenomena that reflect substantive changes to economic and social conditions, either adversely or favourably, and are pervasive in their impact on large swaths of populations of all ages but in different ways depending on the age cohort. Examples may include steady improvements to living conditions, sanitation and nutrition; major changes such as cultural revolutions experienced around the 1960s in Western societies which pervasively impacted values and lifestyles; the 1990s technological revolution reflected in the spread of PCs and the internet; and, the recent spread of social media. Social changes of this nature may affect the skill development of particular cohorts more than others.

53. A simple example of a cohort effect that is more directly implicated in skill development is a change to compulsory schooling laws which mandates an extension of compulsory schooling beginning with a particular age cohort while those who are older are not affected by the structural change. Another example is the fact that for a variety of reasons, higher proportions of younger populations have received extended formal schooling compared to older populations. Yet another, the quality of education may not be constant across all age cohorts and may have steadily improved over time.

Period effects

54. Period effects are similar to cohort effects but the term is often reserved for effects that could have impacted everyone at the time of assessment. Such occasion-specific influences may include economic conditions or the occurrence of war or famine at the time of the study. Assessing the skills of the same population at a later time in a different period may thus lead to problems in understanding the underlying reasons for the observed changes in performance. For example, is the observed change the consequence of the underlying differences in the contextual conditions between the measurement points or is it due to skill gain or loss? In practice, it is difficult to separate age, cohort and period effects (Winship & Harding, 2009). This is because one effect is a perfect linear combination of the other two. Although they may be important, period effects are for this reason not considered in any great detail in this study.

AN OVERVIEW OF THE EVIDENCE ON AGE-SKILL PROFILES

55. This section examines the evidence on the age-skill profiles of cognitive skills in more detail. In reviewing the evidence, a focus was maintained on the main literature, citations and journals explicitly addressing cognitive ageing (e.g., the journal of *Psychology and Ageing*) as well as research undertaken in the last 20 to 30 years. Added weight was placed on meta-reviews, experimental studies and longitudinal studies. An attempt was made to take account of critiques or commentaries so as to cover as broad range of opinions as possible since these can vary widely. Evidence based on cross-sectional studies is expressly designated as such since age and cohort effects are most confounded in this type of design. Other studies are included however, where appropriate for enhancing the analysis and discussion of the evidence.

Distinguishing between different types of cognitive skills

56. There are several different types of measures of cognitive skills. This has evolved over the years from a uni-dimensional perspective with roots in the concept of general intelligence (Spearman, 1904) to a multi-dimensional perspective with roots in the concept of multiple intelligences (Cattell, 1941; 1971; 1987; Horn & Cattell, 1966a; 1966b; Gardner, 1983).

57. For the purposes of this paper, a distinction is made between two types of cognitive skills measures, namely measures of *basic cognitive skills* and *cognitive foundation skills*. The distinction is not neat, one of convenience and is primarily for expositional purposes. An in depth elaboration of this distinction is beyond the scope of this paper, but nevertheless some discussion of the motivation for doing so is necessary. Both basic and cognitive foundation skills are measured via performance on psychometric tests.

58. *Basic cognitive skills* is meant to refer to concepts and measures which have been devised in disciplines that are linked to the cognitive sciences for the purposes of studying and understanding better cognitive functioning. These cover a range of the underlying components of cognition (e.g., perceptual speed, inductive reasoning, spatial orientation, memory, vocabulary) that are thought to be needed to acquire knowledge and perform cognitive tasks (for a more detailed overview of these types of measures see Salthouse, 2004a).

59. In contrast, *cognitive foundation skills* tend to be more complex and involve higher order thinking skills which requires an integration of the basic components mentioned above. Examples include literacy, numeracy and problem solving skills as measured in the OECD Programme for International Student Assessment (PISA) and OECD Programme for International Assessment of Adult Competencies (PIAAC) and other recent national and international skills surveys (e.g., IALS, ALL). A typical feature of these measures is functionality – i.e., being able to integrate cognitive elements to perform tasks of practical relevance in daily life. For example being able to read a text and use it to understand or achieve a well-defined task, such as how to set up a DVD player. In contrast to basic skills measures, these measures have been conceived from an educational perspective, for the purposes of teaching and learning knowledge and skills. Cognitive foundation skills however, remain 'basic' and can also be seen as building blocks needed to perform more advanced and complex 'real-life' tasks (e.g., overall job performance).

What are the trajectories of cognitive skills over time?

60. A consistent finding emerges from a wide range of studies, even if they are conducted from different disciplinary perspectives (e.g., cognitive scientists, gerontologists, medical doctors, educationalists...) and interpretations of the data vary. Namely, performance measures in several cognitive skills domains are found, on average, to be consistently negatively related with age, including when a lifespan perspective is taken (Weinberg, 1989). This stylized finding has been observed at least since the

1930s (Jones & Conrad, 1933) and many recent studies have examined this relationship for *basic cognitive skills* (e.g., reasoning, episodic memory, vocabulary or processing speed) and *cognitive foundation skills* (e.g., literacy, numeracy and problem solving).

Basic cognitive skills measures

61. The observed age-skill profiles are not uniform across all types of basic cognitive skills measures, however. Thus it is useful to take a separate look at measures relating to Cattell's (1987) distinct concepts introduced in Figure 2, namely traditional/general intelligence, crystallized intelligence and fluid intelligence.

Measures relating to 'traditional' or 'general' intelligence (G)

62. Measures of *traditional* or *general intelligence* are closely aligned with the concept of cognitive skills, although many scholars including Gardner (1983) have pointed out that intelligence may include aspects beyond cognition (e.g., emotional intelligence). The initial popularization of the concept of *general intelligence* has its roots in the work of Alfred Binet and Théodore Simon who developed the first intelligence test at the beginning of the 20th century. This garnered wide interest and led to the popularization of intelligence as a concept, particularly *IQ* or *Intelligence Quotient*, and the IQ test[4,5]. These measures are typically a composite of both fluid and crystallized intelligence.

63. Test scores that purport to measure traditional intelligence have been reported as being fairly stable from the age of 20 as depicted in Figure 2. Many claim that IQ may even be fixed at an early age (e.g., Gow *et al.*, 2011), probably before school entry (Blaga *et al.*, 2009). Deary *et al.* (2000) for example, retested 101 Scots at the age of 77 who had also taken the same test (Moray House Test) at age 11. Their results showed a substantial stability of intelligence over the lifespan, where individuals who scored high at a young age were found to also score high at older ages. However, these results neglect biases caused by selection and retest effects (to be discussed in more detail). Mean scores for both sexes were similar at the age of 11 but men obtained higher IQ scores than women, possibly pointing to the benefits of further education and learning since men were found to have higher overall rates of participation in learning over their lifespan.

64. Contradicting the claim that general intelligence measures are stable over the lifespan, a common practice is to adjust IQ scores for age. For example, this is done in results reported for one of the most common tests, namely the Wechsler Adult Intelligence Scaled III (WAIS-III) (see Ryan *et al.*, 2000). This effectively means that individuals in different age groups receive different IQs even if they obtain a similar score on the same test. In other words, middle-aged cohorts (i.e., 40 to 50) need to score higher on the same test than younger cohorts to achieve a similar IQ. But adults aged 60, for example, can score lower than younger cohorts to achieve a similar IQ. Age based norms are derived by testing many people – typically at least 200 per age group. For each age group a normal distribution of intelligence is assumed (norms are calculated on the basis of a mean of 100 and a standard deviation of 15). De-normalized scores on the WAIS-III indeed display a negative relationship between age and IQ test performance (see Ryan *et al.*, 2000). It is thus worthwhile to point out two distinct ways of perceiving the stability of IQ scores

[4] IQ testing has in general garnered a lot of interest partly because scores have proved to be a fairly good predictor of various outcomes. For example, IQ measured at a young age is a strong predictor of educational success ($\rho \approx 0.55$), attending college and also performance in college. Its prediction of earnings or job performance is more modest but remains substantial (Neisser *et al.*, 1996, Bowles *et al.*, 2001, Heckman *et al.*, 2006). Furthermore, IQ scores show a positive relationship with several social outcomes such as good health, longevity, social status and reduced criminal or deviant behaviour. This relationship tends to remain significant even after other factors such as education, socio-economic background or race are taken into account.

[5] Already by the 1930s and 1940s, the militaries of several nations became interested in psychometric measurement for the purposes of selecting and placing officers. For example, the Swedish military began using psychometric tests in its recruitment practices already by 1930s. To this day there is wide interest in assessing cognitive abilities and the field of psychometric measurement has blossomed.

over the lifespan. First, IQ scores can be seen as stable if individuals score similarly over time. Second, the scores can be seen as stable if individuals preserve their relative rank within a certain group, such as a birth cohort.

65. Claims that intelligence was dominated by a general factor (Spearman, 1904), and that a single general dimension could explain the majority of the variance in test performance came to be challenged by several scholars (Cattell, 1941). Already by the late 1930s, for example, intelligence tests aimed to measure several dimensions separately (e.g. verbal comprehension, visualization, memory). Wechsler (1939) developed an intelligence test measuring several dimensions which is still widely used, i.e., an early version of the commonly used WAIS-III. Today, evidence suggests that about 50% of variance in performance can be explained by one common factor (Almlund *et al.*, 2011, p. 58). Otherwise, there is much evidence to suggest that a single 'general' factor does not describe adequately the complexity of cognitive ageing. In particular, fluid and crystallized intelligence are expected to diverge over time as suggested by *Gf-Gc theory*.

Measures relating to 'fluid' (Gf) and 'crystallized' (Gc) intelligence

66. Evidence from a wide range of studies including both cross-sectional (e.g., Horn & Cattell, 1967; Horn & Noll, 1997; Lindenberger & Baltes, 1997) and longitudinal (e.g., Baltes & Mayer, 1999; Donaldson & Horn, 1992; Schaie 1996) designs support the predictions of *Gf-Gc theory*. Namely, that in early adulthood *Gc* may rise further while *Gf* levels off, begins its decline earlier in mid-adulthood and accelerates more sharply in late adulthood. However, this evidence is not necessarily always neat, which is in part due to the complexity of the underlying concepts, but also very much because of the difficulties associated with fielding appropriate methodologies and measures.

67. Measures of fluid intelligence include those that pertain to perceptual speed, reasoning, spatial ability or memory. These are derived indirectly on the basis of response patterns to assessment batteries involving, for example: the deciphering of letter, word or number series; the comparisons of symbols or patterns; and, memory recall. In contrast, measures of crystallized intelligence include those pertaining to general or vocabulary knowledge. These are derived by asking questions that are factual in nature and either right or wrong (see Sternberg, 2008). The following provides the reader with an overview of the observed patterns of change over the lifespan and over time for these different measures.

Measures relating to 'fluid' intelligence (Gf)

68. Cross-sectional data on measures of fluid intelligence tend to show early negative effects of ageing (Salthouse, 2004b). In a meta-analysis covering 91 studies of the relationship between ageing and cognitive skills, Verhaeghen and Salthouse (1997) found early negative effects for memory, reasoning, speed and spatial ability. Figures 3A and 3B display early declines for several measures of fluid intelligence on the basis of cross-sectional findings. For example, reasoning, speed and memory are shown to begin declining already at the early age of 20.

69. Figures 4A through 4D reproduce findings from Schaie (1994) which were based on the Seattle Longitudinal Study[6]. The figures display the trajectories of select measures of fluid intelligence over the lifespan using both cross-sectional and longitudinal data. These are helpful because they portray differences between within-person and between-person comparisons over time.

[6] The Seattle Longitudinal Study which began in 1956 and have been continued in 7-years intervals since then. In 2005, 26 individuals had been in the study for 50 years and participants range in age from 22 to 101 years. For more information, see Schaie (2005).

Perceptual speed as shown in Figure 4A was found by Schaie (1994) to decline steeply already at the early age of 20 in both cross-sectional and longitudinal designs. These data support the *general slowing hypothesis* predicted on the basis of neurological maturation.

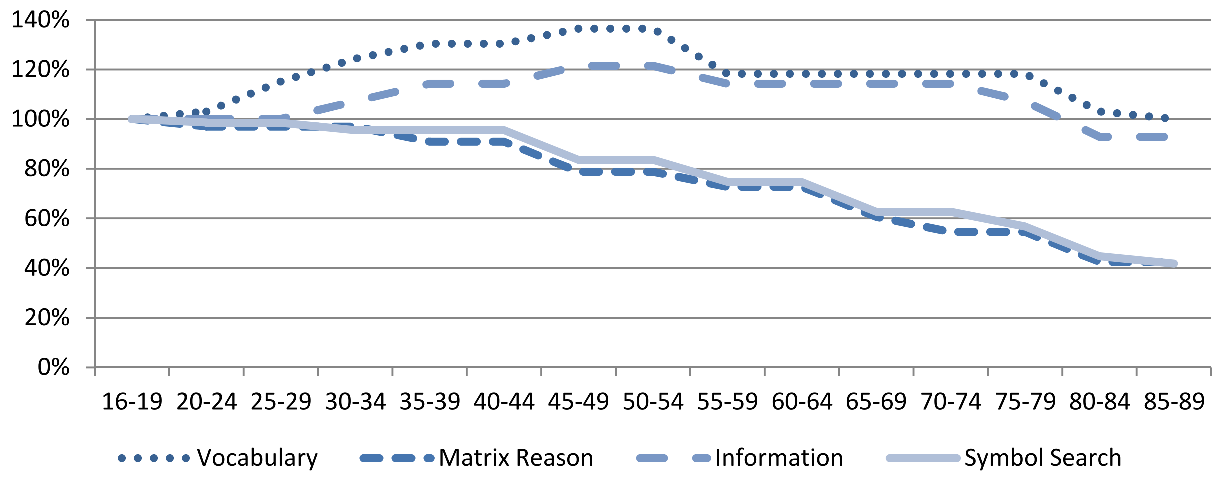
70. In Figure 4B, Schaie's (1994) cross-sectional and longitudinal findings portray distinct trajectories for the ability to reason. In the former case, *reasoning* is found to decline already at 20 with the prospect of a much steeper decline. In the latter case, *reasoning* appears to rise further until about 46, levels off until about 53, and then begins to decline but less sharply than in the cross-sectional data.

71. A similar pattern can be observed for *spatial orientation* and *verbal memory* as shown in Figures 4C and 4D, respectively. In the longitudinal case, *spatial orientation* appears to rise further until about 39, then levels off until about 53 and then begins to decline; whereas, verbal memory steadily increases to the late age of about 67, and only thereafter experiences a sharp decline.

72. Further analyzing the within-person comparison over time, Schaie (2005) reported that statistically significant declines for *reasoning* began at about 53, and for *spatial orientation* at about 46 (see Figure 5). Declines for perceptual speed were significant already from the age of 20.

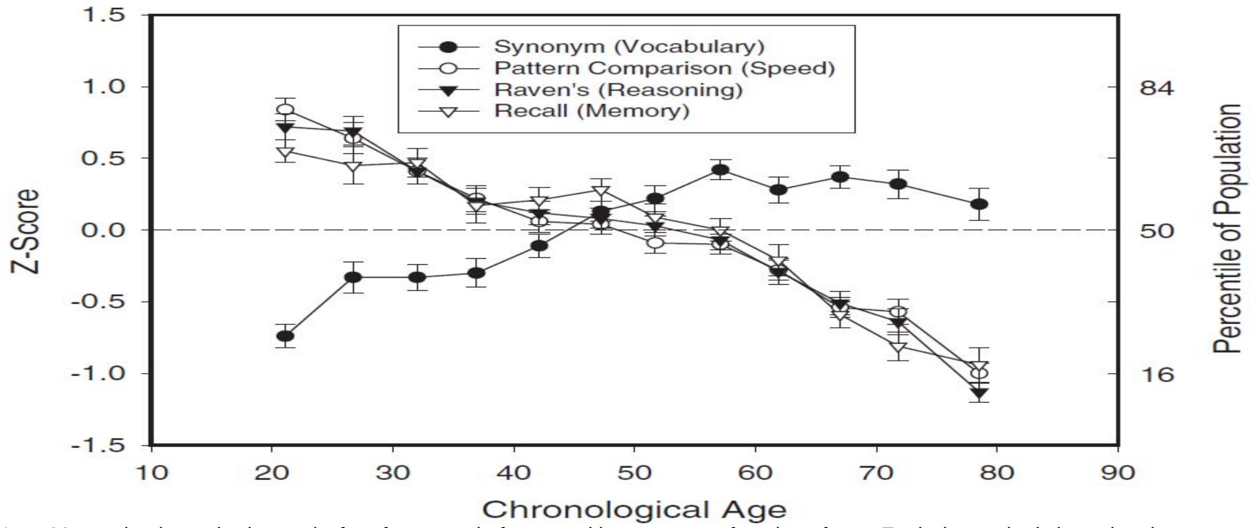
Figure 3. Cross-sectional age trajectories for different cognitive skills measures

A. Cross-sectional age trajectories for four different cognitive skills measures (normalized to 16-19)



Source: Based on data in Table 2 reported in Ryan *et al.* (2000).

B. Cross-sectional age trajectories for four different cognitive skills measures (normalized to the age of 50)

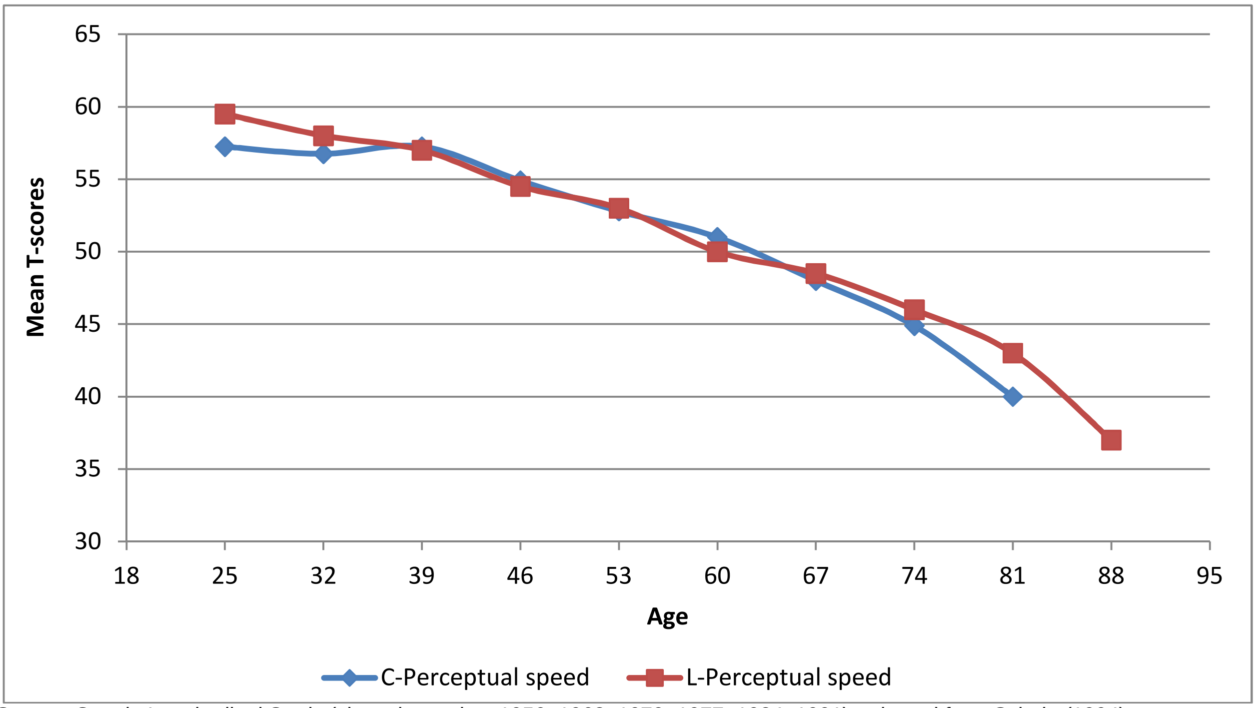


Note: Means (and standard errors) of performance in four cognitive tests as a function of age. Each data point is based on between 52 and 156 adults.

Source: Reproduced from Salthouse (2004b) with permission from Sage publications.

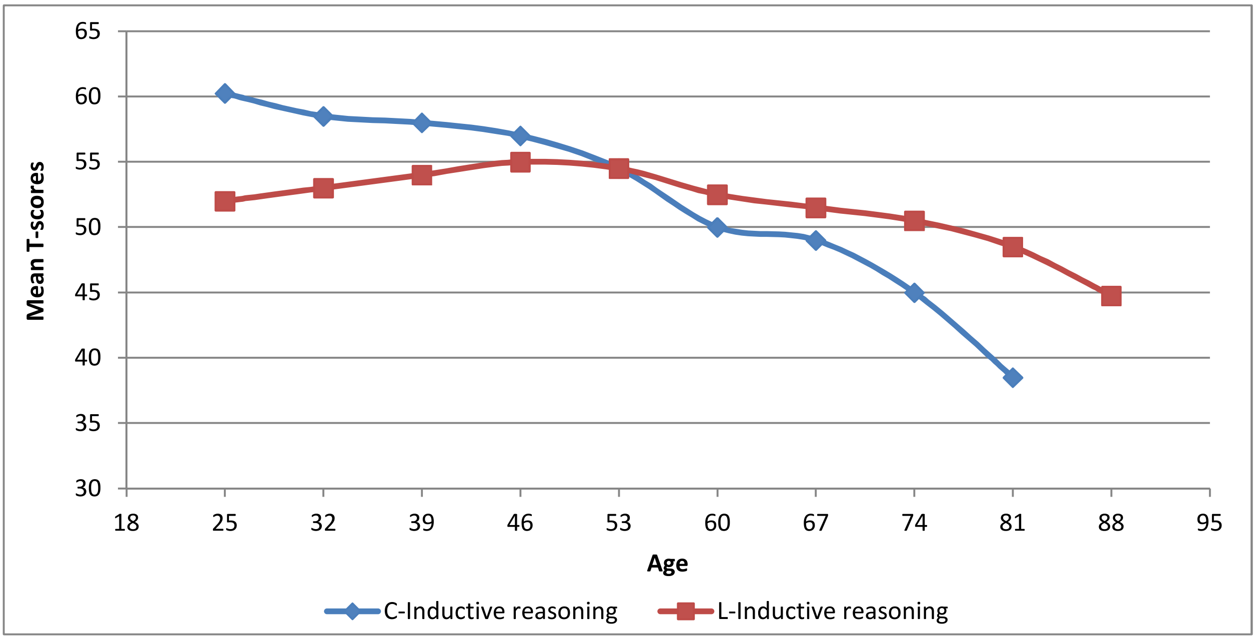
Figure 4. Cross-sectional and longitudinal (7-year within subject) trajectories

A. Perceptual speed



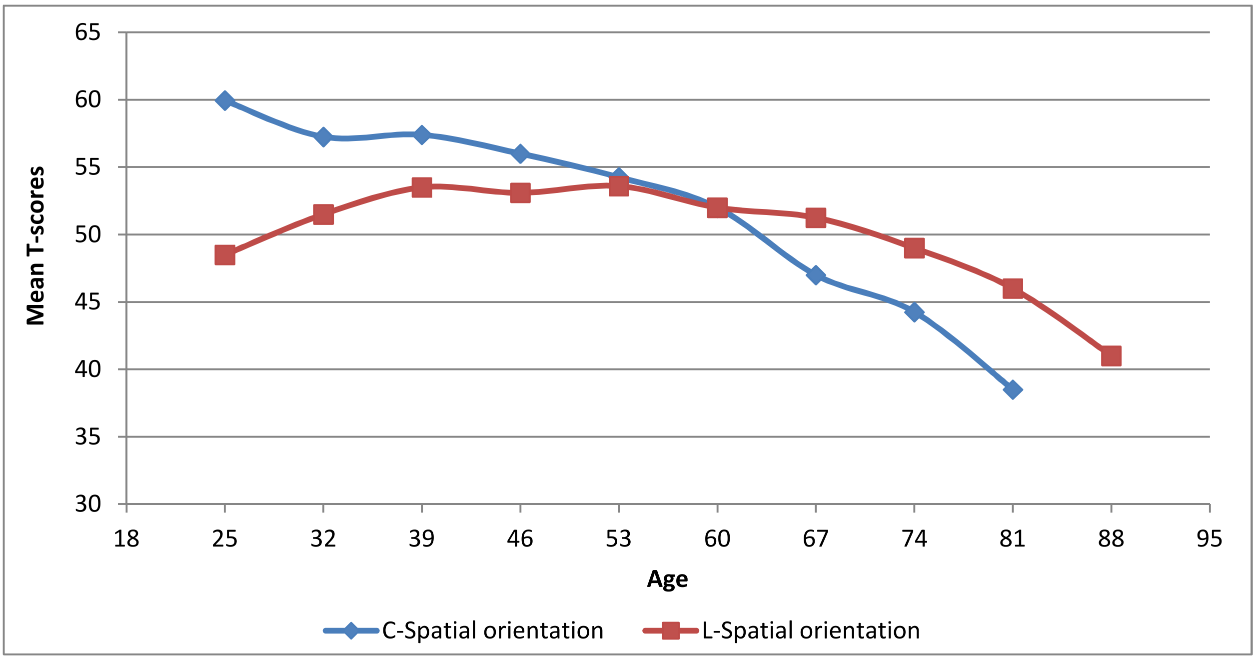
Source: Seattle Longitudinal Study (six major cycles: 1956, 1963, 1970, 1977, 1984, 1991); adapted from Schaie (1994).

B. Inductive reasoning



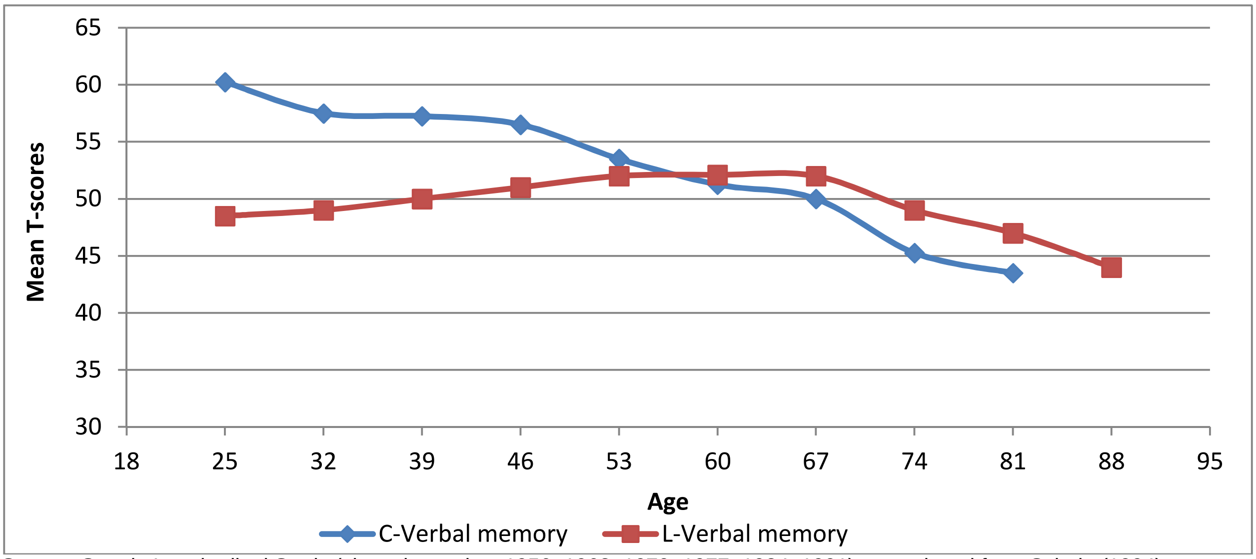
Source: Seattle Longitudinal Study (six major cycles: 1956, 1963, 1970, 1977, 1984, 1991); adapted from Schaie (1994).

C. spatial orientation



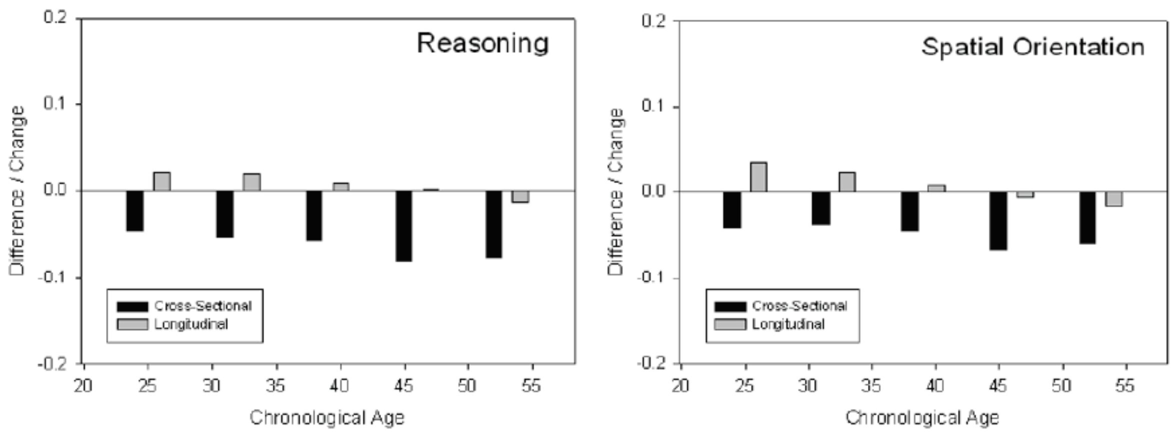
Source: Seattle Longitudinal Study (six major cycles: 1956, 1963, 1970, 1977, 1984, 1991); adapted from Schaie (1994).

D. Verbal memory



Source: Seattle Longitudinal Study (six major cycles: 1956, 1963, 1970, 1977, 1984, 1991); reproduced from Schaie (1994).

Figure 5: Age-skill development (cross-sectional and longitudinal) over 7 years (Schaie 2005)



Source: Salthouse (2009a). Reproduced from Schaie (2005) with permission from Elsevier Science.

Measures relating to 'crystallized' intelligence (Gf)

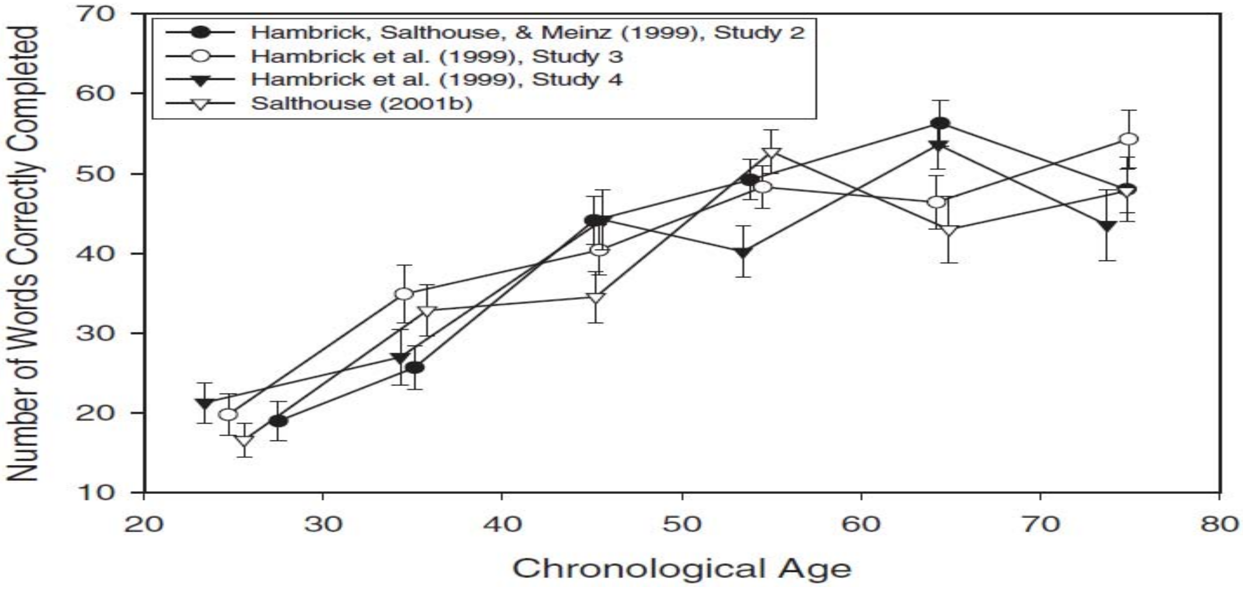
73. Consistent with *Gf-Gc theory*, measures of crystallized intelligence appear to increase further in the early to mid years of the lifespan, and then decline only later in adulthood.

74. Ryan *et al.* (2000) presented cross-sectional findings (see Figure 3A) suggesting that *vocabulary knowledge* increases steadily from a low level and peaks at about 50-54, then drops off sharply but remains stable thereafter until 79, where it begins to drop off again. The pattern is virtually identical for the *information* construct which can also be seen as a measure of crystallized intelligence. Salthouse (2004b) found a similar pattern on the basis of cross-sectional data for a *vocabulary* measure (see Figure 3B). Likewise, Figure 6 shows a cross-section of performance of individuals at different ages in crossword puzzles. There is a clear positive association between age and correct words completed.

75. In summary, cross-sectional measures of knowledge such as *vocabulary* or *information* are found to increase steadily from the early age of 16 until about the mid-50s and either remain stable or decrease slightly afterwards (Schaie, 2005).

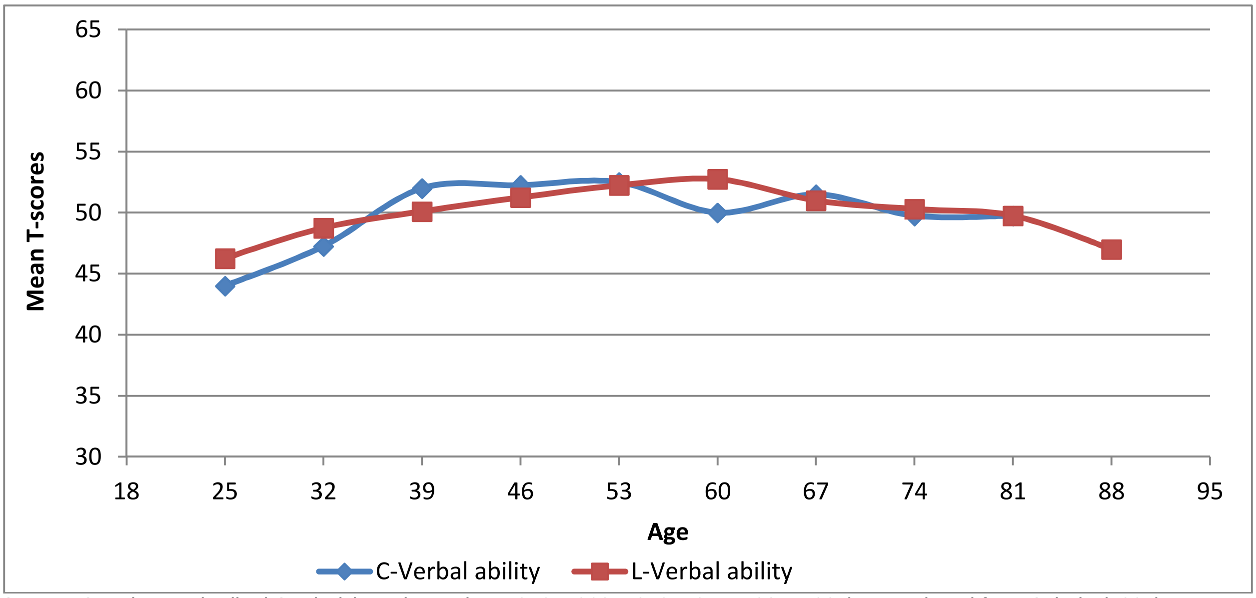
76. Helping to portray differences between within-person and between-person comparisons over time, Figure 7 again reproduces findings from Schaie (1994) which were based on the Seattle Longitudinal Study. In the longitudinal case, *verbal ability* increases steadily until about 60 and then begins to decline. By construction, verbal ability as measured in Schaie (1994) relates primarily to vocabulary knowledge.

Figure 6. Means (and standard errors) for the number of words in a New York Times crossword puzzle correctly answered in 15 minutes as a function of age. Between 195 and 218 adults participated in each study. The crossword puzzles required either 76 or78 words for their solutions.



Source: Reproduced from Salthouse (2004b) with permission from Sage publications.

Figure 7. Cross-sectional and longitudinal (7-year within subject) trajectories for verbal ability



Source: Seattle Longitudinal Study (six major cycles: 1956, 1963, 1970, 1977, 1984, 1991); reproduced from Schaie (1994).

Cognitive foundation skills measures

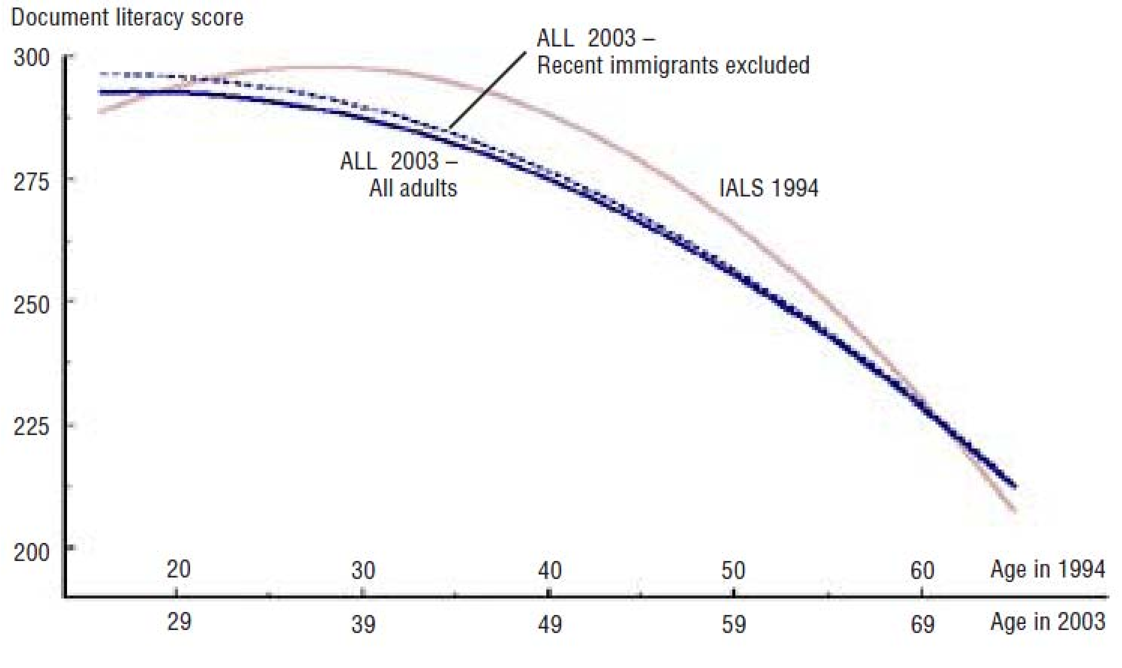
77. Cross-sectional measures of cognitive foundation skills display a similar pattern to that of basic cognitive skills, namely early decline beginning already in the mid-20s (see Statistics Canada & OECD, 2000; 2005). This is the case for nearly all the countries that participated in the 1994-1998 International Adult Literacy Survey (IALS) and the 2003-2007 Adult Literacy and Lifeskills Survey (ALL) (see Annex 1).

78. In comparing average literacy skills by single age cohorts over time between IALS and ALL, Willms and Murray (2007) demonstrated that middle-aged adults experienced significant skill loss in Canada between 1994 and 2003. Figure 8 is reproduced from the Willms and Murray (2007) study. It shows that adults who were aged 25 to 55 in 1994 scored on average significantly less on the same test 9 years later. Employing a similar strategy, Green and Riddell (2007) found a significant decline in the literacy skills of Canadian cohorts aged less than 46, even after controlling for education and immigration.

79. In a separate analysis using the IALS data, Cascio, Clark and Gordon (2008) showed that literacy gains into adulthood varies across countries, which suggests that there are structural factors at the country level affecting the overall age-skill profile of a population (e.g., differences in the proportion of adults graduating with a tertiary degree, quality differences in higher education, differences in occupational structures).

80. See section entitled *A further analysis of age-skill profiles using IALS, ALL and PIAAC data* for a more detailed analysis of change in age-skill profiles.

Figure 8. Literacy-age curves in Canada for two periods (1994, 2003)



Source: Willms and Murray (2007).

81. Longitudinal studies containing measures that allow the development of cognitive foundation skill to be tracked over time are less common but there are some related studies that are worth mentioning.

82. Using the New Zealand Competent Learners Study, Wylie and Hodgen (2007) concluded that literacy appears to be fixed early in life because the correlation in performance on tests measuring literacy seemed to be high after the age of eight. Similarly, Wylie and Hodgen (2011) showed with the same longitudinal data but using a longer time span that literacy, numeracy and attitudinal competencies were good predictors of school achievement at the age of 20. Nevertheless, attitudinal competencies and social competencies were found to be less consistent over time. The results imply that initial education systems tend to amplify inequality at school entry.

83. Bynner and Parsons (2009) also concluded on the basis of data from the British Cohort Study, that the key period for literacy acquisition is up to age 10 since they found that only a little amount of variance in literacy scores could be explained at age 34 but not already at age 10.

84. In contrast, Reder (2009) found that literacy and numeracy continue to develop into adulthood. His analysis is based on data from the Longitudinal Study of Adult Learning (LSAL) in Portland (5 different waves over 6 years), which tracked similar measures to those used in IALS and ALL (i.e., literacy and numeracy). He concluded that the longitudinal profiles of the skills measured in LSAL were remarkably consistent with the cross-sectional age-skill profiles found using data from IALS and ALL. The peak age in LSAL was found to be 35. Thus older adults over 35 show a tendency to lose proficiency as they age, and younger adults show a tendency to gain proficiency until they reach the age of 35. Longitudinal analysis thus help to confirm the maturational nature of age based cross-sectional differences in literacy skills as seen in IALS and ALL.

Summary of observed patterns and peak ages for cross-sectional and longitudinal findings

85. Due to the high quality of the Seattle Longitudinal Study, findings from Schaie (1994; 2005) are used as reference point for summarizing the patterns and peak ages.

86. Cross-sectional age-skill profiles for fluid intelligence measures tend to start from a higher level and decline more steeply than in longitudinal profiles of the same measures. For measures pertaining to reasoning, spatial orientation, and verbal memory, patterns based on cross-sectional data suggest a peak age in young adulthood, around the age of 25, with virtually linear negative *age differences* from young adulthood to old age. This is observed in the Seattle Longitudinal Study but also a wide range of other studies based on cross-sectional designs.

87. Longitudinal age-skill profiles depict a pattern of linear *age-related decline* from young adulthood only for perceptual speed. The observed decline is substantial with processing and response speeds slowing by a full standard deviation between the ages of 25 and 88. This is especially significant because when age-related declines in perceptual speed are controlled for, the age-related declines in other abilities are significantly reduced, especially in old age. Schaie (1989) suggested that much of the late life decline in cognitive abilities can thus be attributed to a general slowing of processing and response speed. Individuals who maintain high levels of perceptual speed are thus more likely to maintain other cognitive abilities. Nevertheless, reduced attention, memory capacity and motivation among older adults are expected to contribute to lower test scores (Ng & Feldman, 2008).

88. Otherwise, the net age-related decline between the age of 25 and 88 for reasoning and verbal memory is half of a standard deviation, while it is a full standard deviation for spatial orientation. An important difference however, reasoning and spatial orientation register modestly positive change from young adulthood until the age of 53, and then begin to decline substantially.

89. In the case of verbal ability – a measure of crystallized intelligence – positive change is registered from young adulthood until the age of 60, and only then begins to decline. The net difference between 25 and 88 however, is virtually zero.

90. In summary, some measures of fluid intelligence show a pattern of early and steep decline, while others level off in mid-adulthood, and then begin to decline only later in old age. In contrast, measures of crystallized intelligence are found to increase steadily from low levels and peak at a later age than measures of fluid intelligence. This supports the notion that crystallized intelligence continues to accumulate over the lifespan into old age, possibly due to continued *behavioural and practice effects* (Drag & Bieliauskas, 2009).

91. Two conclusions can be drawn. First, the evidence suggests that changes in cognitive skills are not uniform throughout adulthood and that there are different patterns for different types of skills. Second, the precise age at which skills can reliably be said to decline on average, depends highly on the type of skill. Table 2 provides a brief overview on a selection of studies of the ages at which different cognitive skills have been found to peak.

Table 2. Overview of peak ages found in cognitive ageing literature

Source	Type of design	Variable	Type of measure*	Peak age
Schaie (1994; 2005)	Cross-sectional	Perceptual speed Inductive reasoning Spatial orientation Verbal memory Verbal ability	Fluid Fluid Fluid Fluid Crystallized	25 25 25 25 53
	Longitudinal (7-year within subject)	Perceptual speed Inductive reasoning Spatial orientation Verbal memory Verbal ability	Fluid Fluid Fluid Fluid Crystallized	25 53 53 60 60
Salthouse (2009b)	Cross-sectional	12 variables	Mixed	22-27
Baltes & Lindenberger (1997)	Cross-sectional (1600 participants aged 25-103)	5 measures	Mixed	25
Verhaeghen & Salthouse (1997)	Cross-sectional (meta-study)	Speed Primary/Working Memory Episodic Memory Reasoning Space	Fluid Fluid Fluid Fluid Fluid	Young adulthood (negative correlation for individuals under the age of 50)
Verhaeghen (2003)	Cross-sectional (meta-study)	Vocabulary	Crystallized	late middle age
Rönnlund & Nilsson (2006)	Cross-sectional (controlled for education)	Visuospatial	Fluid	55
	Longitudinal (controlled for practice effects)	Visuospatial	Fluid	55
Rönnlund *et al.* (2008)	Longitudinal (5-year within subject)	Episodic Memory Semantic Memory	Fluid Crystallized	60 55-65
	Longitudinal (controlled for practice effects)	Episodic Memory Semantic Memory	Fluid Crystallized	35-60 55-60
	Cross-sectional (controlled for education)	Episodic Memory Semantic Memory	Fluid Crystallized	35-55 50-65
	Cross-sectional	Episodic Memory Semantic Memory	Fluid Crystallized	35 40-50

Ryan *et al.* (2000)	Cross-sectional	Vocabulary Similarities Arithmetic Digit Span Information Comprehension Letter-Number Sequence Picture Comp Digit Symbol Block Design Matrix Reason Picture Arrangement Symbol Search Object Assembly	Crystallized Crystallized Crystallized Crystallized Crystallized Crystallized Crystallized Fluid Fluid Fluid Fluid Fluid Fluid Fluid	45–54 30-54 45–54 16-54 45-54 45-54 16-44 16-44 18-19 16-29 16-17 16-34 18-19 16-34
Kaufman, Reynolds & McLean (1989)	Cross-sectional (controlled for education)	Verbal Performance	Crystallized Fluid	45-54 20-24
Sattler (1982)	Cross-sectional	Vocabulary Similarities Arithmetic Digit Span Information Comprehension Picture Comp Digit Symbol Block Design Picture Arrangement Object Assembly	Crystallized Crystallized Crystallized Crystallized Crystallized Crystallized Fluid Fluid Fluid Fluid Fluid	35-44 20-34 20-54 20-34 20-54 20-54 20-34 20-34 20-34 20-34 20-34
Crum *et al.* (1993)	Cross-sectional	Mini-Mental State Examination Score (MMSE)	Mixed (ceiling effects)	25-34 (below 5 years of schooling) 18-29 (5-8 years schooling) 18-34 (high school diploma) 18-69 (tertiary education)
McArdle *et al.* (2000)	Longitudinal	Block Design Vocabulary Digit Span Forward Speed	Fluid Crystallized Other Fluid	42+ 60+ 18-26 18-23
Avolio & Waldman (1994)	Cross-sectional	General Ability Verbal Ability Numerical Ability Spatial Ability Form Perception	Mixed Fluid Fluid Fluid Fluid	25-34 20-24 25-34 25-34 <20
Burke *et al.* (1991)	Cross-sectional	Tip-of-the-tongue (TOT, word retrieval failure)	Crystallized	20s
Kaufman & Horn (1996)	Cross-sectional (controlled for gender and education)	Rebus Learning Logical Steps Mystery Codes Memory for Block Design	Fluid Fluid Fluid Fluid	20-24
		Definitions Auditory Comprehension Double Meanings Famous Faces	Crystallized	45-49
Tombaugh *et al.* (1999)	Cross-sectional	Number of words generated in 1 minute for the letters F, A, and S	Crystallized	40–49
		Animals Named in 1 Minute	Mixed	16-39
Zelinski & Burnight (1997)	Longitudinal (16 year within subject)	Text recall List recall List recognition Reasoning Spatial ability Vocabulary	Fluid Fluid Fluid Fluid Fluid Crystallized	Early adulthood 30s 55-63 40s 40s 55-63

Giambra *et al.* (1995)	Longitudinal (up to 27 year within subject)	Vocabulary Visual Retention	Crystallized Mixed	65-74 Early adulthood to 63
Alder *et al.* (1990)	Longitudinal (14 year within subject)	Vocabulary Visual Retention	Crystallized Mixed	30-60 Early adulthood
Zimprich & Mascherek (2010)	Longitudinal (12 year within subject)	11 measures	Fluid Crystallized Memory Speed	Before middle-age After middle-age Before middle-age Before middle-age
Finkel *et al.* (2005)	Longitudinal (13 year within subject above age of 50)	Verbal Spatial Memory Speed	Crystallized Fluid Mixed Fluid	Decline after age of 65 Decline with age 50 Decline with 55 Decline with age 50
Christensen (2001)	Longitudinal (7.5 year within subject above age of 70)	Knowledge (e.g. Vocabulary) Memory Speed	Crystallized Mixed Fluid	No decline after 70 Before the age of 70 Before the age of 70
Arbuckle *et al.* (1998)	Longitudinal (40-45 and 5 year within subject for WWII veterans)	Picture Completion Picture Anomalies Paper Formboard Arithmetic Verbal Analogies Vocabulary	Fluid Fluid Fluid Fluid Mixed Crystallized	Decline before late life Decline before late life Decline before late life Decline before late life Decline before late life Increase in late life
Rabitt *et al.* (2004)	Longitudinal (7.5 year within subject community residents above age of 49; controlled for practice and drop-out effects etc.)	AH4-1 (e.g. Arithmetic) AH4-2 (e.g. Logical Series) MHA (Vocabulary) MHB (Vocabulary) CVL (Memory) VFR (Memory)	Fluid Fluid Crystallized Crystallized Mixed Mixed	49-51 Decline before 49 49-54 Decline before 49 Decline before 49 Decline before 49
Park *et al.* (2002)	Cross-sectional (345 individuals 20-92)	Processing Speed Working Memory Long-term Memory Short-term Memory Verbal Ability	Fluid Fluid Mixed Fluid Crystallized	20s 20s 20s 20s 70s
Dixon *et al.* (2004)	Longitudinal (Two studies, 3 year within subject change)	Episodic Memory	Fluid	No decline before 75
Small *et al.* (1999)	Longitudinal (3 year within subject change above age of 55)	Word Recall Category Recall Word Recall per Category Intrusions Words Repetition Clustering	Fluid Fluid Fluid Fluid Fluid Fluid	Decline before late life Decline before late life Stable in late life Decline before late life Decline before late life Old age
Small *et al.* (2011)	Longitudinal (up to 12 years within subject above age of 55)	Lexical decision time Semantic decision time Word recall Story recall Fact recall Vocabulary	Fluid Fluid Fluid Fluid Fluid Crystallized	No Decline before 75 No Decline before 75 Decline before 55 No Decline before 75 Decline before 55 No Decline before 75

Note: * Measures do not necessarily correspond neatly to the concepts of fluid and crystallized intelligence. This is only an indication.

Implications of study design differences in interpreting the patterns

92. Observed differences in trajectories and peak ages between cross-sectional and longitudinal findings merit further discussion. The following discusses some of the major differences between the designs that are worthwhile noting when interpreting the data.

93. It is important to point out that *age differences* (between-person comparisons) and *age changes* (within-person comparisons) in cognitive skills are not the same thing. The two can only be identical under conditions of a perfectly stable environment over time (i.e., no cohort or period effects due to social factors) and that there are no changes in the cognitive abilities of successive birth cohorts (i.e., no cohort effects due to evolution-based neurophysiological changes) (see Schaie, 1965). Only then, are observed differences attributable to ageing effects. No research design has yet to provide data which would allow for

these distinct effects to be perfectly isolated (Schaie & Hofer, 2001). Both cross-sectional and longitudinal designs have weaknesses in this regard.

Cross sectional designs

94. Cross-sectional data are well suited to provide an accurate picture of *age differences* in cognitive skills, i.e., differences between individuals of different ages, at one period in time (Schaie, 1996), especially if the sample sizes are large. A single cross-section however, is neither well suited for explaining observed age differences, nor to provide an accurate picture of the trajectory of skill development over an individual's or age cohort's lifespan (i.e., age-related decline). As such, it is important to note that *age differences* do not necessarily reflect processes intrinsic to ageing (ageing effects). In a single cross-section, changes due to ageing are confounded with factors related to social change or circumstances (e.g., cohort and period effects). Nevertheless, *age differences* remain a substantively important issue for policy purposes, either in their own right or in establishing a need to understand better the underlying reasons for the observed differences.

95. Repeated cross-sections or panels help to provide good estimates of the trajectory of skill development over an age cohort's lifespan, provided that samples by age cohort are representative and large. These data are also advantageous because they are much less likely to be biased as a result of attrition and retest effects as in longitudinal designs (Verbeek 2008). They are disadvantageous however, because they do not allow for the empirical analysis of individual level factors that may influence skill gain or loss over the lifespan.

96. Comparing average skill scores by cohorts over time is nevertheless helpful to identify whether it is *older cohorts* who are experiencing *skill* loss, or whether it is *younger cohorts* who are experiencing *skill gain*. This helps to confirm whether there are age-related changes and the direction of change. Repeated cross-sectional measures thus help to identify whether a particular age cohort is gaining or losing skill over time, provided that the data are representative of the age cohort at the population level. It remains impossible however, to identify precisely with these data the underlying reasons for any observed age-related changes.

97. Younger adults today tend to feature higher levels of cognitive skills then younger adults in the past. This is reflected in the higher scores of younger adults in the cross-sectional profile than in the longitudinal profile. Evidence thus suggests that there are substantial generational (cohort) differences in cognitive skills (see discussion of evidence on social change affecting skills). Whether these are the result of the enduring effects of experiences in a particular time period, i.e., unique age and period combinations (e.g., exposed to particular methods of learning and memorization during early schooling years), or systematic change (e.g., better nutrition and sanitation), successive cohorts have nevertheless been found to display progressive increases in the level of their cognitive performance. The performance of an average adult aged 50, therefore, is expected to be higher in 10 years than the performance of an average adult aged 60 today.

98. Several cohort effects may be behind this tendency. For example, younger adults today receive more extended periods of schooling than their earlier cohorts. They may also be exposed to more cognitive demands at an earlier age for everyday tasks such as ones involving the use of computers or other technological devices, and the use of the Internet.

99. The existence of positive cohort effects suggest that age-skill profiles which are based on cross-sectional data will tend to overestimate cognitive decline in old age.

Longitudinal designs

100. In providing repeated observations for the same individuals over time, longitudinal data are well suited to provide good estimates of the trajectory of skill development over an individuals' lifespan (i.e., age-related decline). These data allow for the possibility to control for within-person characteristics that are observed as well as unobservables which are time invariant. Like repeated cross-sectional data however, longitudinal data are unable to explain fully the source of age-related decline. In particular, ageing effects continue to be confounded between intrinsic neurological and behavioural maturation effects, on the one hand, and on the other hand the extrinsic effects due to changes in the social, cultural and physical elements of contexts that individuals interact with as they age. In other words, while individuals change so do the contexts in which they live in, making it difficult to pinpoint precisely the reasons underlying the observed age-related decline.

101. Moreover, longitudinal data may lead to biased results and an underestimation of cognitive decline because of re-test effects associated with prior test experience and selection effects due to non-random attrition (Frees, 2004). For example, performance may be influenced because respondents have learned from prior measurement episodes that had the same or similar test (see Salthouse 2010a). Selection effects due to attrition are also a major disadvantage in longitudinal data. Participants drop out for several reasons. Some individuals move away and can no longer be found, some no longer want to respond, and others may not participate due to illness or death. These would not be a problem if the chance to drop out of the study was not related to cognitive skills, but often it is. Schaie (1994) reported that in the Seattle Longitudinal Study, those who returned for the retest, on average, were more likely to outperform those who did not return because the former had somewhat more favourable demographic characteristics and base ability levels.

102. Additionally, longitudinal data should contain at least three observations of skill at different points to make it possible to differentiate actual change from measurement error, re-test effects as well as regression toward the mean (Morris *et al.*, 1999). Sample sizes are also often too small especially over longer periods of time due to attrition, making observed longer-term trajectories unreliable. This combined with the fact that within-person changes in skills are likely to materialize over time spans that are longer than seven years severely limits the usefulness of longitudinal designs for studying ageing and skills.

103. While many researchers favour longitudinal data for investigating age-related change in skills, Salthouse (2009a; 2009b; 2010b) argued that longitudinal findings on age-skill profiles are too unreliable due to re-test and selection effects. Salthouse maintains that cross-sectional findings provide a more accurate picture of the age-related decline of cognitive skills though these claims are contested by many researchers (e.g., Abrams, 2009; Nilsson *et al.*, 2009; Schaie, 2009).

104. Interestingly, Rönnlund and Nilsson (2006) found that for a measure of spatial orientation, cross-sectional and longitudinal age-skill profiles have a very similar shape if one controls for education differences in the former and for practice effects in the latter. This latter finding suggests that the observed change over time may to a large degree be accounted for by the cohort effect associated with the expansion of education, on the one hand, while on the other hand, the observed change over the lifespan of individuals may to a large degree be accounted for by behavioural and practice effects.

A FURTHER ANALYSIS OF AGE-SKILL PROFILES USING IALS, ALL AND PIAAC DATA

105. This section examines age-skill profiles in greater detail by making use of data from two large scale comparative studies of cognitive foundation skills, namely the 1994-1998 International Adult Literacy Survey (IALS) and the 2003-2007 Adult Literacy and Lifeskills Survey (ALL). Up to date evidence on adult cognitive foundation skills as measured in these two surveys will be available from the OECD Programme for the International Assessment of Adult Competencies (PIAAC) for 24 countries in late 2013. PIAAC was designed to provide high quality comparative information on the cognitive foundation skills of adult populations[7]. Specifically, the aim of PIAAC is to monitor the distribution of cognitive foundation skills in the adult population, to keep up to date estimates on their economic and social value, and not least, to help develop a better understanding of the factors that influence skill gain and skill loss over the lifespan as well as over time.

106. The first subsection provides an overview of the countries that participated in IALS, ALL and PIAAC and for which it will be possible to undertake a more detailed analysis of changes in skill by age cohorts. The second subsection provides an overview of the average international age-skill profiles observed with these data. Finally, a detailed analysis of the change in age-skill profiles between the IALS and ALL survey periods is undertaken for nine countries for which it is possible to do so.

An overview of IALS, ALL and PIAAC data observation points on skills

107. For countries that will have participated in all three surveys (i.e., IALS, ALL and PIAAC), it will be possible to track developments in the literacy skills of representative age cohorts over three time points, each approximately 8-11 years apart. Otherwise, for countries who have participated in at least two of these panels, it will be possible to track the performance between two time points. For example, by comparing the average performance of Canadian adults aged 45 in the 1994 IALS study with the average performance of the same cohort but 9 years later in the 2003 ALL study, it will be possible to decipher whether that age cohort on average has maintained, gained or lost literacy skills over the 9-year period. The following provides details about which countries have trend data and how this will be expanded with PIAAC.

108. The International Adult Literacy Survey (IALS) provided the world's first comparable estimates of the levels and distributions of cognitive foundation skills in the adult population. The foundation skills measured included prose literacy, document literacy and quantitative literacy. Three separate data collections spanning a four year period were conducted in 24 countries or regions:

- In 1994, data collections were conducted in nine countries (see column 1 in Table 3A) – Canada, France, Germany, Ireland, the Netherlands, Poland, Sweden, Switzerland (German and French-speaking regions) and the United States. Data for seven of these countries were published in *Literacy, Economy and Society: Results of the First International Adult Literacy Survey* in December 1995 (Statistics Canada & OECD, 1995). France decided to withdraw from the study in November 1995, citing concerns over comparability. Data processing for Ireland was unfortunately delayed and so its results were included in a subsequent IALS publication.

- In 1996, five additional countries or regions conducted a data collection (see column 2 in Table 3A) – Australia, the Flemish Community in Belgium, Great Britain, New Zealand and Northern Ireland. Comparative data from this round of collection were released in November

[7] Competencies are defined as the ability to successfully meet complex demands in a particular context through mobilization of psychosocial prerequisites including both cognitive and non cognitive elements (see Rychen & Salganik, 2003). The internal structure of a competence includes knowledge, cognitive skills, practical skills, attitudes, emotions, values and ethics. The focus of PIAAC is on the measurement of observable cognitive skills that underlie the key competencies of literary, numeracy and problem solving in the context of technology rich environments.

1997 in *Literacy Skills for the Knowledge Society: Further Results from the International Adult Literacy Survey* (HRDC & OECD, 1997).

- In 1998, nine other countries or regions conducted a data collection (see column 3 in Table 3A) – Chile, the Czech Republic, Denmark, Finland, Hungary, Italy, Norway, Slovenia and the Italian-speaking region of Switzerland. Results for most of these countries are included in *Literacy in the Information Age: Final Report of the International Adult Literacy Survey* (Statistics Canada & OECD, 2000). Limited literacy data became available for Portugal in 1998. Due to concerns by experts about data quality as a consequence of a low response rate, data for Italy were only published separately in *La competenza alfabetica in Italia : Una ricerca sulla cultura della populazione, Centro Europeo Dell' Educazione, Frascati, and F. Angeli, Milan*.

109. The Adult Literacy and Lifeskills Survey (ALL) built on the IALS study. The foundation skills measured include prose literacy, document literacy, numeracy and problem solving. The prose and document literacy measures in IALS and ALL are comparable over time (see Statistics Canada & OECD, 2005). Two separate data collections spanning a four year period were conducted in 11 countries or regions:

- In 2003, data collections were conducted in seven countries or regions (see column 4 in Table 3A) – Bermuda, Canada, Italy, Norway, Switzerland (German, French and Italian-speaking regions), the United States, and the Mexican State of Nuevo Leon. Results for these countries are published in *Learning a Living: First Results of the Adult Literacy and Life Skills Survey* (Statistics Canada & OECD, 2005).

- In 2007, four other countries or regions conducted a data collection (see column 5 in Table 3A) – Australia, Hungary, the Netherlands and New Zealand. Results for these countries are published in *Literacy for Life: Further Results from the Adult Literacy and Life Skills Survey* (Statistics Canada & OECD, 2011).

110. As of early 2012, there are 24 countries or regions preparing for their data collection as part of the OECD Programme for the International Assessment of Adult Competencies (PIAAC) – (see column 6 in Table 3A) – Australia, Austria, Belgium, Canada, the Czech Republic, Cyprus[8,9], Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Japan, Korea, Norway, Poland, Portugal, Russia, the Slovak Republic, Spain, Sweden, the United Kingdom, and the United States. The foundations skills measured include literacy (a combined version of prose and document literacy based on some common test items from IALS and ALL), numeracy (based on some common test items from ALL) and problem solving in the context of technology rich environments. The prose and document measures in IALS and ALL will be rescaled to be comparable to the literacy measure in PIAAC. Numeracy is comparable between PIAAC and ALL, but not IALS. Deliberations for a second cycle of data collection to be held in 2014 are underway with a number of countries including New Zealand which participated in IALS.

111. In summary, the observations points over time in a number of countries or regions mean that a measure of <u>literacy</u> skills will be comparable over time as follows (see Table 3A):

[8] Footnote by Turkey
The information in this document with reference to « Cyprus » relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognizes the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

[9] Footnote by all the European Union Member States of the OECD and the European Commission
The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

- 9 countries currently have <u>two</u> observation points
- 6 countries will have <u>three</u> observation points after PIAAC 2012 (round 1)
- 1 other country will have <u>three</u> observation points after PIAAC 2014 (round 2)
- 10 countries will have <u>two</u> observation points after PIAAC 2012 (round 1)
- 9 countries will have <u>one</u> observation point after PIAAC 2012 (round 1)

112. Similarly, the observations points over time in a number of countries or regions mean that a measure of <u>numeracy</u> skills will be comparable over time as follows (see Table 3B):

- 6 countries will have <u>two</u> observation points after PIAAC 2012 (round 1)
- 1 other country will have <u>two</u> observation points after PIAAC 2014 (round 2)
- 19 countries will have <u>one</u> observation point after PIAAC 2012 (round 1)

Table 3A. The IALS, ALL and PIAAC data observation points for a measure of literacy skills

	IALS			ALL		PIAAC	
	1994	1996	1998	2003	2007	2012	2014
Canada	X			X		X	
Germany	X					X	
Netherlands	X				X	X	
Poland	X					X	
Sweden	X					X	
Switzerland	X			X			
United States	X			X		X	
Australia		X			X	X	
Belgium		X				X	
Ireland		X				X	
New Zealand		X			X		X
United Kingdom		X				X	
Chile			X				
Czech Republic			X			X	
Denmark			X			X	
Finland			X			X	
Hungary			X		X		
Italy			X	X		X	
Norway			X	X		X	
Portugal			X			X	
Slovenia			X				
Bermuda				X			
Mexico (Nuevo Leon)				X			
Austria						X	
Cyprus[10]						X	
Estonia						X	
France						X	
Japan						X	
Korea						X	
Russia						X	
Spain						X	
Slovak Republic						X	

9 countries currently have <u>two</u> observation points
6 countries will have <u>three</u> observation points after PIAAC 2012 (round 1)
1 other country will have <u>three</u> observation points after PIAAC 2014 (round 2)
10 countries will have <u>two</u> observation points after PIAAC 2012 (round 1)
8 countries will have <u>one</u> observation point after PIAAC 2012 (round 1)

Note: The United Kingdom includes data collections held in Great Britain and Northern Ireland.

[10] Refer to footnotes 8 and 9.

Table 3B. The ALL and PIAAC data observation points for a measure of numeracy skills

	ALL		PIAAC	
	2003	2007	2012	2014
Canada	X		X	
Germany			X	
Netherlands		X	X	
Poland			X	
Sweden			X	
Switzerland	X			
United States	X		X	
Australia		X	X	
Belgium			X	
Ireland			X	
New Zealand		X		X
United Kingdom			X	
Chile				
Czech Republic			X	
Denmark			X	
Finland			X	
Hungary		X		
Italy	X		X	
Norway	X		X	
Portugal			X	
Slovenia				
Bermuda	X			
Mexico (Nuevo Leon)	X			
Austria			X	
Cyprus[11]			X	
Estonia			X	
France			X	
Japan			X	
Korea			X	
Russia			X	
Spain			X	
Slovak Republic			X	

6 countries will have <u>two</u> observation points after PIAAC 2012 (round 1)
1 other country will have <u>two</u> observation points after PIAAC 2014 (round 2)
19 countries will have <u>one</u> observation point after PIAAC 2012 (round 1)

Note: The United Kingdom includes data collections held in Great Britain and Northern Ireland.

[11] Refer to footnotes 8 and 9.

Age-skill-age profiles based on internationally pooled data from IALS and ALL

113. This subsection summarizes age-skill profiles for the internationally pooled datasets from both IALS and ALL. Figures 9A and 9B present the relationships for IALS and ALL respectively, between cognitive foundation skills (as measured by literacy skills) and age while allowing for non-linearity, with and without adjustment for education. All profiles adjust for immigration status.

114. As highlighted in the preceding sections, the profiles are not easy to interpret because inferring developmental change from cross-sectional age differences confounds maturational effects of ageing with changes in social factors which may be correlated with age (i.e., cohort effects). For example the quality of education may not be constant across all age cohorts. Moreover, although the profiles are remarkably similar over the two survey periods, the pooled datasets do not comprise the same number or composition of countries.

115. Nevertheless, a number of observations are worth noting from these average international age-skill profiles.

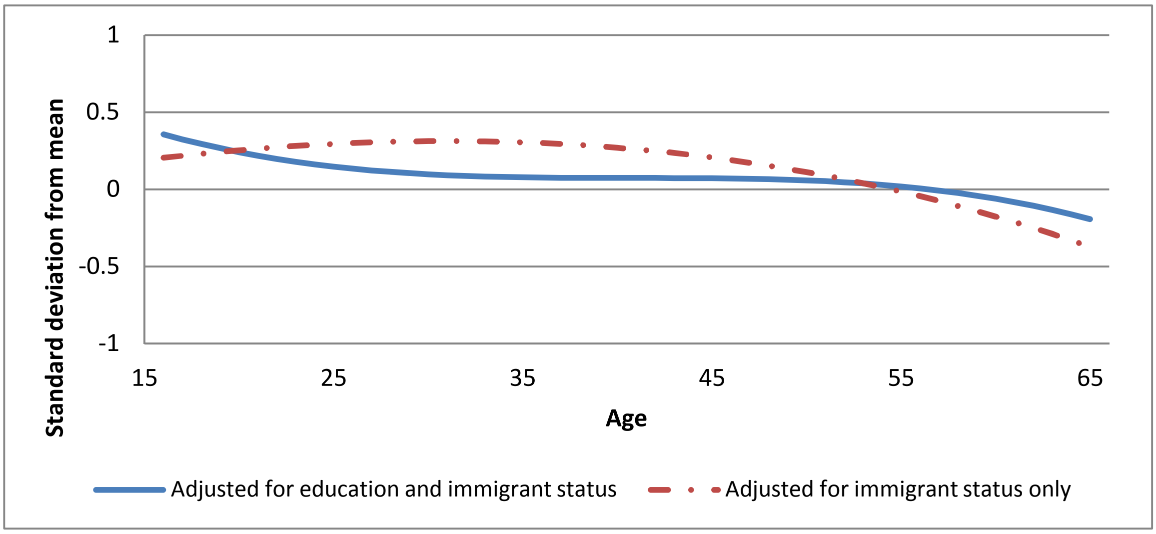
116. First, it can be seen that the relationship between a foundation skill measures (literacy) and age is on average negative when the entire lifespan of working age adults (from 16 to 65) is considered. Older cohorts in both IALS and ALL, regardless of country, are found to perform consistently lower on the measured skill on average than younger cohorts.

117. Second, when education is not controlled for, cohorts up to about the age of 31 are found to score higher on average than younger cohorts but by progressively smaller increments. After the age of 31, older cohorts score on average progressively lower than younger cohorts.

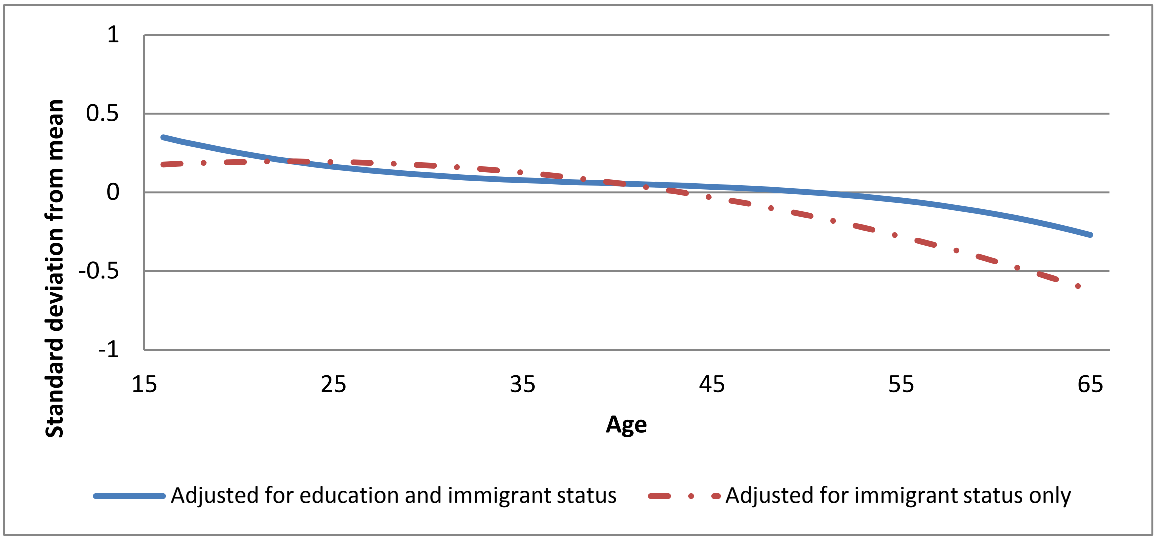
118. Third, when education is controlled for, older cohorts score on average progressively lower than younger cohorts, already from the early age of 16, but the differences from mid 20s to mid 50s are not large.

Figure 9. The relationship between AGE and literacy proficiency

A. Literacy skill proficiency of adults aged 16 to 65, 2003-2007 ALL



B. Literacy skill proficiency of adults aged 16 to 65, 1994-1998 IALS



Source: Adult Literacy and Lifeskills Survey, 2003-2007; International Adult Literacy Survey, 1994-1998.

Country specific analysis of change in age-skill profiles using IALS and ALL

119. This subsection provides a detailed analysis of changes in age-skill profiles for two select countries, namely Australia and the Netherlands. See Annex 1 for the same analysis using data for seven additional countries that participated in both IALS and ALL. The results reveal important country differences. A decomposition of change in age-skill profiles is done from two perspectives in order to estimate *ageing effects* associated with skill gain and loss within cohorts over time; and, *cohorts effects* associated with skill gain and loss between cohorts over time. Skill gain and loss are thus interpreted in two distinct ways as follows.

- First, in the same way that an individual may gain or lose skill as they age, a particular age cohort (i.e., all adults born in 1965) may on average as a collective gain or lose skill as they age. IALS, ALL and PIAAC do not track all adults of any cohort, but they track a representative sample of all adults for a range of cohorts. For example, in Canada adults who were born in 1965 were about 34 in IALS, about 43 in ALL and will be about 51 in PIAAC. Even if it is not the same adults who participate in all three panels, the representativeness of the sample allows for the tracking of a particular age cohort to decipher if on average as a collective they have gained or lost skill as they aged. This can be linked to ageing effects.

- Second, a country may gain or lose skill as time passes via generational change. In this analysis, the net gain or loss is considered at the cohort level, with some cohorts either adding or subtracting to the skill base of a country relative to the cohorts of the same age in an earlier period. For example, if the average skill score of adults aged 35 in 1994 is higher or lower than the average skill score of adults aged 35 in 2003, then it may be said that there is an average skill gain or loss in terms of what that cohort contributes to the overall skill base of a country. This can be linked to cohort effects.

120. It is worthwhile to note before describing the patterns that analysis of within-person growth curves using longitudinal data (see analysis of LSAL by Reder, 2009) confirms that individual change in skill diverges from overall population change at the cohort level, where some individuals are seen to display positive growth whereas others show negative growth and yet for others there is little change in proficiency. Two important conclusions can be drawn from these observations. First, behavioural and practice factors affect the amount of individual gain or loss of proficiency over the lifespan of individuals (discussed in further detail in the section providing an overview of the evidence on the factors causing skill gain and skill loss). Second, the overall population change could be close to zero if the proficiency gains of some individuals are offset by the losses of others.

121. In summarizing the changes in age-skill profiles by country, emphasis is placed on describing the observed pattern. While some interpretative commentary of the patterns is provided, a more detailed empirical analysis of the underlying factors which may explain the observed patterns is left for further study. PIAAC will permit some analysis of these factors at the macro level but in limited ways due to the fact that the data are cross-sectional.

122. The following describes in detail what Panels A, B, C and D display in Figures 10 and 11 as well as in Figures A1 to A7 in Annex 1:

- Panel A compares the trend in the average scores of cohorts in IALS with the trend in the average score of cohorts of the same age in ALL. This helps to reveal whether specific age cohorts of the same age but in different periods are, adding to, or subtracting from, the overall skill base of a country over time. This can be linked to a cohort effect.

- Panel B displays whether the difference in the average score of each age cohort between IALS and ALL is statistically different. This helps to reveal the reliability of the observed trends in skill gain or loss shown in Panel A.
- Panel C compares the trend in the average scores of cohorts in IALS with the trend in the average scores of those same cohorts but 5-13 years later in ALL. This helps to reveal whether a specific age cohort has on average as a collective gained or lost skill as they have aged. This can be linked to an ageing effect.
- Panel D displays whether the difference in the average score of a cohort in IALS is statistically different than the average score of the same cohort but 5-13 years later. This helps to reveal the reliability of the observed trend in skill gain or loss shown in Panel C.

Australia (1996-2006: 10-year span)

123. Figures 10A and 10B reveal a trend of a net negative cohort effect for adults aged 16-21 but this is only statistically significant (p<.05) for adults aged 19 and 21. There is also a statistically significant decrease for adults aged 28 but this does not show up in the trend due to the averaging out of differences in the cohorts immediately younger or older than 28. Similarly, there is an observed trend of a net positive cohort effect for adults aged 43-65. This latter result is statistically significant (p<.05) for adults aged 48, 53-54, 58 and 61. In summary, there is some evidence of both skill loss and skill gain via cohort effects. The expansion of educational attainment seems to have had some impact in offsetting the age-related decline of literacy skills for some adults aged 48 and over, at least compared to a decade earlier. Otherwise, the decline among some younger cohorts is an indication that changes to education systems in the last decade may have contributed to a small average decline in foundational skills for these cohorts. This needs to be considered more carefully in light of actual changes that have taken place.

124. Figures 10C and 10D reveal a trend of net positive ageing effects 10 years later for adults aged 16-28 in 1996 but this is only statistically significant (p<.05) for adults aged 16, 17 and 23. Similarly, there is an observed trend of net negative ageing effects 10 years later for adults aged 29-55 in 1996. This latter result is statistically significant (p<.05) for adults aged 36, 40, 45-46, 49-50, 52 and 55 in 1996. In summary, there is some evidence of skill gain via ageing effects but only for a narrow range of younger cohorts. The evidence for skill loss via ageing effects is more widespread starting at the age of 36 in 1996. Results suggest that in Australia, literacy skills (as measured in IALS and ALL) continue to be gained on average up until about the late 20s, and then begin to decline on average with progressively larger losses as one ages. The observed gains and losses are in the expected age ranges.

The Netherlands (1994-2007: 13-year span)

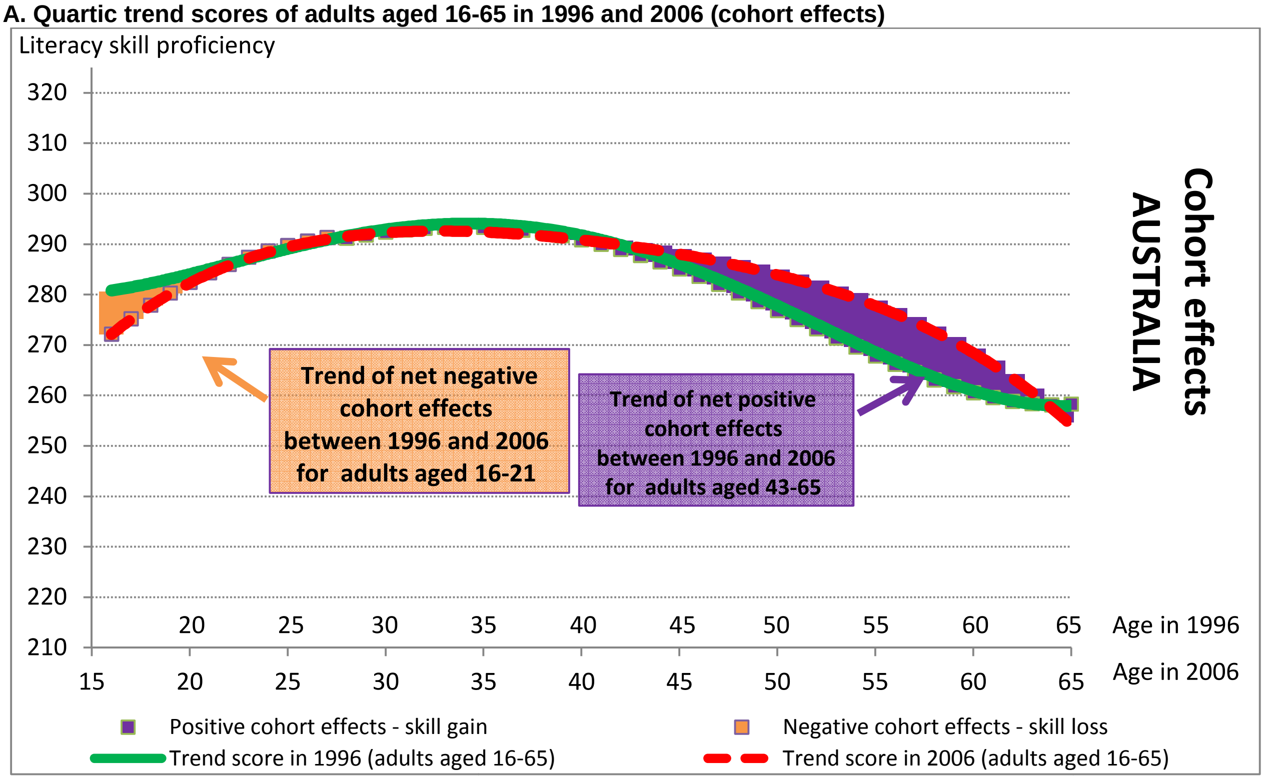
125. Figures 11A and 11B reveal a trend of a net negative cohort effect for adults aged 16-35 but this is only statistically significant (p<.05) for adults aged 24 and 27. Similarly, there is an observed trend of a net positive cohort effect for adults aged 36-65 but this is only statistically significant (p<.05) for adults aged 59. In summary, there is limited evidence of skill loss and gain via cohort effects. While social factors may have led to positive effects among adults aged 59, the expansion of educational attainment seems to have done very little to offset the skill loss due to age-related decline.

126. Figures 11C and 11D reveal a trend of net positive ageing effects 13 years later for adults aged 16-19 in 1994 but this is only statistically significant (p<.05) for adults aged 16. Similarly, there is an observed trend of net negative ageing effects 13 years later for adults aged 20-52 in 1994 and this is statistically significant (p<.05) for adults aged 27-29, 32-35, 37-41, 44, 46-49, and 51-52. In summary, there is some skill gain via ageing effects but only for those aged 16 in 1994. The evidence for skill loss

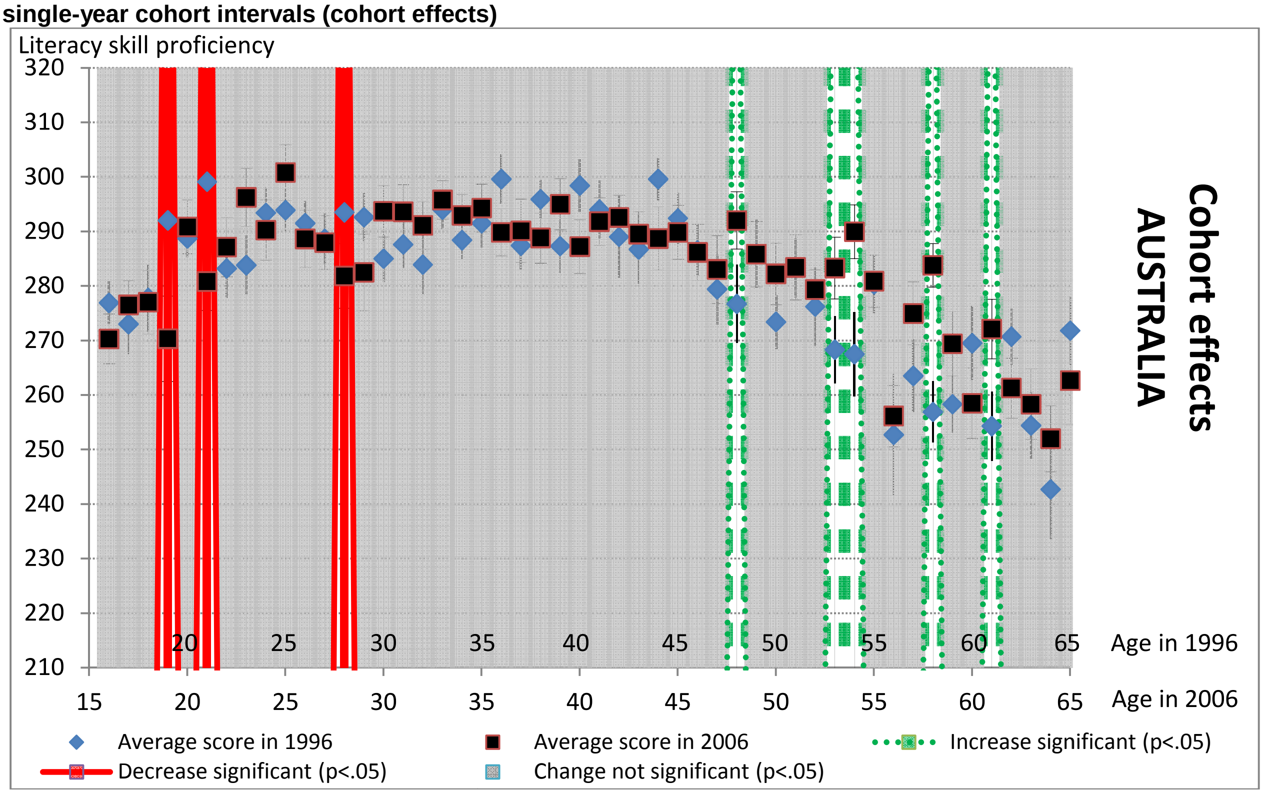
via ageing effects is more widespread starting as early as age 27. It is worthwhile to note that the age-skill profiles in the two periods are remarkably similar suggesting that the measured skills are strongly subjected to age-related decline in the Netherlands.

Figure 10. Change in literacy skills between and within cohorts from 1996-2006, foreign-born adults excluded, Australia

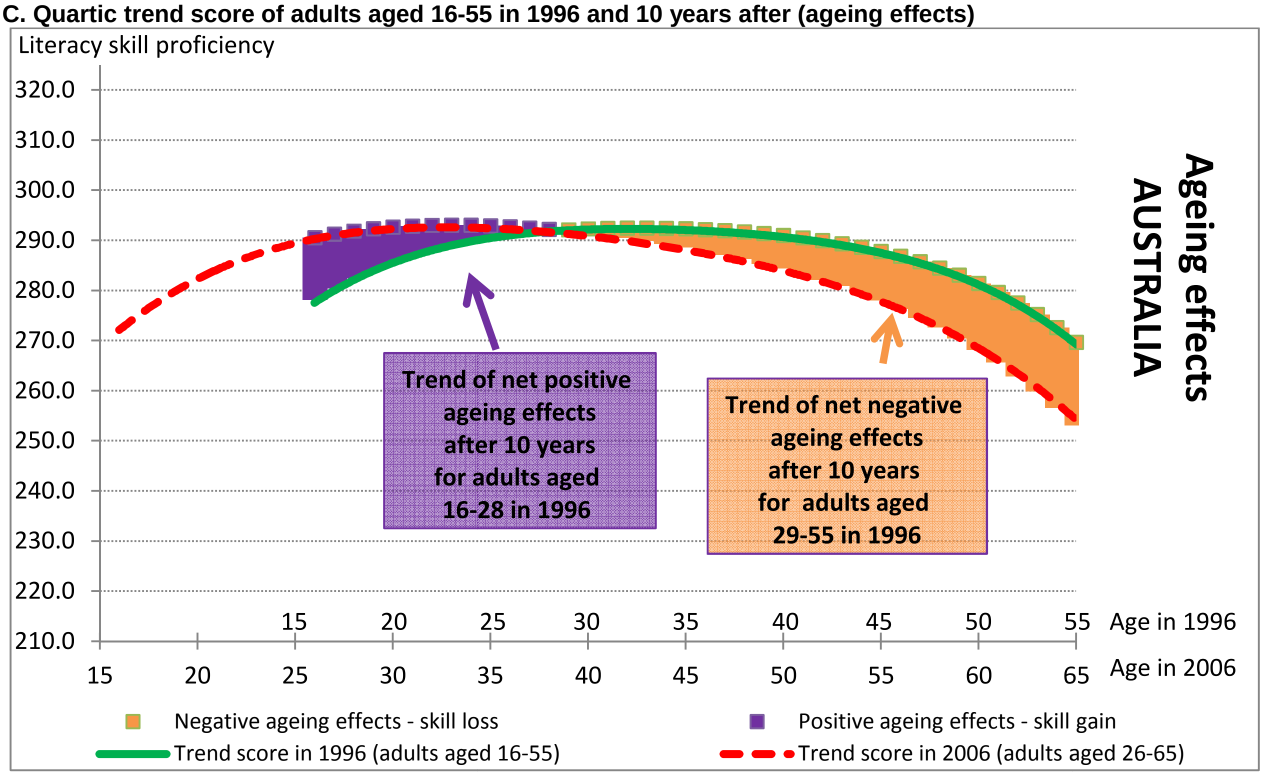
A. Quartic trend scores of adults aged 16-65 in 1996 and 2006 (cohort effects)



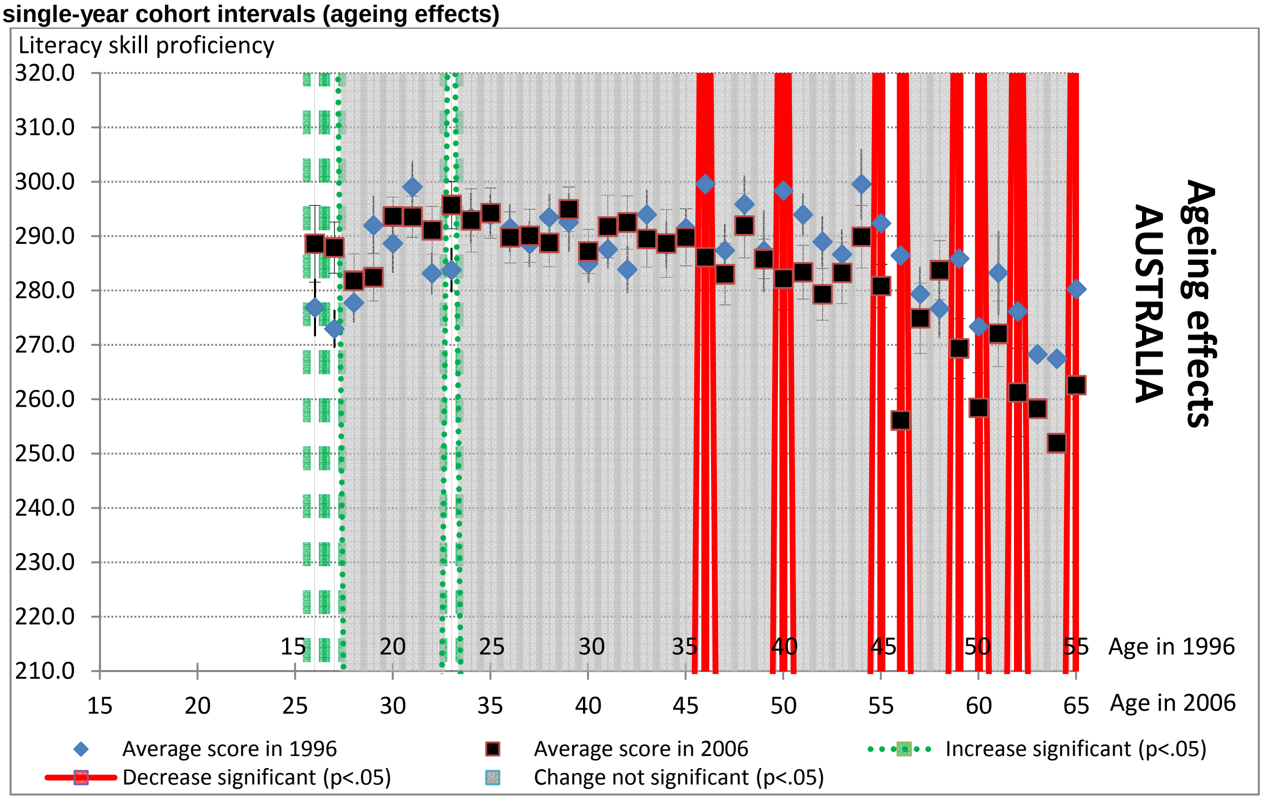
B. Statistical significance (p<.05) of difference in scores of adults aged 16-65 between 1996 and 2006 by single-year cohort intervals (cohort effects)



C. Quartic trend score of adults aged 16-55 in 1996 and 10 years after (ageing effects)



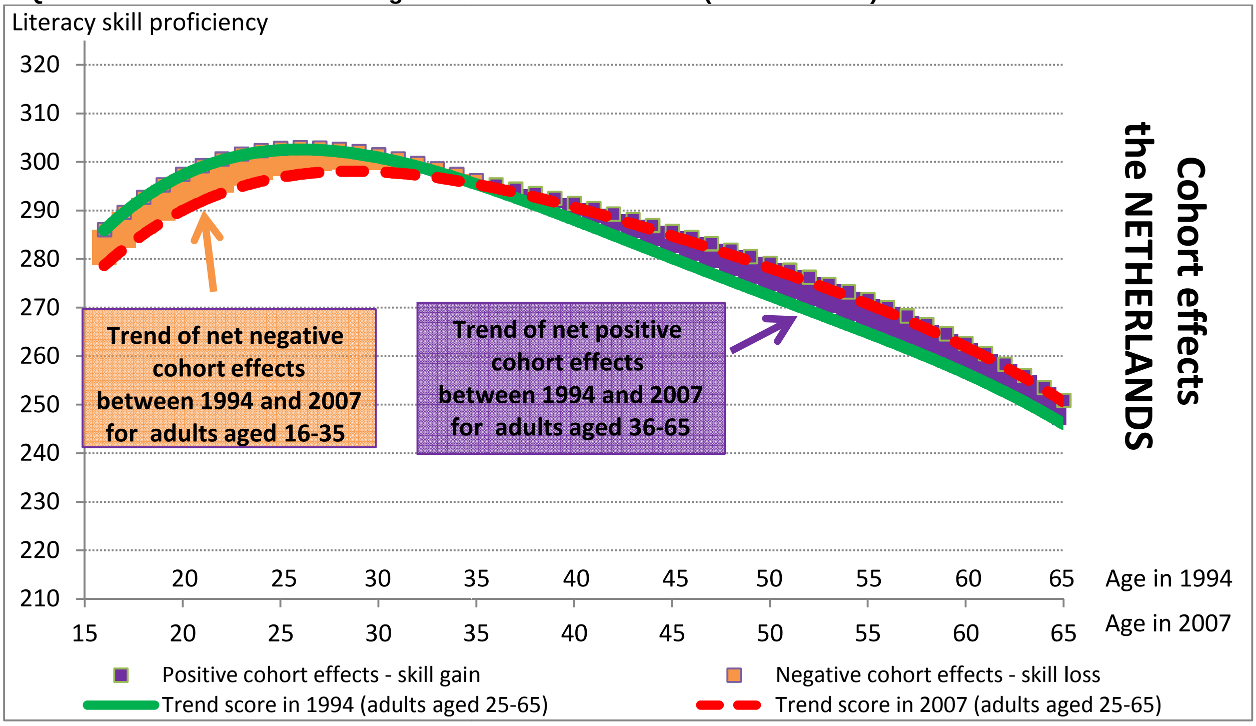
D. Statistical significance (p<.05) of difference in scores of adults aged 16-55 in 1996 and 10 years after by single-year cohort intervals (ageing effects)



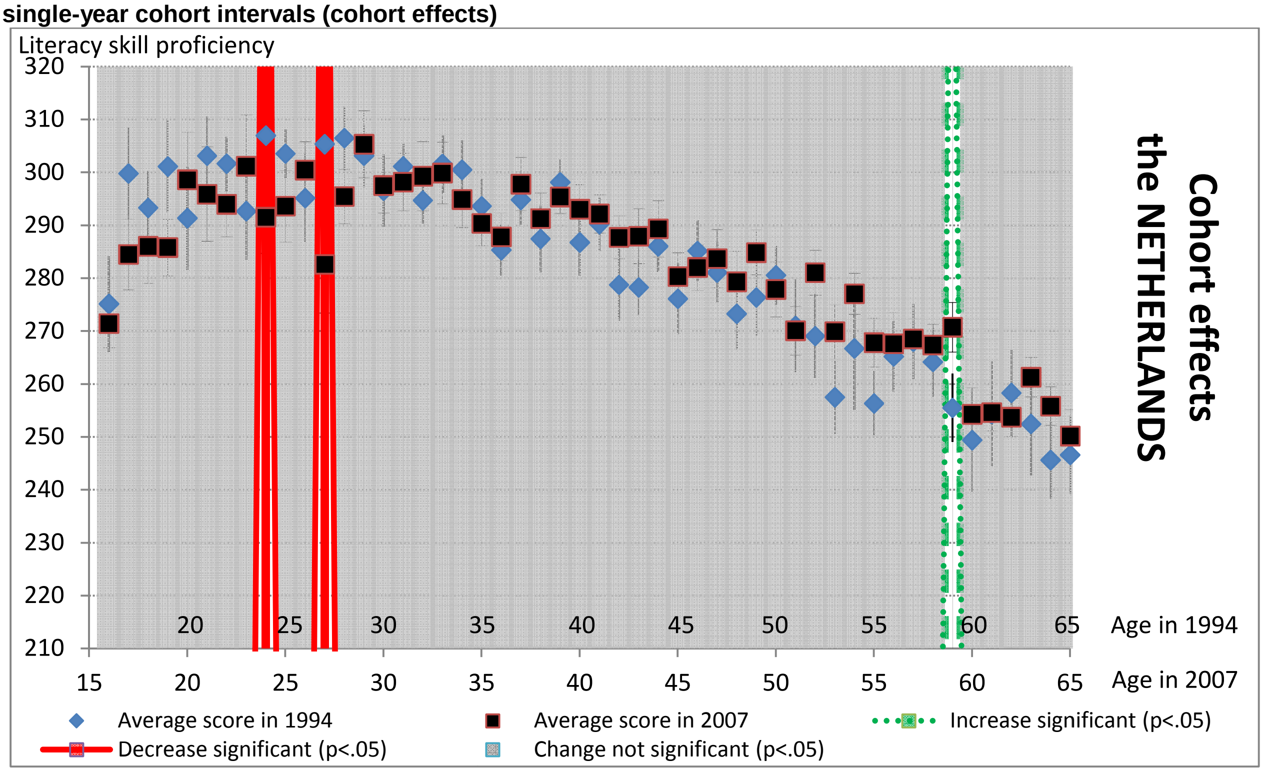
Source: International Adult Literacy Survey, 1994-98; Adult Literacy and Lifeskills Survey, 2003-07.

Figure 11. Change in literacy skills between and within cohorts from 1994-2007, foreign-born adults excluded, Netherlands

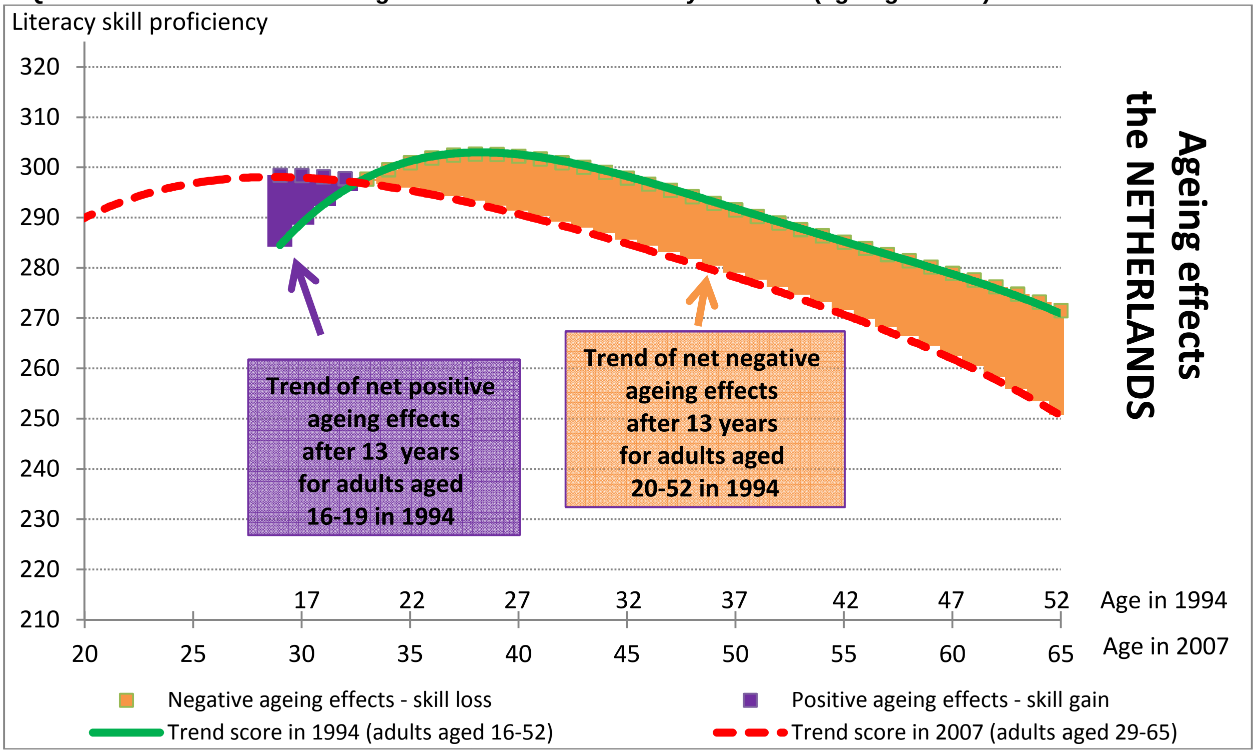
A. Quartic trend scores of adults aged 16-65 in 1994 and 2003 (cohort effects)



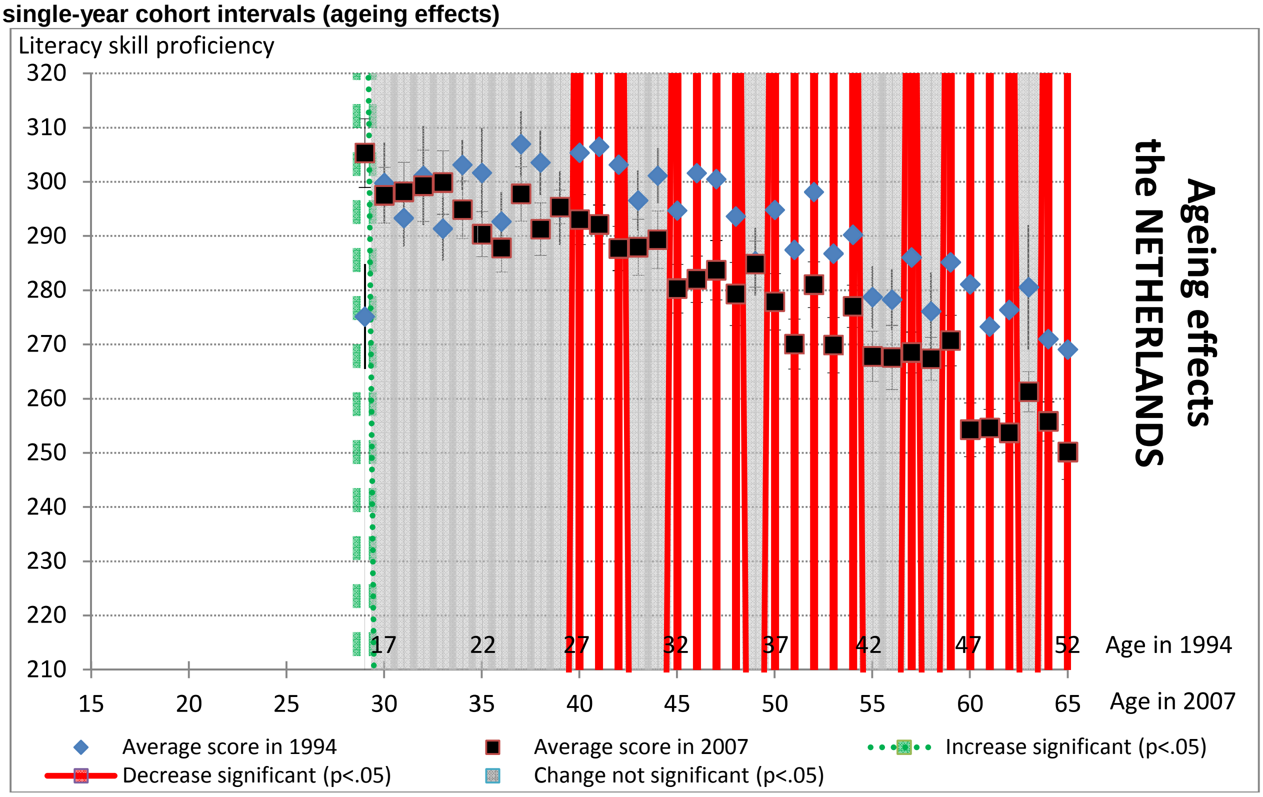
B. Statistical significance (p<.05) of difference in scores of adults aged 16-65 between 1994 and 2003 by single-year cohort intervals (cohort effects)



C. Quartic trend score of adults aged 16-56 in 1994 and nine years after (ageing effects)



D. Statistical significance (p<.05) of difference in scores of adults aged 16-56 in 1994 and nine years after by single-year cohort intervals (ageing effects)



Source: International Adult Literacy Survey, 1994-98; Adult Literacy and Lifeskills Survey, 2003-07.

AN OVERVIEW OF THE EVIDENCE ON THE FACTORS CAUSING SKILL GAIN AND SKILL LOSS

127. What causes skill gain or skill loss over the lifespan of an individual or over time at the country level? The following provides a brief overview of what is known about the factors thought to influence skill gain and skill loss over the lifespan and over time. The factors covered include education and training, a range of behavioural and practice factors as well as social factors.

What is the impact of education and learning interventions on cognitive skill trajectories over the lifespan?

128. Average declines in age-skill profiles, whether based on within-person or between-person comparisons do not do justice to the vast individual differences that are observed. An important question is whether prior levels of education or educational interventions in adulthood can help to reverse age-related decline in cognitive skills.

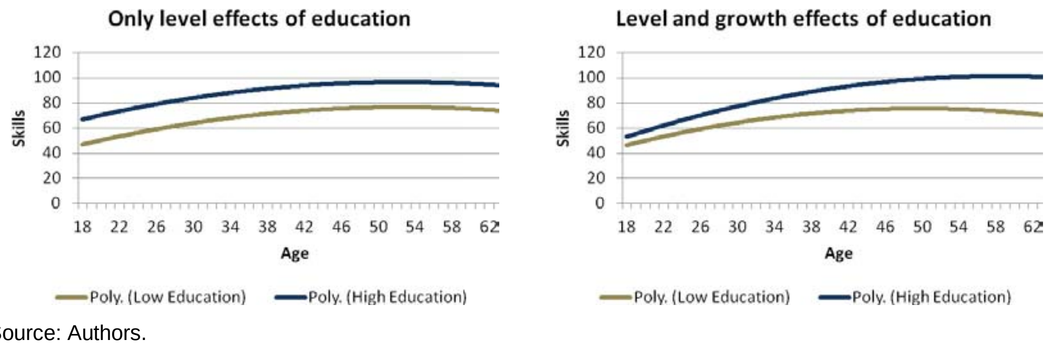
Initial formal schooling

129. Many studies have shown that adults of all ages who have a higher level of education attainment tend to score higher on measures of cognitive skills. See for example, the average literacy skills by age cohort based on data from the IALS and ALL studies (Statistics Canada & OECD, 2000; 2005). It is possible that this relationship is observed only because those people who are already highly skilled go on to take additional schooling. There is however, strong evidence that education enhances skills (see the meta review of adoption studies by IJzendoorn *et al.*, 2005).

130. Other evidence suggests that enhanced skills due to education and other factors predict the maintenance of good cognitive functioning into old age. Yaffe *et al.* (2009) for example, in a study of more than 2,500 elders over an eight year period with four measurement points found that initial education as well as other factors predicted the maintenance of high cognitive functioning.

131. While there is evidence that formal education influences the level of cognitive skills, less is known on whether formal education influences the rate of change in cognitive skills. Figure 12 illustrates the distinction between the level and growth effects of education. If education only affects the level of skills, then age-skill profiles for adults with different levels of education will run parallel (left panel). In contrast, if education affects both the level and growth of skills, then the profiles of those with different levels of education may diverge over time (right panel).

Figure 12: Distinguishing between the level and growth effects of education



Source: Authors.

132. Research has found that cognitive skills in childhood either as a consequence of nature (i.e., genetics) or nurture (i.e., education) predict the level of cognitive skills in later life but not the rate of change in skills as people age. The issue of whether *age is kinder to the initially more able* has been extensively researched, but among the few high quality studies, results reveal only level effects, not growth effects (see Gow *et al.*, 2011; Deary *et al.*, 1999).

133. For example, using a longitudinal study spanning 14-years with data collections at three-year intervals and a sample of more than 6,000 elderly, Wilson *et al.* (2009) found that education affects the level of cognitive skills but not the rate of their decline. The same study claimed that the results of other studies including longitudinal ones had mixed results for both the level and growth effects of education on cognitive skills.

134. Similarly, in a review of 14 longitudinal studies with a sample size of at least 300 and a follow-up period of at least one year for the purposes of assessing the effect of education on cognitive decline, Plassman *et al.* (2010) did not find consistent evidence that education affects the rate of decline in cognitive skills.

135. Education, however, has been found to reduce the risk of experiencing dementia in old age and to delay the onset of Alzheimer's (Andel *et al.*; 2005; Valenzuela & Sachdev, 2005; Paradise *et al.*, 2009). In their review of longitudinal studies which observed at least 100 participants, Valenzuela and Sachdev (2005) reported that in 10 out of 15 studies, education was found to exert a protective effect against the risk of experiencing dementia, while no significant effects were found in the other five studies. Individuals with higher levels of education were found to have about half of the risk of experiencing dementia compared to individuals with low levels of education. Moreover, in their analysis of data from a large-scale longitudinal study covering 2,000 individuals and spanning on average 21 years, Ngandu *et al.* (2007) showed that the association between dementia and low education cannot be explained entirely by an unhealthy lifestyle. This evidence supports the cognitive reserve theory discussed earlier in the section providing a conceptual and theoretical background.

136. Other studies have found that higher levels of education lead to later onset of dementia, but then to an eventual decline that is more rapid (Wilson *et al.*, 2004; Scarmeas *et al.*, 2006; Wilson *et al.*, 2010). In a review of longitudinal studies with a minimum sample size and a minimum follow-up period, Paradise *et al.* (2009) contested the claim of an eventual decline that is more rapid, however. Either way, evidence suggests that education reduces the number of years spent in cognitive impairment.

Further learning interventions (training)

137. Training which is task specific (e.g., individual strategy training) has been found to improve performance in cognitive tests. In a randomized-control study of 2,800 individuals which was embedded within a longitudinal design, Willis *et al.* (2006) showed that task specific training in domains relevant to memory, inductive reasoning and processing speed, improved domain-specific performance after five years. Booster sessions after 11 and 35 months also had clear positive effects. There were also some indications that training in strategies to reason reduced self-reported difficulties in coping with cognitive demands in daily life.

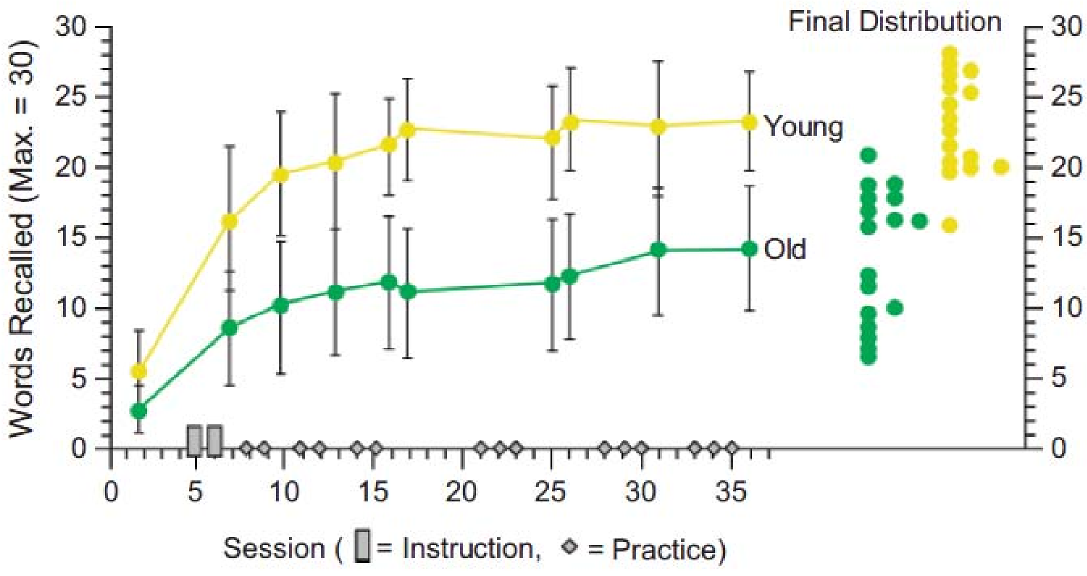
138. Whether the benefits of task specific training transfer to, or are applicable in, daily living contexts is an important issue. Approaches that train individuals on multiple strategies seem to work better in terms of transfer and applicability in everyday life compared to approaches that train only on a single strategy.

139. Willis and Schaie (1988) designed interventions specific to the basic skills of inductive reasoning and spatial orientation and argued that their laboratory tasks were relevant to cognitive demands in daily life. They found that those who were trained showed on average a substantial advantage when it came to retesting even after seven years. Five-hour booster courses further increased performance substantially. They concluded that age-related decline in cognitive skills are probably due to disuse and are consequently reversible, at least in part, for many persons.

140. In a meta-study of results from different longitudinal and randomized-control studies, Plassman *et al.* (2010) found strong evidence that cognitive training helped to mitigate the age-related decline of skills.

141. Training, however, has been found to be more effective among higher ability individuals (Hertzog *et al.*, 2009, p. 16; Lustig *et al.*, 2009). There are also differences related to age with younger cohorts showing an advantage over older cohorts (Hertzog *et al.*, 2009, p. 17). Figure 133 shows the effect of training respondents with word recall for both younger and older adults. Both benefited from the training sessions but the gain for the older individuals was considerably less and the difference did not seem to narrow as the number of sessions increased.

Figure 13. Results of training of younger and older adults in the Method of Luci, plotting serial-recall scores against number of session for both age groups. Despite extensive training improvements, distributions of final serial-recall scores for older and younger individuals (right-hand area of graph) are widely separated



Source: Reproduced from Hertzog *et al.* (2009, p. 17) with permission from Sage publications. Adapted from Baltes and Kliegel (1992).

What is the impact of behavioural and practice factors on cognitive skill trajectories over the lifespan?

142. Beyond intentional learning interventions or training, there are behavioural patterns that lead to early decline in skills for some persons and maintenance of high levels of functioning for others. A number of behavioural and practice factors help to account for observed individual differences. These can be broadly categorized into behaviours involving physical, social and mental activity.

Physical activity

143. There are different meta-reviews available which describe the effects of physical and other activities on cognition, particularly cognitive decline and dementia. These studies consistently find positive effects of physical activities on cognition (e.g., Colcombe & Kramer, 2003; Fratiglioni, Paillard-Borg & Winblad, 2004; Heyn, Abreu & Ottenbacher, 2004; Netz *et al.*, 2005; Etnier *et al.*, 2006; Lautenschlager & Almeida, 2006; van Uffelen *et al.*, 2008; Plassman *et al.*, 2010). Several studies have found positive effects of physical activity on the level of cognitive skills and on the rate of change in children (e.g., Sibley & Etnier, 2003), middle-aged adults (e.g., Richards, Hardy & Wadsworth, 2003) and the elderly (e.g., Colcombe & Kramer, 2003). Only very few studies have not found significant results (Hertzog *et al.*, 2009, p. 28), even after controlling for mental activities (Sturman *et al.*, 2005).

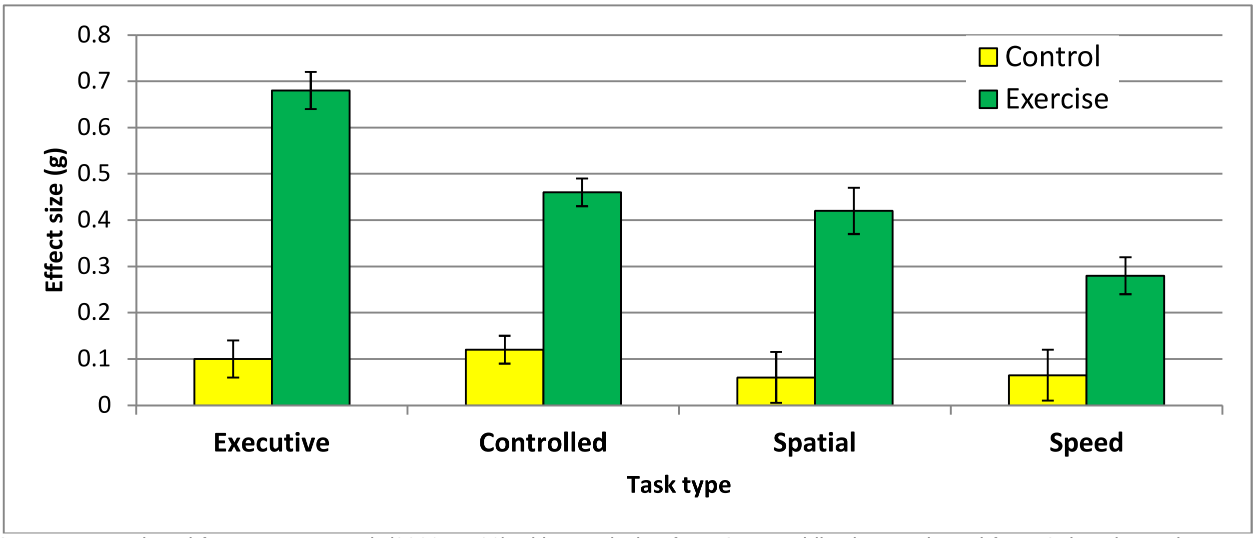
144. Figure 14 reproduces results from a meta-analysis conducted by Colcombe and Kramer (2003). It highlights the magnitude of the effects of physical activity on performance in different types of cognitive tasks vs a control group. Physical activity was found to exert the largest effect on executive-control processes including planning, working memory and multi-tasking. Effects were larger for physical exercise lasting more than 30 minutes and/or involving aerobic training combined with strength and flexibility training. Older participants showed larger improvements than younger ones.

145. In one study, 6,000 women over the age of 65 were observed from four different medical centres in the United States. The women had neither physical limitations, nor cognitive impairment. Findings showed that higher physical activity reduced the likelihood of experiencing age-related cognitive decline (Yaffe *et al.*, 2001; 2009). Some intervention studies have replicated this finding by randomly assigning older individuals to physical training activities (e.g., Lautenschlager *et al.*, 2008).

146. Other studies have found that smoking is linked to cognitive decline and the risk of experiencing dementia (see Anstey *et al.*, 2007; Yaffe *et al.*, 2009). Psychological stress has also been implicated in cognitive decline (Hertzog *et al.*, 2009, p. 7).

147. In a meta-study of results from different longitudinal and randomized-control studies, Plassman *et al.* (2010) found that physical activity, vegetable intake and other non-cognitive as well as non-physical leisure activities lowered the risk of cognitive decline.

Figure 14: Effects sizes of mean differences in cognitive performance between adults in aerobic fitness training and those in a control condition for different types of cognitive tasks



Source: Reproduced from Hertzog *et al.* (2009, p. 29) with permission from Sage publications. Adapted from Colcombe and Kramer (2003).

Social activity

148. Sharp *et al.* (2010) found that social engagement has positive effects on the level of cognitive performance but not on the rate of decline. In particular, loneliness has been found to increase cognitive decline (Hertzog *et al.*, 2009, p. 7).

149. Fratiglioni *et al.* (2004) summarizes observational longitudinal studies which investigate the relationship between social networks or non-physical leisure activity and cognition or dementia. The authors conclude that their review supports the hypothesis that elderly which live a socially active lifestyle may reduce their risk of dementia.

150. Bielak (2010) provides a summary of the state of the art in the relationship between social as well as mental activity and cognition in old age. The author summarizes as follows:

> *The number of studies failing to find a significant relationship are substantially fewer than those in support of the hypothesis, and most tend to be examples of failing to find significant effects of a particular activity domain, or are related to a particular time frame rather than a complete lack of support for the activity cognition relationship (p. 508)*

General mental activity

151. Perhaps one of the most important factors that can account for individual differences is the extent of mental activity that an individual engages in both daily life but also very much at work. The so-called mental-exercise or “use it or lose it” hypothesis was constructed already in the 1920’s (Salthouse, 2006). Despite this long time period, the debate is still vivid and remains controversial (Schooler, 2007; Salthouse, 2007; 2006).

Occupation

152. In the same way that educational careers can be seen as a proxy for the mental stimulus experienced during the childhood to young adulthood years, occupational careers can be seen as an indication of the extent of cognitive practice over an extended number of years into late adulthood. For a large proportion of the population, work forms a substantial part of their daily life for an extended number of years. Thus what people do at work is a potentially key factor influencing the development of their skills over the lifespan.

153. The various tasks that workers engage in on a day to day basis require different types of skills to complete them in a satisfactory manner. Thus certain skills are closely related to specific job tasks. Some jobs require higher levels of mental activity such as solving new problems on a daily basis and the need to adjust to new technologies — this is especially the case in more complex occupations such as professional or managerial jobs.

154. Several studies have found a link between occupations requiring the performance of complex tasks and the level of cognitive skills, even after controlling for education (e.g., Andel *et al.*, 2007; Finkel *et al.*, 2009). There are also some indications that job-complexity has an effect on the growth rate of skills (see Schooler, Mulatu & Oates, 1999; Baldivia, Andrade & Bueno, 2008; Potter, Helms & Plassman, 2008).

155. Engaging in complex tasks at work has been found to decrease the risk of experiencing dementia and Alzheimer's (Andel *et al.*, 2005; Valenzula & Sachdev, 2005). In reviewing several longitudinal studies, Valenzuela and Sachdev (2006) reported consistent findings which suggested that engagement in mental activities as well as having had certain occupations reduced the risk of experiencing dementia in old age, even after adjusting for the observed influence of education. Stern (2009, p. 2017) also suggested that mental activity and complexity of occupation reduced the risk for dementia.

156. Several studies have investigated the effects of retirement on cognitive functioning. Using longitudinal data, Bonsang, Adam and Perelman (2010) and Mazzonna and Peracchi (2009) found significant negative causal effects of retirement on cognitive decline.

What is the impact of environmental and social factors on skill development over the lifespan and over time?

157. An important question is whether and to what extent changes over time to the physical environment, or to social and cultural contexts including the conditions under which they are experienced by individuals at different stages of their lifespan, affect skill development either at the individual or population level. Similar to the way height – a characteristic highly influenced by genetics – has increased considerably over time possibly due to the effects of changes in nurture (i.e., improved nutrition in early childhood), cognitive skills may be subject to intermittent and systematic change across generations. There is some evidence to suggest that this is the case.

Cohort effects as unique combinations of age and period

158. Almond (2006) demonstrated that cohorts in utero during the 1918 influenza pandemic in the U.S. had lower levels of educational attainment on average, as well as lower income, lower socioeconomic status, higher transfer payments, and higher rates of physical disability compared with older and younger birth cohorts. Indirectly, it might be inferred that this single event also affected cognitive skills in a negative manner, although there is no direct link established.

159. Similarly, Almond, Edlund and Palme (2009) demonstrated that prenatal exposure to the Chernobyl fallout in Sweden was linked to lower school grades and a lower likelihood of completing upper secondary education. The findings increased in strength the closer the children were to the regions that had the greatest exposure.

Cohort effects as systematic change

160. Several researchers have found evidence to suggest considerable average increases in IQ scores during the second half of the 20^{th} century, about 3–5 IQ points per decade, in developed countries. John Flynn (1984; 1987) was among the first scholars to document this phenomenon and to his credit this is now often referred to as the Flynn effect. The effect has been attributed by different authors to biological, social and/or educational factors.

161. Interestingly, the increase in cognitive scores has been more twice as large for fluid intelligence than for crystallized intelligence (Hiscock, 2007). Figure 155 shows the increase in IQ scores for different types of tests. Average performance on Raven's Matrices test increased from a base line of 100 in 1952 to nearly 125 in 1992. An interesting question is whether it is more able individuals that have gained or whether it is individuals at the lower end of the distribution that have improved? Lynn (2009) provided a short overview of research on this question and concluded that findings do not reveal a consistent pattern.

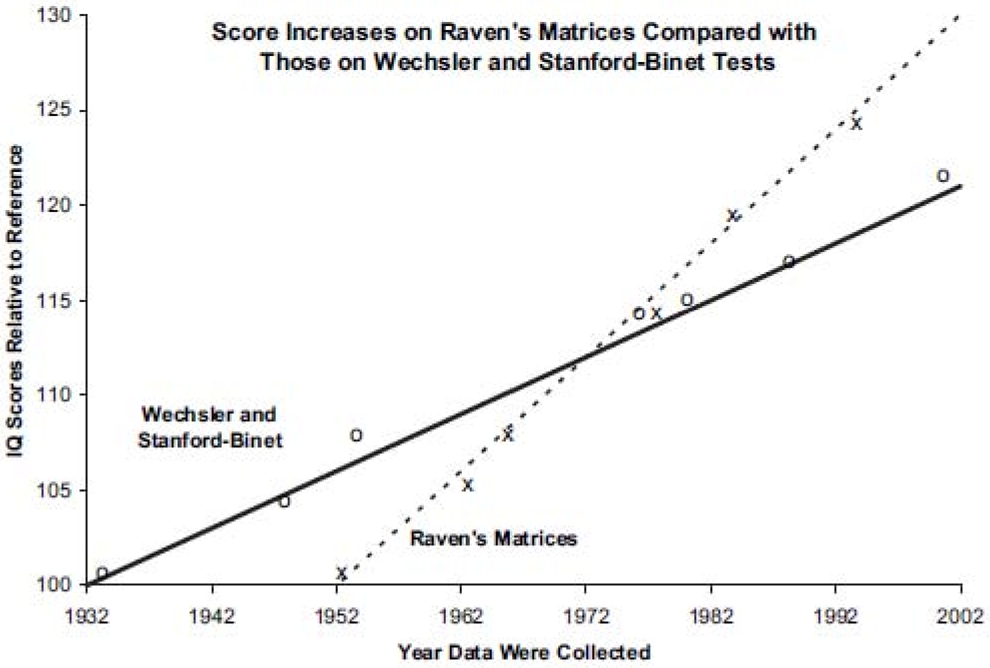
162. Rönnlund and Nilsson (2008) found that in Sweden the average IQ performance increased by a full standard deviation (equivalent to 15 IQ points) between 1909 and 1969. Three factors were found to explain most of the between cohort variance, namely levels of educational attainment (most important factor), height and number of siblings. Similarly, Finkel *et al.* (2007) examined Swedish twin data and concluded that there are important cohort differences in the average performance of four cognitive domains.

163. Schaie (1994) reported that results from the Longitudinal Seattle Study have conclusively demonstrated the prevalence of substantial generational (cohort) differences in cognitive skills over time. Cohort trends however, differ in magnitude and direction depending on the type of skill measured. He therefore concluded that trends observed on the basis of composite IQ indices are confounded. Substantial positive cohort shifts were observed for reasoning, verbal meaning and spatial orientation, equivalent to more than one standard deviation between the earliest and latest cohorts. In contrast, numerical ability was found to peak for the 1924 cohort and fell thereafter by about half a standard deviation. Similarly, younger cohorts show lower scores than older cohorts in word fluency. From these findings, Schaie concluded that cross-sectional age-differences overestimate age-related decline for skills that show positive cohort gradients and underestimate age-related decline for skills that show negative cohort gradients.

164. Similarly, Huang (2003) reported findings on the "great decline" in vocabulary scores of US adults beginning in 1950. Jameson (2007) also suggested that the reading and writing skills of American youths age 17 have stagnated and remained fairly stable since the 1970s or 1980s.

165. Teasdale and Owen (2005; 2007) found that the trend of increasing IQ scores may have stopped or even reversed in Denmark. Using intelligence test results from over 500,000 young Danish men, tested between 1959 and 2004, they showed that performance peaked in the late 1990s, and has since declined moderately to pre-1991 levels. Similarly, Sundet, Barlaug and Torjussen (2004) using the intelligence scores of nearly one million young men concluded the same for Norway.

Figure 15. Score increases on Raven's matrices compared with those on Wechsler and Stanford-Binet tests



Source: Reproduced from Hiscock (2007) with permission from Taylor and Francis.

CONCLUSIONS

166. Understanding better the link between ageing and skills is an important aspect to various issues that surround the phenomena of population ageing. This study has thus sought to provide an overview of age-skill profiles and what is known about the potential factors influencing skill gain and skill loss at both individual and population levels. Several major points elucidated in the study can be summarized as follows:

167. First, the negative empirical relationship between ageing and skills that is observed on the basis of data from IALS and ALL is consistent across a wide range of countries. These data provide a good picture of *age differences* (between-person comparisons) in cognitive skills at one period in time.

168. Second, empirical evidence on *age changes* (within-person comparisons) based on longitudinal research designs portray remarkably similar age-skill profiles to those based on IALS and ALL data. Specifically, there is ample evidence of age-related decline in cognitive skills. While the two may be inter-related however, *age differences* based on between-person comparisons and *age changes* based on within-person comparisons are not the same thing.

169. Third, observed age-skill profiles on the basis of cross-sectional data reflect a number of complex inter-relationships among various individual and social factors which affect skill gain and skill loss within-persons over the lifespan and between-persons over time.

170. Fourth, it is possible for certain age cohorts to distinguish between skill gain and skill loss within-cohorts over the lifespan (ageing effects) and between-cohorts over time (cohort effects) on the basis of repeated cross-sectional measures which are representative at the cohort level, such as those based on IALS, ALL and PIAAC.

171. Fifth, although the evidence regarding the age-related decline of cognitive skills is widespread and the explanation that this may be part of '*normal ageing*' is intuitively appealing, it is not possible regardless of research design to identify whether ageing effects are caused by neurological maturation effects, behavioural and practice effects, or the interaction of these with contextual effects. Moreover, there is some evidence to suggest that there are several factors that can mitigate, delay or prevent the cognitive decline that is associated with so called '*normal ageing*'. Education, training, and a number of physical, social and mental activities have all been implicated as possible factors which help to mitigate the age-related decline in cognitive skills. This suggests that policy can make a difference.

172. Sixth, cross-sectional data designs are neither well suited for explaining observed age differences, nor to study the influence of various factors on age-related decline. However, repeated cross-sectional measures may be helpful to explore this in limited ways at the macro level.

173. A next step is to explore how data from IALS, ALL and PIAAC may be used to examine in more detail the link between educational expansion or compositional changes in the population and changes in age-skill profiles. Likewise, it may be possible to explore the link between changes in aggregated individual behaviours (e.g., changes to overall reading practices or job tasks) and changes in population level age-skill profiles. Another element that is important to address in more detail is the relationship between skill loss and productivity into old age.

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ANNEX 1. ANALYSIS OF CHANGE IN AGE-SKILL PROFILES FOR ADDITIONAL COUNTRIES IN WHICH DATA IS AVAILABLE IN BOTH IALS AND ALL

The following provides a detailed analysis of changes in age-skill profiles for seven countries that participated in both IALS and ALL, namely Canada, Hungary, Italy, New Zealand, Norway, Switzerland and the United States. See the section entitled *A further analysis of age-skill profiles using IALS, ALL and PIAAC data* for a detailed description of the analysis as well as a presentation of the results for Australia and the Netherlands.

Canada (1994-2003: 9-year span)

Figures A1A and A1B reveal a trend of net negative cohort effects for adults aged 16-20 but this is statistically significant ($p<.05$) only for adults aged 20 and 44. Similarly, there is an observed trend of net positive cohort effects for adults aged 21-64. This latter result is statistically significant ($p<.05$) for adults aged 24, 28, 42, 56 and 58. In summary, there is limited evidence of skill loss and skill gain via negative cohort effects. There is some evidence that social factors have led to some positive effects among older cohorts – possibly the overall expansion of educational attainment over the last decades. However, there are indications of a structural change that may have adversely affected the skills of younger cohorts aged 16-20 in 2003 relative to the same age group in 1994 – possibly a lowering of the quality of education.

Figures A1C and A1D reveal a trend of net positive ageing effects nine years later for adults aged 16-27 and 46-56 in 1994 but this is only statistically significant ($p<.05$) for adults aged 19 and 25. Similarly, there is a trend of net negative ageing effects nine years later for adults aged 28-45 in 1994. This latter results is only statistically significant ($p<.05$) for adults aged 35 and 39. In summary, the pattern is as expected but with only limited evidence of skill gain among adults aged 16-30 and skill loss among those aged more than 30.

Hungary (1998-2007: 9-year span)

Figures A2A and A2B reveal a trend of net positive cohort effect for adults aged 16-65, which is found to be statistically significant ($p<.05$) for adults aged 16-19, 21-24, 27-30, 32-36, 38-40, 42-54, 56-65. Figures A2C and A2D reveal a trend of net positive ageing effects nine years later for adults aged 16-56 in 1998 which is found to be statistically significant ($p<.05$) for adults aged 17-18, 21-25, 27-31, 32, 34-36, 38-48, 42-54, 56. In summary, there widespread evidence of skill gain via cohort and ageing effects in Hungary over a nine year period between 1998 and 2007. The positive shift in skills is much more than what may otherwise be expected from the expansion of educational attainment suggesting that other social factors may be involved. In terms of ageing effects, the pattern is contrary to expectation with no apparent age-related skill loss – there is only skill gain for nearly every age cohort.

It is important to note that the shift in skills may reflect a period effect (either a negative one in 1998 or a positive one in 2007) – a situation in which the performance of respondents may have been affecting by the prevailing condition economic and social conditions at the time of either survey. The dramatic change in age-skill profiles in Hungary also raises questions about the comparability of the cognitive data for this country between IALS and ALL.

Italy (1998-2003: 5-year span)

Figures A3A and A3B reveal a trend of net negative cohort effect for adults aged 16-59 which is found to be statistically significant (p<.05) for adults aged 16-17, 19, 21-25, 28-29, 31, 35, 37, 48 and 59. There is also an observed trend of net positive cohort effect for adults aged 60-65 but this is not statistically significant (p<.05). Figures A3C and A3D reveal a trend of net negative ageing effects five years later for adults aged 16-60 in 1998. This latter result is statistically significant (p<.05) for adults aged 16-17, 19-28, 30-37, 41-42, 44-46, 48, 53, 57 and 59. In summary, there is in Italy over a five year period between 1998 and 2003, widespread evidence of skill loss via cohort and ageing effects. Like Hungary, but in the opposite direction, the negative shift in skills is more than may otherwise be expected and suggests that major structural changes may have led to skill loss. Yet it is worthwhile to note that the inter-survey period was only five years – a time span that is perhaps too short to explain this major shift. In terms of ageing effects, there is widespread skill loss beginning already at the early age of 16. The ageing effect is so strong that in it is likely to comprise the cohort effect as well. In other words, the evidence suggests that ageing effects during this period are themselves much stronger than they have been in the past, effectively making them cohort effects.

The dramatic change over just five years brings the quality of the data for comparisons over time into question. As in the case of Hungary, the pattern may reflect period effects or a lack of comparability of the cognitive data for Italy between IALS and ALL. Italy had a very low survey response rate in 1998 (less than 40%) and it was 44% in 2003, which raises doubts about data quality.

New Zealand (1996-2007: 11-year span)

Figures A4A and A4B reveal a trend of net negative cohort effect for adults aged 16-27 but this is only statistically significant (p<.05) for adults aged 16 and 19. Similarly, there is also an observed trend of net positive cohort effect for adults aged 28-65. This latter result is statistically significant (p<.05) for adults aged 47, 62 and 64. In summary, there is in New Zealand over a 11 year period between 1996 and 2007, limited evidence of skill loss and gain via cohort effects. Social factors may have led to positive effects among older cohorts. For example, the expansion of educational attainment seems to have had limited impact among adults 35 or over.

Figures A4C and A4D reveal a trend of net positive ageing effects 11 years later for adults aged 16-35 in 1996 but this is only statistically significant (p<.05) for adults aged 18. Similarly, there is an observed trend of net negative ageing effects 11 years later for adults aged 36-52 in 1996 but this is only statistically significant (p<.05) for adults aged 41. In summary, there is limited evidence of skill gain and loss via ageing effects. There is as expected skill loss in 30 or over group and skill gain among the less than 30 age group, but the evidence is narrowly spread with only one cohort in each group registering a statistically significant difference between the two surveys.

Norway (1998-2003: 5-year span)

Figures A5A and A5B reveal a trend of net negative cohort effect for adults aged 16-24 but this is not statistically significant (p<.05). Similarly, the chart reveals a trend of net positive cohort effect for adults aged 25-65. This latter results however is statistically significant (p<.05) for adults aged 42 and 44. In summary, there is limited evidence of skill gain via cohort effects among older cohorts which may be due to social factors. For example, the expansion of educational attainment seems to have had limited impact among adults 35 or over.

Figures A5C and A5D reveal a trend of net positive ageing effects five years later for adults aged 16-29 in 1998 but this is only statistically significant (p<.05) for adults aged 16-17 and 27. Similarly, there is an observed trend of net negative ageing effects five years later for adults aged 30-60 in 1998, and this is only statistically significant (p<.05) for adults aged 28 and 50-51. In summary, there is in Norway over a five year period between 1998 and 2003, limited evidence of skill gain and loss via ageing effects. This is occurring in expected age ranges.

Switzerland (German and French- speaking regions) (1994-2003: 9-year span)

Figures A6A and A6B reveal a trend of net negative cohort effects for adults aged 16-20 but this is not statistically significant (p<.05). A trend of net positive cohort effects for adults aged 21-65 is however, statistically significant (p<.05) for adults aged 20, 25, 44-45, 54 and 65. In summary, there is limited evidence of skill gain via cohort effects, possibly the overall expansion of educational attainment over the last decades and improvements in the quality of education among younger cohorts.

Figures A6C and A6D reveal a trend of net positive ageing effects nine years later for adults aged 16-28 in 1994 but this is only statistically significant (p<.05) for adults aged 16 and 19-20. Similarly, there is observed trend of net negative ageing effects nine years later for adults aged 29-56 in 1994 but this is only statistically significant (p<.05) for adults aged 52. In summary, there is in the French and German speaking regions of Switzerland over a nine year period between 1994 and 2003, limited evidence of skill gain and loss via negative ageing effects. This occurs in the expected age ranges but for very narrow ranges.

The United States (1994-2003: 9-year span)

Figures A7A and A7B reveal a trend of net positive cohort effects for adults aged 16-23 but this is not statistically significant (p<.05). In contrast, the observed trend of net negative cohort effects for adults aged 24-65 is statistically significant (p<.05) for adults aged 27, 31-32, 36-37, 40, 42, 45, 52, 55 and 58. Figures A7C and A7D reveal a trend of net positive ageing effects nine years later for adults aged 16-24 in 1994 but this is only statistically significant (p<.05) for adults aged 16-17. There is also an observed trend of net negative ageing effects nine years later for adults aged 25-56 in 1994 and this is statistically significant (p<.05) for adults aged 27, 31, 34-37, 40, 42-43, 45, 49, 52-53, and 55-56.

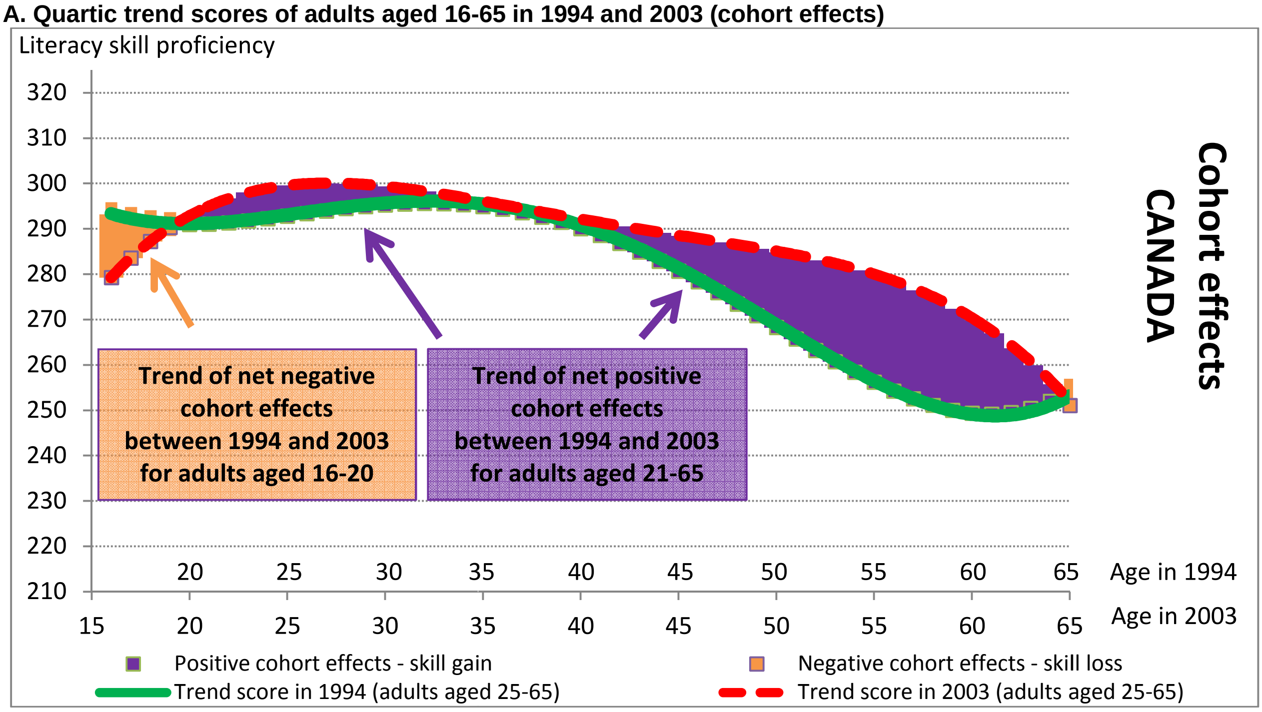
In summary, there is in the United States over a nine year period between 1994 and 2003, widespread evidence of skill loss via both cohort effects and ageing effects, and only very limited evidence of skill gain via ageing effects for the two youngest cohorts in the study. The widespread skill loss is contrary to expectations that increasing educational attainment and other social factors lead to positive cohort effects. The United States is an exception in this regard since younger cohorts do not necessarily have higher levels of attainment compared to older cohorts. The depth of the cohort effect and the fact that educational attainment has peaked and remained fairly stable in the last decades suggests that other social factors may be involved in this observed shift.

In terms of ageing effects, skill loss is observed to start as early as the age 27. The depth of skill loss associated with ageing is much stronger than expected for a nine year period. In fact, the ageing effects are so strong that in this situation it is likely to comprise the cohort effects as well. In other words, the evidence suggests that ageing effects during this period are themselves much stronger than they have been in the past, effectively making them cohort effects.

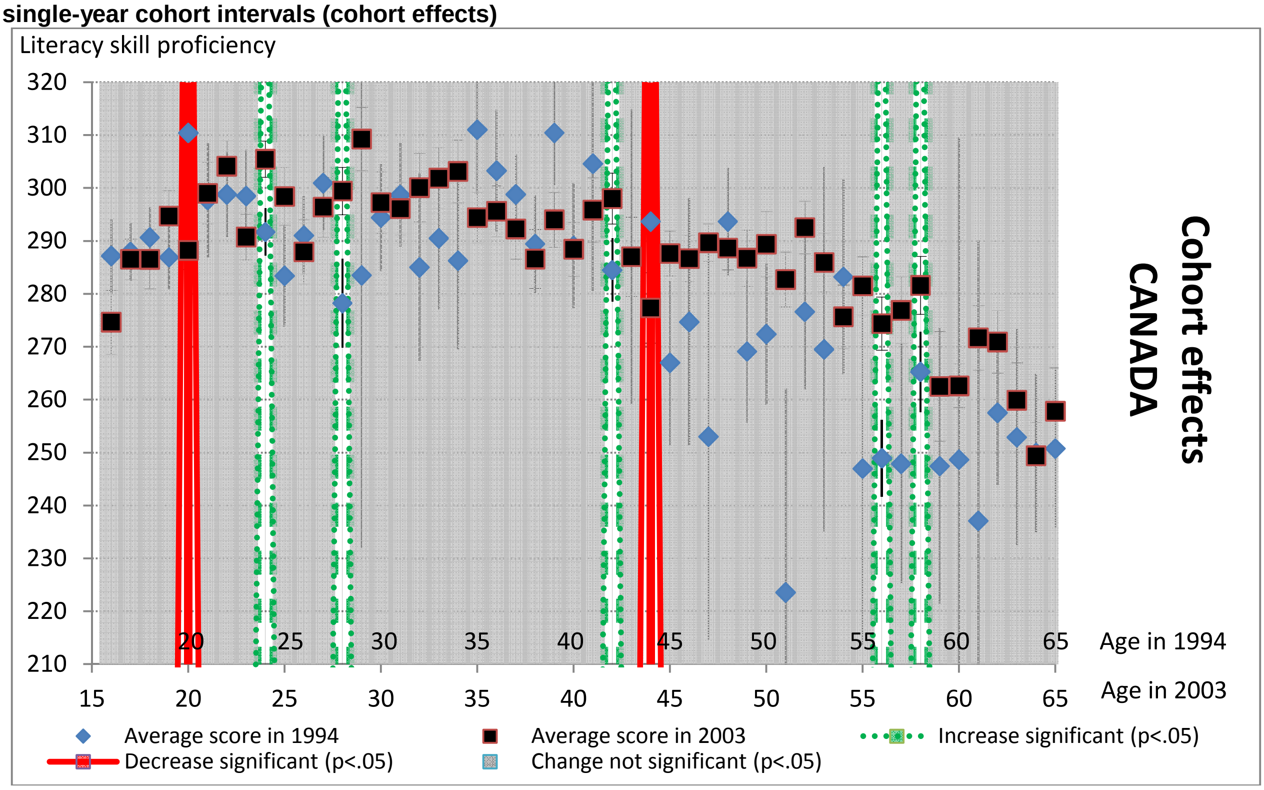
Alternatively, the major shift in skills may reflect a period effect (either a positive one in 1994 or a negative one in 2003) – a situation in which the performance of nearly all respondents may have been affected by the social circumstances surrounding the time of either survey. Yet another alternative as in the case of Hungary and Italy, the pattern raises questions about the comparability of the cognitive data for the United States between IALS and ALL.

Figure A1. Change in literacy skills over time and over the lifespan between 1994-2003, foreign-born adults excluded, Canada

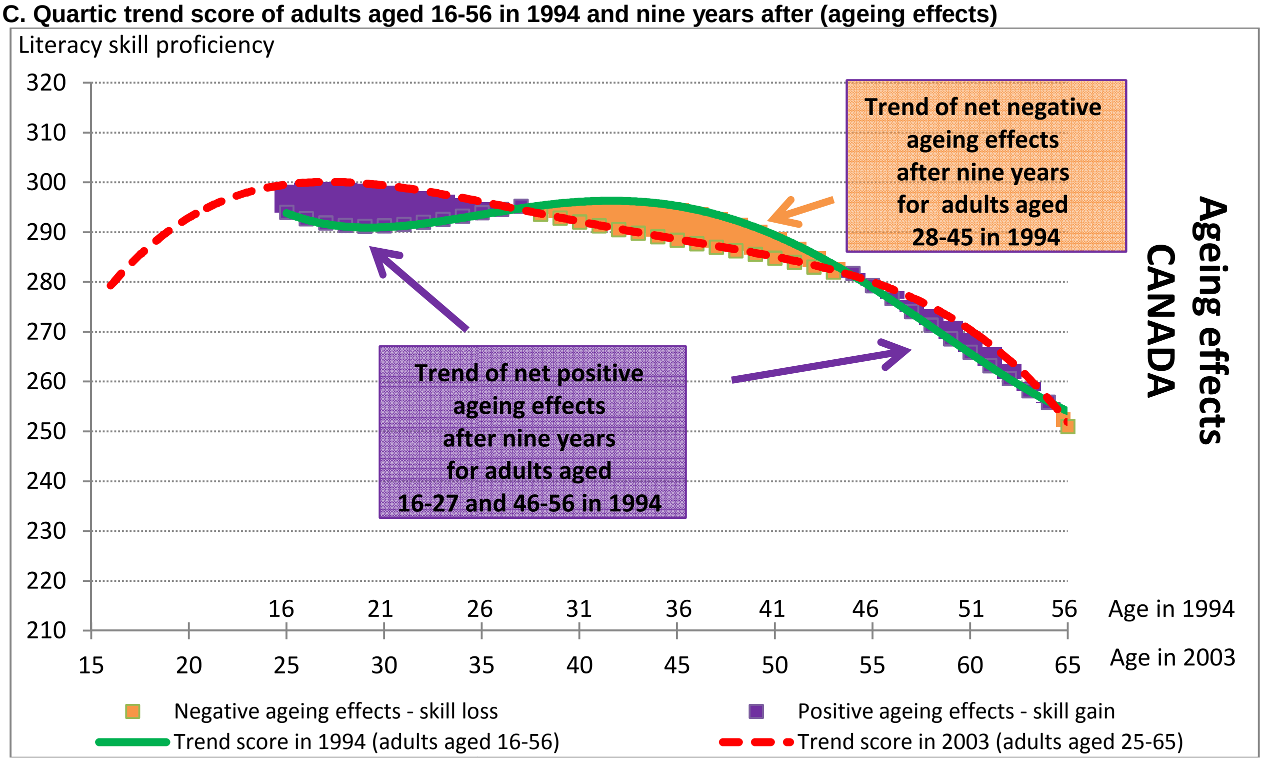
A. Quartic trend scores of adults aged 16-65 in 1994 and 2003 (cohort effects)



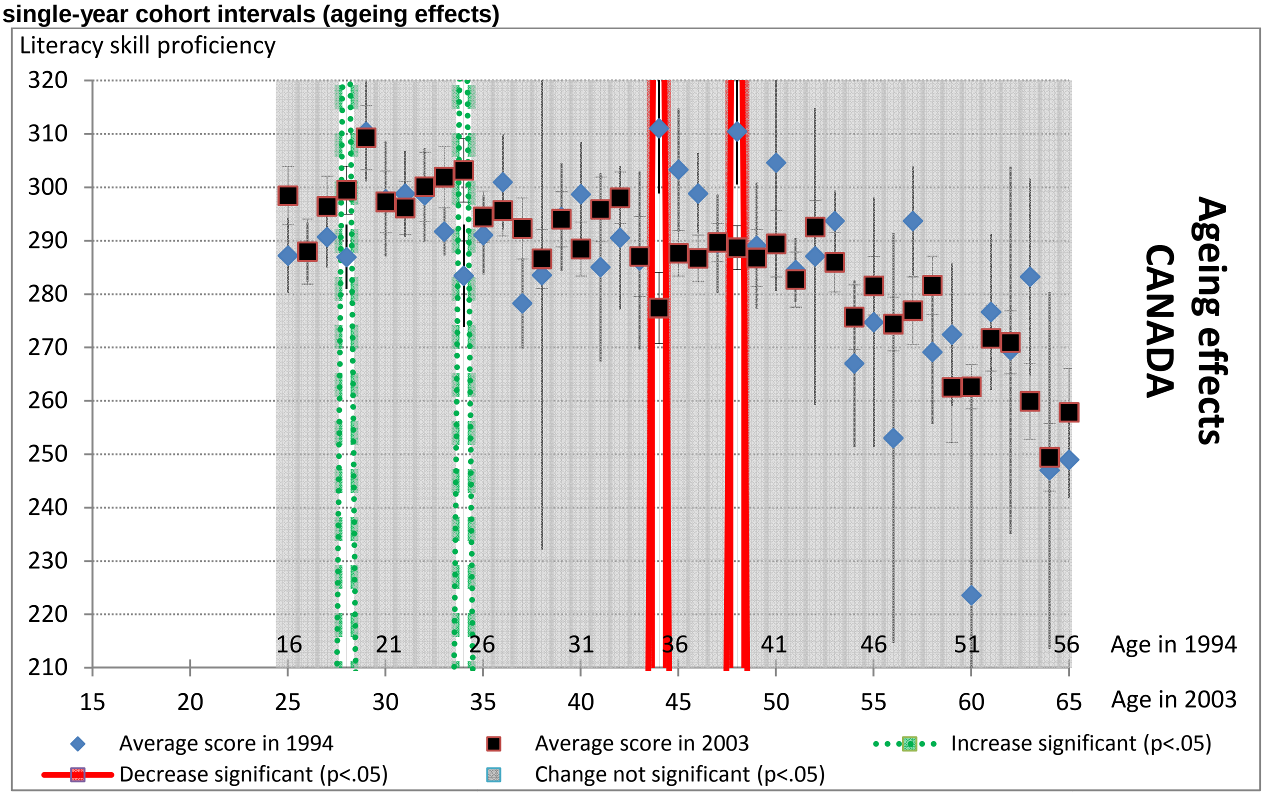
B. Statistical significance (p<.05) of difference in scores of adults aged 16-65 between 1994 and 2003 by single-year cohort intervals (cohort effects)



C. Quartic trend score of adults aged 16-56 in 1994 and nine years after (ageing effects)



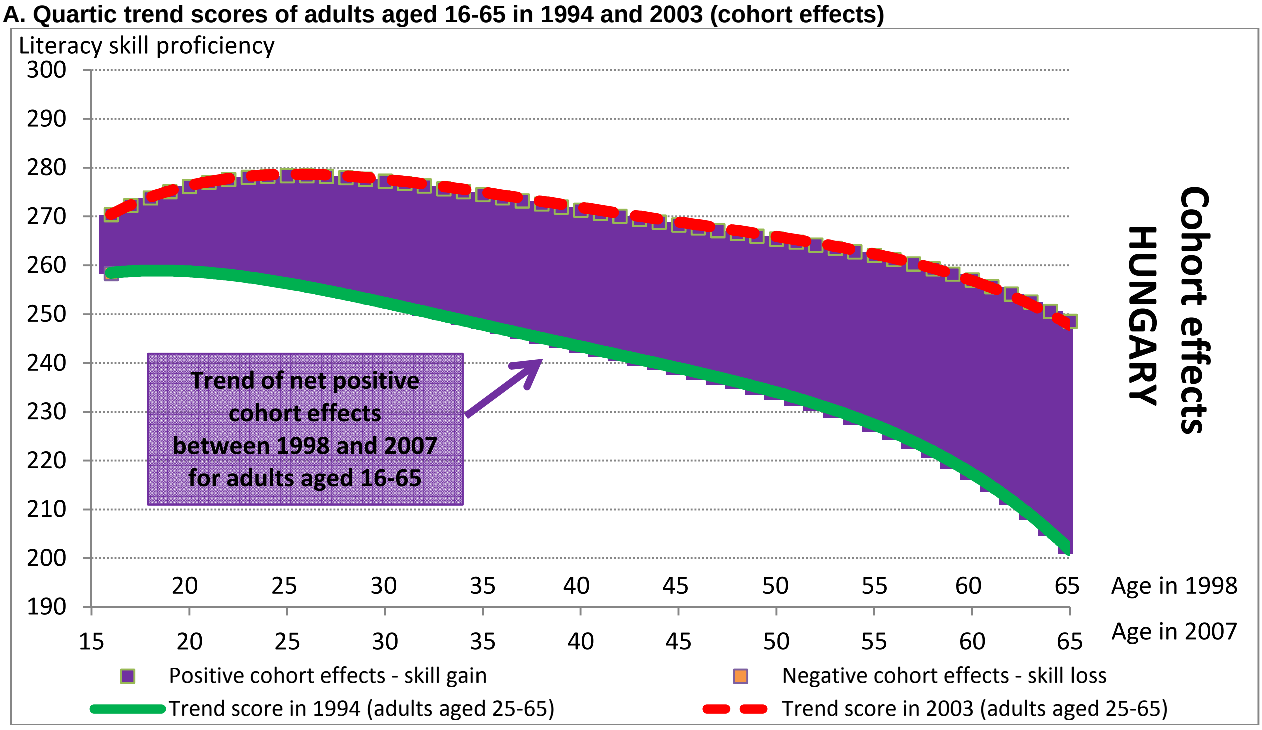
D. Statistical significance (p<.05) of difference in scores of adults aged 16-56 in 1994 and nine years after by single-year cohort intervals (ageing effects)



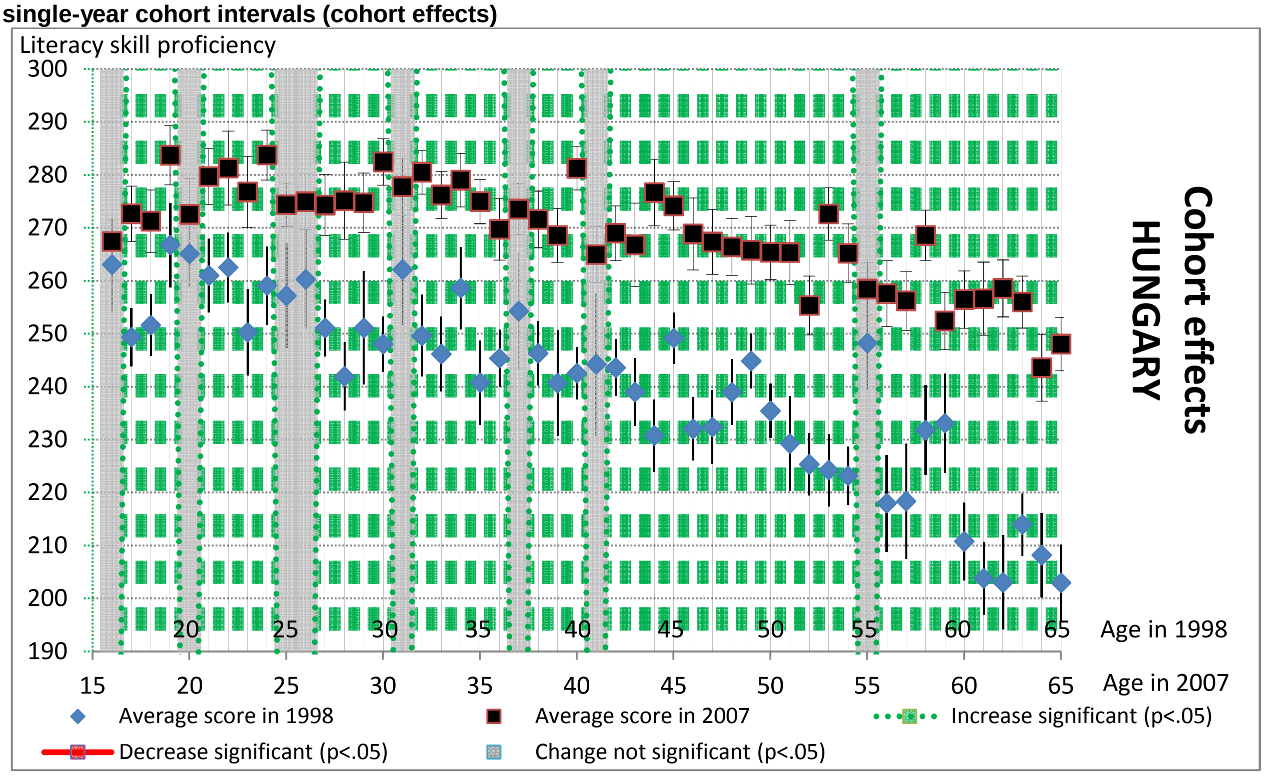
Source: International Adult Literacy Survey, 1994-98; Adult Literacy and Lifeskills Survey, 2003-07.

Figure A2. Change in literacy skills between and within cohorts from 1994-2003, foreign-born adults excluded, Hungary

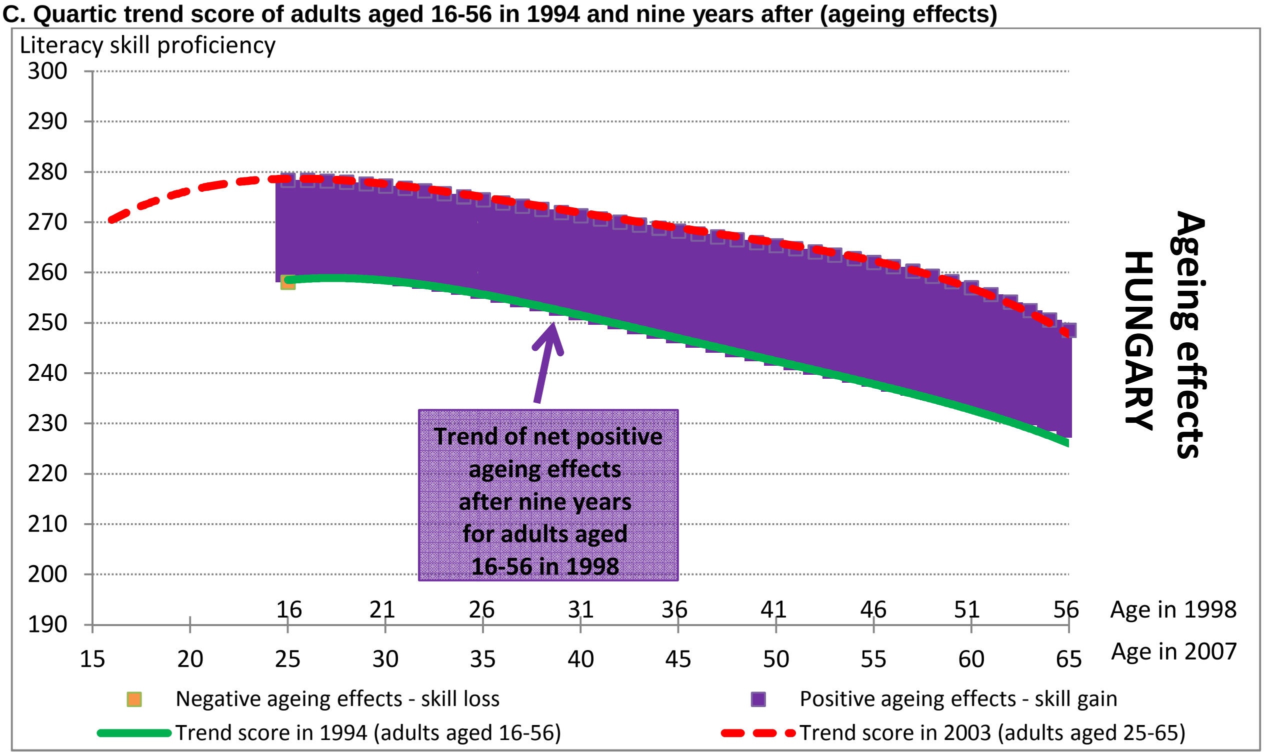
A. Quartic trend scores of adults aged 16-65 in 1994 and 2003 (cohort effects)



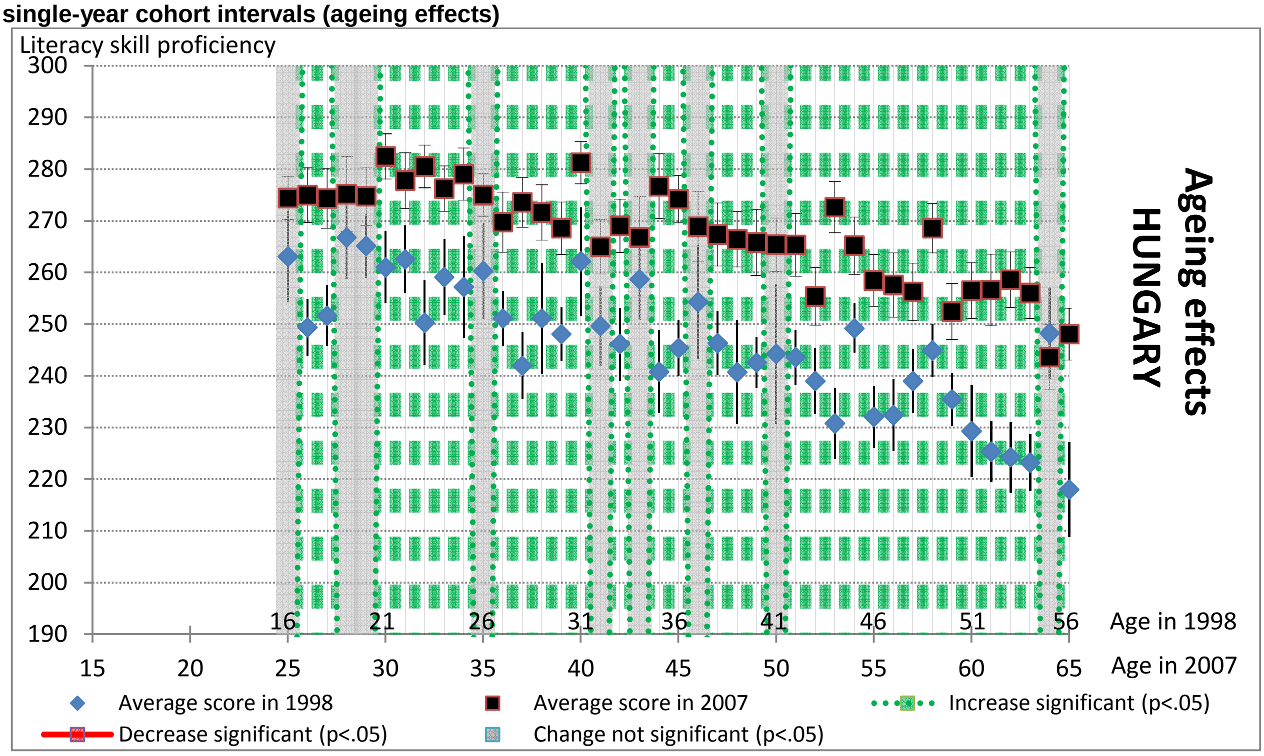
B. Statistical significance (p<.05) of difference in scores of adults aged 16-65 between 1994 and 2003 by single-year cohort intervals (cohort effects)



C. Quartic trend score of adults aged 16-56 in 1994 and nine years after (ageing effects)



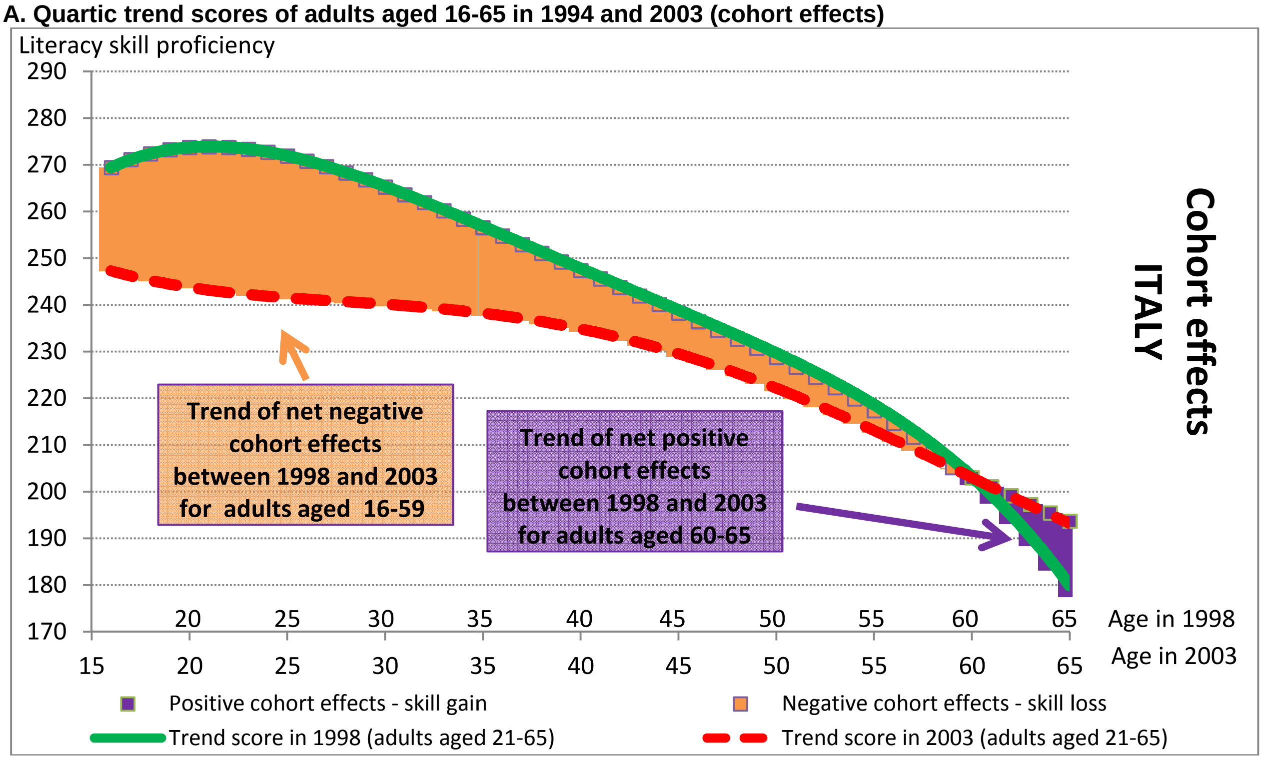
D. Statistical significance (p<.05) of difference in scores of adults aged 16-56 in 1994 and nine years after by single-year cohort intervals (ageing effects)



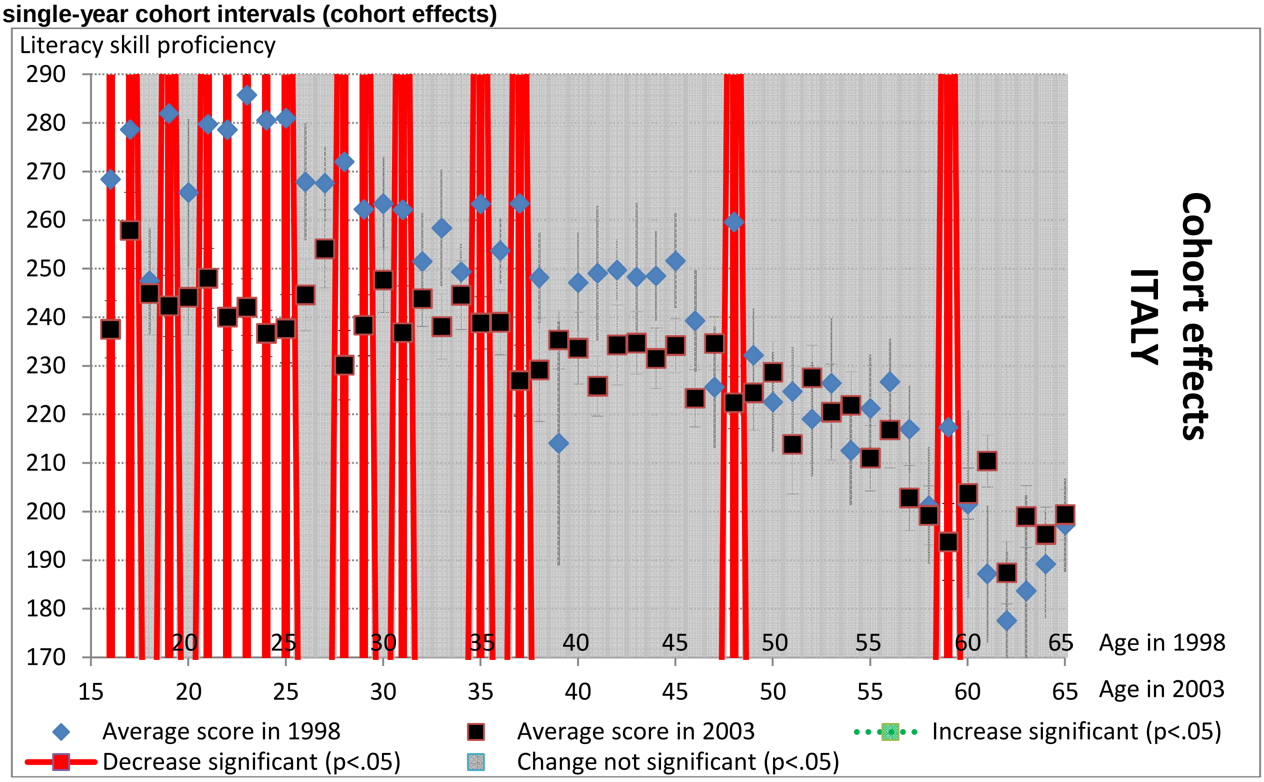
Source: International Adult Literacy Survey, 1994-98; Adult Literacy and Lifeskills Survey, 2003-07.

Figure A3. Change in literacy skills between and within cohorts from 1998-2003, foreign-born adults excluded, Italy

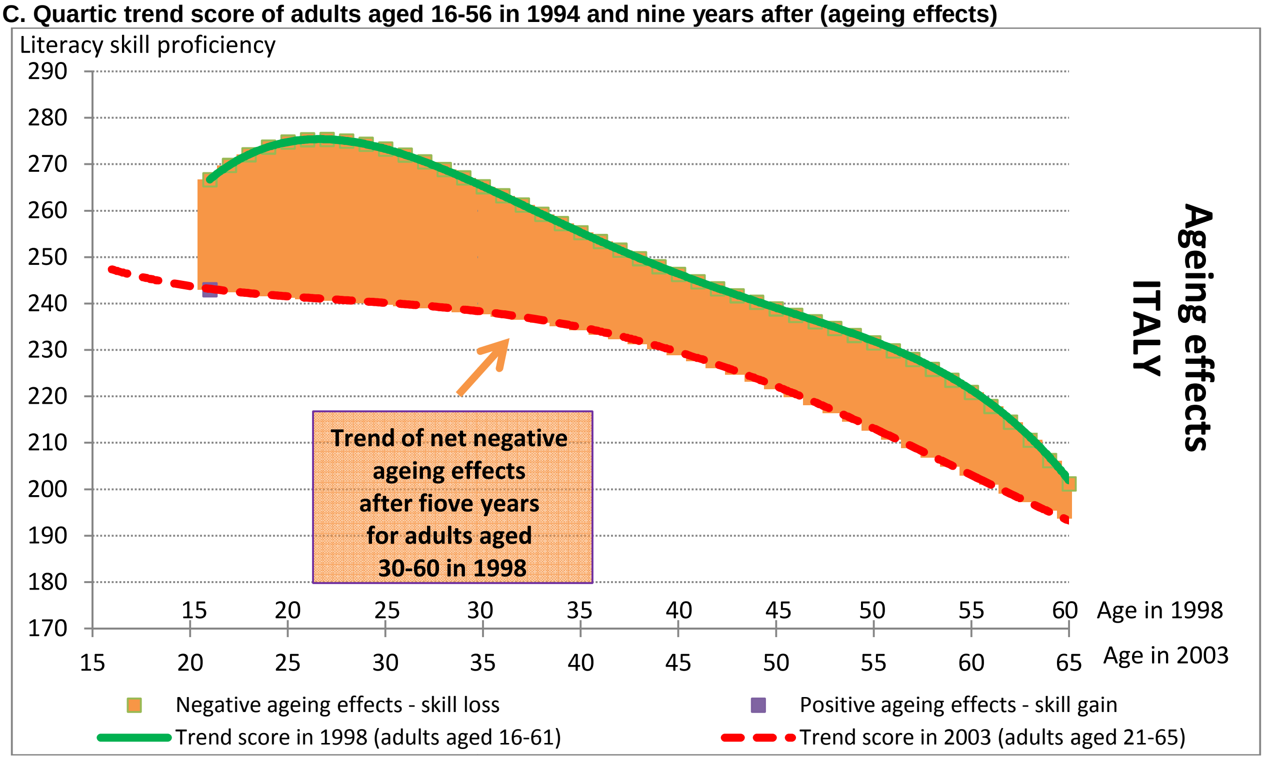
A. Quartic trend scores of adults aged 16-65 in 1994 and 2003 (cohort effects)



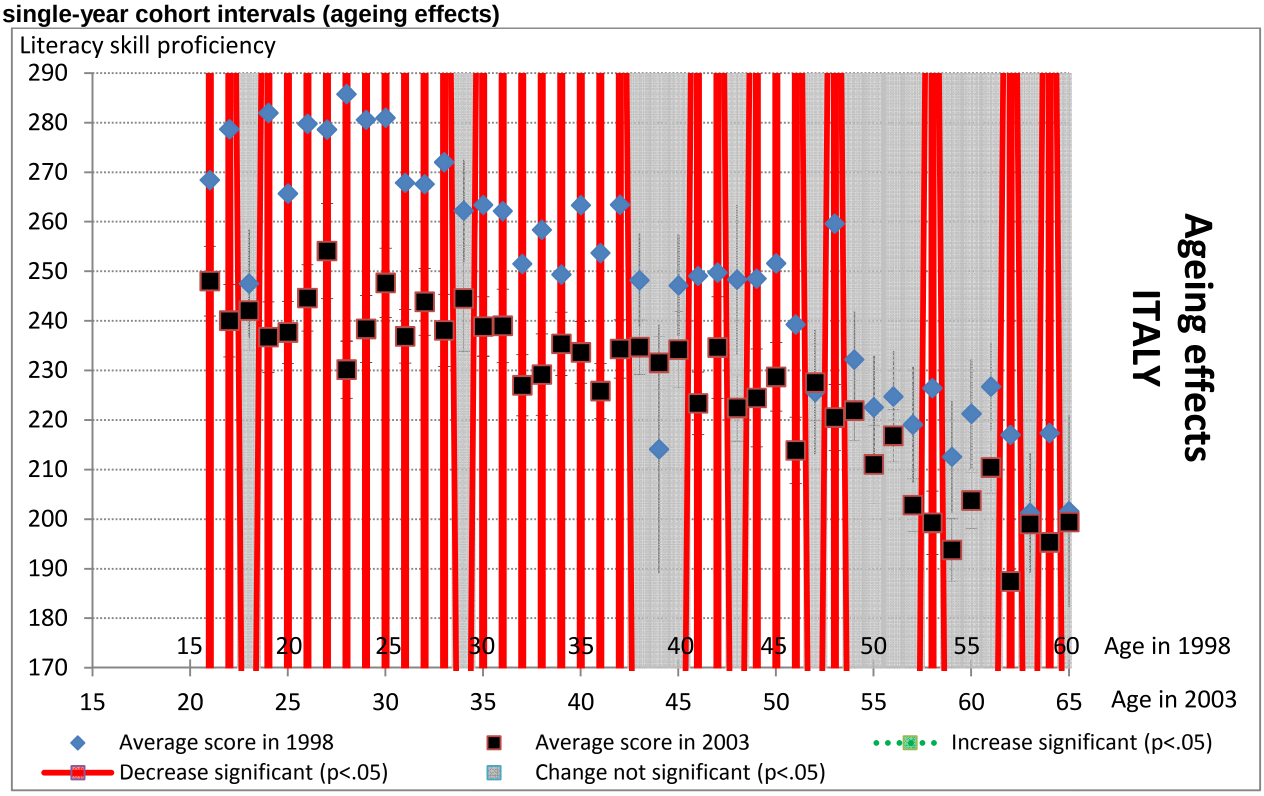
B. Statistical significance (p<.05) of difference in scores of adults aged 16-65 between 1994 and 2003 by single-year cohort intervals (cohort effects)



C. Quartic trend score of adults aged 16-56 in 1994 and nine years after (ageing effects)

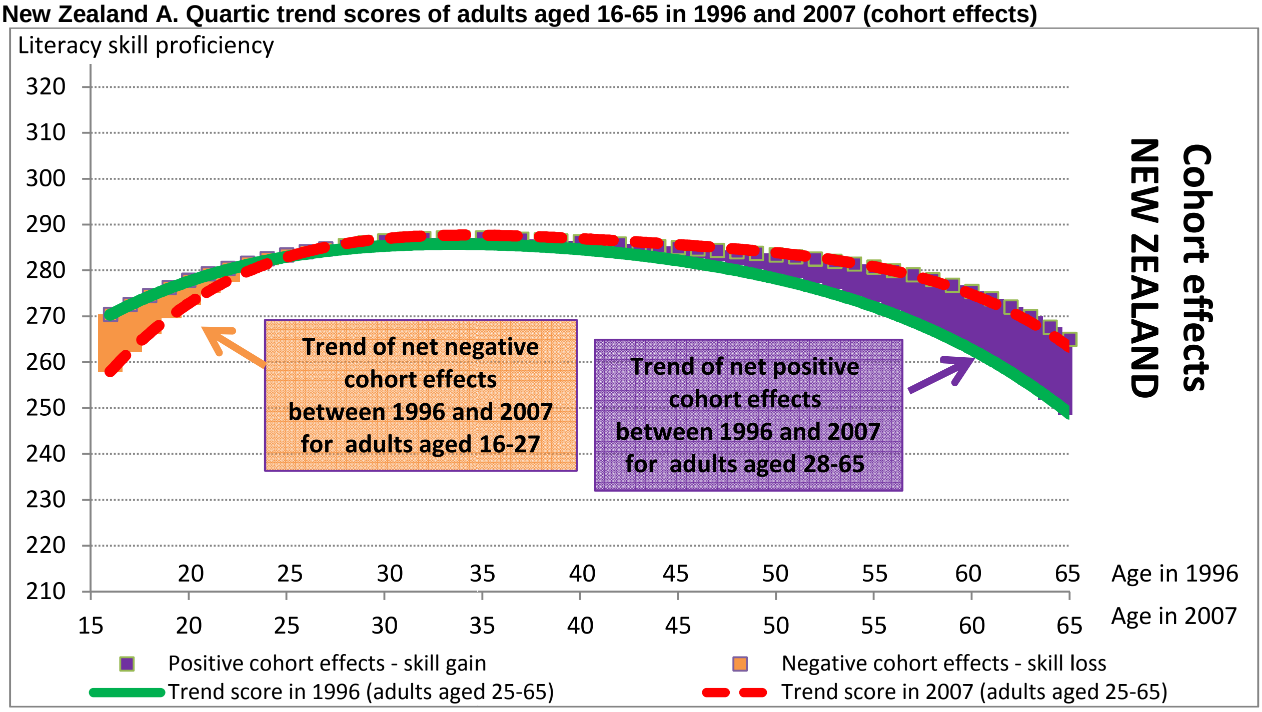


D. Statistical significance (p<.05) of difference in scores of adults aged 16-56 in 1994 and nine years after by single-year cohort intervals (ageing effects)

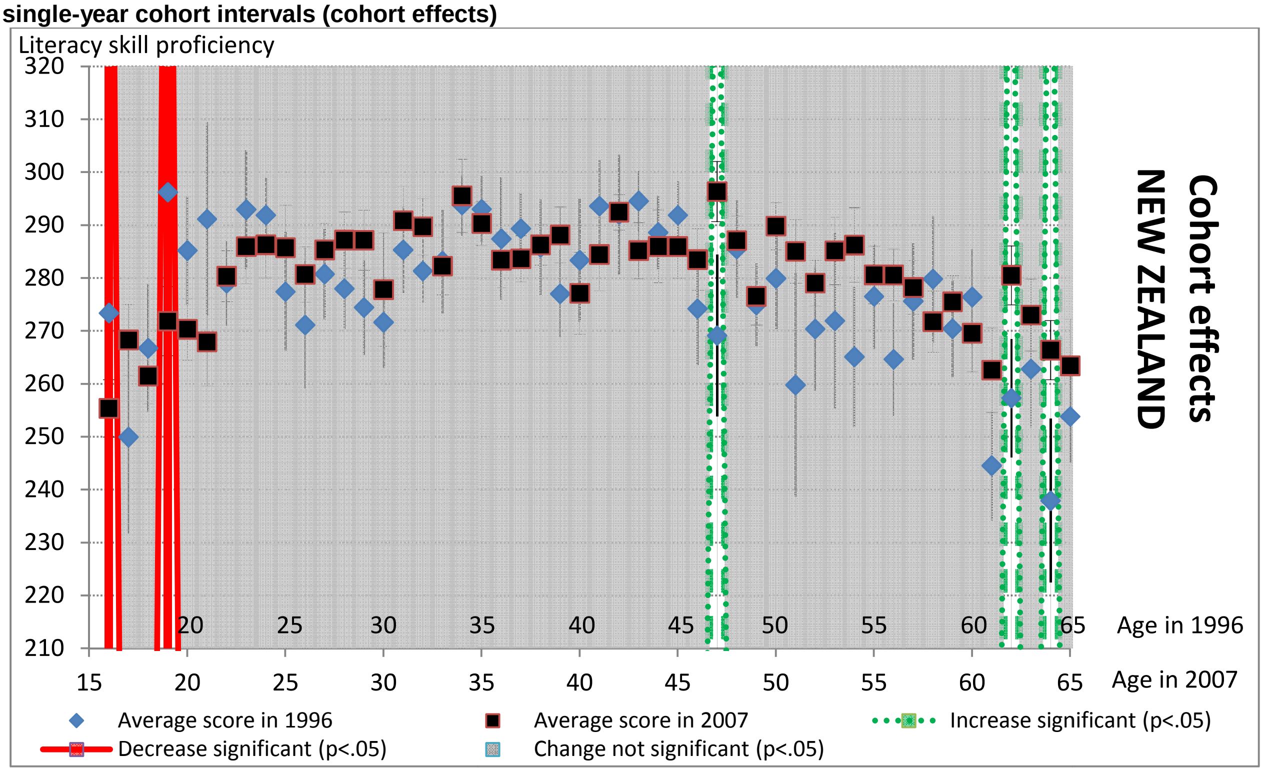


Source: International Adult Literacy Survey, 1994-98; Adult Literacy and Lifeskills Survey, 2003-07.

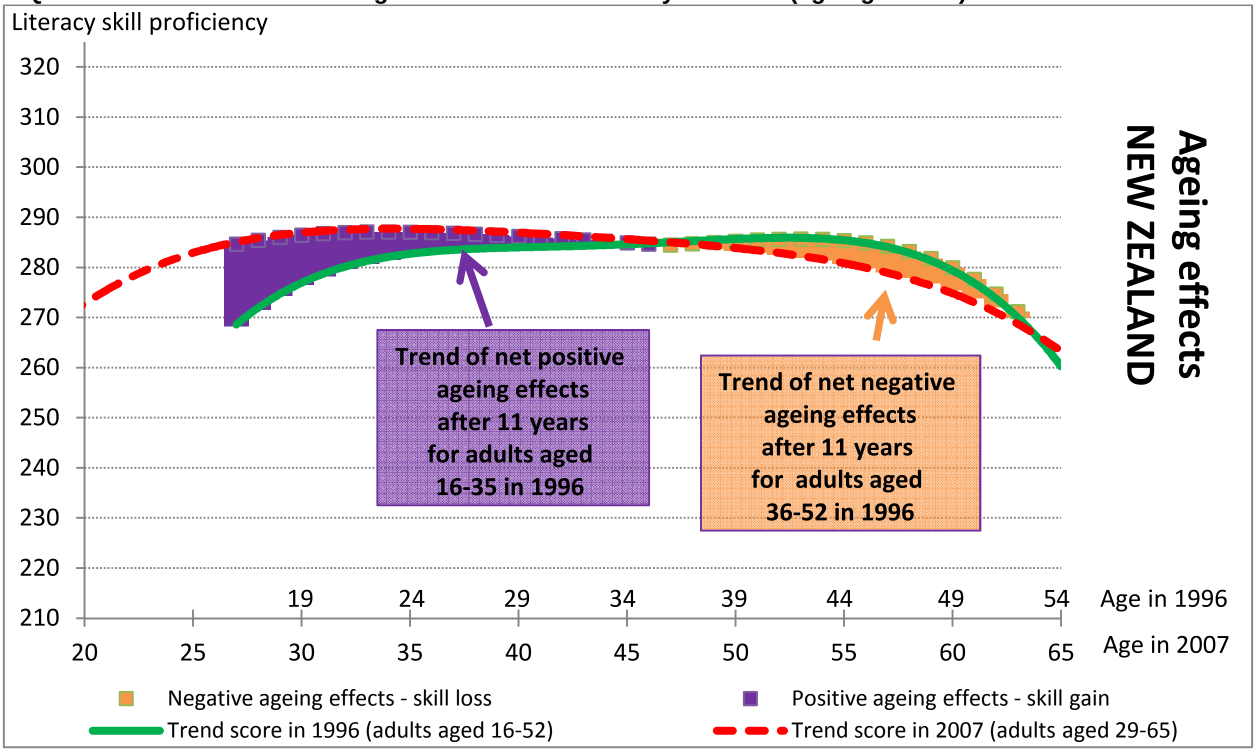
Figure A4. Change in literacy skills between and within cohorts from 1996-2007, foreign-born adults excluded, New Zealand A. Quartic trend scores of adults aged 16-65 in 1996 and 2007 (cohort effects)



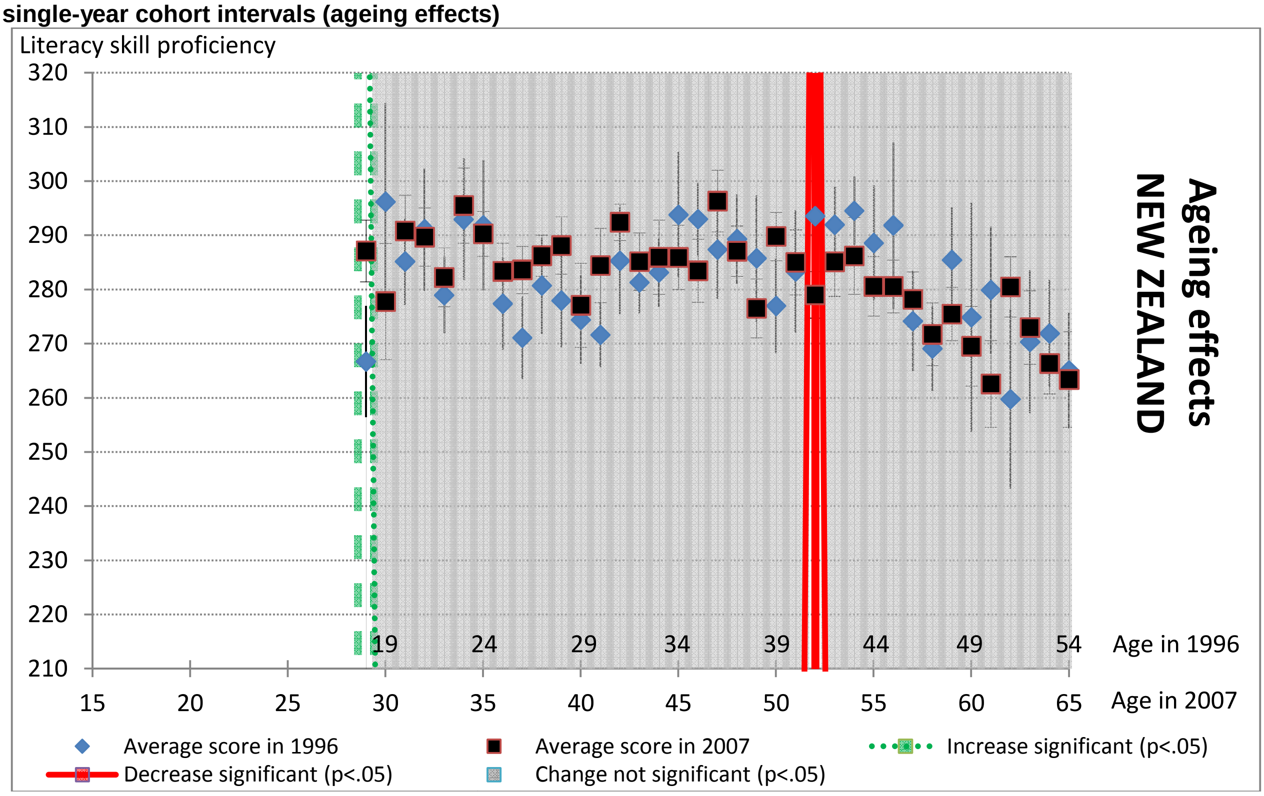
B. Statistical significance (p<.05) of difference in scores of adults aged 16-65 between 1996 and 2007 by single-year cohort intervals (cohort effects)



C. Quartic trend score of adults aged 16-56 in 1996 and 11 years after (ageing effects)



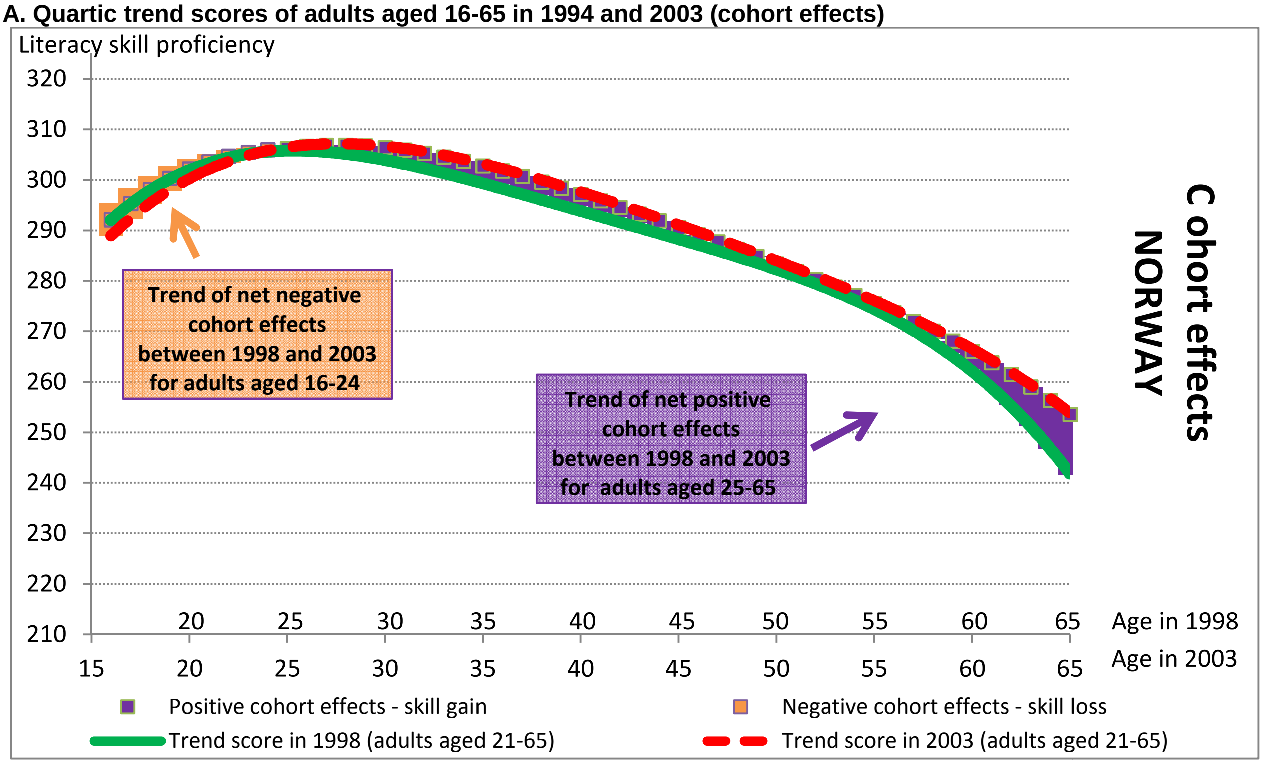
D. Statistical significance (p<.05) of difference in scores of adults aged 16-56 in 1996 and 11 years after by single-year cohort intervals (ageing effects)



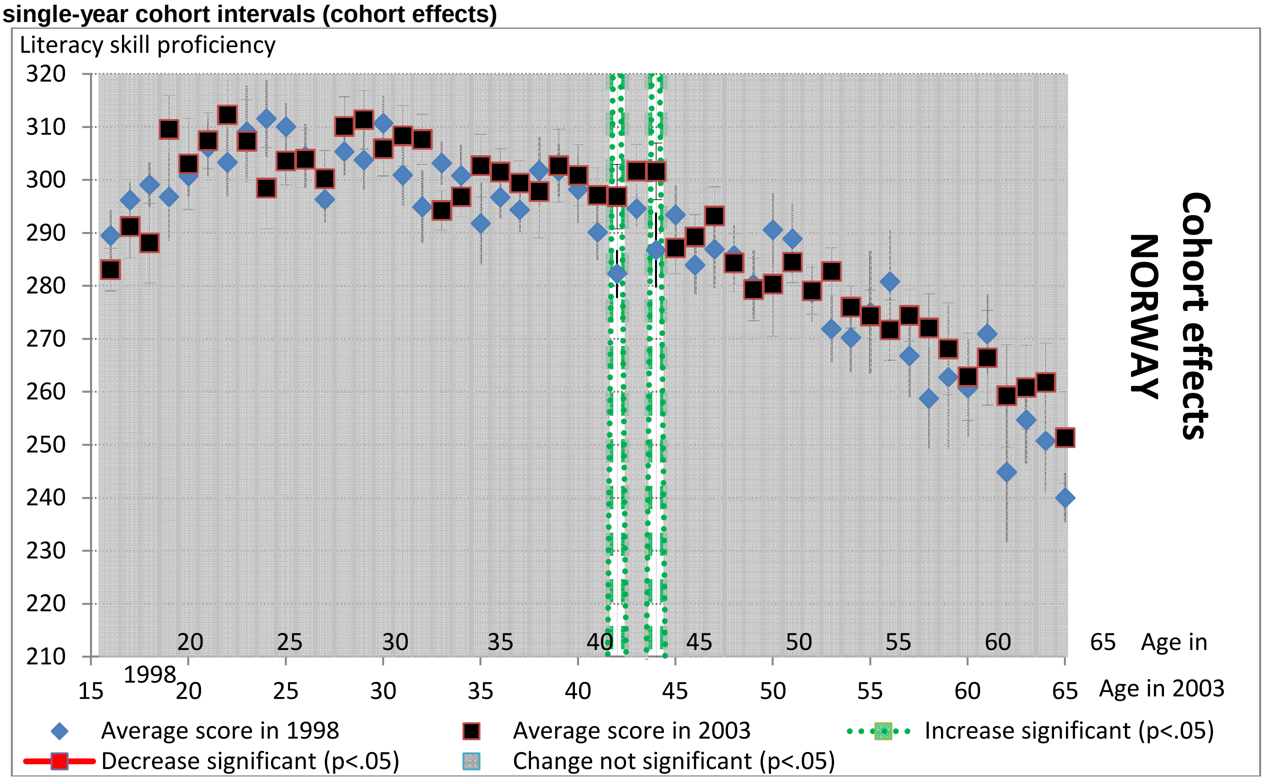
Source: International Adult Literacy Survey, 1994-98; Adult Literacy and Lifeskills Survey, 2003-07.

Figure A5. Change in literacy skills between and within cohorts from 1998-2003, foreign-born adults excluded, Norway

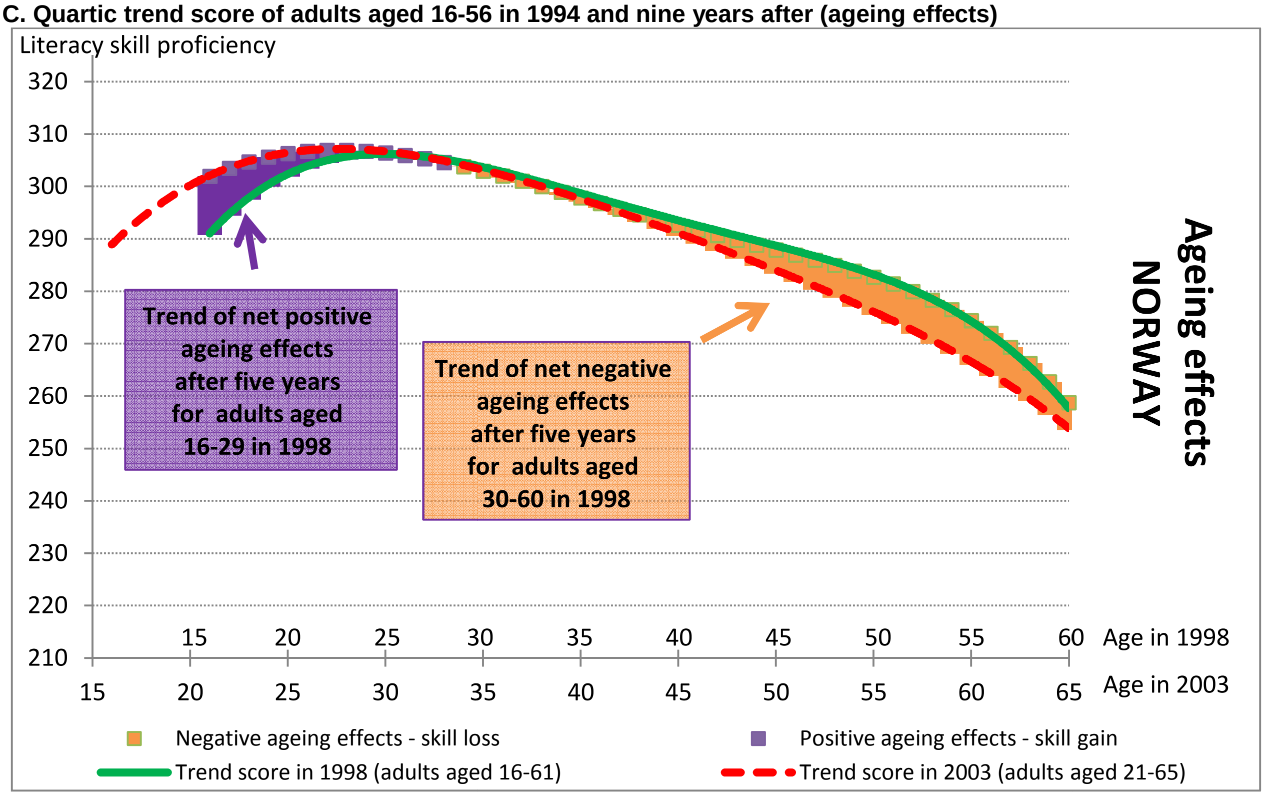
A. Quartic trend scores of adults aged 16-65 in 1994 and 2003 (cohort effects)



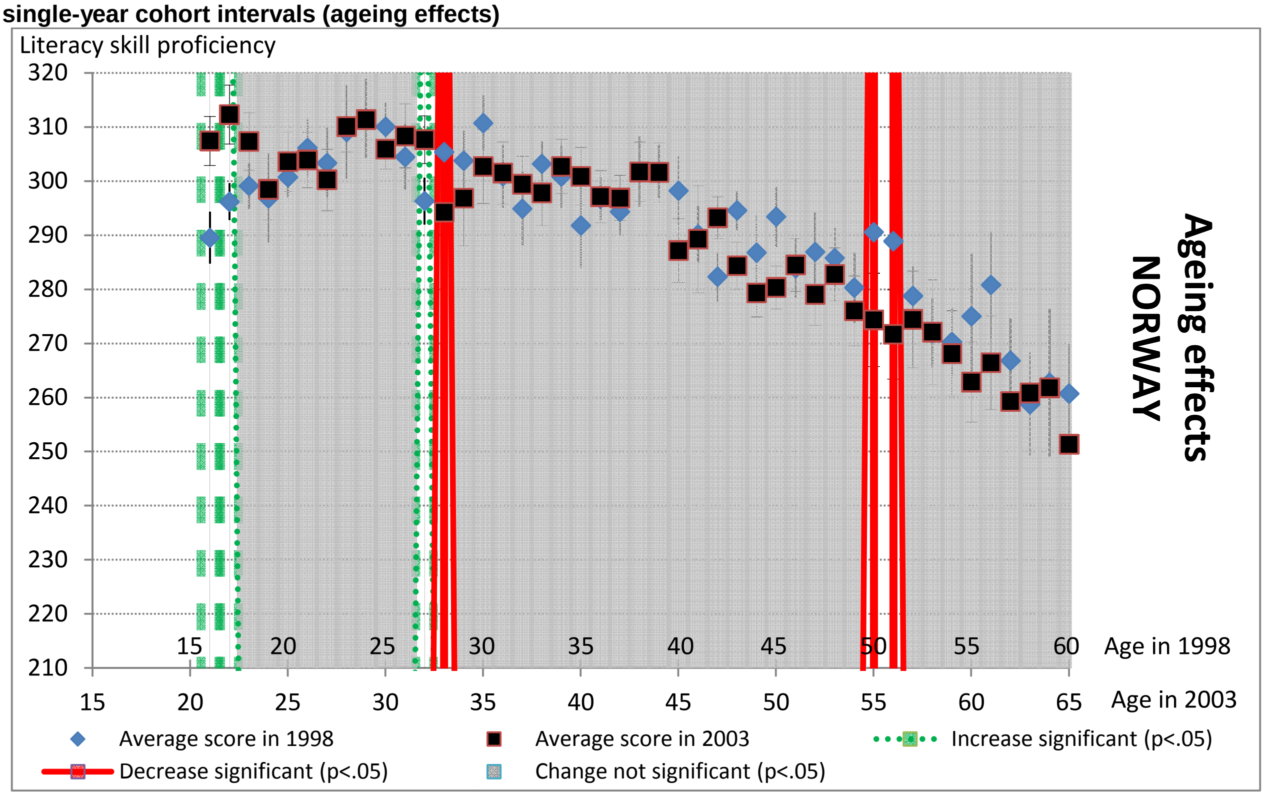
B. Statistical significance (p<.05) of difference in scores of adults aged 16-65 between 1994 and 2003 by single-year cohort intervals (cohort effects)



C. Quartic trend score of adults aged 16-56 in 1994 and nine years after (ageing effects)



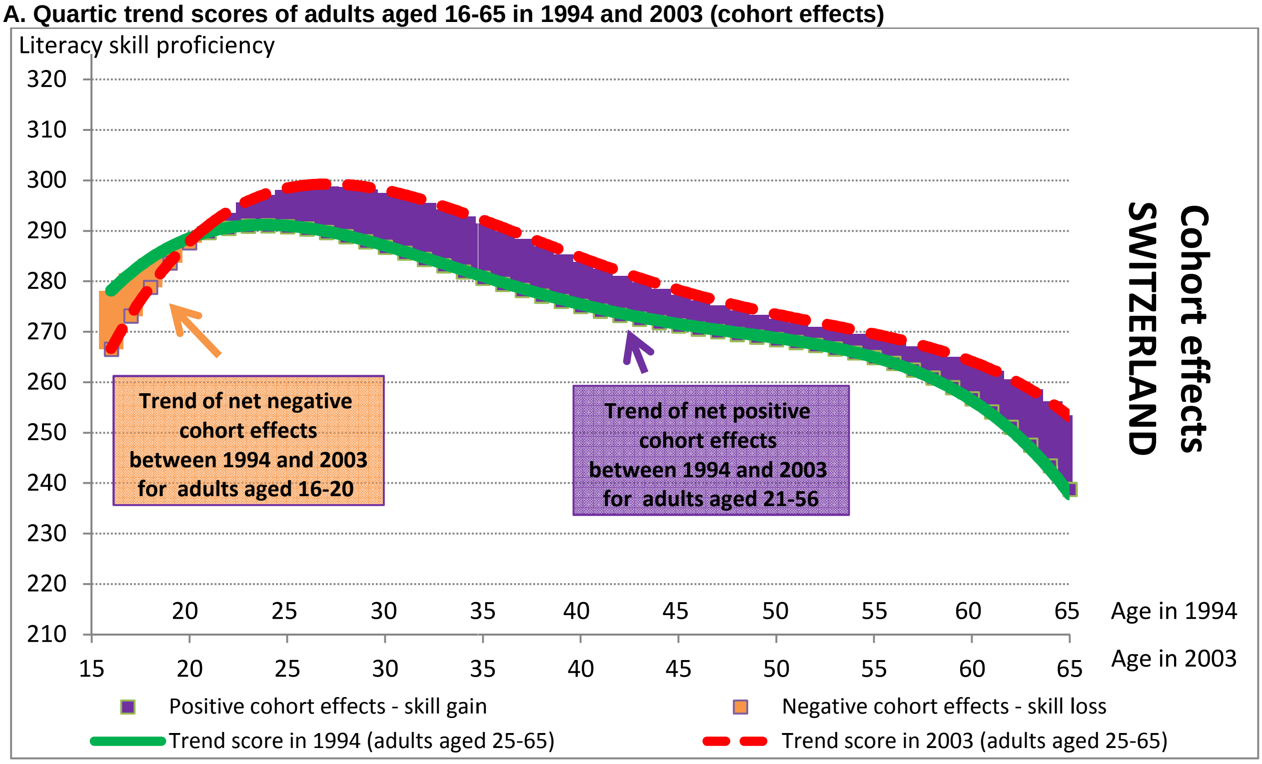
D. Statistical significance (p<.05) of difference in scores of adults aged 16-56 in 1994 and nine years after by single-year cohort intervals (ageing effects)



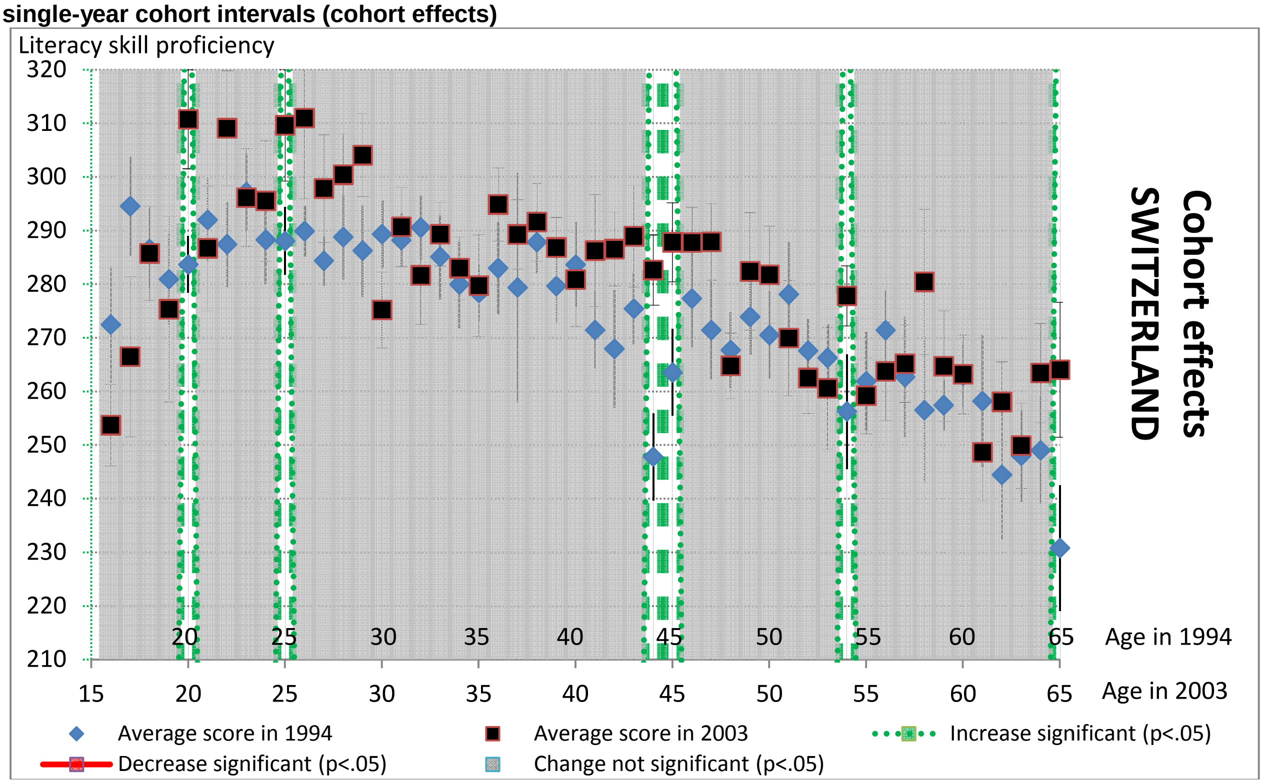
Source: International Adult Literacy Survey, 1994-98; Adult Literacy and Lifeskills Survey, 2003-07.

Figure A6. Change in literacy skills between and within cohorts from 1994-2003, foreign-born adults excluded, Switzerland

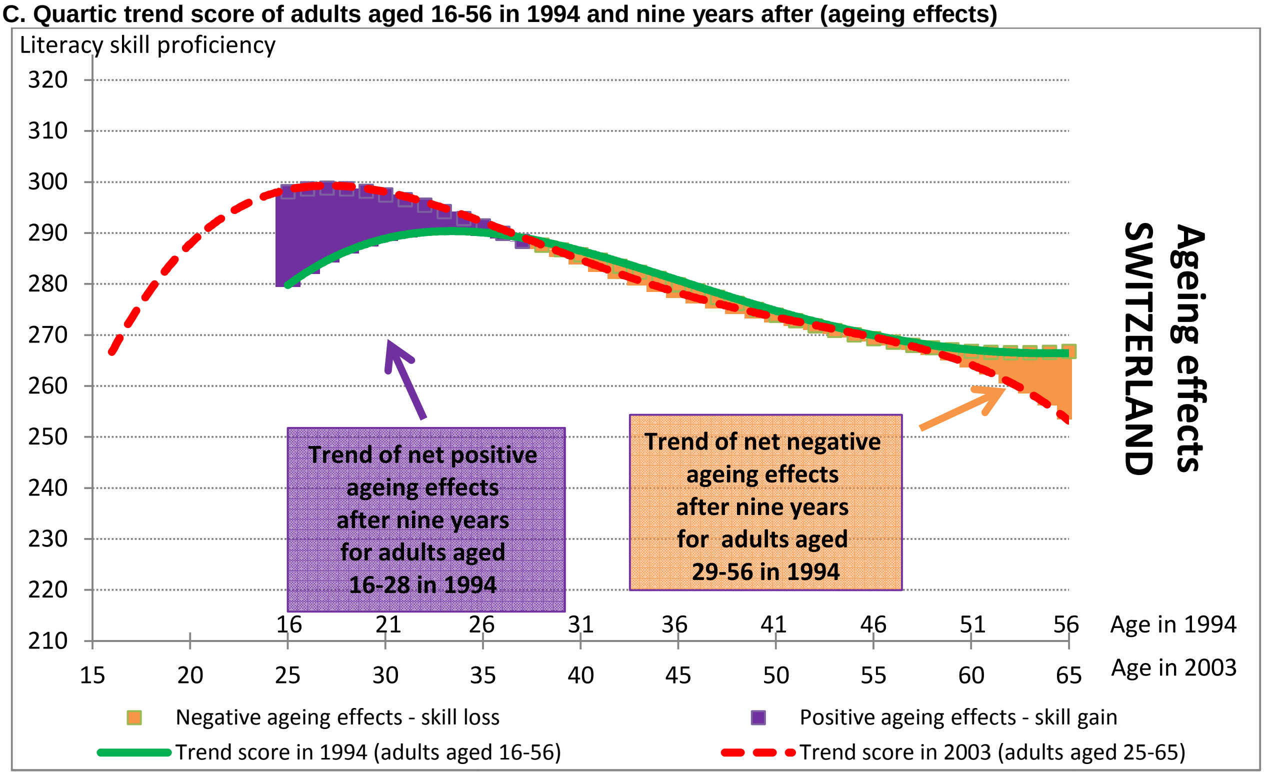
A. Quartic trend scores of adults aged 16-65 in 1994 and 2003 (cohort effects)



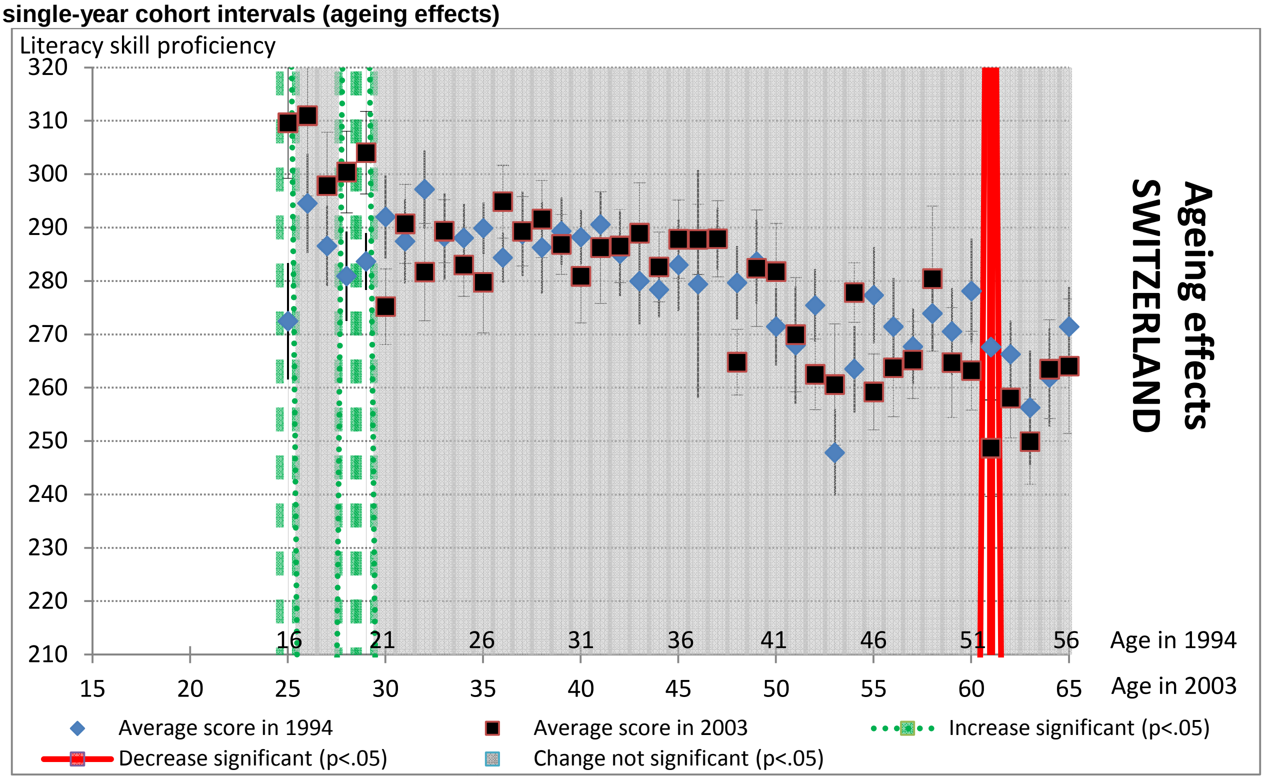
B. Statistical significance (p<.05) of difference in scores of adults aged 16-65 between 1994 and 2003 by single-year cohort intervals (cohort effects)



C. Quartic trend score of adults aged 16-56 in 1994 and nine years after (ageing effects)



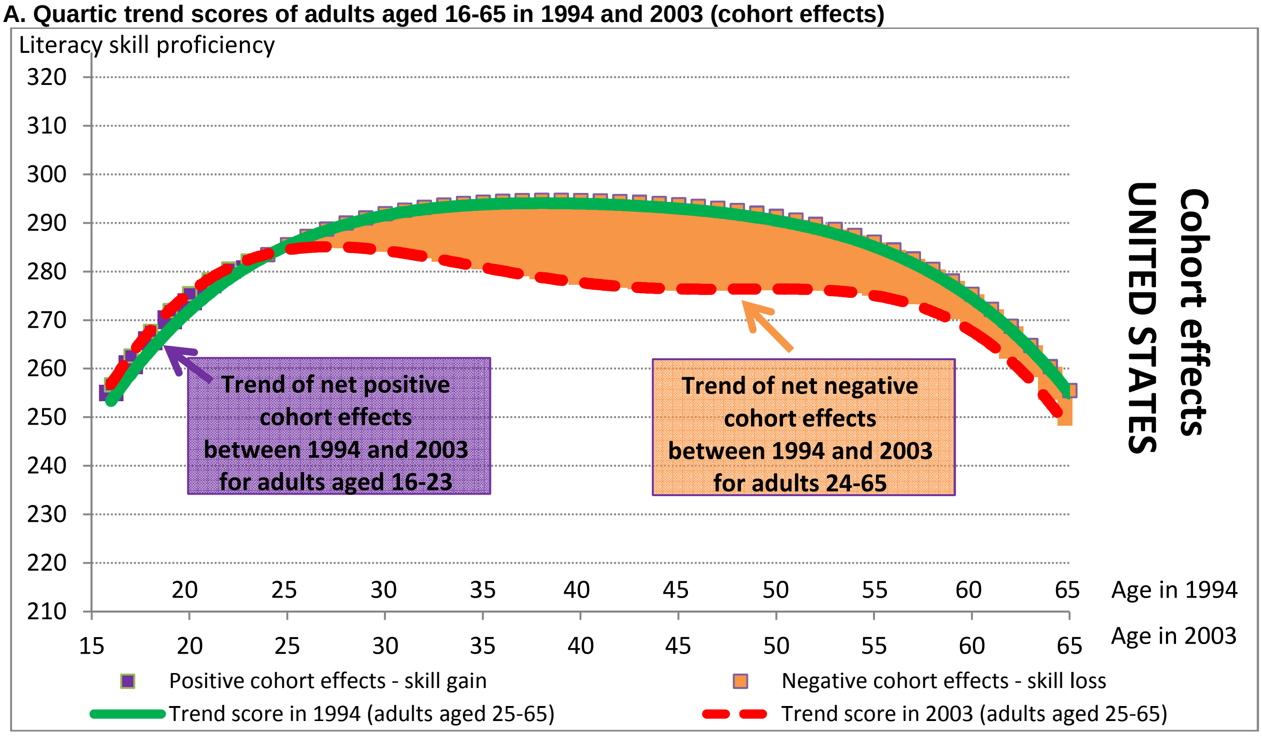
D. Statistical significance (p<.05) of difference in scores of adults aged 16-56 in 1994 and nine years after by single-year cohort intervals (ageing effects)



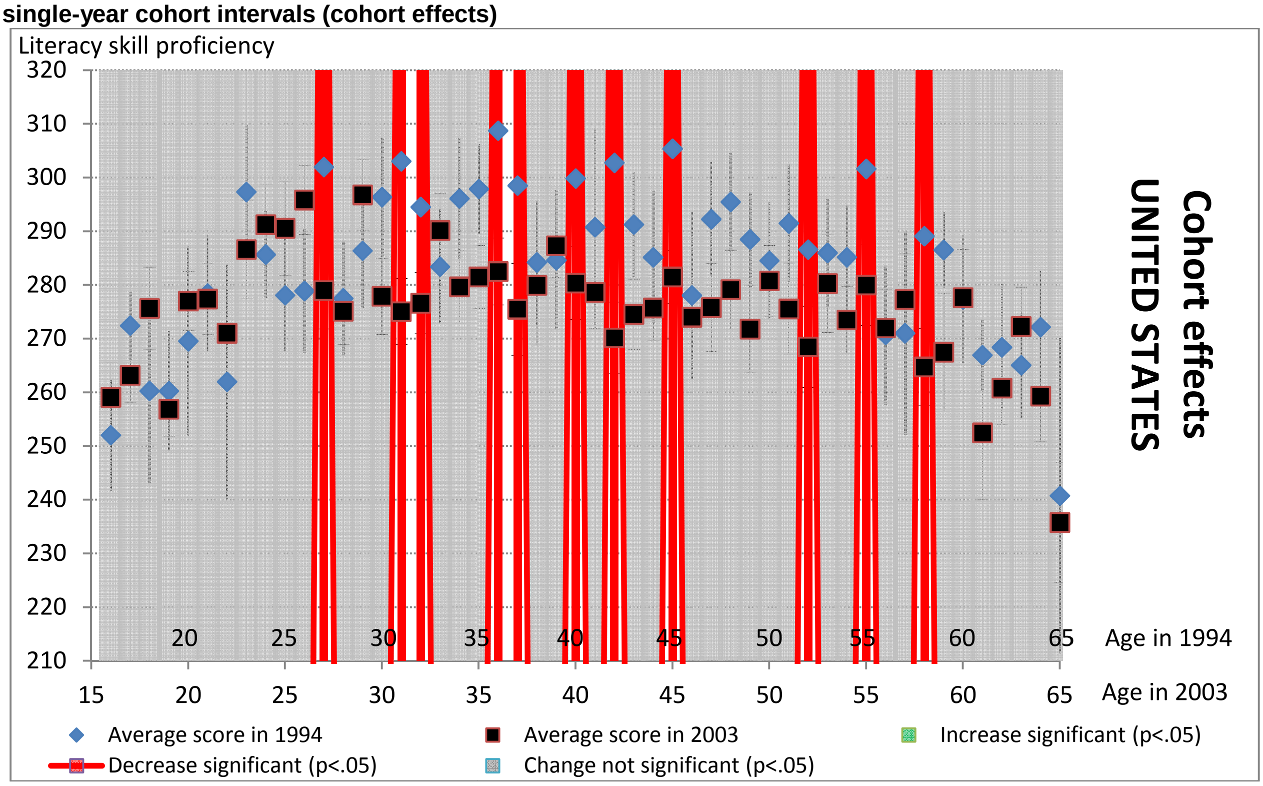
Source: International Adult Literacy Survey, 1994-98; Adult Literacy and Lifeskills Survey, 2003-07.

Figure A7. Change in literacy skills between and within cohorts from 1994-2003, foreign-born adults excluded, United States

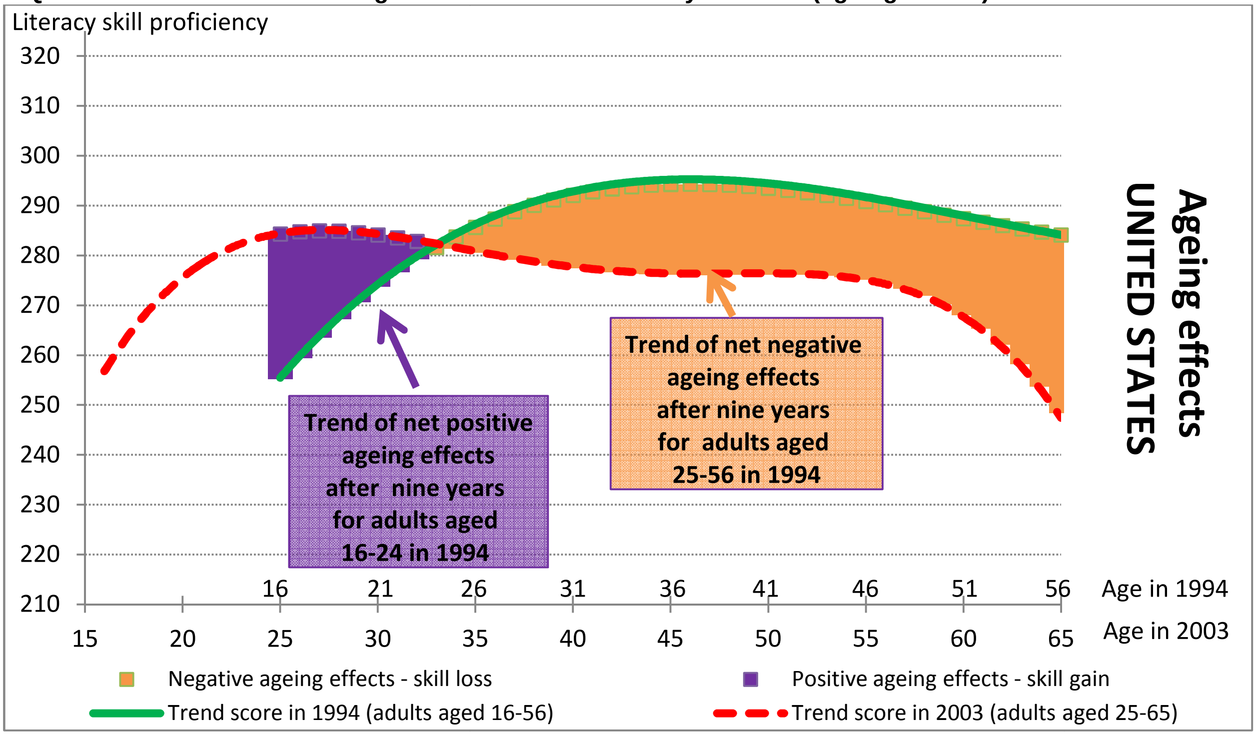
A. Quartic trend scores of adults aged 16-65 in 1994 and 2003 (cohort effects)



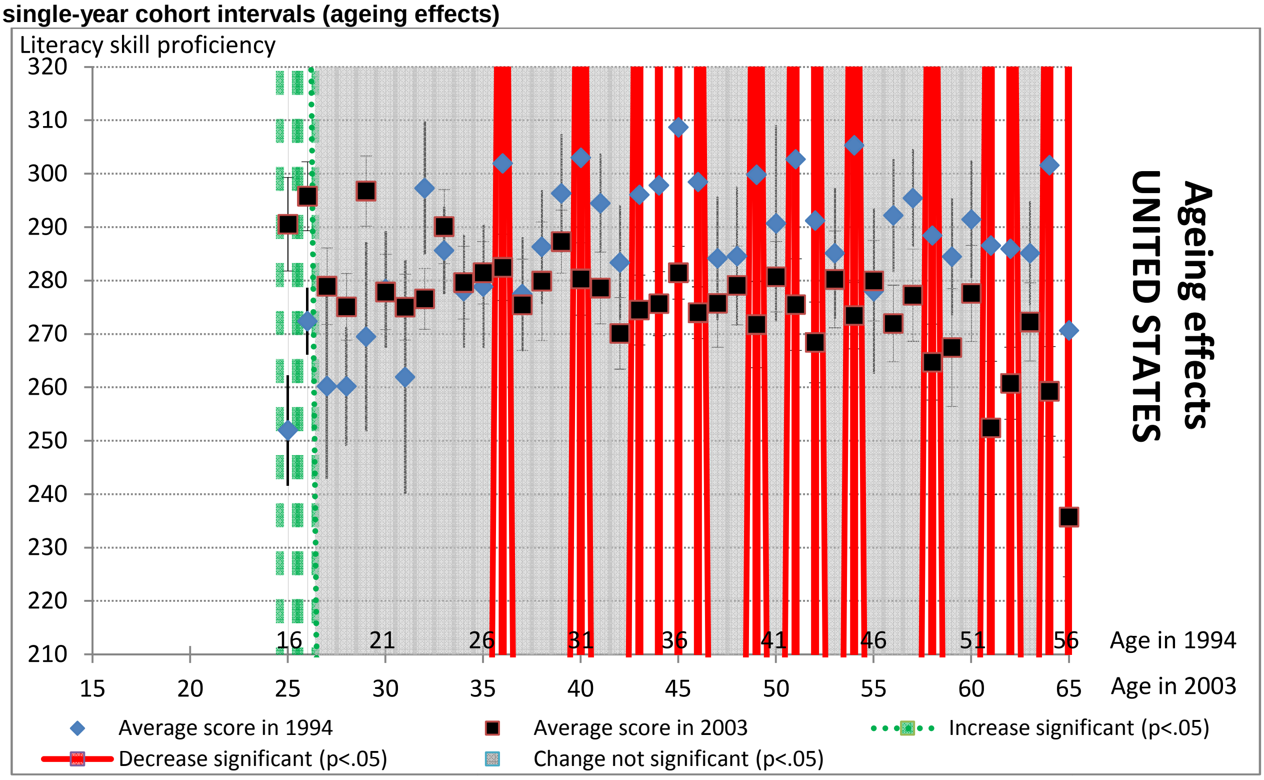
B. Statistical significance (p<.05) of difference in scores of adults aged 16-65 between 1994 and 2003 by single-year cohort intervals (cohort effects)



C. Quartic trend score of adults aged 16-56 in 1994 and nine years after (ageing effects)



D. Statistical significance (p<.05) of difference in scores of adults aged 16-56 in 1994 and nine years after by single-year cohort intervals (ageing effects)



Source: International Adult Literacy Survey, 1994-98; Adult Literacy and Lifeskills Survey, 2003-07.

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