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Foresight

What differences are there across the life course in learning processes, and how might public policy enhance learning capacity?

Future of an ageing population: evidence review

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What differences are there across the life course in learning processes, and how might public policy enhance learning capacity?

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Contents

Executive summary

The aims of this Evidence Review are:

- to examine the evidence relating to differences in learning processes and capacity across the life course;
- to look forward to 2025 and 2040 in order to assess what changes might be expected in the learning capacity of older adults;
- to discuss how public policy might enhance learning capacity, as well as mental capacity, throughout life.

Changes in learning processes were interpreted as the changes discernible in cognitive capacities and sensory abilities as people grow older, taking individual differences into account. Cognition generally refers to the range of mental activities that are involved in learning, remembering and using knowledge but there is little agreement as to its definition. Learning capacity was understood here as the extent to which individuals are able to absorb knowledge, to develop skills and to use both effectively in their own lives.

Recent insights from neuroscience and cognitive psychology are shedding more light on some of the basic processes involved in learning through empirical study of the brain and connected nervous systems. It appears that the brain changes constantly throughout life as a result of learning and remains 'plastic'; resilience can be built up through education with favourable effects lasting into old age.

Life course studies have an important role to play in understanding changes in cognition. Cognitive ability in childhood was found to correlate strongly with cognitive ability in midlife and in old age but education has the potential to augment cognitive skills independently of existing cognitive ability.

There is evidence that older people may experience impairment in prospective memory and a certain degree of literacy and numeracy impairment, especially over the age of 80. There was some evidence that cognitive training can have lasting and durable results but questions remain as to whether gains can be transferred to activities of everyday life and which older people could benefit.

One study showed that high levels of psychological well-being in later life were associated with better cognitive function but it was difficult to draw any conclusions as to whether sensory decline can play a part in age-related aspects of cognition, although it can be a risk factor for depression. As people grow older, social factors become important.

Normal brain ageing does result in decline in some cognitive functions but mild cognitive impairment and dementia are not part of normal brain ageing. At present, most people do not develop dementia but the incidence may increase in future. It is likely that damage to the brain begins several decades before symptoms appear. Dementia appears to have mixed genetic and environmental causes. There is weak evidence of the benefit of various therapies although social stimulation in itself may be beneficial for cognition.

Looking forward to 2025, emerging digital technologies and the move to a ‘connected’ community may help to ‘rewire’ the brain. Paradoxically, older people’s cognitive and social skills may be enhanced through participation in local learning initiatives such as U3A, Men’s Sheds and intergenerational learning. People with dementia may be helped by new and stronger drugs for cognitive enhancement.

By 2040, many older people will have experienced higher levels of education and a longer period in the workforce, which may offer a protective effect, although the foundation for cognitive and social skills will still be laid in childhood.

Public policy initiatives to enhance learning capacity could include a realistic strategy for learning across the life course including:

- childhood education that stresses motivation, confidence and self-regulation and learning to learn;
- teacher training that incorporates knowledge of findings in neuroscience;
- improvement of opportunities for education, learning and training in adulthood;
- encouragement of later life learning that involves inputs by older people themselves and which targets isolated older people;
- public health messages regarding the importance of following a healthy lifestyle and ensuring healthy brain ageing by maintaining cognitive function;
- building on current dementia strategies to inform and educate the public and to help remove the stigma associated with cognitive impairment;
- encouragement for interdisciplinary research to incorporate findings from neuroscience with evidence from education and cognitive psychology.

1. Introduction

1.1 Aims

The aims of this Evidence Review are:

- to examine the evidence relating to differences in learning processes and capacity across the life course;
- to look forward to 2025 and 2040 in order to assess what changes might be expected in the learning capacity of older adults;
- to discuss how public policy might enhance learning capacity, as well as mental capacity, throughout life.

In examining the evidence, attention has also been paid to historical drivers of change; socio-economic/socio-demographic factors; gender issues where appropriate; factors that may drive change at 2025/2040 junctures; and relevant cross-cutting issues in relation to the overall project, especially whole life course, intergenerational focus and technology.

1.2 Background

Although academic interest in exploring different aspects of learning has evolved over many years, it might be said to have been accelerated over the last 25 years or so by a combination of factors – demographic trends, what Field (2006) calls 'globalising tendencies' and rapid advances in communications technology. In an ageing society, it has become increasingly apparent that participation in learning, both formal and informal, plays an important role not just in relation to the nation's economic competitiveness but also as a means of helping people to lead active and personally satisfying lives as they grow older in what is increasingly a diverse and unequal society. Related to this, the need to understand the factors that promote healthy and productive ageing has become a particular government concern, as has interest in ensuring that people remain intellectually and socially connected as they grow older. Yet the scientific field of learning has proved to be necessarily complex in that it frequently draws on interdisciplinary expertise from education, psychology, sociology, gerontology, anthropology and more recently neuroscience, as well as other fields, particularly as the potential of technology-enhanced learning currently attracts considerable investment.

To supply some context, the review follows on from a previous closely related Foresight project which investigated mental capital and well-being across the life course (Government Office for Science, 2008). A life course approach was also taken in Schuller and Watson's (2009) inquiry into the future for lifelong learning, although this has been subject to some criticism largely on account of its 'stages' model of the educational life course. Certainly, in investigating the processes involved in learning and of people's learning capacities using a life course approach, an appreciation is also required of the context of people's lives: how they negotiate changing circumstances and new challenges in their lives together with the impact of the changing policy context. In this respect, the Learning Lives project, part of the ESRC Teaching and Learning Research Programme (Phase 111, 2003–7), provides an important antecedent in that it offers a comprehensive picture of what learning means to different people and its role over time and across generations (Biesta *et al*., 2011).

The review takes account of all stages of learning – from childhood to old age – but in view of its potentially wide scope, existing literature has been selected and appraised mainly from an educational perspective with the main focus being on UK publications, although some international evidence has been incorporated. Account has been taken of both peer-reviewed empirical studies and of expert commentaries where appropriate, as well as of some theoretical perspectives.

2. Methodology

Search procedure:

Keywords: learning process; cognition; life course; learning capacity; sensory loss; adult learning; older adults

Databases searched: Web of Science; Google Scholar; ASSIA; IBSS; PsycINFO; IALSA; Educational Research Abstracts Online; PubMed

Websites consulted:

www.newdynamics.group.shef.ac.uk	www.alzheimers.org.uk	www.ons.gov.uk/
www.tlrp.org	www.actiononhearingloss.org.uk	
www.halcyon.ac.uk	www.rnib.org.uk	
www.ageuk.org.uk	www.gov.uk	
www.elsa-project.ac.uk	www.niace.org.uk	

Hand search of identified relevant book chapters, official reports.
All English language peer-reviewed papers/articles considered for inclusion.

Review of reference lists of papers/articles/websites identified above. Identification of additional papers not captured in original search.

Inclusion criteria: Published between 1990 and 2014; peer reviewed; systematic review; surveys; quantitative studies; qualitative studies; expert commentaries.

Filters: dissertations; grey material; conference proceedings; not primarily concerned with, or relevant to main themes.

Appraisal of quality and relevance: Use of research appraisal questions framework developed by Gomm *et al*. (2000) for application to published research studies. This consists of a checklist of seven sets of critical questions to ask about data collection instruments and different types of studies in order to judge the level of confidence with which their results can be accepted and lessons for practice derived. The appraisal questions relating to data collection instruments, experiments, systematic reviews and meta-analysis, and qualitative research, were employed here.

A total of 57 papers/articles/commentaries were included or consulted for the review.

Synthesis: A mixed methods synthesis was used to bring together analyses of data from different research traditions together with perspectives from expert commentaries.

Figure 1: Methodology

3. Definitions

3.1 Learning

A preliminary task was to establish a definition of 'learning' and then to consider what is generally understood by 'learning processes' and 'learning capacity'. Learning is so fundamental to human experience that it has been studied and debated over many years with a very wide range of theories, models and frameworks developed. From the 1950s onwards and derived mainly from the work of psychologists, a commonly accepted definition of learning was that it involved a change in behaviour or the potential for change. However, in recent years, other more complex models have been proposed which focus on learning, whether formal or informal, from a holistic perspective involving mind, body and emotions, as well as environmental influences and personal experiences "for acquiring, enhancing, or making changes in one's knowledge, skills, values and world views" (Merriam *et al*., 2007: 277). These models have been mainly developed by educators of adults (Illeris, 2002; Jarvis, 2009), although they do not claim that the models relate specifically to adult learning. In addition, Biesta *et al*. (2011) provide compelling evidence as to the importance of taking a comprehensive view of the meaning and significance of learning throughout people's lives and understanding the circumstances in which they see it as valuable.

3.2 Learning processes

Learning processes might then be understood as what happens when learning takes place. Again, a range of different theoretical perspectives has been developed but for the purposes of this review, a cognitive orientation has been adopted. Cognition generally refers to the range of mental activities that are involved in learning, remembering and using knowledge. These may involve perception, attention, language, different aspects of memory, planning and complex decision making and speed of information processing, as well as problem-solving abilities. The rationale for taking this approach is that cognitive psychologists are interested in these internal mental processes from a largely developmental perspective – that is, how ageing affects an individual's abilities to carry out the tasks involved in learning and in relation to this, his/her mental structures (Merriam *et al*., 2007). However, Bender and Beller (2013) suggest that cognition may be fundamentally a cultural concept. Certainly, it appears that although the term is widely used, it is seldom clearly defined and is still subject to some controversy (Whissell *et al*., 2013). In reviewing evidence it is obviously important to bear in mind that the term may have been defined differently in different types of studies.

In addition, recent insights from the emerging field of educational neuroscience, combined with findings from cognitive psychology, are shedding more light on some of the basic processes involved in learning through empirical study of the brain and connected nervous systems. In this respect, Rees (2011) discusses the advantages of neuroimaging, the technologies that permit certain aspects of human brain structure and function to be observed and measured non-invasively. A report from The Royal Society (Rees, 2011) points out that neuroscience research has demonstrated that biological factors as well as the environment play an important part in explaining differences in learning abilities between individuals. It has also been shown that the brain changes constantly throughout life as a result of learning and remains 'plastic'; learning a particular skill can change the brain although the changes revert if practice of the skill ceases. A further finding has been the extent to which resilience (an aspect of mental capital) can be built up through education, with favourable effects lasting into old age. Neuroscience also has an

important role to play in discovering how brain power can be boosted, with implications for learning and teaching at any age; there is no age limit to learning (Blakemore and Frith, 2005).

Nevertheless, as pointed out in the above reports, there is still something of a gulf between psychologists, neuroscientists and educators, perhaps exacerbated by lack of a common language, a view also put forward by Howard-Jones (2007); this makes defining learning processes a challenging task. For the purposes of this review, changes in learning processes have been interpreted broadly as the changes discernible in cognitive capacities and sensory abilities as people grow older, taking individual differences and circumstances into account.

3.3 Learning capacity

Learning capacity is understood here as the extent to which individuals are able to absorb knowledge, to develop skills and to use both effectively in their own lives. However, as above, it is also acknowledged that people's capacity to learn may be affected by their particular circumstances and by the opportunities and barriers they may encounter during their lives. In spite of this caveat, research by Biesta *et al*. (2011) has demonstrated the ubiquity and the range of learning adults undertake during their lives. The research also showed that adults can have a wide variety of dispositions towards learning so that in considering learning capacity, this perspective has been taken into account.

4. The evidence

4.1 Approaches to exploring cognitive ability over the life course

Life course studies have come to play a particularly important role in understanding changes in cognition, sometimes in conjunction with the investigation of physical functioning and psychological well-being in later life. Richards and Hatch (2011) have drawn on research from a range of disciplines to identify the factors across the life course that can jointly influence both cognitive and emotional development. They suggest that cognition and socio-emotional function gradually fuse to form the necessary mental skills for life which have long-term outcomes for the emergence of competence that will persist into later life. They trace a thread of human development from genetic influences through uterine and early childhood development, socialisation and family and neighbourhood environment, including socio-economic factors. They also consider the role of compulsory education and how it provides a credential for moving the individual into the workforce, thereby stratifying adult socio-economic status.

Among other findings is that cognitive ability in childhood and early adulthood correlate strongly with cognitive ability in midlife and old age. Conversely, lower cognitive ability at younger ages is associated with an increased risk of emotional problems in midlife and these are also associated with cognitive impairment later in life. However, good-quality early education, where attention is paid to shaping confidence, motivation and self-regulation (control of thoughts, emotions and behaviour) can augment cognitive skills independently of existing cognitive ability. The authors go on to cautiously suggest that higher cognitive ability may lead to more complex and demanding work and a longer period spent in the labour force, which may further increase benefits to cognitive function, as can leisure activities that involve intellectually challenging activities. On the other hand, this may depend on the nature of engagement with the labour market; a French study found that shift work can chronically impair cognition, although deficits were reversible if shift work was stopped (Marquié *et al*., 2014).

Other studies have generally confirmed the above findings. The HALcyon collaborative research project, which primarily aims to discover the lifetime determinants of healthy ageing through inter-cohort comparisons in nine UK cohort studies, confirmed that childhood cognitive ability is associated with adult cognitive capability. However, this capability, which here includes memory, reasoning, information processing speed and the functions responsible for tasks such as planning and multi-tasking, grows very fast in the early stages of life, reaches a peak in early adulthood and then declines with age in most people. Yet the researchers point out that another kind of cognitive capability is based on knowledge ‘reserves’ that many people accumulate over their lives and for most people this remains stable later in life. They also found some evidence that cognitive ability in early life appears to be protective against cognitive decline, but in later life, social relationships also become particularly important in helping to maintain cognitive abilities (Kuh *et al*., 2013).

There is also other evidence of the effect of socio-economic position early in life on cognition. A Danish study found that adverse social circumstances early in life were associated with lower cognitive function at ages 12, 18 and 57 years, together with a decline between these ages. Having an unskilled father at birth, a low level of education and few intellectual activities in childhood, as well as low social class, were associated with a decline in cognitive function (Osler *et al*., 2012). This largely confirms earlier findings by Singh-Manoux *et al*. (2005), whose study used data from a longitudinal study of British civil servants to investigate the association between socio-economic position over the life course and cognitive function in middle age.

However, an earlier cross-sectional population-based Finnish study found that whilst there was an association between cumulative socio-economic disadvantage and cognitive function in late middle age, men who had experienced upward mobility over the life course demonstrated better cognitive performance at ages 58 and 64 (Turrell *et al*., 2002). Women were not included in this study.

It has been seen that quality education in early life has the potential to improve cognitive ability but Richards and Hatch (2011) did not comment on the possible impact of further education or training undertaken in mid- and later life in their analysis (discussed above). However, there is previous evidence that adult education can have an impact on cognitive ability in midlife. Hatch *et al*. (2007) used data from the British 1946 birth cohort to demonstrate that the continued effect of education was apparent in the associations between adult education and specifically, higher verbal ability, verbal memory and verbal fluency in late midlife, although no association was found between adult education and mental speed and concentration. It may be that the link between adult education and midlife cognitive ability is also important for delaying cognitive decline in later life.

Another study examined the effects of education on cognitive abilities in old age. Using data from the English Longitudinal Study of Ageing (ELSA), Banks and Mazzonna (2012) analysed the effect of the 1947 rise in the compulsory school-leaving age from 15 to 16 (a reform which decreased by about 50% the proportion of people who left full-time education before the age of 15 as compared with the previous year) to establish the effect of this additional year of schooling on cognitive abilities 50 to 60 years later. Childhood schooling levels were found to have a strong and positive effect on subsequent later life memory and verbal fluency, although the effect was stronger for men than for women. The researchers conclude that the extra year of schooling raised a person's labour market opportunities and thus the findings may be reflective of more cognitively demanding and productive occupations, which may have positive implications for life course trajectories of cognitive function. The weaker effect for women is thought to be reflective of women's lower participation in the workforce for much of the second half of the 20th century. Another less plausible explanation is that greater earnings that may have resulted from the extra year of schooling enabled individuals to engage in a wider range of social and cultural activities over the life course, which have helped to stave off age-related cognitive decline.

4.2 Cognition in later life

It has already been seen that the ELSA has been an especially rich source of data about growing older and Wave 2 in particular has yielded detailed information concerning cognitive function in people aged 50 plus. Naturally, there will be a very broad range of cognitive functioning among middle-aged and older people from those who are fully functioning to those with dementia (Huppert *et al*., 2006). In the previous Wave 1, the sample was drawn from three separate years of the Health Survey for England (HSE) to provide a large representative sample (11,234 people) of the English population aged 50 or over and living in private households. The cognitive processes that were assessed included learning and memory, word finding ability, executive function and numerical ability (which incorporates problem solving); assessment of memory was further subdivided into retrospective and prospective memory and a wide range of cognitive measures were used (Steel *et al*., 2003). In Wave 2, carried out two years later, the processes assessed in Wave 1 were repeated with an added question concerning self-reported changes in memory and a literacy test was substituted for the numeracy test.

Analysis of the results derived from cross-sectional data in ELSA Wave 2 gives a useful picture of cognitive function in mid- and later life. Although it is noted that the time that had elapsed between Waves 1 and 2 was possibly too short to provide reliable estimates of cognitive decline, it was apparent that speed of information processing was the most sensitive measure and the older the group, the greater degree of decline. In general, there was a slight improvement in memory performance overall but this was more evident in younger groups; older groups had a very noticeable impairment in prospective memory and an age-related loss was apparent on tests of word recall. Indeed, one-third of the sample reported that their memory had worsened over the previous two years, although self-rating was not felt to be a reliable guide. High literacy and numeracy impairment was also observed among older people, especially in the oldest group (aged 80 plus), with men showing greater levels of impairment in literacy than numeracy and the opposite result for women. This could be partially explained by age differences in education. However, a certain degree of literacy impairment was found, perhaps surprisingly, in one-third of the overall sample.

The researchers focused briefly on two aspects of socio-economic position – wealth and employment status. As expected, the higher the levels of wealth the better the cognitive performance across all measures apart from that of speed of processing. As in other research previously discussed, higher levels of wealth in the individual's family are likely to be associated with better access to education and possibly a more rewarding career. A different explanation is that having a high level of cognitive ability may lead to the individual seeking out more financially rewarding activities. Similarly, it was found that those currently employed (or self-employed) performed best on almost every measure of cognitive function, whilst poor performance came from the permanently sick or disabled (Huppert *et al*., 2006).

Other research using data from ELSA Wave 1 found that higher levels of psychological well-being in later life were associated with better cognitive function (Llewellyn *et al*., 2008); and in a prospective study of older people, there was no conclusive evidence that being depressed led to an actual acceleration in cognitive decline (Gale *et al*., 2012), although meta-analysis has shown that depression and the risk of dementia are related (Prince *et al*., 2014).

Longitudinal studies are obviously important in helping to explore and account for changes in cognitive function and thus in learning capacity at different points of later life. In addition, there has been considerable interest in exploring whether various types of interventions can have durable effects on cognitive function in older adults (Rebok, 2008). A major cognitive training initiative, the ACTIVE project, was designed as a randomised controlled single-blind trial with volunteer samples of 2,832 very diverse people aged 65 to 94 years living independently in six metropolitan areas of the USA. The aim was to evaluate whether three cognitive training interventions, conducted in small group settings for a short time (over 5–6 weeks) would improve mental abilities and daily functioning. Participants were assigned to one of four groups undergoing memory training or reasoning tasks or speed-of-processing training with one no-contact control group. Booster training was offered to a random 60% sample 11 months later. Overall results supported the effectiveness and durability of the cognitive training interventions in improving the targeted cognitive abilities of the trained groups after two years (Ball *et al*., 2002).

ACTIVE has since continued and over time, the project has generated a considerable number of research papers. In general, results of this and other projects continue to confirm the effectiveness of cognitive interventions in preserving cognitive health long term although, as expected, only a 'modest' indication of transfer of gains to instrumental activities was detected here after five years. Retention of the sample after five years was 67% but it has also been

acknowledged that the final sample was generally more advantaged in terms of age and education than the general population and therefore, results should be interpreted with some caution (Tennstedt and Unverzagt, 2013). Questions still remain concerning the underlying mechanisms of transfer of gains to everyday life and which older people can benefit most from this kind of training.

A different kind of intervention can be seen in the outputs of an international project 'Memory in Later Life', funded under the European Union (EU) Grundtvig Learning Partnership Programme 2012–14. Here, groups of older people representing a range of organisations in six European countries voluntarily worked together over a two-year period to investigate various aspects of memory, to pool knowledge on the subject and to test out and describe some practical memory and mnemonic methods and techniques which might be implemented by older people themselves. The partnership resulted in the production of a practical handbook (Percy, 2014). Participants generally found it personally beneficial to have been involved but the project was not a research-based study and has not yet been subject to rigorous evaluation or wider dissemination.

4.3 Cognition and sensory loss

There are, of course, a whole range of physical and sensory changes that individuals undergo in adulthood and in later life. Sensory loss, which is particularly relevant to cognition, is taken to include vision and hearing (although it can also refer to smell, taste and touch). In respect of vision, it has been established that normal age-related changes in the eye affect visual acuity from the age of about 40; there are also a number of eye diseases, the prevalence of which tend to increase in later life. These include cataracts, age-related macular degeneration and glaucoma, one of the leading causes of blindness. In respect of hearing, some degree of age-related hearing loss is considered normal (Whitbourne, 2001), although there are many types of auditory differences among older people and the impact is not always well understood (Scheuerle, 2000).

An extensive literature relating to the possible association between measures of sensory function and cognitive function was identified but much of it has necessarily been excluded from this review because studies were mainly published in the USA and were not readily accessible. These studies appear to be mainly confined to one or two senses and measures of acuity. An extensive range of other studies, again mainly carried out in the USA, have investigated whether sensory decline can play a role in age-related differences discerned in different components of memory (for example, Naveh-Benjamin and Kilb, 2014). However, because of the different populations investigated, the wide range of methods involved and the different context, it is difficult to draw any definitive conclusions. Glisky (2007), in a detailed review of changes in memory and perception as people age, observes that older people with declining sensory loss tend to develop compensatory strategies but this may bring about changes in performance on other cognitive tasks which may then be less efficient. She advocates retraining and practice on such tasks to improve performance.

Possible connections between depression, identified earlier as a risk factor for dementia, and dual sensory loss (vision and hearing) have also been investigated. Chou (2008) examined the relationship between dual sensory loss in the onset and persistence of depression in a prospective observational study of 3,782 older adults aged 65 years or more selected from the ELSA Waves 1 and 2. Vision loss emerged as a consistent predictor of both onset and persistence of depression but the association between dual sensory loss and depression

disappeared once health indicators were controlled for. In a smaller American study, McDonnall (2009) sought to identify risk factors that are identified with depression among older adults with dual sensory loss. Some of the variables found to be associated with depression were communication problems and loss of activity. No definitive conclusions can be drawn from just two studies but research in this area is still being developed.

The impact of overall health status in relation to sensory decline and cognition was not specifically investigated for this review but it is important to take into account the range of illnesses that are thought to affect the efficiency of the brain and thus both the capacity to learn and the processes of learning themselves. These include diabetes and chronic bronchitis. Some psychologists also believe that feelings of stress and anxiety as well as depression, identified above, may have an effect on general cognitive performance (Whitbourne, 2001), although stress is generally difficult to measure and assess.

4.4 Normal brain ageing

It has been seen that normal brain ageing does result in decline in some cognitive functions, but such age-related changes vary enormously among individuals and across different cognitive domains. Some cognitive functions such as aspects of attention, speed of information processing and memory have been shown to be more susceptible than others to the effects of ageing and this has implications both for how learning takes place and older people's capacity to learn. Glisky (2007) observes that much of this variability can be attributed to a range of factors including health and lifestyle as well as biological, psychological and environmental mechanisms. Active lifestyles are generally recognised as being beneficial to cognitive function, although advice as to what constitutes optimum activity levels tends to change frequently as research advances. Glisky also comments on how advances in neuroimaging have already revealed how adults who are ageing normally have frequently been observed to activate different brain structures from young people when performing cognitive tasks; the reasons for this are still subject to debate. This finding does, however, have implications for formally organised learning (and teaching) in mixed age groups.

4.5 Mild cognitive impairment/dementia

What is known as mild cognitive impairment (MCI) and manifestations of dementia are not part of normal brain ageing. In MCI, people are generally able to retain critical thinking and reasoning skills and to manage everyday activities but learning capacity is disrupted by short-term memory loss and sometimes difficulties with attention and planning greater than would be expected for the person's age and level of education. Long-term memory generally remains intact. Ray and Davidson (2014), in a review of evidence of dementia and cognitive decline, suggest that MCI affects between 5% and 20% of the population aged 65 and over, although there is no real agreed definition. Some cases are amenable to treatment but one in six cases can progress to dementia within a year.

At present, most people do not develop dementia as they age but it will continue to pose a problem in future years as discussed later. Over 100 types of dementia have been identified, with Alzheimer's disease (AD) the most common form of the disease, with prevalence of dementia in the UK population increasing with age; from 1.7% in the age group 65–69 up to 41.4% in people aged 95 or over. However, Ray and Davidson (2014) note that figures need to be treated with some caution on account of the lack of good definitions and diagnostic data. Nevertheless, dementia and AD is now recorded as being the leading cause of death for women

in England and Wales (12.2% of all female deaths registered in 2013) but not for males (Office for National Statistics, 2014). This is presumably a reflection of women's greater longevity.

It has been shown that during the course of AD, the structure of the brain undergoes significant changes, causing malfunction and eventual death of neurons. Initially, areas of the brain that are important for learning new information are affected but eventually all other areas of cognitive function are implicated, although different types of dementia cause different types of damage to the brain and at different rates for different people. Ray and Davidson (2014) observe that damage to the brain is actually likely to have begun several decades before symptoms appear, which makes the identification of both risk and protective factors through observation studies particularly difficult. This early damage has particular implications for an individual's learning processes and capacity to learn.

Other research has investigated the concept of cognitive reserve, which aims to provide an explanation for observable differences between people with advanced pathological brain changes who do not always show symptoms of dementia and appear to be able to maintain function including cognitive skills. For example, Stern (2012) refers to epidemiological studies which suggest that lifelong experiences including educational and occupational attainment and leisure activities in later life might increase this reserve, although the concept remains controversial.

It appears that most forms of late-onset dementia have mixed genetic and environmental causes and emerging evidence on a global scale has identified a range of risk factors other than age. These include low levels of education in early life, hypertension in midlife, and smoking and diabetes across the life course. Depression is also implicated. There is also some evidence of an inverse association between cognitive activity in later life and the incidence of dementia, although the Alzheimer's Disease Association suggests that the benefits of cognitively stimulating activities need to be tested in randomised controlled trials (Prince *et al*., 2014). In a qualitative study of older people involved in learning activities, Withnall (2010) noted that many of the participants in her research stressed the importance of 'keeping an active brain', maintaining self-esteem and social contact. She commented that they appeared to have internalised the popular message that 'exercising' the brain might help to guard against cognitive decline in later life, perhaps fuelled by the range of commercial 'brain training' opportunities being marketed, even though there is no conclusive evidence that these are effective.

Post diagnosis, Ray and Davidson (2014) point out that the progression of dementia and the impact it can have on an individual's capacity depends to some extent on their overall health. There are no rigorously proven interventions that can prevent or cure dementia, although drug treatments are commonly used to manage other associated conditions or challenging behaviour. They found poor evidence of any benefits to cognition specifically of medication, cognitive training or art, music or reminiscence therapies, although they point out that these therapies could be useful in that social stimulation in itself is beneficial for cognition. However, they note that several research studies have shown physical activity to be beneficial in terms of cognitive function with the parts of the brain most associated with memory being most notably affected in AD.

Once individuals with dementia progress to requiring residential care, their opportunities to take part in any activities that might enhance their individual cognitive abilities appear to become more limited due to environmental factors and physical function, and they may lack motivation (Tak *et al*., 2015). Withnall (2012) suggests a systems approach to facilitating appropriate

activities in such settings in order to acknowledge the complexity of stimulating cognitive enhancement in the unique and dynamic setting of each individual care home.

4.6 Comments on the evidence

In considering evidence about changes in learning processes and learning capacity, the review adopted an approach largely derived from cognitive psychology, although it appears that there is still some debate about the meaning of cognition. Developments in neuroscience are coming to play an important parallel role by investigating age-related changes in the brain, so closer interdisciplinary working would help to advance knowledge of these changes.

Life course and longitudinal studies, especially those using data from ELSA, have mainly informed the review, although the increasing number of intervention studies was acknowledged. Surprisingly, very little qualitative evidence was uncovered, although further results from the recent EU Lifelong Learning Programme (2008–13), which funded a significant number of international projects concerned with ageing and different aspects of learning, may redress the balance. Socio-economic conditions and their relation to cognition at different points of the life course were addressed in some of the research cited but there seemed to be less attention paid to issues of gender and in the UK research cited, no mention of ethnicity. However, much of the evidence stressed the importance of recognising the heterogeneity of individuals as they age and corresponding differences in cognitive ageing as well as variability within the individual; but there is still scope for further inquiry as successive cohorts move through the life course.

5. Looking ahead: What changes might be expected in the learning capacity of older adults?

The evidence examined in the review suggests that education and learning across the life course can be a powerful form of cognitive enhancement. Future developments in neuroscience may help us further understand the neurological basis of learning at all stages of the life course and particularly in later life, in order to help older people to enjoy personal fulfilment in their daily lives and to counteract the effects of cognitive decline (The Royal Society, 2011). However, it is important to acknowledge that older people are not all the same and that they age in different ways depending on a range of factors including their gender, ethnic and cultural backgrounds and their socio-economic circumstances, as well as their personal dispositions. Similarly, people vary in their learning ability. However, looking forward to the two junctures 2025 and 2040, it is possible to identify some factors that might be expected to drive changes to the learning capacity of older adults over time and to make some suggestions as to how public policy could enhance learning capacity throughout life. There are strong links to the cross-cutting issues of the whole life course, adopting an intergenerational focus and technology.

5.1 By 2025

5.1.1 Emerging technologies

Emerging digital technologies for learning might be expected to be a major factor in driving change. As people will now remain for longer in the workplace, they are more likely than previous generations to become accustomed to using computers and mobile technology although they would still need to continually update their skills. The move towards forms of more personalised learning through new learning, consumer and visualisation technologies and social media, are all expected to develop further over the next few years. This has led to the suggestion that learning in a 'connected' community, where learning to learn rather than acquiring skills and knowledge will take precedence, and where an individual's brain will become 'rewired' as a result, although this is still controversial (Kop and Hill, 2008; Johnson *et al*., 2014). Also predicted are further developments in assistive and wearable technology which can help people (of any age) with visual, hearing or physical impairments to get online and to ensure they are able to benefit from opportunities to participate in digital learning. However, not all older people will be able to afford the necessary technology or be comfortable in using it and lack of access to technology may increase as a major source of inequality. A particular challenge will be ensuring sufficient numbers of people with experience in digital literacy who can provide accessible training and support, bearing in mind how rapidly technologies evolve.

5.1.2 Community learning

Paradoxically, it is likely that the growing popularity of learning informally in the local community will also continue to grow, offering the opportunity not just for cognitive enhancement but also for socialising and remaining vitally involved at little or no cost. The University of the Third Age (U3A) has been remarkably successful in this respect, although Formosa (2014) suggests that as a worldwide movement it needs to move forward to become more socially inclusive and responsive to societal change. Other developments likely to expand include interventions for older men in danger of social isolation and physical and cognitive decline (Beach and Bamford,

2014). The most effective innovation so far appears to be the Men's Sheds movement, which originated in Australia. It offers men the chance to be co-participants in shared learning and productive activities in safe spaces (Golding *et al*., 2014; Milligan *et al*., 2014). A related strategy is intergenerational learning which, although still facing a range of challenges, can offer the chance to develop stronger and more resilient communities in which older people can strengthen their cognitive capacities through cooperative learning with other generations. Its potential has already been recognised in several strategy documents produced by the devolved administrations (Withnall, forthcoming).

5.1.3 Projected increase in numbers of people with dementia

Unfortunately, it is also predicted that there will be a steady rise from the current estimate of 850,000 people with dementia in the UK to 1,142,677 by 2025 and to 2,092,945 by 2051, even though it has been seen that it is possible to reduce the risk of cognitive decline through attention to certain lifestyle factors. A seven-fold increase is forecast in the numbers diagnosed from black, Asian and minority ethnic groups as their populations age, although they are less likely than other groups to receive a diagnosis. Apart from any other considerations, the cost to both the state and to people with dementia and their families is likely to be very high (Alzheimer's Society, 2014). Accordingly, Howard-Jones (2008) predicts the production of new and stronger drugs for cognitive enhancement which he believes, perhaps controversially, may eventually become more socially acceptable for use among the general population in order to boost individual learning power in otherwise healthy younger people.

5.2 By 2040

5.2.1 Life course changes and learning capacity

By 2034, it is expected that the percentage of the population who are over 60 years of age will already have increased from 23% at present to nearly 29%, and will continue to rise. The number of people aged over 85 will have more than doubled (Office for National Statistics, 2013). By 2040, numbers may be even higher. However, many older people will remain for longer in the labour force as the State Pension Age continues to rise and some may be employed or have worked in occupations that do not yet exist. It is also likely that each successive cohort will have had a higher level of education than is now the case, with more people having participated in further and higher education as well as increased levels of vocational training. Higher levels of education should have a protective function. As older people may be part of four- or even five-generational families, the potential for intergenerational learning within the family and the community may also expand with cognitive benefits for all involved. Yet as Harper (2009) observes, the foundation for the development of both cognitive and social skills across the life course is still likely to have been established in childhood.

5.2.2 Illness and learning capacity

It has been seen that unless preventative action is taken, the incidence of dementia is likely to continue to rise. However, less is known about the possible effects of other serious illnesses on cognition. For example, it has been predicted that by 2040, almost a quarter of people aged at least 65 will be cancer survivors (Maddams *et al*., 2012). Because stress is difficult to measure, there is no conclusive evidence as to how the experience of stressful illness and possibly aggressive chemotherapy treatments earlier in life might affect their cognitive abilities. However, researchers are beginning to explore the connections between cognitive function and different types of cancers (Wefel *et al*., 2011) and valuable insights should emerge in future. Similar

research into stroke and cognition should also yield informative results so that appropriate action can be taken.

6. How might public policy enhance learning capacity, as well as mental capacity, throughout life?

Overall evidence discussed in this review confirms that learning is possible at any age and that education and learning can assist people to become productive and resilient individuals in spite of changing cognitive abilities as they age. Accordingly, the following suggestions are made as to how public policy might enhance learning capacity, as well as mental capacity, throughout life.

6.1 A realistic and sustainable strategy for learning across the life course

6.1.1 Learning in childhood

It was seen that the foundations for cognitive (and emotional) development are laid in childhood and the evidence showed that cognitive ability in childhood is closely related to cognitive ability in midlife and old age. It also appears that cognitive ability earlier in life may help to develop 'cognitive reserve', which may be built up across the life course and provide some resilience to cognitive decline in later life. In other studies, disadvantaged socio-economic circumstances in childhood were generally predictive of lower cognitive function later in life. Yet evidence also showed that education in early life has the potential to improve cognitive ability and thus boost learning capacity, by providing learning experiences that focus particularly on motivation, boosting confidence and learning to learn through self-regulation at a time when brain functions are at their peak. The Royal Society (2011) suggests that findings from neuroscience might be incorporated into teacher training and continued professional development in order to accommodate different learning processes and inform different teaching approaches for young learners of varied abilities. The possibilities offered by new technology and the move towards more personalised learning could also help to foster a positive attitude towards learning throughout life and an emphasis on learning to learn at an early age.

6.1.2 Learning in midlife

Although there was less evidence about learning processes and capacity in midlife, one study showed how adult education, which was not actually defined but might include learning and training in the workplace, could have an impact on cognitive ability in midlife, and specifically on verbal abilities. This will be especially important in the future when flexibility will be required as the nature of the labour market changes and workers need to train or retrain for jobs that may not yet exist. These issues were discussed more fully in a previous Foresight project but still remain relevant (Government Office for Science, 2008).

Evidence that damage to the brain that eventually results in some form of dementia may begin several decades before symptoms appear suggests that this is the time when people should be particularly encouraged to adopt healthier lifestyles. Public health messages regarding healthy brain ageing and the factors that encourage it might be expanded to keep the public informed and to help them learn about evidence-based ways in which cognitive function and mental capacity can best be maintained across the life course and improved as people grow older, especially if they have survived a life-threatening illness.

6.1.3 Learning in later life

Evidence showed that, in later life, some cognitive capabilities begin to decline even in normal ageing, notably speed of information processing and some aspects of memory. However, high levels of psychological well-being were associated with better cognitive function and some types of cognitive training could help to maintain cognitive function, although questions remain about how far this can be transferred into functions of daily life. High levels of literacy and numeracy impairment among older people, shown in one study, suggest that it may be beneficial for older people to have opportunities to improve their basic skills with appropriate instruction, in the same way as younger people can benefit from opportunities to participate in functional skills training.

It was also shown that in later life, social relationships become important in maintaining cognitive function and capacity. Older people have demonstrated that they are capable of organising their own learning including investigating memory issues, and social activities. This could be encouraged on a wider scale, especially through the use of technology. In addition, sensory problems in later life may cause withdrawal and isolation, possibly leading to depression, and this may affect mental capacity. Interventions that target isolated older people and encourage networking could be expanded through designated funding to older people's organisations.

6.2 Dementia

Although it has been shown that most people do not develop dementia, numbers of sufferers are still predicted to increase as the older population grows. Through initiatives such as the National Dementia Strategy (Department of Health, 2009) and the Prime Minister's Challenge on Dementia (Cabinet Office, 2015), some progress is being made, but there is still a need for information across all generations to keep people informed about the factors that cause brain degeneration, to allay fears and to remove the stigma attached to this disease.

Finally, emerging research evidence from neuroscience should be assessed and incorporated into the above policy areas. Mechanisms might be developed to help developmental psychologists, educationists and neuroscientists to work more closely together to ensure that interdisciplinary research on which any interventions are based is of the highest quality.

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