Quarterly Journal Fides et Ratio
Issue 4(52)2022, ISSN 2082-7067, Pages 104-113

Can our life resources support successful aging?

Czy nasze zasoby życiowe wspierają pomyślne starzenie się?

https://doi.org/10.34766/fetr.v4i52.1141

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Abstract: The projections showing trends towards increased ageing of the populations and the resulting challenges to the welfare system, health care or economy have led to a great number of publications exploring possible ways to prevent cognitive decline in late life. Successful ageing, in accordance with the definition of the term, is reflected by cognitive, motor and social capacities maintained at a level incommensurate with normal aging. Attempts to explain this aging pattern refer to the so-called cognitive reserve. The concept relates to the resources acquired from early childhood through education or activity in various domains of life. These resources help maintain and compensate for age-related cognitive deficits. The article discusses the role of various components in the process of building the reserve, the relationship between the reserve and neurobiological factors, and some disputable issues.
Keywords: brain reserve, cognitive reserve, successful ageing

Abstrakt: Prognozy wskazujące na wzrost tendencji do starzenia się populacji i powiązane z tym wyzwanie dla systemu opieki społecznej, ochrony zdrowia czy ekonomii stały się powodem wzrostu publikacji dotyczących profilaktyki zaburzeń poznawczych w późnym etapie życia. Starzenie się pomyślne jest rozumiane jako niewspółmiernie do wieku zachowana sprawność poznawcza, ruchowa oraz aktywność społeczna. Wyjaśnienie takiego wzorca starzenia się nawiązuje do tzw. rezerwy poznawczej. Są to zasoby, które zdobywamy od wczesnego dzieciństwa, poprzez edukację czy aktywność w różnych obszarach życia. Zasoby te pozwalają utrzymywać i kompensować powiązane z wiekiem deficyty poznawcze. Artykuł omawia rolę różnych składowych w budowaniu rezerwy, związek rezerwy z czynnikami neurobiologicznymi oraz kwestie dyskusyjne.
Słowa kluczowe: rezerwa mózgowa, rezerwa poznawcza, starzenie się pomyślne

Introduction

The phenomenon of population ageing involves an increase in the number of senior citizens in the society, including those aged 80+ (double ageing) (Jarzebski et al., 2021). This trend is associated, on the one hand, with advances in medicine (enabling diagnosis and treatment of diseases ultimately leading to death or disability in people entering late adulthood, e.g. hypertension) and greater awareness of healthy lifestyles, and on the other hand, with declining fertility rates and decreasing young adult populations. Because of such factors typical of late adulthood as the co-occurrence of cardiovascular, psychiatric and neurological disorders, the experience of loss (of loved ones, financial resources, and independence), and lack of social support, in addition to the significant economic burden posed on health systems, longer life span does not correspond to better quality of life. Projections showing a trend towards increased demographic aging as well as the anticipated challenges faced by the welfare, healthcare and economic systems, provide rationale for more extensive research focusing on the ways to prevent cognitive impairments in late life (Pestana, Sobral, 2019).

Ageing as a process can take different forms, ranging from physiological (typical, normal) changes, characterised by a decline in physical and cognitive performance, to pathological deficits, leading to cognitive disorders or dementia, and a degree of dependency that requires the assistance of others (Rowe, Kahn, 2015). Changes in cognitive capacities are a natural component of normal ageing, but they are non-linear in nature. Disturbances affect various cognitive processes

at different rates. Crystallised intelligence remains unchanged, in fact its resources may increase, whereas deterioration affects fluid intelligence, including speed of information processing, ability to learn new information, and to solve problems as well as the executive functions, defined as the ability to plan, organise, and control or as cognitive flexibility (Harada, Natelson Love, Triebel, 2013). These phenomena result from changes in brain structures and functions occurring in a non-uniform manner, and including loss of grey and white matter, and decrease in the number of synapses, as well as neuronal atrophy. With age, there is a slow decline in the volume of such structures as the amygdala and thalamus, with hippocampal volume and total brain volume decreasing after 50 and 60 years of age, respectively (Fjell et al., 2013). Age-related changes also affect the cerebral vascular system (e.g., they lead to remodelling of large arteries–increased wall thickness and lumen, arterial stiffening) (Zimmerman, Rypma, Gratton, Fabiani, 2021). These characteristics affect various regions and structures at different rates, altering the integration of neural networks (Bennett, Madden, 2014) locally and globally, which is the reason for the non-linearity of changes in cognitive performance in normal ageing (Li et al., 2020).

The continuum of ageing patterns also comprises successful ageing reflected by cognitive, motor and social capacities maintained at a level incommensurate with normal aging (Rowe, Kahn, 2015). Irrespective of the disputed definitions and indicators of successful ageing, most researchers suggest that its characteristics, assessed objectively and subjectively, include reasonably good health, age-appropriate activity and cognitive performance, productivity and a good quality of life (Urtamo, Jyväkorpi, Strandberg, 2019). Which factors, and in what way might promote this pattern of ageing?

1. Historical background

Research in causes of successful aging has been conducted for many years. Earlier studies focused on the ability of senior citizens to take active approach to life despite illnesses, disability or the experienced traumatic events, whereas more current works discuss issues related to well-being and preventive measures (Lavretsky, 2014). The phenomenon of preserved or slightly disturbed cognitive capacities and the ability to function independently despite brain pathology, common in Alzheimer's disease, described as early as the 1960s, occupies an important place in these considerations (Blessed, Tomlinson, Roth, 1968). The related evidence was acquired for instance owing to fascinating research conducted from 1992 in the frames of the Nun Study project (Danner, Snowdon, Friesen, 2001; Mortimer, Snowdon, Markesbery, 2003; Snowdon, 1997). It initially involved 678 School Sisters, aged 75-102 years, from the Notre Dame congregation in the USA. The findings showed no correspondence between the subjects' good activity level, the presence of brain pathology and satisfactory cognitive performance. All the sisters were born before 1917, some were assessed for cognitive performance on two occasions, and assessment of brain lesions was done post-mortem. An important component of the research was an interview about the early life environment, parental education, socio-economic status and activities undertaken by the sisters in their earlier years. Extensive research was also conducted by Bennett, Schneider, Arvanitakis and Wilson (2012). The project carried out between 1994 and 2011 involved a total of 1,168 subjects, on average aged 75.7 years, who were members of various religious communities. The models and concepts proposed today (such as cognitive reserve, cognitive resilience, compensation and maintenance), despite the different emphasis on specific aspects and the understanding of the mechanisms of successful ageing, consistently show that this pattern can be explained by the existence of resources (reserve), which are in focus of current research (Stern et al., 2019).

2. Cognitive reserve and its positive effects

Our cognitive reserve (CR) is produced jointly by knowledge, skills and life experiences. It is the result of our education, as well as occupational, social and intellectual activities, leisure activities, hobbies, etc. The reserve is therefore a resource that we acquire

through our activity in different areas of life. It is a modifiable factor, and this means that through our own activities we can increase the reserve and, consequently, its positive impact on cognitive functioning at a later stage of life. Other components adding to the reserve include multilingualism, travel, the quantity and quality of social interactions and many other regular engagements (Farina et al., 2018). Findings of numerous studies seem to reflect a general principle–higher level of CR, associated with more active involvement in various domains in course of one's life, promotes positive ageing, and plays a compensatory function with respect to cognitive competences that decline with age. The underlying element in the process of building the reserve is the interaction of genetic (Perneczky et al., 2019), cultural, economic (Cermakova, Formanek, Kagstrom, Winkler, 2018), historical and geopolitical factors, determining the capacity for acquiring competences and experiences even during the early years of development (Stern, 2002; Yang, Wang, 2020). In contrast, factors affecting one's performance later in life, but existing in adolescence and early adulthood include external determinants (e.g. health care system, socio-economic conditions), lifestyle, health status and personal activity (Yang, Wang, 2020).

The mechanism of the relationship between CR and cognitive functioning in late life has been extensively investigated, and two major trends can be identified in the related research; more specifically, some studies focus on the impact of lifetime experiences on the currently assessed cognitive capacities or particular domains of cognitive performance, whereas other researchers focus on longitudinal studies assessing the dynamics of cognitive capacities over the years of life, in an attempt to determine whether CR can delay or minimise the risk of cognitive disorders, including dementia.

The studies following the former approach, in most general terms, show that higher level of CR favourably affects both general cognitive functioning (Clare et al., 2017) and its specific domains (Perneczky et al., 2019). This positive effect was found e.g., in memory (Lavrencic et al., 2018), semantic and phonological fluency, subscales of Mini Mental State Examination (MMSE) and Clock Drawing Test (Grasso et al., 2021) and in executive functions (Oosterman, Jansen, Scherder, Kessels, 2021). This is significant since the latter capacities affect performance in other cognitive domains and in daily life (e.g., independence). The protective effect of CR on cognitive performance may be linked to the so-called brain reserve (BR, neurobiological resources). It comprises both structural and functional properties of the brain which can be modified by activity, education, etc. Better brain parameters not only explain good cognitive performance at later stages of life but are also associated with a lower risk of age-related cognitive decline (Stern et al., 2020). CR components affect BR efficiency by improving blood perfusion in brain vessels, reducing oxidative stress and inflammatory processes, stimulating growth factors, especially brain-derived neurotrophic factor (BDNF), and by preventing beta-amyloid deposition (Cheng, 2016). Higher CR contributes to the integration of neural networks despite the fact that this integration decreases with age (Marques et al., 2015). This characteristic, as some studies have shown, is particularly related to the cortex of the left frontal lobe, an area important for executive functions involved in other cognitive processes (Franzmeier et al., 2018). This pattern may be gender-related.

On the other hand, longitudinal studies reported various findings. Williams, Pendleton and Chandola (2021) found no evidence showing that CR, understood as the level of education, protects against the development of deficits in certain cognitive domains. In fact, a study by van Loenhoud et al. (2019) has shown that once the threshold of cerebral pathology is crossed, higher levels of CR cease to play a compensatory or masking role and promote rapid progression of cognitive deficits.

3. Role of various factors contributing to CR versus cognitive functioning in late adulthood

Although CR is an effect of interaction between various factors, attempts have been made to identify the distinctive role of each of these.

3.1. Early childhood

Risks related to the development of CR over the years are primarily linked to adverse impact of biological factors (low birth weight, malnutrition, neurodevelopmental deficits) and environmental factors (various forms of deprivation, national social policies) (Mosing et al., 2018). Meta-analyses have shown that in developing countries and those with low GDP, there is less opportunity for building the reserve (illiteracy, poverty) (Prince et al., 2012). In the absence of such risks, better socioeconomic status of the family fosters higher psychophysical competences later in life, but it does not affect the trajectory of cognitive ageing (Aartsen et al., 2019). A study (Aartsen et al., 2019) showed a positive correlation between socioeconomic status and the efficiency of selected cognitive functions in late adulthood, however higher socioeconomic status was also shown to be related to deficits in certain cognitive domains (e.g., verbal fluency deficits) emerging in late life.

3.2. Parental education

Education is not only about the formal level achieved, but also about the commitment to the learning process. Parents with a higher level of education create a nurturing environment for the child by providing financial, and psychological support, and by promoting spiritual values and a healthy lifestyle (Yang, Wang, 2020). However, as shown by interviews with sisters participating in the Nun Study (Snowdon, 1997), most of them came from large families, with poor economic status, working physically, and many had lost parents and siblings at an early age, but still received various forms of support and role models (Danner et al., 2001) that determined the need for education. Owing to education, they were able to acquire higher occupational competences and most of them took up teaching jobs. Parental education level does not necessarily explain the trajectory of their children's ageing; indeed, there are other factors that either interfere with the child's normal development by adversely affecting their education in the early years (low IQ) or make impact during later stages of life (e.g. acquired CNS diseases, deterioration of socioeconomic status, political changes e.g. wars, etc.).

3.3. Acquired education

Conroy et al., (2010), Prince et al., (2012), Bruno et al., (2014) and Wilson et al., (2019) showed that a higher level of education, as a component of CR, promotes better cognitive capacities later in life. Higher educational attainment corresponds to greater tendency to continue intellectual activity after the period of formal education, and to be involved in various forms of activity (social or physical) in leisure time; it is also associated with a greater awareness of healthy lifestyles. Importantly, even 6 years of education, despite such conditions as extreme poverty, can be conducive to better functioning in middle and late adulthood (Then, Riedel-Heller, Luck, Chatterji, 2017). Finally, evidence reported by Thow et al., (2018), Wilson et al., (2019) and Williams et al., (2021) shows that early education may promote cognitive functions up until adulthood, but not during advanced age. Meta-analyses also suggest that early education does not predict the course of cognitive ageing (Lövdén et al., 2020). A study involving 10,000 subjects from ten European countries, aged 65+, conducted by Cadar et al., (2017), showed a positive relationship between education level and memory efficiency, but this factor did not protect against a decline of this competence at older age. It was also observed that the strength of the positive relationship between higher educational attainment and cognitive capacities was varied, relative to ethnicity. This relationship is clear in the group of white subjects; according to the researchers, this may be linked to the fact that subjects of a different ethnic origin, often immigrants, were given the opportunity to learn or return to education much later than white children, hence their early experiences (poor quality education, racial segregation, poor economic and health status of their families) and forms of activity taken later (manual work) possibly were not conducive to building CR (Avila et al., 2020).

3.4. Social activity and social relationships

The factor contributes to the development of CR and, consequently, to good cognitive performance in late life, in a multidimensional way. Social activity, understood as involvement in voluntary work, interest groups, and work for loved ones, or religious groups, etc., fosters intellectual and physical activity, improves self-esteem, reduces feelings of loneliness or depression, and strengthens social competences in later stages of life (James, Wilson, Barnes, Bennett, 2011; Kelly et al., 2017; Lee, Kim, 2016). A study involving a large cohort (N = 2788) of subjects aged 65–101 years showed that a large network of family relationships during childhood, adolescence and early adulthood promoted better cognitive well-being later in life (Sauter, Widmer, Ihle, Kliegel, 2019). A study by Conroy et al., (2010), involving subjects aged 65+ years, showed that low levels of social support as a result of divorce in earlier years and living alone, lack of social engagement or hobbies adversely affected the subjects' cognitive performance. A review of research (Håkansson et al., 2009) confirms that single or divorced people are twice as likely to develop cognitive deficits due to a lack of daily stimulation, as well as depression or addictions and nearly 8 times more likely to develop Alzheimer's disease. It is obvious that social engagement requires diverse competences, and therefore a failure to get socially involved may be due to poor health, cognitive problems or lifestyles typical for the given community; inactivity negatively reinforces existing difficulties (Aartsen et al., 2002).

3.5. Physical activity

Meta-analyses show that physical activity undertaken from an early age stimulates cognitive performance at each stage of development (Greene, Lee, Thuret, 2019). People reporting higher levels of physical activity during earlier years of life face a lower risk of dementia or cognitive impairment which may progress into dementia (Blondell, Hammersley-Mather, Veerman, 2014). Different evidence has also been reported. Sabia et al. (2017) found no relationship between cognitive performance at older age and physical activity during middle adulthood and they suggest there may be a reverse relationship (cognitive decline may adversely affect the ability to engage in this type of activity). At present, research focuses on the relationship between specific types of physical activity (exercise/sport, frequency and intensity) and effects observed in cognitive performance (Greene et al., 2019).

3.6. Leisure time and hobbies

Leisure activities, their type and intensity, are part of our lifestyle, just as some other forms of activity, constituting an essential part of our lives. They also change with age. They comprise various components described above–intellectual, social or physical engagements and their interactions, also subject to change with age. A study by Lee et al. (2020) found a positive relationship between only this aspect of CR and performance in many cognitive domains; no such link was identified in the case of education and occupational activity. According to these and other authors (Sauter et al., 2019), a high frequency of various leisure time activities during the week or year (reading books, cinema, theatre, sports, dance and learning as well as using advanced technologies) promotes language, memory, executive and visuospatial functions through cognitive stimulation. Lower activity during leisure time over the course of subjects' life led to a three-fold increase in the risk of cognitive deficits in the cohort (mean age M = 75.6). Importantly, the type, intensity of leisure time engagements and their impact on cognitive performance, particularly executive functions, are linked to ethnicity (Peterson et al., 2020).

3.7. Spirituality and intangible values

Although religiosity of older people has been extensively investigated, few studies have focused on the role of religion in maintaining cognitive capacities in later stages of life. A study of a large cohort (N = 2,938) of subjects reporting varied religious engagement showed that greater attendance was associated with lower cognitive decline in a period of three years (a longitudinal study). The authors point out that through religious attendance (meet-

ings, services, clubs), the subjects also benefit from cognitive stimulation and social support, which are important for CR (Corsentino, Collins, Sachs-Ericsson, Blazer, 2009). This type of engagement evokes hope, encourages a healthy lifestyle and alleviates symptoms of depression, one of the causes of cognitive deficits. However, a study involving adults aged 65+ years, showed that subjects reporting significant religious engagement, understood as highly frequent attendance in services, exhibited poorer working memory and lower general cognitive performance than the subjects attending religious functions less frequently (Hill, Carr, Burdette, Dowd-Arrow, 2020). According to the authors, this result should be linked to the operationalisation of the variable 'religious engagement', as attendance at church celebrations cannot be a determinant of religious involvement.

3.8. Occupation

It is not only the fact of being economically active but also the type of challenges and responsibilities at work that can contribute to CR and, consequently promote cognitive capacities in late life. Researchers tends to use country-specific classifications of occupations, or, in general terms, it is assumed that more demanding jobs involve managerial, technical and professional responsibilities, whereas physical work, sorting, machine operation, etc. are seen as less demanding. A study by Smart, Gow and Deary (2014) found that personal history of more demanding and complex jobs was conducive to cognitive efficiency at 70 years of age, whereas less demanding jobs (e.g. manual labour) may be associated with a greater risk of cognitive deficits later in life, which is mainly linked to lower educational attainment (Perneczky et al., 2019). A similar tendency was observed in the case of unemployed individuals and homemakers (Chung, Kim, 2020). However, another study showed that the protective effect of education and occupation (elements of CR) on cognitive performance is observed only in healthy individuals or those exhibiting mild cognitive impairments with a risk of dementia (β-amyloid [Aβ] positivity); paradoxically, following the onset of clinical characteristics of dementia, CR defined this way promotes more rapid progress of the condition (van Loenhoud et al., 2019). Retirement from work may by a risk factor for cognitive deficits. Although such change in economic activity is naturally associated with age or health status, when controlling for these factors, verbal memory, for example, has been shown to decline as much as 38% faster compared to the period before retirement, while decline in other cognitive domains is associated with age rather than occupational status (Xue et al., 2018). Research also showed a different relationship between type of occupation and gender; a study involving 5,865 Korean people aged 45–64 years showed an over three times higher risk of cognitive deficits in female homemakers compared to individuals performing highly demanding jobs (Chung, Kim, 2020). Looking for possible explanation, the authors of the study point to cultural and economic determinants; giving up work by women to take care of their families is one possible explanation.

3.9. Gender

Gender determines the acquisition of resources and consequently cognitive functioning in late life in many different ways (Subramaniapillai, Almey, Rajah, Einstein, 2021). Women and men differ with regard to the risk factors for developing conditions that negatively affect cognitive function. Female gender is associated with a greater risk of depression and AD due to hormonal changes during puberty, childbearing and menopause. Risk factors for diseases in men may be related to unhealthy lifestyles. Early education enables women to build their reserve, but the typically more demanding jobs performed later in life by men present more advantages for further enhancement of CR. Poorer education and physical work for women but not men are among risk factors for dementia, but if such work is done under healthy conditions, its positive effects will manifest themselves in women to a greater extent than in men (Subramaniapillai et al., 2021). It has also been reported that social engagement and social relationships may be of greater value for women than for men in building CR (Hwang, Park, Kim, 2018), whereas physical activity appears to be of greater importance for men than for women. However,

women's greater social involvement can result in burnout and exposure to stress, and these promote cognitive disorders developing in late life.

3.10. Stress and traumatic events

Seil, Yu and Alper (2019) investigated a possible association between the experience of trauma or PTSD and later cognitive performance in a study taking into account 14,576 subjects, aged 35-64 years, enrolled in the World Trade Center Health Registry in connection to September 11 terrorist attacks in New York City. Cognitive reserve was measured using dichotomised indicators of educational attainment, social integration, numbers of close friends, people the respondent had communicated with in the last 30 days and people knowing their problems, as well as marital status, employment status and physical activity. The study showed that higher CR was associated with lower likelihood of cognitive deficits being reported by subjects with PTSD. According to the authors, cognitive reserve acts as a buffer by modifying or delaying cognitive deficits. Another study emphasises the role of trauma experienced earlier in life as a risk factor for early cognitive decline and dementia at later stages of life (Burri, Maercker, Krammer, Simmen-Janevska, 2013). The authors point out that there is ample evidence showing that stress experienced early in life induces structural and functional changes in those areas of the brain that are closely involved in cognitive processes and cognitive development i.e. the frontal and temporal regions, including the hippocampus.

Conclusions

Cognitive reserve is a hypothetical construct devised in an attempt to explain the causes of the differences in the trajectory of cognitive ageing. It is difficult to account for biological, environmental, and self-activity related factors contributing to CR, and to identify their role in cognitive capacities in late life because these factors are interrelated, and change significantly over the life cycle. Undoubtedly, development of CR begins at an early age and, in the absence of adverse events, the accumulation of experiences contributing to cognitive performance at later stages can continue throughout one's life. Greater CR promotes cognitive efficiency in late life, but does not eradicate the negative impact of genetic factors (e.g., risk factors for Alzheimer's disease). It is with attention and hope that researchers look at the modifiable aspects of CR, i.e. those factors which at least partly are under our control (e.g., taking various activities in middle and late adulthood, cognitive training).

On the other hand, the construct of CR and the ways in which it is operationalized raise many doubts (Nilsson, Lövdén, 2018). In research, measurement of CR commonly is based on isolated indicators (e.g. level of education) or on combinations of various data acquired by means of interview or self-report questionnaires. The latter include: Cognitive Reserve Index questionnaire (CRIq) (Nucci, Mapelli, Mondini, 2012), Cognitive Reserve Questionnaire (CRQ) (Rami et al., 2011), Cognitive Reserve Scale (CRS) (Leon, Garcia, Roldan-Tapia, 2011), Lifetime Experience Questionnaire (LEQ) (Valenzuela, Sachdev, 2007) and Retrospective Indigenous Childhood Enrichment scale (RICE) specifically designed for the needs of Australian Aboriginal communities) (Minogue et al., 2018). A lot of questions are raised by the fact that different methods are applied to measure CR (different indicators, different populations), and the CR indicator is largely based on self-reported data (Kartschmit, Mikolajczyk, Schubert, Lacruz, 2019). Furthermore, CR has rarely been investigated in the context of culture-related factors or through longitudinal studies. There is also a difficulty in understanding causal relationships; for example, does a better level of education contribute to greater CR, consequently favourably affecting cognitive performance at old age, or does a higher level of CR acquired in childhood enable better educational attainment, which at later stages promotes cognitive capacities? Additionally, the different CR and BR indicators (volumetric or CNS functional data) explain only a part of the variation in cognitive performance observed in senior citizens. The question about factors enabling successful aging is still relevant.

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