

## The aging mind: A complex challenge for research and practice

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### ARTICLE INFO

#### Article history:

Received 5 June 2022

Revised 10 December 2022

Accepted 10 December 2022

#### Keywords:

Cognitive aging

Mental aging

Functional cognition

Coping

Resilience

Life quality

ADL

Aging research

### ABSTRACT

Cognitive decline as part of mental ageing is typically assessed with standardized tests; below-average performance in such tests is used as an indicator for pathological cognitive aging. In addition, morphological and functional changes in the brain are used as parameters for age-related pathological decline in cognitive abilities. However, there is no simple link between the trajectories of changes in cognition and morphological or functional changes in the brain. Furthermore, below-average test performance does not necessarily mean a significant impairment in everyday activities. It therefore appears crucial to record individual everyday tasks and their cognitive (and other) requirements in functional terms. This would also allow reliable assessment of the ecological validity of existing and insufficient cognitive skills. Understanding and dealing with the phenomena and consequences of mental aging does of course not only depend on cognition. Motivation and emotions as well personal meaning of life and life satisfaction play an equally important role. This means, however, that cognition represents only one, albeit important, aspect of mental aging. Furthermore, creating and development of proper assessment tools for functional cognition is important. In this contribution we would like to discuss some aspects that we consider relevant for a holistic view of the aging mind and promote a strengthening of a multidisciplinary approach with close cooperation between all basic and applied sciences involved in aging research, a quick translation of the research results into practice, and a close cooperation between all disciplines and professions who advise and support older people.

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**Introduction**

Aging and cognitive decline appear often as inevitably linked in human aging research. According to the “mainstream” scientific perspective, cognitive decline is becoming an increasingly and almost mandatory characteristic for people over the age of 65 years [33]. It has been known since the seminal Seattle longitudinal study [118] that cognitive performance changes over the course of adult life. But the “decline” in cognitive performance is not fundamentally synonymous with actual cognitive impairment or disability but mostly reflects the normal development of cognition during adulthood. Possibly the rather pessimistic view on age-related cognitive decline is mainly based on laboratory results on cognitive performance but not on observations on the cognitive competence and cognitive behavior in everyday life conditions of the same individuals [113]. If there is cognitive decline, when in life has an individual reached the peak of cognition, from where the decline starts, and at what level of cognitive decline can one speak of a significant loss? There is no

doubt that cognitive performance does not persist regardless of age, but rather shows an age-related decrease, which is also experienced and reported by older people [149] (Table 1).

An age-related decrease in functionality can also be found in other domains, such as emotion, motivation, language or motor skills. However, these domains are often neglected and not routinely assessed in research or clinical practice. This is all the more astonishing because cognition critically depends on motivation and emotional evaluation also in older age [88,34]. However, the scientific literature of the past decade gives the impression that research on aging is somehow biased and has mainly focused on cognition and the underlying neurobiological factors. It seems like cognition is a major player among mental functions. In a certain way this may be true if cognition is understood as the ability to analytically reflect on one’s own thinking, feeling and behavior and its social and moral evaluation, and to search for and find meaning in life as the highest mental level. On the other hand, cognition can also be understood as a universal set of tools for developing, exe-

**Table 1**  
 Proposal for a possible comprehensive standard on mental aging studies with focus on non-biological (A) and involved disciplines (B).

**A Focus on functional mental aging**

- Perception:** Vision, audition, somatosensory perception, olfactory and gustatory perception
- Cognition:** Attention (alertness, cognitive speed, sustained attention; focused and divided attention; spatial attention)
- Memory (episodic, semantic and procedural memory; short-term, working and long-term memory; prospective memory)
- Executive functions (planning, problem solving, cognitive flexibility, adaptation of routines to changing task requirements)
- Language/Speech:** Language comprehension and expression; reading (incl. reading habits) and writing
- Motivation:** Engagement in daily and social activities
- Emotion:** Emotion recognition (social perception); expression of emotions
- Mood:** Symptoms of depression and anxiety
- Subjective cognitive complaints**
- Instrumental activities of daily living:** ideally performance-based measures plus an informant rating
- Social networks**
- Sleep**
- Life quality**
- Physical activity**
- Aging perceptions**
- Biological variables:** Health status (e.g., blood pressure, blood glucose status, hormonal status, alcohol consumption, smoking, drug abuse), current medications, BMI, medical history, neuroimaging, genetics (APOE status)
- Demographic variables:** Age, sex/gender, family status, level of education, regular earlier occupation, current occupation, living arrangement, ethnicity.

**B Disciplines involved in the study of mental aging**

- Psychiatry**
- Neurology**
- (Neuro-) Psychology**
- Occupational therapy**
- Neuroimaging**
- Neuroendocrinology**
- Internal Medicine**
- Genetics**

cuting and supervising mental and behavioral routines and habits that enable people to deal well with the personal challenges of life. Above all, this ability includes adaptive strategies to changing physical and social environments, but also to cope flexibly with unsolvable problems and challenges. Maintaining good health and independence while avoiding or coping appropriately with disability, functional and cognitive decline are key challenges of aging. The meaning of one's own life and its realization may play a special role in older age, as meaningful factors in earlier life, e.g. occupation, care for one's own children and their development, or special social roles, do typically no longer exist. The individual definition of meaningfulness depends on one's own ideas, wishes and positive and negative life experiences and their evaluation [102]. Of course, good or at least sufficiently good physical and mental health, wellbeing, positive social contacts with family and friends, other social roles (e.g., grandparenthood, caregiver, volunteer), mobility, and the availability of sufficient financial resources are essential for assessing and experiencing one's own life in older age as meaningful [54,62,134]. In addition, values attributed to positive aging depend significantly also on cultural factors [75]. Aging research has also paid attention to aging perceptions which refer to the stereotypes and attitudes an individual holds towards aging, as well as their personal experiences associated with aging. Not surprisingly, negative aging perceptions are associated with decline in cognitive and functional performance [89,148].

As already mentioned, cognition undoubtedly plays a decisive role when it comes to the development or planning, implementation and supervision as well as the proof of functional adaptation strategies [44,136]. This applies to dealing with professional, economic, social and health challenges. A necessary mastery of the listed challenges includes not only the current handling of problems, but also preventive activities and measures. Of course, prevention should not and cannot only begin when mental, physical, economic or social difficulties are already visible or have arisen. The ability to plan and to solve foreseeable problems or to develop alternatives are necessary prerequisites for successful coping with difficulties in life in general [56].

Given a lack of reviews that include a holistic view of the aging mind, this selective narrative review aims to give an overview of different aspects of the aging mind that extend beyond cognitive decline. After a brief outline of morphological and functional changes of the aging brain, we will give an overview of brain and cognitive reserve, individual and general characteristics of cognitive aging, the interplay between mental health, cognition and influencing factors as well as resilience, meaning of life, and life quality in older people. We will describe the assessment and rehabilitation of older people with impaired cognition, outline the relationship between cognitive performance, as assessed in standardized tests, and functional cognition, defined as cognitive performance required to cope with individual activities of daily living, and finally, give recommendations for bridging interdisciplinary gaps in future research.

## Morphological and functional changes of the aging brain

Research on the development of cognitive skills with age has consistently shown that cognitive performance decreases with age. The performance in the domains of perception, attention, memory and executive functions, in particular selective attention, planning, problem solving and multi-tasking, decreases with increasing age, largely independently of unfavorable influencing factors. In other domains, e.g. general knowledge and vocabulary and life experience (wisdom), is older adults' performance as good as, or even superior to, that of young people [38].

The age-related decline in cognitive performance is mainly explained by morphological and functional changes in the brain. Not only does the number of cortical neurons and thus the thickness of the gray matter decrease [146], but also of intra- and intercortical connections, so that brain networks thin out [31]. As a consequence, exchange of information between and cooperation of local, regional and supra-regional brain structures is impaired or lost [95]. Frontal, temporal (including the hippocampus), and parietal structures show age-related loss of gray matter, while the primary sensory cortices are relatively or completely preserved in aging [37,51,105]. This morphological brain aging pattern is called the 'first-in, last-out' hypothesis, which means that the brain regions that develop earlier are also less affected by age-related decline than those that develop later [74]. A similar picture emerges for age-related white matter changes, which are particularly pronounced in the prefrontal regions, as observed in a longitudinal study [111]. However, the trajectories of the gray matter and white matter alterations may differ; the loss of gray matter generally begins in early adulthood whereas the white matter volume decreases after middle age [35,106]. The most consistent finding in aging is a general decline (or disconnection) in the connectivity within individual networks [30]. In his comprehensive overview, Kawagoe [74] has pointed out that there is still "no consensus about a comprehensive theory of the aging brain. Obtaining such a consensus remains a challenge because even the relationship between structural connectivity and functional connectivity is not clearly established, although the structural connectivity can be expected to be a basis for functional connectivity" (p. 14). In light of this conclusion, the claim of some authors is even more surprising, that one could derive the diagnosis of cognitive decline, mild cognitive impairment and (early) dementia with sufficient certainty from brain imaging alone [39,128]. Such a far-reaching (diagnostic) conclusion would presuppose that there is a close connection between the trajectories of changes in cognition and of the morphological and functional changes in the brain.

The assumption that morphological brain changes in older people are basically always associated with a decline in cognition was seriously questioned already by the outcome of the pioneering study by Ince & colleagues in 2001 [69]. They showed that striking age-related morphological changes in the brain were not compulsorily associated with a loss of cognitive abilities. Later studies have

confirmed this result and have shown that various compensation mechanisms can be responsible for this discrepancy (e.g., [96]). The assumption of takeover of impaired functions by other structures or by co-activation of additional structures within a functional network are among the preferred explanations [12].

In summary, age-related morphological and functional changes in the brain are often, but not always, associated with a decline in cognitive performance.

### Brain reserve and cognitive reserve

In this context, the concepts of brain reserve and cognitive reserve play an important role in understanding and explaining the discrepancy between morphological and cognitive measures. Brain reserve refers more to the “passive” capacity of the aging brain to cope with morphological alterations and consequent functional losses, while cognitive reserve means that the brain actively tries to compensate for functional losses with the help of already established, successful cognitive processes and individual strategies [135]. The question remains which factors contribute to acquiring, increasing and conserving this cognitive reserve, or reducing or impairing it. Individual genetic factors or predispositions [64,84], health, mood, lifestyle, and social factors play a significant role [16,62,117]. Activities and measures exist to maintain or regain mental health or at least to prevent the pathological consequences of unfavorable developments. In addition, there are ways to keep oneself mentally fit, including an engaged lifestyle [137], and regular physical [11,140] and social activities [86]. The increased prevalence of multimorbidity in older age can lead to more rapid functional decline in individuals with less cognitive reserve and even relatively minor illness or injury may result in significant functional impairment. Maintaining physical fitness and building cognitive (and thus functional) reserve to optimise functional ability is a life-long journey that should be promoted and implemented early in life. It is important to note, that higher resilience levels earlier in life are associated with lower risk of progressive cognitive decline [17].

In summary, there are large interindividual differences in brain and cognitive reserve, which can at least partly explain the differences in cognitive performance between individuals with similar brain pathology.

### Resilience, meaning of life, and life quality

The constructs of brain reserve, cognitive reserve, and functional compensation are used to explain the preservation of cognition in the presence of (pathological) brain alterations; this capacity is also called “resilience” [135]. In a psychological sense, resilience means the “ability to overcome the difficulties experienced in the different areas of one’s life with perseverance, as well as good awareness of oneself and one’s own internal coherence by activating a personal growth project” ([125], p. 1). Resilience plays an essential role in the entire development of life, but especially in the early [47] and late stages, when personality factors also come more into play [61]. Resilience shows a

stronger positive relationship with openness and agreeableness, and a stronger negative relationship with neuroticism [101]. Undoubtedly, providing and supporting the acquisition of personally suitable resilience strategies is one of the most important processes in the first phase of human life. Finding an individual meaning in life and the resulting actions and evaluations seem to be decisive for how satisfied people are or can be with their own quality of life. The final reflection of the meaning of one’s own life takes often place in older age when special events or big changes are no longer expected [43]. Of course, concerns with the limited remaining time of life and with one’s legacy as well as health and financial issues may become key themes [102,131]. Decisive for the evaluation of one’s own quality of life and its subjective assessment (life satisfaction) seem to be the values and criteria used for it. These values and criteria are, of course, essentially personal in nature, and typically comprise health, functional capacity and autonomy, emotional comfort, leisure, environmental quality, level of satisfaction, social networks, and positive social interactions, spirituality, home and neighbourhood, and financial security [20,57,78,112,143]. These values depend on and play a key role in the respective culture, society, and religion [5,75,77]. Furthermore, gender differences [73,82] and cross-cultural aspects of life quality that apply to all people, also have a significant impact, regardless of their ethnic, cultural or religious affiliation. Among these aspects are: the ability to perform activities of daily living (ADL), general health, sensory abilities, mobility and autonomy and energy [26,91,144]. The loss of independence in ADL is a key factor affecting the quality of life in older individuals and their families.

As already mentioned, the adoption of criteria and values regarding satisfaction with and quality of life and their implementation in one’s own life as well as the development of strategies begin already in childhood [48,161]. Therefore, these processes should also be imparted and practiced in this early development phase. In a broader sense, education should not only include the acquisition of the cultural techniques of reading, writing and arithmetic and knowledge of the world and of professional activities. From childhood on, knowledge about different forms of life quality and life satisfaction, and their influences on one’s own long-term mental life development, should be passed on. This knowledge should include both the corresponding semantic and procedural components that are important for implementation of appropriate coping strategies in different life situations. Based on the combination of both forms of knowledge, personalized strategies can then be developed, which ultimately result in routines and habits. Such routines and habits make it easier to cope with the various demands of life. They represent mental and behavior programs that can be used flexibly according to the actual circumstances [127]. Routine learning and habit formation play an important role in behavior change [59], in particular in health behavior [58], health-related quality of life [66] and in developing and maintaining resilience [153] and stress tolerance [150]. However, habit formation may take quite a long time of systematic repetition of the desired behavior

[79,142]; rapid effects can therefore not be expected. But it seems more than worthwhile to guide and help children and adolescents to develop, learn, optimize and maintain routines and habits that are relevant for healthy mental aging and thus also for personal quality of life (an individual's perception of their position in life in the respective cultural context and in relation to their goals, expectations, standards and concerns [57], and life satisfaction (an individual's self-evaluation of their life quality using their personal criteria [5,78]). It should, therefore, become and be an essential part of lifelong education to train and use different adaptive coping strategies, which suit changing contexts (internally or externally driven) [100]. We all agree that every-one should be happy according to their own way and values. Happiness is a purely subjective feeling and therefore depends on what personal values a person uses to judge it for themselves as long as it is not at the expense of others and affect others in a negative way. That is why every-one should also grow old happily according to their own lifestyle and evaluation [6]. Whatever individual values a person develops and relies on, mood and motivation play a crucial role in this [34,72,141]. Therefore, it seems very important that the development of mood disorders, especially depression, and apathy are early recognized as early as possible and treated properly.

In summary, resilience and satisfaction with life have an influence on brain aging and strategies to build resilience and life satisfaction should be part of early and lifelong education.

### Individual and general characteristics of cognitive aging

Older, like younger people, individually show very different cognitive characteristics [22,110,129]. Trends and average changes of cognition in older people can be derived from large group studies, but these changes cannot be validly transferred to individual subjects. Cognitive performance of older people is often compared with that of younger people, but changes in cognition may be found across a larger range of adulthood [114], and performance in a complex cognitive task can overlap in older and younger subjects [159]. Older people may still have good ability in learning and memory, particularly in collaboration with social interactions [41], and may even show improvements in attention and executive function [44,145]. However, an increased time requirement appears to be a typical "symptom" of cognitive aging and time-dependent cognitive test performance ("power tests") [162] as well as cognitive activities under time pressure are often less successful and can also show more errors [115]. However, the adaptation of the individual time schedule allows a personalized prospective time-pressure management [147] and can also enhance wellbeing [2]. Notably, centenarians can still have good cognitive skills that also ensure appropriate time and task management for a sufficiently independence in daily life [13,105]. Empirical evidence suggests not only a large inter-individual variability in cognitive aging, but also significant intra-individual differences in the trajectories of the various cognitive domains [67]. Motivation can diminish in

older subjects, when self-generated, while motivation-related cognitive performance enhancements are still present [157].

In summary, cognitive aging goes often along with a slowing down of cognitive processes but this does not necessarily lead to worse cognitive or functional performance.

### Mental health, cognition, and influencing factors

Following Galderisi et al. ([55], p. 408), mental health can be defined as "a dynamic state of internal equilibrium which enables individuals to use their abilities in harmony with universal values of society. Basic cognitive and social skills; ability to recognize, express and modulate one's own emotions, as well as empathize with others; flexibility and ability to cope with adverse life events and function in social roles; and harmonious relationship between body and mind represent important components of mental health which contribute, to varying degrees, to the state of internal equilibrium". Thus cognition, emotion, resilience, life satisfaction and social skills represent some of the most important and essential factors contributing to mental health.

Mental health and cognitive function interact in many ways through the life span. Poorer mental health (defined as anxiety and depression), social dysfunction, and loss of confidence can be associated with lower cognitive function [21], and in particular cognitive skills in social processes and interactions contribute significantly to mental health [116]. A broad range of physical, biological, lifestyle, and psychological factors are known as either protective or risk factors [49,117]. In addition, cognitive and social activities in older age appear to depend on education level [14], but of course also on motivation for cognitive activities in general [52,88]. Mood trajectories may also change with aging, with the most extreme (positive and negative) subgroups in older adults [133]. Negative and positive events associate differently with cognition and psychological status. A study from Northern Portugal has shown that the vast majority of older individuals report more positive than negative life events. Individuals with more reported positive events also show better cognitive performance and lower depressive mood and perceived stress compared to those who report more negative life events [25]. Personality traits do not appear to change significantly with aging and do only modestly influence longitudinal changes in cognition [119].

Regular physical, cognitive and social activities and engagement are known to have protective effects [3,23,24], possibly via cardiovascular fitness [130]. Postponing retirement, if possible, particularly in cognitively and socially "enriched" occupations, can also be a favourable factor [63,155].

Among diseases, which may affect cognition and mental health in older age, hyperglycemia (supraphysiological blood sugar levels) appears crucial [9]. An important aspect of mental health, not just, but also in older age, is coping with stressful conditions, so that chronic consequences remain as low as possible. It is known that chronic stress is associated with various biological alterations, including

in the brain, and can have deleterious effects on cognition [94,121,108]. This also applies to daily stressors [98] and permanent social stress conditions, for example, in partnerships [15]. The acquisition of helpful strategies for dealing with stress and especially for preventing chronic consequences is therefore an important component of mental health maintenance, especially mood [27,81] and belief in control and prevention of loss of control, which are not reduced in older age [4]. Sufficient cognitive, motivational and emotional resources act as protective reserves and have a very beneficial effect on the quality of life in older age. Studies on centenarians have shown, that despite biological risk factors, cognitive abilities [13,104] and helpful stress coping strategies [68] are preserved and can reduce the severity of mental disability [28]. Of course, functional loss of vision [138], audition [53] or motor skills [65,143] can limit social participation and mobility, but not necessarily prevent it.

In summary, mental health and cognitive function interact with each other throughout the life span and both can be influenced by a range of factors including stress and lifestyle.

### **The assessment and rehabilitation of older people with impaired cognition and related difficulties**

As discussed earlier, aging of the brain is also associated with mental aging. In individual cases, this can lead to an impairment relevant to everyday life, e.g. if the previous level of cognitive performance is no longer available or if mild cognitive impairment is already present. Cognitive performance and its loss is assessed with the help of standardized test procedures. The comparison of the individual test result with normative data enables the classification of the individual result as 'above average', 'average' or 'below average'. Normative values usually take age, gender and education into account. So-called cut-off scores are used to classify a test result as "below average". This procedure applies in particular to the distinction between 'normal' age-related changes in cognitive performance from mild cognitive impairment or dementia. Whichever test procedure is used and which cut-off scores are set to characterize a test result as "below average", it always relates to the cognitive performance under standardized conditions. It should be noted, however, that the conditions for cognitive assessment may have little or no commonality with the everyday conditions and requirements of the individual [113]. It is of course correct to speak of underperformance in a cognitive test; whether this performance also means an individual handicap under more 'real' everyday conditions can only be assumed very indirectly. Thus, cognitive test procedures have limited and often insufficient ecological validity for such a far-reaching diagnostic conclusion, for example 'cognitive impairment' or 'disability'. According to the WHO, dementia "is a syndrome, usually of a chronic or progressive nature, caused by a variety of brain illnesses that affect memory, thinking, behaviour and ability to perform everyday activities" ... "there is deterioration in cognitive function beyond what might be expected from the usual consequences of biological age-

ing" [154]. This characterization contains two main points: (1) the loss of cognition must be (significantly) greater than the "normal" age-related cognitive changes, and (2) this loss must also (in a significant way) affect individual everyday activities, i.e. represent a personal disability. The use of screening procedures alone is definitely not sufficient for this, and does not allow any statements about (still) average and (already) below average performance in the various cognitive domains [7,123]. For standardized cognitive tests, appropriate age-related norms are essential for the classification into "average" and "sub-average" performance [90], and follow-up examinations are required to determine changes in individual test scores over time. The second characteristic can only be provided to a limited extent by cognitive tests alone in mild and moderate cases of cognitive changes, e.g. in mild cognitive impairment or mild to moderate forms of dementia. In severe forms of dementia, cognitive difficulties become manifest in nearly all everyday life activities, and standardized tests can no longer be carried out. Systematic behavior observations and surveys are important and helpful amendments for the evaluation of cognitive difficulties in everyday activities and requirements, whereby the latter should also include the family and caregivers [42,103,139,158].

Cognitive rehabilitation of older subjects with cognitive impairment usually consists as a kind of mental exercise using guided practice with tasks that reflect particular cognitive functions, such as perception, attention, memory, problem-solving or multi-tasking. In neurorehabilitation after acquired brain injury, age is an important general predictor for long-term outcome [18,70]. This statistical evidence does not mean, however, that there is no success even in very old subjects and that the rehabilitation effort is less justified than in younger patients [83]. Unfortunately, the influence of age is rarely considered in neuropsychological rehabilitation studies because of the statistical comparability between groups (e.g. treatment vs waiting group), and is even neglected in *meta*-analyses on neuropsychological treatment effects. Interestingly, some studies have shown no age-specific influence on the treatment outcome or the long-term course, e.g. in visual perception [160], attention and global functional capacities (ADL) [1,10].

In case of reduced cognitive functions and resulting difficulties in ADL, i.e. in mild cognitive impairment and mild to moderate dementia, training may be supportive for improving cognition. However, evidence for the efficacy of such practice regimes is still preliminary and controversial [80,156]. Technologies for the remediation of cognitive impairments may be useful, for specific personalized training, when optimized for portable devices, and user-friendly [71]. Music activities in the broadest sense can offer a rich mean for cognition (particularly attention and memory), health and wellbeing independent of age, background, and setting [46].

In summary, the assessment of cognitive function is based on standardized tests and cut-offs that not always reflect the ability to carry out everyday activities. Cognitive rehabilitation programs can be beneficial for improving cognition, but more research is needed on age-specific influence of these programs.

## Cognitive performance and functional cognition

As mentioned above, cognitive performance as assessed with standardized tests alone, may not show meaningful ecological significance for the individual. Therefore, such test results cannot be used to reliably infer the availability or impairment of cognitive functions in ADL. In milder forms of cognitive decline, the determination of the “critical minimum” of cognition actually required in the individual life situation appears to be more suitable for the valid assessment of the degree of cognitive disability. For this, a systematic survey of the individual everyday requirements in the relevant areas of life is necessary, especially in the case of older people. Interestingly, even centenarians may still possess cognitive functional capacity for coping with everyday life challenges [87]. The systematic investigation of individual living conditions in older age and their cognitive requirements, taking into account the previous acquired executive strategies and habits, could lead to a catalog that focuses on functional cognition that is based on ecologically valid measures. Functional (or also instrumental) cognition can then be used to describe the actual use of a person’s cognitive abilities in different situations and/or environments. The focus is therefore on the importance of the individually available cognitive abilities and skills in activities of daily life [93,151]. Systematic observation and the diagnostic assessment should, therefore, be based on the specific use of the existing cognitive capacities in everyday situations without and/or with assistance. The assessment of functional cognition could be part of a more general functional assessment in older people [109]. While assessments of cognitive function are standardized with the use of objective neuropsychological tests, objective assessments of functional performance or functional cognition are limited and not standard in clinical practice, partly due to constraints in time and resources, and lack of standardised processes [97]. However, reliable and objective assessments of functional ability and change over time are critical to monitor decline to enable focussed support and intervention, and to monitor improvement after targeted interventions.

In summary, functional cognition refers to how an individual integrates cognition to accomplish everyday activities. Longitudinal assessments of functional cognition are important to monitor change over time.

## Bridging the interdisciplinary gaps in future research strategies

Which central topics for mentally healthy aging seem important for future research, but also for social and health services and institutions and for health policy? From what has been said so far, it follows that non-pharmacological preventive measures can make a significant contribution to maintaining cognitive functions in older people. Preventive measures in the mental area include cognitive strategies, routines and habits that enable the individual to master the challenges of life and to acquire and maintain a good quality of life. These preventive measures refer to aspects of both, the physical and mental health. However,

you shouldn’t start when you’ve gotten old, but rather already in childhood and adolescence in an appropriate form [99]. But even if there is cognitive impairment in older age, improvements can be sometimes achieved through suitable treatment [8,24,76,152,156].

There are numerous scientific findings on mental aging in basic neurobiological research and in medical, psychological and social applications. For the future cognitive and mental age research it would be very desirable that all basic and applied disciplines engaged in aging research cooperate more closely to guarantee an early, successful translation of the scientific findings into more ‘real’ life conditions of older people. At the same time, bridges between science and in health and social policies should be increased in number and widened to further reduce the gaps between science and translation to the reality of older age [45,50,132]. The integration of brain, mind, and biological body factors with the aim of greater applicability, particularly in clinical conditions, appears a crucial prerequisite for future comprehensive research on aging [32]. Cox & Deary [36] recommend a “multidisciplinary openness”, whereby “the collaboration has to work; there is no point in collaborating with a specialism with which one cannot shake hands; there should be no understanding gap in the collaboration. Not all new variables will make a contribution (p. 7). In addition, these authors endorse the recruitment of large and more diverse subject samples, because only multiple small group effects are to be expected, and a broader search for explanatory variables. Large samples with large variation in variables would also allow specific subgroups to be discovered, defined and then examined separately with regard to special characteristics or profiles. The essential prerequisite for this is the consideration of as many biological and non-biological variables as possible in an approach that is as holistic as possible. This would mean setting a mandatory minimum of aging characteristics for multidisciplinary studies. In the second step, the individual disciplines can then use their respective subject-specific methods to characterize the subgroups defined in this way more precisely. As far as possible, all variables should be taken into account in order to be able to make general statements about the (favorable or unfavorable) influence of these variables on aging processes. Such an approach would also represent a valid basis for modeling aging processes and courses. For studies with large samples as well as for studies with smaller specific groups, a close linking of all research disciplines involved from planning to implementation, data analysis and classification of the results is desirable. Of course, each research discipline has its own specific approach and research methods, and pursues its own research goals with different outcome variables. However, the combination of the different, complementary approaches fits better to a complex topic such as mental aging because it focuses on the human being as a whole. Finally, the individual research contributions should (be able to) be classified in a higher-level, more holistic context of ageing. An important prerequisite for multidisciplinary and cooperative research this should be the interdisciplinary scientific training, especially of young scientists, and close networking between research groups of the disciplines involved. Of

course, it must be taken into account that a broad research approach always requires a higher expenditure in terms of personnel, money and time and the establishment and safeguarding of the required project organization. On the other hand, in practice, it must be possible to reliably classify the individual test results for mental functions, taking into account the influencing variables. Of course, this means that these influencing variables are also known in individual cases.

Based on the existing empirical evidence, prevention and exercise programs also appear to have a beneficial effect in old age. It seems important, however, that such programs are also checked for ecological validity and functional significance. Smart technologies can assist older people and can help to facilitate and maintain their own independence [92], but their ecological validity must be demonstrated. In addition, a valid measurement of reserve/resilience in aging may help to better assess and understand this obviously important factor, and to implement early measures for prevention [17]. Finally, for as complete an understanding as possible, the influence of genetic factors in addition to environmental factors on diverse trajectories of human aging, and their interaction, should also be taken into account in aging research [40].

As discussed earlier, cultural factors play an important role in understanding and dealing with mental aging and values about quality of life. Cultural differences should therefore be considered when evaluating differing research results, because they cannot be compared directly. However, differing study outcomes can be used to gain valuable suggestions for one's own cultural area. Interestingly, there are shared cross-cultural meanings of quality of life, both in personal and in more general terms. Personal indicators include emotional and physical well-being, interpersonal

relations and social inclusion, financial well-being, and self-determination [120]. The more general indicators include spiritual qualities on meaning in life, awe and wonder, wholeness and integration, and kindness to others [126]. In contrast, in mental health the different cultural factors play a major role [60,124]. Taking these criteria into account would certainly also be helpful when dealing with older people and their problems, especially under pathological conditions, e.g. dementia, and should be included especially in applied aging research as well as in clinical practice. Health systems need to ensure access to assessment and care focusing on the needs, rights, culture, and capabilities of older individuals.

A higher age is associated with cognitive, mental and physical changes, but older people can retain their individuality and personality, which is also made up of their life history and individual experiences. That is why personalized programs are important for maintaining functionality in everyday life. However, this also implies that older people accept such offers and (are able to) translate them into their personal lives. To be curious about and interested in problem solving and flexible adjustments of routines and habits to the age-related requirements is supportive for coping with everyday challenges. This attitude is acquired at an early stage in life, but should be further developed, depending on the respective individual requirements and necessities. The development and adaptation of routines and habits, and their continuous optimization in the context of current living conditions and their challenges requires the flexible use of cognitive reserves under the guidance of executive functions, including development, selection and use of current problem solutions and adaptation strategies, error control and, if necessary, error correction. Motivation for cognition and the emotional (positive

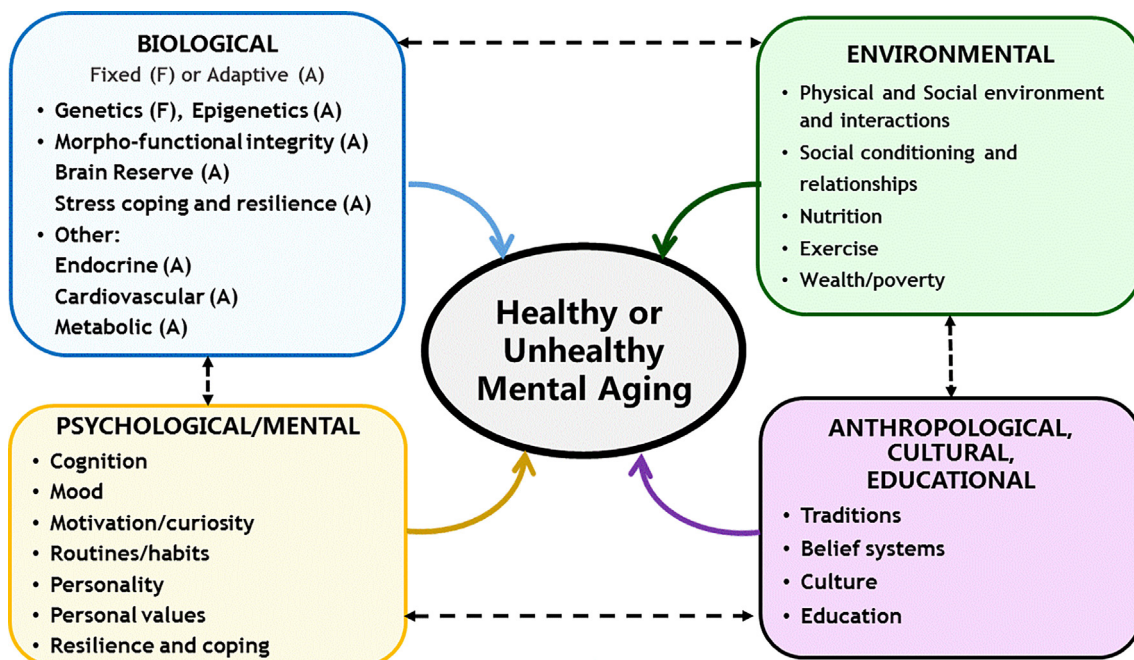


Fig. 1. Some of the main factors contributing to healthy and unhealthy mental aging, and their interactions.



and negative) evaluation of one's own routines and habits play a powerful role in this groundbreaking developmental process. The positive or negative confirmation of successful action acts as an amplifier in reinforcement learning of action routines [19] and is based on a widespread system of potential reward in the brain [85]. In this context, the assessment of aging attitudes of an individual may assist in the holistic assessment of mental aging. Aging attitudes can be changed and are a potential target for intervention to reduce negative aging attitudes and enforce positive aging experiences [122].

The functional adaptation to the various objective and subjective challenges of life is a highly complex, dynamic process that requires appropriate mental resources. The magic word is learning; learning means regular practice, which is seldom possible without exertion. Learning in terms of adaptation of functional abilities to changing life conditions is still possible in older age [29,107]. However, it is important that learning goals are set in such a way that they are individually meaningful and necessary, and remain feasible. Despite the age-related biological and mental changes, growing older is a normal process, which can be positively influenced and does not have to be negative, fateful process.

In summary, interdisciplinary collaboration in aging research and closing the gap between research findings and their application in practice and policy is crucial to advance progress in this area.

## Conclusion

This contribution aimed to provide a holistic overview of the aging mind. When assessing the aging mind and brain, cognition is just one of many mental functions. Cognitive reserve, resilience, functional cognition, and life satisfaction, but also biological, mental, environmental and anthropological, cultural and educational factors are important aspects that have an impact of an individual's brain aging. In Fig. 1, some of the main factors contributing to healthy and unhealthy mental aging, and their interactions, are summarized. Each of these factors contributes significantly to aging of the mind, however, the various direct and indirect interactions between these factors are just as decisive for the favorable or unfavorable development of mental health in aging. The success of the joint interdisciplinary efforts to understand the various processes involved in mental aging will also determine how well these complex relationships can be dealt with in research and practice.

Promotion and funding of multidisciplinary research is an important step to advance knowledge and progress in this area. Not only collaboration between basic and applied research and professions but also timely knowledge translation to clinical practice and policy is recommended.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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