Nutrition for Brain Health and Cognitive Performance

Edited by
Talitha Best and Louise Dye

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Dedicated to my dad, Robert Dye, who died before I could show it to him and who I miss everyday

Louise Dye

Dedicated to my family who inspire me with their commitment to share their lives with others

Talitha Best

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SECTION III The Story So Far: Foods and Nutrition for Performance across the Lifespan

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Preface

This book critically reviews the evidence surrounding the impact of dietary patterns and nutrition on brain function and cognitive performance and the mechanisms which underpin this. The increase in public awareness of the role diet can play in brain function has been accompanied by a significant development of products, dietary supplements, functional foods, nutraceuticals, food programs and submissions of dossiers for health claims and public health recommendations for maintaining brain function. The area of nutrition–cognition research is an emerging interdisciplinary field of work that examines the impact of food, nutrients and diet on everyday aspects of cognitive performance and brain function. It is our hope that this book serves its purpose: to make available a detailed and innovative scientific summary of nutrition–cognition research to provide valuable information regarding nutritional and lifestyle choices for cognitive health.

We have purposefully sought to balance rigorous scientific information and analysis, with information for readers who are 'non-experts'. We have sought out contributions from internationally recognised scholars alongside the next generation of researchers to provide accessible, up-to-date reviews that consider the impact of dietary patterns, nutritional components, methods of assessment and technology and the underpinning physiological processes to support brain health and performance. This book is appropriate for health professionals, researchers, teachers, educators, health service providers, food and nutraceutical industry personnel, nutritionists, dietitians, psychologists and psychiatrists, public health workers and the general public. We trust it will serve as a valuable resource for your research, teaching and client support.

We offer our appreciation and thanks to the authors of each chapter for their thoughtful and skillful contributions. Their time, expertise and willingness to support this project to equip others with up-to-date information in this broad, multi-disciplinary field of cognition and nutrition is greatly valued.

Look out for the recommendations and summary boxes throughout the book that provide a summary of the key points to take away from the chapters that we hope support you in your life-long learning.

May your food choice promote a cognitively healthy life.

Talitha Best
Louise Dye

Editors

Talitha Best is a researcher, practicing psychologist and lecturer with a passion for solution-oriented thinking and process innovation. Dr. Best addresses critical innovation related to translation of research into workable solutions for researchers, practitioners and industry in the areas of nutrition, food systems and products, brain function and cognitive performance.

Dr. Best received her PhD in clinical psychology and nutrition–cognition research from Flinders University, Adelaide, South Australia, and completed a joint post-doctoral position at the Nutritional Physiology Research Centre at University of South Australia (UniSA), Adelaide, and the Centre for Human Psychopharmacology, Swinburne University, Melbourne. Her research and clinical interests focus on the effects of nutrition to improve mood and neurocognitive function. Her research has explored the role of non-starch polysaccharides in everyday cognitive abilities and the well-being of middle-aged adults in order to understand the potential mechanisms by which dietary polysaccharides may have beneficial effects across the lifespan. In addition, Dr. Best's research focuses on processes of knowledge transfer between the research and industry sectors to promote innovation in food and nutrition research and development.

She has taught advanced statistics and research methods and psychological assessment at the undergraduate, master's and postgraduate levels, and currently teaches 'psychological assessment methods' at the honours level. With experience in clinical and research supervision, Dr. Best supervises undergraduate and postgraduate students across multidisciplinary settings within the food, nutrition, health and agriculture nexus at Central Queensland University, Bundaberg, Australia.

Talitha frequently speaks, writes, reviews, edits and lectures across multidisciplinary settings and contributes to national and international not-for-profit organisations committed to supporting health through community development in food, agriculture and education.

Louise Dye is professor of nutrition and behaviour in the Human Appetite Research Unit at the Institute of Psychological Sciences, University of Leeds, Leeds, United Kingdom. She received her BSc in human psychology from the University of Aston in Birmingham and her PhD in psychopharmacology from the University of Leeds. She has held Medical Research Council and Royal Society post-doctoral fellowships in the United Kingdom and Europe, including a Marie Curie professorial fellowship in Jena, Germany. Professor Dye is a chartered health psychologist and member of the British Psychological Society. She is associate editor of *Nutritional Neuroscience* and the *European Journal of Nutrition* and a member of the editorial board of *Human Psychopharmacology*. Currently, Professor Dye sits on four expert groups for the International Life Sciences Institute (ILSI). These are Postprandial Carbohydrate Metabolism, Benefits of Satiety, Measuring Subjective Mental Performance and Mood and BioMarkers for Cognitive Function. She has supervised

more than 20 doctoral students and currently has seven doctoral students under her supervision, many in collaboration with industry or National Health Service partners.

For more than 20 years, her research has examined functional foods for cognitive performance and well-being across the lifespan. She has conducted numerous studies of the effects of foods and food components on glycaemic response, cognitive function and appetite control. In the last decade, she examined stress, obesity and cognitive function and the effects of breakfast interventions on cognitive performance and appetite control in children, adolescents and younger and older adults. Her research has been funded by ESRC, TSB, MRC, BBSRC and many food companies with whom she has formed strategic partnerships and led Knowledge Transfer Partnerships. Her recent research involves the effects of food components on digestive function and the impact of metabolic diseases such as cystic fibrosis and phenylketonuria on cognitive function. Louise has taught biological psychology and advanced statistics and research methods at the undergraduate, master's and postgraduate levels. Currently, Louise teaches a course called "Food and Health" on the MSc Psychological Approaches to Health at the University of Leeds and contributes to the Health Food Innovation Management Masters at Maastricht University, Maastricht, the Netherlands, and to an undergraduate module on "Nutrition and Behaviour" on the BSc psychology programme at the University of Leeds, alongside supervising undergraduate and postgraduate research in these areas.

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Section I

Big Picture: Nutrition for Brain Health

1 Good News Story
Nutrition for Brain Health

Talitha Best and Louise Dye

CONTENTS

SUMMARY

The idea that nutrition can influence our health is not new. Most are aware of the significant impact food choices can play in health conditions such as obesity, type 2 diabetes and cardiovascular function and the importance of nutrition for physical and psychological well-being. Importantly, nutrition for brain function and cognitive performance is a rapidly increasing area of interest for scientists, industry and the general public. As a modifiable lifestyle choice, diet and nutrition are important contributors to brain health across the lifespan. In the chapters that follow, exciting, innovative research regarding the role of nutrition and diet in brain health is discussed. This chapter discusses a broad, good news story for *brain health*, innovative changes in nutrition–cognition research and provides suggestions for how to utilise the material presented in this book.

1.1 GOOD NEWS: PROMOTING BRAIN HEALTH

Developments from the fields of neuroscience, nutritional neuroscience and neurology provide converging evidence that the structure and function of the brain changes as a result of nutritional status (Lieberman et al., 2005). These changes and adaptations are called neuroplasticity, whilst neurogenesis refers to the creation of new neurons. These two properties of the brain underpin a good news story about how and why brain health can be supported with appropriate nutrition.

This good news helps to buffer some of the fear around the increasing prevalence rates of cognitive decline and neurodegenerative disease, such as dementia, the incidence rates for which range from 1.5% in over 65-year-olds to almost 25% in over 85-year-olds in western Europe with similar rates in North America (Alzheimer's Disease International, 2008). Worldwide, there are 4.6 million new cases annually. Dementia is estimated to affect over 65 million adults in countries with low and middle incomes by 2030 (Prince et al., 2013) which have far fewer resources to deal with its social and economic consequences. The prospect of *losing one's mind* and the ability to engage and remember interactions in the world due to declining brain health is frightening on an individual level, as it impacts at the core of how we define our identity and meaning in the world (Fjell et al., 2014). It is perhaps no surprise that across the world, there is a dramatic demand for pharmaceuticals, food products, nutraceuticals and technologies to support brain health from early childhood to allow optimal development into late adulthood to prevent or slow the progression of age-related cognitive decline.

Like any other organ in the body, the health of our brain relies on food and nutrients. The human brain requires a large proportion of the energy that is consumed because of high energy demands made by neuronal tissue. Twenty to twenty-five percent of our resting metabolic rate is utilised by the brain (Leonard et al., 2007). This energy is essential to maintain function (e.g. fundamental functions such as synaptic transmission and complex functions such as behaviour, cognitive performance and well-being) and structure (tissue connectivity and density of neuronal networks). Nutritional compounds are involved in the complex interactions and activity of the brain, from neurogenesis in the infant brain through to adulthood (Uauy & Dangour, 2008) to metabolic pathways, such as glucose regulation and inflammation involved in brain ageing and neurological disorders (Cutler et al., 2004). Nutrients also help maintain specific structures in the brain, such as the hippocampus which is directly associated with learning, memory and mood (Deng et al., 2010). Changes in dietary patterns and nutritional status, such as increased vitamin B, have been shown to impact the function and structure of the hippocampus in terms of size, activity and production of neurotransmitters related to cognitive performance (Deng et al., 2010; Monti et al., 2014; Stangl & Thuret, 2009; Stranahan et al., 2008).

The performance of the brain in terms of overall neural activity and cognitive ability, however, sits within a complex network of interactions. There are many external and internal influences such as changes in emotional states (Compton, 2003), social attachment (Young et al., 2001) and physical activity (Lista & Sorrentino, 2010) that can exert a direct effect on the neuronal circuits of the brain (Adolphs, 2003; Davidson & McEwen, 2012). For example, emotional states such as stress and low self-esteem have been associated with smaller hippocampi (McEwen et al., 2012) and disrupted neuronal function within the hippocampus and medial prefrontal cortex (McEwen & Gianaros, 2011). In addition, certain activities, such as prayer and meditation, can alter brain function in terms of neurochemical changes within the norepinephrine, dopaminergic and serotonergic receptor systems (Hölzel et al., 2011; Newberg & Iversen, 2003) and improve attention and executive function (Lutz et al., 2008).

Therefore, brain health can be influenced by a range of diverse external conditions, beyond the scope of this book. Although these are important, and there are networks of interactions that support brain health, we focus here on nutrition as one modifiable lifestyle factor that influences brain function. The focus of this book is to consider nutrition and how it might be studied, evidenced and ultimately applied in practical and public health settings to improve, maintain and promote brain health and cognitive function.

1.2 BRAIN, FOOD AND BEHAVIOUR

In the chapters that follow, we discuss dietary patterns, specific nutrients that may confer benefit for cognitive performance following both acute and habitual consumptions, with reference to how diet and nutrition may offer protection against cognitive impairment as we age. The diet contains hundreds of naturally occurring components that could impact a number of physiological and neurological mechanisms that underpin everyday cognitive functions. Dietary components can affect any one, or a series, of the processes that regulate hormone and neurotransmitter pathways, synaptic activity and connections between cells, membrane fluidity and signal-transduction pathways and neurogenesis (Gomez-Pinilla, 2008; Gomez-Pinilla & Tyagi, 2013).

Throughout the following chapters, the impact of dietary patterns (Chapter 2), micronutrients such as vitamins and minerals (Chapter 8) and omega-3 fatty acids (Chapter 7), as well as dietary constituents such as polyphenols and glucose (Chapters 6 and 10) and nutraceuticals and herbal remedies such as ginseng and green tea (Chapter 9) on cognitive function and mood, are discussed. Importantly, the potential impact of dietary interventions on cognition may be mediated by effects of these interventions on gene expression, as discussed by Ordovas in Chapter 3. In addition, technological advancements in techniques that could be used to capture nutrition effects on cognition and brain function are developing our knowledge of the effects of diet on brain health; see Chapters 11 and 12.

There is a pressing need to *round-out* the discussion and awareness of the relationship between nutrition and brain health. Due to the *brain diets* and *nutrients to help your brain* campaigns appearing in public awareness and media and drawing strong interest, the field of nutrition and cognition has a requirement to provide methods and evidence-based recommendations to government agencies, industry and consumers to support the substantiation of cognitive performance and mood claims for foods and food products.

The global demand for foods that are marketed for, or perceived to have, a significant health or performance benefit is growing exponentially. Innovative food products are continually launched and the market is estimated to be growing at a rate of 8%–14% per year, with an estimated value of US$477 billion by 2015 (Nutrition Business Journal, 2013). Less than a decade ago, estimates for complementary nutritional supplement and product consumption were $8.5 billion a year in United States and $4.05 billion in Australia (Xue et al., 2007).

Specifically, the consumption of brain/mental/cognitive supplements was reported to be around US$631 million in 2013, with an uptake of *cognitive-related*

health products estimated to be a $2 billion industry (Nutrition Business Journal, 2013; Watson, 2013). As industry searches for new ingredients for product development, the value chain of information and knowledge about health claims will be important for long-term, beneficial impact for public health. In particular, claims which relate to the improvement of particular aspects of cognition and mood such as memory, alertness, mental energy, stress, depression and anxiety as functional outcomes will need critical appraisal via rigorous methodology. In order to provide recommendations for health claims related to nutrition, sound methodology and process innovation are needed in research questions, design and analysis.

1.3 BROAD METHODS AND INNOVATION IN NUTRITION–COGNITION RESEARCH

It is important that coherent and appropriate research methods are used to determine the quantity and quality of nutrition across the lifespan that may assist cognitive abilities (Kuczmarski et al., 2014). For example, higher intake of whole food dietary patterns has been associated with lowered risk of cognitive deficit compared to processed food dietary patterns (Kuczmarski et al., 2014). This finding was still significant after factors such as demographic characteristics (gender, age and marital status), comorbidities (diabetes, hypertension, coronary heart disease and mental health) and physical and behavioural factors (BMI, energy intake, smoking and physical activity) were controlled for. However, clear evidence on the association between dietary patterns and cognition is often diverse and may be related to methodological differences.

Throughout this book, a number of methods and critical factors for interpretation of nutrition–cognition research outcomes, such as cognitive and mood test selection, sources of nutrients and acute and chronic testing environments, are discussed. Thus, this book offers ideas to address the emerging opportunities to develop critical effectiveness in the design and conduct of nutrition–cognition trials that may increase the efficiency of recruitment, retention, testing and data management and potential data sharing that promotes the quality of the outcome (Ioannidis et al., 2014).

Nutrition–cognition research outcomes hold an intrinsic market value for investigators, sponsors, regulators and industry, as well as the community. Collection of data through mobile devices and Internet-based assessment and measurement tools, together with technologies for stimulation and imaging of the brain, is ushering the field into an increasingly competitive information environment (Berger & Doban, 2014). Innovation in tools and methods for collecting real-time data about everyday function could direct research outcomes into an entirely new, information value chain. This value chain of information is a competitive space underpinned by *big data* about health and health outcomes (Raghupathi & Raghupathi, 2014). The changing regulatory and economic environment may be a tremendous catalyst for competitive innovation and novelty in research and health care. It is exciting to consider where the next generation of research in this field will lead.

1.4 NEXT PART OF THE GOOD NEWS STORY: HOW TO USE THIS BOOK

The changing landscape for nutrition, food systems and sustainability, as well as food products and personalised nutrition, poses a unique challenge and opportunity for research into nutrition for brain health. The twenty-first century challenge has been called the *nutrition transition* or *nutrition paradox*, in which obesity coexists with malnutrition and vitamin deficiencies (Kearney, 2010). As practitioners, scientists and consumers, it is important to consider the types of psychosocial and economic influences on consumer behaviour underpinning the demand for and use of nutritional products. The interface between product health claims, generation of knowledge and information for public health provides great scope for nutrition and cognition research and nutritional neuroscience to interact with both industry and consumers. The role of industry is recognised by government and non-government organisations as critical to address under-nutrition and improve nutrition-related health outcomes (Luijten et al., 2012; Yach et al., 2010). Thus, it is important for research into effects of nutritional products, ingredients and formulations on brain function to consider and balance the input and goals of the manufacturers, developers, industry and marketeers of products and ingredients with those of the consumers and public health organisations.

The challenge ahead in the twenty-first century for the field of nutrition and behaviour is not only to address gaps between research, industry and the consumer but also to think about application and interpretation of the research findings. Research examples throughout this book highlight methodology (types of extract, tests, populations and cohort characteristics, such as age and level of ability) and offer a critical appraisal of the evidence about the impact of whole diets, nutrients, techniques and methods likely to confer benefit for brain function and structure across the lifespan.

1.4.1 For Industry

Use this book to support your research and development (R&D) agenda which might include the pursuit of health claims or the development of new products/modification of existing formulations. This book might suggest the methodologies and considerations required to develop the evidence base for claims of nutritional effects on brain health. In addition, use this resource as a guide from a range of highly regarded experts about the level of evidence available to you currently to develop and disseminate rigorous, high-quality information for your consumers.

1.4.2 For Health-Care Professionals, Researchers, Teachers, Educators and Interested Public

Use this book to guide you in your understanding and appreciation of the role of nutrition to support psychological (cognitive function and mood) health and brain health. We hope that the explanations of the mechanisms and critical appraisal of the quality of the evidence will give you an awareness of issues that will enable you to make critical evaluations of key topics and methodological issues in the field.

Furthermore, we trust that this will enhance your knowledge and enable you to reduce confusion and assist your students and clients to appreciate the importance of nutrition for supporting brain health.

1.5 CONCLUSION

The subtle effects of food on the brain and behaviour mean that it is a complicated task to organise and distinguish those nutritional components and dietary patterns that are related to or likely to confer benefit for brain health. The promising effects of diet on brain plasticity and neurogenesis, together with the findings from human studies, reinforce the important translational concept that diet and nutrition can modulate brain health and function (Murphy et al., 2014).

This book presents the state-of-the-art scientific evidence, challenges and potential applications within this exciting field. By providing insight into the methodological considerations of research in this area, it is our hope that readers in the community, students, researchers and industry R&D use the information, techniques and insights of the book to support application of this research. In addition, it is our intention that this book be used to promote and extend the research, teach the process of research in this area and promote a collaborative understanding of the field between industry and academia.

More broadly however, we hope that this book is accessible to non-specialist readers and so can also be utilised by those in the community with keen interest in understanding this research to learn more about nutrients and dietary patterns which may confer cognitive protection or benefit. Use the summary boxes provided within each chapter that offer, from the authors' perspective, quick reference points to the key material and are a guide to the main issues and recommendations of the research in this area.

TOP 4 SUMMARY POINTS FROM THIS CHAPTER

- Brain health can be impacted by a range of external factors, such as exercise, meditation, social interaction and imagination that can influence/alter the function and structure of the brain.
- Nutritional intake and dietary patterns are critical for brain health across the lifespan. Certain dietary patterns and intake of particular nutrients are associated with both improved function and reduced risk of cognitive decline.
- Key methodological considerations in this field include appropriate methodology, research question and processes, type of intervention and design and sample selection especially the target group of the intervention.
- Innovation in research design, tools and methods is likely to support the transition of research outcome of this field into the twenty-first century information value chain which drives consumer and industry outcomes.

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2 Nutrition and Cognition in the Context of Ageing

Role of Dietary Patterns

Valentina A. Andreeva and
Emmanuelle Kesse-Guyot

CONTENTS

SUMMARY

The worldwide increase in life expectancy portends serious consequences in all areas of life. As physical and mental health status generally deteriorates with advancing age, researchers forecast an unprecedented rise in disability and healthcare costs, concomitant with marked declines in the quality of life of the elderly. Hence, the role of various modifiable lifestyle factors, such as healthy diets and engagement in physical activity (PA), has been evoked as paramount prevention strategies. Nutrition-based strategies – especially those focused on overall dietary patterns (DPs) which account for the marked synergies and interactions among nutrients in the food matrix – merit particular attention as primary prevention options regarding cognitive ageing and impairment. This chapter explores the current evidence that suggests a Mediterranean-type diet rich in fruit and vegetables (FVs), plant-derived products and seafood, with relatively low alcohol intake and low intakes of meat, saturated fatty acids and added sugar, could have important benefits for brain health. Beginning early in life, individuals can help reduce their risk of physical and mental impairment in the course of ageing by following a well-balanced, nutritious dietary regimen, maintaining a healthy weight and being physically active.

2.1 WORLDWIDE POPULATION AGEING AND ITS IMPLICATIONS FOR HEALTH CARE

Advances in medical science and technology, notable social and economic improvements and the demographic transition from high to low levels of fertility and mortality, initially observed in developed regions and gradually spreading to less developed regions of the world, have led to an unprecedented increase in life expectancy and population ageing (Korczyc et al., 2013; United Nations, 2002). In most developed countries, the age of 65 years or older has been accepted as a definition for elderly or older persons, whereas the age of 60 years has been used to mark the beginning of old age in less developed countries in Africa (World Health Organization, 2014). Whereas in the 1950s, the proportion of older persons worldwide was approximately 8%, at the beginning of the twenty-first century, it was approximately 10% (i.e. 600 million people), and by the year 2050, it is expected to reach 20% (i.e. 2 billion people). The annual increase of 2% of the elderly population is higher than the overall population growth rate, with individuals aged 80 years and over representing the fastest-growing segment (i.e. annual increase of 3.8%). Despite demographic heterogeneity across different world regions, female life expectancy is generally higher than that for males. In the United States, for example, by the year 2050, there will be more than 48 million women and about 40 million men aged 65 and over (Figure 2.1).

The worldwide population ageing portends serious consequences in all areas of life, including decreasing labour force participation owing to retirement and increasing demand for health care, special housing and changing family composition (Korczyc et al., 2013; United Nations, 2002). As physical and mental health status

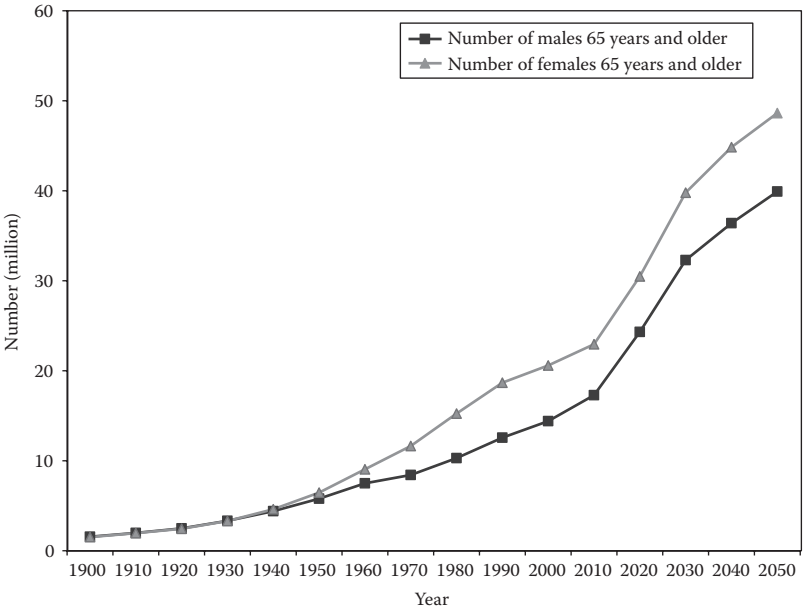

FIGURE 2.1 The U.S. population 65 and over by sex: 1900–2050. (From Projections of the population by age and sex for the United States: 2010 to 2050 (NP2008-T12), Population Division, U.S. Census Bureau; Release date: August 14, 2008; Data for 1900–2000 from Census 2000 Special Reports, Washington, DC, Series CENSR-4, Demographic Trends in the 20th Century, 2002.)

generally deteriorates with increasing age, demand for long-term care is likely to grow (United Nations, 2002). In addition, given the impact of population ageing along with that of the obesity epidemic, the increasing cardiovascular disease (CVD) morbidity and declining CVD mortality (partly due to improvements in treatment), researchers forecast an unprecedented rise in disability and health-care costs, concomitant with marked declines in the quality of life of the elderly (Pandya et al., 2013). A recent report by the American Academy of Neurology Workforce Task Force also predicted a marked future shortfall of neurologists provoked, in part, by ageing of the population and by increased health-care utilization rates of neurologic services (Freeman et al., 2013).

In Europe, one-third of the population is expected to be aged 60 and over by the year 2050 (Korczyc et al., 2013). The rapidly declining share of the working-age segment of the population concomitant with an increasing demand for long-term care services and the rising costs for supporting an expanding elderly population are seen as major challenges throughout the region, with especially serious repercussions for Bulgaria, Croatia, the Czech Republic, Estonia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia and the Slovak Republic (Korczyc et al., 2013). In turn, alarming social security data from Germany suggest that by the year 2030, employed individuals will be working to sustain twice as many retired elderly as they did in the early 1990s (Borsch-Supan, 1992).

2.2 COGNITION, COGNITIVE AGEING AND COGNITIVE IMPAIRMENT

Cognition comprises the numerous and complex mental processes involved in acquiring knowledge, learning, attention, memory, intelligence and consciousness (Harada et al., 2013; Lezak et al., 2012). These processes are dependent on the transmission of electrical and chemical signals between neurons (nerve cells). With age, the rate at which neurons receive and transmit such signals declines which leads to declines in learning, recall and multitasking skills (Institute for the Study of Ageing, 2005). Importantly, there is marked variation in the age-related rates of decline across the various cognitive abilities, with some abilities, such as those related to vocabulary, knowledge and social cognition possibly improving with age (i.e. crystallized intelligence), while others, such as working memory, reaction time and processing speed (i.e. fluid intelligence), typically show salient age-related decline (Depp et al., 2012; Lezak et al., 2012). Despite substantial heterogeneity among individuals, normal ageing generally leads to a reduction in the volume of different brain structures (e.g. caudate nucleus of the basal ganglia, cerebellum, hippocampus, prefrontal areas), decreasing number of synapses and decreased integrity of white matter tracts, all leading to potential cognitive deficits (Depp et al., 2012).

Cognitive decline represents a continuum of subjective and objective symptoms, ranging from normal (healthy) cognitive ageing through subjective memory complaints, mild cognitive impairment (MCI) and preclinical dementia and ending with Alzheimer's disease (AD) (American Psychiatric Association, 2013). Reviews of the scientific evidence suggest that the prevalence of memory complaints – defined as everyday memory problems – varies between 25% and 50% in the general elderly population. Older age, female sex and low education have been linked to an increased risk of memory complaints which are regarded as a risk factor for cognitive impairment and dementia in community-dwelling elderly (Jonker et al., 2000).

MCI represents a heterogeneous cluster of symptoms, which might not always be detected (Shankle et al., 2005). Despite the lack of a precise definition, MCI pertains to some cognitive impairment (in recall, judgment, etc.) that does not affect instrumental activities of daily living (shopping, housekeeping) (Shankle et al., 2005). Its overall prevalence varies widely across different populations of elderly, ranging from 3% (Ritchie et al., 2001) to 46% (Drexler et al., 2013). In fact, much of the variation can be attributed to the diagnostic criteria used, for which there is currently no consensus (Drexler et al., 2013). Generally, MCI increases the risk of dementia (Brodaty et al., 2013), which consists of marked and irreversible cognitive decline from a previous level of functioning. Dementia is characterized by progressive deterioration in different cognitive domains (attention, concentration, memory, executive function) that is severe enough to interfere with daily life (American Psychiatric Association, 2013). In epidemiological studies, cognitive decline is typically assessed via neuropsychological tests measuring global cognition, such as the mini-mental state examination (MMSE) (Folstein et al., 1975) or its modified version (Teng & Chui, 1987), administered at least twice over a period of several years.

Each individual cognitive domain (language, memory, visuospatial ability, information processing speed, attention, executive functioning) can be evaluated by specific neuropsychological tools (Reichman et al., 2010); see also Chapter 4. Generally, impairment in episodic (autobiographical) memory and impairment in executive functioning are considered as principal markers of dementia (Lezak et al., 2012). Magnetic resonance imaging (MRI) has shown that episodic memory loss is associated with hippocampal deterioration (due to lipid peroxidation, loss of neuronal integrity, oxidative stress, etc.), primarily involving the left hemisphere (Thomann et al., 2012); see Chapter 12. Other cognitive domains (abstract reasoning, conceptual formation) also become progressively impaired in the preclinical phase of AD (Amieva et al., 2008; Jacobs et al., 1995).

AD is the most common cause of dementia among the elderly, accounting for up to 70% of all dementia cases (Querfurth & LaFerla, 2010). It is a complex multifactorial disease characterized by two principal neuropathological features: increased extracellular amyloid plaque deposits in the brain and presence of intracellular neurofibrillary tangles (Querfurth & LaFerla, 2010). Such lesions gradually result in neurodegeneration, associated with increased inflammation and oxidative stress (Querfurth & LaFerla, 2010). Neuroimaging studies have reported that the AD process is initiated many years before the manifestation of cognitive impairment (Masdeu et al., 2012). In turn, epidemiological studies have shown that abnormally low performance in different cognitive domains (e.g. semantic memory and concept formation) can be seen a decade or more before the clinical diagnosis of AD, underscoring the existence of a very long and progressive prodromal phase of AD, with successive emergence of cognitive deficits, depressive symptoms and functional impairment (Amieva et al., 2005, 2008). Finally, vascular dementia is the second most common cause of dementia in the elderly and is defined as loss of cognitive function resulting from ischemic, hypoperfusive or haemorrhagic brain lesions due to CVD (Roman, 2003).

2.3 MENTAL HEALTH PROMOTION: MODIFIABLE FACTORS WITH A FOCUS ON NUTRITION

The increasing life expectancy across the world necessitates urgent public health action aimed at preserving the physical and mental health status and autonomy of the elderly via optimal control of chronic diseases and a focus on the various dimensions of quality of life (physical, psychological, social) (Woo, 2011). In fact, cognitive impairment and AD have a profound negative impact on health and quality of life not only of patients but also of their caregivers. Given the current lack of a cure for dementia, prioritizing prevention is critical. The role of various modifiable lifestyle factors, such as healthy diets, prevention of nutritional deficiencies, engagement in PA and social interaction, has been proposed as paramount prevention strategies (Hughes & Ganguli, 2009; Solfrizzi et al., 2008).

Nutrition-based strategies – focused on individual nutrients or on overall DPs – merit particular attention as prevention options regarding cognitive ageing and cognitive decline, with potentially far-reaching public health impact (Alles et al., 2012;

Otaegui-Arrazola et al., 2014). These strategies stem from research on the preventive role of nutrition in different age-related chronic diseases. Specific nutrients and dietary components that have received substantial attention in prevention research, albeit with marked heterogeneity among the findings, include B vitamins (see Chapter 8), antioxidants (vitamin C, vitamin E, flavonoids and their principal food vectors – FVs), omega-3 fatty acids (see Chapter 7), vitamin D, fish, (green) tea, caffeine and caloric restriction (Daviglus et al., 2011; Gillette-Guyonnet et al., 2013; Joseph et al., 2009). Conversely, certain dietary components, such as saturated fatty acids, have been linked with increased risk of cognitive impairment and AD (Gillette-Guyonnet et al., 2013).

2.4 DIETARY ASSESSMENT METHODS

In order to study individuals' eating habits and dietary intake, a number of research tools have been developed (Table 2.1). They can be broadly grouped into *real-time* tools, where data are recorded at (or close to) the time of eating, and retrospective tools, where data collection pertains to past (or habitual) intake. The 24 h dietary record (providing detailed information on all foods and beverages consumed during a 24 h period) is an example of the former type of dietary assessment, whereas diet histories (providing information on habitual dietary intake over a relatively long period of time) and food frequency questionnaires (FFQs) are examples of the latter type (Thompson & Byers, 1994; Willett, 1998).

FFQ can be self-administered or interviewer administered and constitute the most common dietary assessment tools used in epidemiological research. They are intended for the collection of information on the type of food and beverage consumed (selected from a predefined list) and the frequency of consumption. FFQs differ in the number of food/beverage items included, the measures of frequency (servings), weight (grams, litres) (Thompson & Byers, 1994), the description of portion sizes (i.e. using photographs or predefined standard portions), the period of time covered (past week, past month, etc.) and the presence of additional questions regarding food preparation methods and dietary supplement use (Thompson & Byers, 1994; Willett, 1998). Validation studies often compare FFQ against another dietary assessment method (e.g. 24 h recalls) or a biomarker of nutritional status (Willett, 1998; Gibson, 2005).

The development of innovative tools allows the collection of dietary intake via information and communication technologies: videotaped dietary assessment (Ortiz-Andrellucchi et al., 2009), computerized FFQ and 24 h recalls (with built-in audio and video aids), personal digital assistants, digital photography and smart cards/phones (Ngo et al., 2009). Such tools have the potential to improve dietary assessment quality and decrease researcher and respondent burden (Ngo et al., 2009). Finally, gathered information on food and beverage consumption can be used to extract data on nutrient intake via food composition tables (Willett, 1998). However, the exact nutrient content of each type of food might be difficult to calculate, as food composition varies by environmental conditions, geographical location, food production and preparation methods (Gibson, 2005; Otaegui-Arrazola et al., 2014).

TABLE 2.1
Comparison of Common Dietary Assessment Tools

Dietary Assessment Tool	Strengths	Limitations
Retrospective assessment		
FFQ	Easy self-administration	Lack of precision in estimating exact quantities consumed
	Assessment of habitual consumption/ intake patterns	Possible over- and/or under-reporting
	Relatively cost and time efficient	Differences in portion size description across FFQ
	Does not impact eating habits	Inconsistent number of items across FFQ
	Can be administered to very large study samples	Heterogeneity in time period covered (past week, past month) across FFQ – difficult to complete when longer time periods assessed
	A number of validated FFQ available	
	Streamlined data format	
Diet history	Assessment of habitual dietary intake over a long period of time	Possible misreporting/ under-reporting
	Information on food intake by meal	Might lack precision in estimating exact quantities consumed
	Structured interview with prompts	Might be burdensome and time-consuming for investigator and for respondent
	Does not impact eating habits	Lack information on current dietary habits/potential dietary modifications
	Stability of dietary intake data	Might not be suitable for very large study samples
	Data available on rarely consumed foods	Cost-efficiency might be low
Real-time assessment		
24 h dietary record/recall	Detailed information on all foods and beverages consumed during a 24 h period	Might impact dietary habits if day of assessment is known in advance
	Precise assessment of quantities consumed	Might be burdensome and time-consuming for respondent
	Assessment of current (actual) eating behaviour	Lack information on past dietary habits

(*Continued*)

TABLE 2.1 (*Continued*)
Comparison of Common Dietary Assessment Tools

Dietary Assessment Tool	Strengths	Limitations
	Possibility to assess rarely consumed food items when multiple 24 h records are administered	Possible under-reporting
	Method appropriate for most study populations	Cost-efficiency might be low
		Time-consuming data entry
Food diary (food record)	Detailed information on all foods and beverages consumed (usually) during a 7-day period	Heterogeneity in data format
	Assessment of current (actual) eating behaviour	Method not optimal for large study samples
	Precise assessment of quantities consumed	Might impact dietary habits
	Can serve as a weight-loss aid	Lack information on past dietary habits
	Method better adapted for small study samples	Investigator and respondent burden
		Time-consuming data entry

It should be kept in mind that research data gathered in nutritional epidemiology might be subject to several kinds of bias due primarily to the fact that individual consumption/intake data are self-reported (Willett, 1998). In particular, the issues of recall bias, prevarication bias, measurement error linked to the estimation of portion sizes and under-reporting, among others, have been extensively discussed (Gibson, 2005; Willett, 1998).

2.5 DPs: DEFINITION, IMPORTANCE AND A PRIORI AND A POSTERIORI INDICES

Food constituents are not independent but are in fact interrelated in complex ways, showing synergistic, additive and antagonistic effects which, in turn, support the idea of dietary variety and the importance of consuming nutrient-rich foods (Jacobs, Jr. et al., 2009). The combination of naturally occurring food components is the food matrix which has a differential, arguably greater influence on the human biological systems and on health overall than the influence exerted by the individual components (Jacobs, Jr. et al., 2009). Generally, DPs fall into two principal categories (see Table 2.2): (1) hypothesis driven, *a priori* indices or scores taking into account the role of nutrition in disease prevention, and (2) data driven, exploratory *a posteriori* factors and clusters (Gu & Scarmeas, 2011; Hu, 2002; Kant, 2010). Recently, a third category which is a hybrid of the hypothesis-driven and data-driven methods has been used for the evaluation of DP reflecting intake

TABLE 2.2
Comparison of *A Priori* and *A Posteriori* DPs

Characteristics (Including Strengths and Limitations)	*A Priori* DPs	*A Posteriori* DPs
Theory (guideline) based	X	
Hypothesis driven	X	
Data (sample) driven		X
Characterize overall (total) diet	X	X
Diet quality index or score	X	
Generalizable (high external validity)	X	
Multiple components included in score	X	
Account for entire quantity of intake		X
Latent factors reflecting correlations among diet variables		X
Nutrient or food group clusters (mutually exclusive)		X
Exploratory in nature		X
Allow for synergy among dietary/nutrient components		X
Describing eating habits/dietary behaviour		X
Subjective decisions about food groups	X	X
Subjective decisions about scoring	X	X
Can be studied in relation with health outcomes	X	X

of specific nutrients or biomarker concentrations with hypothesized associations with predefined health outcomes (Gu & Scarmeas, 2011; Hoffmann et al., 2004; Kant, 2010).

2.5.1 A Priori DPs

The *a priori* approach is based on the investigation of diet quality via dietary intake variables (quantified and summed up) considered important for various health outcomes (Waijers et al., 2007). There are diet quality indices based on nutrients (e.g. micronutrients, dietary fat, total energy), indices based on food or food groups (i.e. FV, dairy products, etc.), as well as indices based on nutrients and foods (Kant, 1996; Waijers et al., 2007). More than 20 different *a priori* DPs have been created, largely belonging to two main categories: (1) indices based on official nutrition guidelines (recommendations) and (2) indices or scores based on specific dietary styles (Gu & Scarmeas, 2011; Hu, 2002; Roman-Vinas et al., 2009). Examples of the former category include the Healthy Eating Index (HEI) (Kennedy et al., 1995), Dietary Approaches to Stop Hypertension (DASH) (Appel et al., 1997), diet quality index (Patterson et al., 1994), healthy diet indicator (Huijbregts et al., 1997), Programme National Nutrition Santé Guideline Score (PNNS-GS) (Estaquio et al., 2009) and the Canadian HEI (Shatenstein et al., 2012). An example of the latter category is the Mediterranean diet (MeDi) (Trichopoulou et al., 2003).

The *a priori* approach entails the assignment of sub-scores for each of the predefined food or nutrient groups and the calculation of a graded score or index using