Eur J Nutr (2005) 44 : 465–484
DOI 10.1007/s00394-005-0584-5

ORIGINAL CONTRIBUTION

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Attention, psychomotor functions and age

Received: 6 February 2005
Accepted: 9 August 2005

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Summary Nutrition might play an important role to ameliorate or to buffer age-related declines in attention and psychomotor functions. The assessment of nutritional effects in aged subjects has to take into account that attention and psychomotor functions can be subdivided in different functions that are differentially affected by age. This paper gives an overview of changes in different facets of attention and psychomotor functions beyond fifty as well as assessment methods for attention and psychomotor performance. It also provides a review of models to explain the pattern of changes with increasing age, and discusses the problems of high performance variance and of age related confounding variables like health status. Two different approaches are discussed that analyse a performance profile and an experimentally oriented functional microanalysis of changes in performance with respect to the effects of nutrition on attention and psychomotor functions. Addressed are examples of missing age-related deficits or even age-related superiority. Caffeine and Ginseng are considered as examples to enhance performance in older persons. Results are in accordance with data on the positive role of physical fitness for mental performance in older persons. Performance of older persons can well be enhanced by functional food components or nutritional supplementation. The effects are comparable to the effects obtained in younger groups, while there is only weak evidence for specific compensatory effects in aged persons. Finally the role of nutrition for the processes of healthy aging is discussed.

Key words attention – age – psychomotor functions – functional foods – caffeine – ginseng

General, psychomotor and attentional changes beyond 50

A broad range of empirical evidence from neuropsychology, differential psychology, selection and psychometry, developmental psychology and gerontopsychology demonstrates changes in information processing with increasing chronological age, which can be summarized by the term "general slowing" in a rough approximation.

Peripheral sensory functions (audition, vision) tend to show increased impairment with age especially after an age of about 50 [1]. Age-related changes in cognition are often referred to as a general slowing of mental processes [2]. In addition to changes in sensory functions and central information processing we find marked changes in executive motor systems. At the age

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of 60 maximum muscular force is reduced by about 50% and maximum movement speed up to 90% [3]. On the other hand submaximal force and speed show only small to moderate reduction.

The impact of these changes is ubiquitous. An age-related analysis of traffic accidents in Finland shows that attention and (to a lesser extent) fatigue show a drastic age-proportional increase as primary causal factor in traffic accidents [4]. Recent studies strengthen the view that these attentional deficits are most critical in complex traffic situations like left turns in dense traffic [5].

Input-related and response-related analyses of brain activity allow to highlight the effects of age on different steps in information processing. Declined sensory functions are reflected in changes of early components of evoked potentials and could be demonstrated repeatedly [6, 7]. Peripheral factors are only partly responsible for age related performance decrements in reaction time as later components, which can be viewed as indicators of central slowing, show far larger effects [2, 8]. All in all, speed of information processing and response speed show a clear-cut reduction with age.

Changes in speed of information processing alone cannot explain the pattern of changes in attention related and psychomotor tests. Increasing support can be found from brain imaging studies for the hypotheses that central inhibition processes are especially impaired. Central information processing seems to become less specific as far as the activity of specific brain regions for specific tasks is concerned. There is direct empirical evidence from studies with topographical recordings of brain activity during specific tasks that topographic specificity and lateralization of neural activity is less pronounced with increasing age [9–13]. Topographic specificity is positively correlated with cognitive performance in a broad range of measures [14]. Functional analysis of brain activity using modern functional assessments of brain activity (PET and fMRI methods) demonstrated that more brain regions are activated in aged SS for the same tasks [15–17]. Thus, reduction in speed might be partially attributed to a central recruitment process in brain activity, which means that new neuronal networks are established to compensate functional impairment. In addition decreased activation of task related brain areas shows that different functional changes have to be considered [18]: under-recruitment, non-selective activation and compensatory recruitment. Comparing high and low performing older subjects Cabeza et al. (2002) [19] support the view that high performing elderly show an activation pattern indicating compensatory recruitment.

Performance data as well as neurobiological evidence for age-related changes in information processing are complicated by a broad range of moderating factors, which result in less clear-cut evidence for age-related declines in attention and psychomotor functions than expected. One major reason is the increasing interindividual variability with increasing age. Thus, some subjects show clear-cut reductions in performance, while others do not or even maintain a beyond average level of proficiency till high age. Specific cognitive functions show less impairment than expected, especially if moderating factors and peripheral changes are controlled for [20]. One important factor in the context of nutrition seems to be the (psycho-)physical state of older people. Physical fitness is associated with better performance and mood state. Physically fit persons maintain high performance levels to considerable age. And physical training programs can increase physical fitness and improve cognitive functioning in the elderly [21]. The fact that a better metabolic situation for the brain is one consequence of physical fitness seems to open interesting options for nutritional interventions.

Attention and psychomotor changes in aged persons

Concept and assessment of attention

Attention is a complex phenomenon with a broad range of facets and functions. Changes in attention processes contribute to performance decrements in a broad range of cognitive tests like memory or psychomotor performance. Attention can be considered as a psychological function, which allows us to focus on information, select information, divide and sustain the limited processing capacity to different tasks and to inhibit distracting information and thus prevent interference with ongoing activities. Parasuraman [22] groups attentional functions into three categories: selection, vigilance, and control. Selection of information from the environment and internal cues is a basic attentional function. Selection can vary with respect to the quantity of selected information ("attention span") and with respect to speed and accuracy of selection. An important function of our attention system is to allocate attention to certain events over a longer period of time (e.g. when we have to monitor the functions of a technical system). This facet is termed vigilance. Attention control encompasses focussing, shifting, and dividing attention with respect to different sources or aspects of information.

One possible taxonomy of attention phenomena comprises of six basic attention facets, which will be considered: attention span, selective attention, vigilance, focussed attention, shifting attention, and divided attention.

Attention span is the amount of information that is represented mentally at one time. Attention span can be measured by reproducing increasing series of digits forward or backward [23]. This test is also used to assess the capacity of the so-called working memory, i.e. this test is sensitive to changes in attention and short-term memory as well. Performance in tests of memory span is decreased with age as Salthouse [24] demonstrated using the computation span as indicator.

A more perceptual based measure of attention span is the "useful field of view (UFOV)", which shrinks with increasing age [25]. The UFOV turned out to be a good predictor of increased driving accidents [26] for aged drivers. A very interesting aspect is the option to increase the UFOV by training, which is possible even in aged persons [27].

Selective attention allows selection of specific sensory inputs and/or specific memory cues. This can be achieved by strengthening selected information and/or inhibit non-relevant signals. The process of selection has been studied primarily in visual (or acoustic) search tasks. A target has to be detected/located in a visual search field (e. g. screen), which contains a larger amount of non-targets. A psychophysiological mechanism named sensory inhibition is an essential factor for selective attention.

One of the best known tests for selective attention is the Attention Capacity Test [28] where persons have to cross out letters (d) which are marked with 2 lines, from a set of non-d or d with less or more than two assigned lines. In addition to these psychometric tests experimental paradigms like the dichotic listening task are classical methods to study changes in selective attention together with self-ratings of subjective states like alertness, concentration, attentiveness. Sometimes psychophysiological recordings like eye-tracking, recordings of electrodermal activity or of brain activity via EEG supplement the experimental tasks.

Especially in working areas with high demands on selective attention, like air traffic controllers, it is essential to check the staff's changes in selective attention due to age.

Age-related declines of selection performance can reliably be measured. In case of difficult features and brief display duration age related impairment is quite large [29]. Madden et al. [29] attribute declines in visual selective attention primarily to a general slowing, which is accompanied by problems in inhibitory processes. Conversely age differences become quite small in case of simple features and after sufficient practice with the task or with the option for proper preparation for the reaction at hand, like provision of relevant cues [30].

Vigilance (sustained attention) describes the ability to maintain attention over longer periods of time. In many instances vigilance is studied in monitoring situations with a low density of relevant signals like the occurrence of technical errors. Sustaining attention over prolonged times is a resource-consuming process, which can actively be prolonged by a motivational mechanism termed effort.

Modern industry and problems in new war-techniques led to examinations in the early 1930. Generally the performance in vigilance tests will be counted by the amount of the not noticed targets or the length of reaction time when targets were named correctly. In addition false alarms are measured in some of the tasks. There are various tests available for this specific area of attention using computerized versions of classical tasks like the Mackworth clock, which shows clearly visible but rare "double steps" of the clock hand, which have to be recognized. The vigilance test or the signal detection test of the Schuhfried test system can be used to assess vigilance and sustained attention in a highly reliable way. Experimental function related analyses (see below) allow multi-level approaches including performance data, subjective state assessment and psychophysiological recording.

While target detection (especially in cases of perceptual discrimination tasks) is impaired in older subjects additional performance decrements over prolonged time are parallel for different age groups [31]. In addition to missing additional age-related declines in vigilance performance with increasing time on task, age differences in sustained attention diminish, if health problems are accounted for [32]. As in other functions practice will diminish age effects, while increasing complexity and memory demand of the task will result in reliable age deficits in vigilance tests.

Focussing attention on a particular informational cue especially in the presence of distracting conditions is a basic function of attention control. This is different from selective attention as in tasks of focussed attention the relevant cue is well known and present. Tasks on selective attention demand the detection of certain informational cues.

The Stroop Colour Word Test and its variants show reliable age related loss in speed in the condition in which target stimuli (physical colour of the word) and semantic aspects of the stimulus (the denominated colour) interfere. There are a number of more global tests where the persons for example have to recognize faces and names, recognize abstract figures, following lines with the eyes, labyrinth-tests etc., which are dependent on focussed attention.

Age differences were repeatedly found in standard tests, which require reaction to a signal or informational component, which is presented together with highly salient competing inputs. These tasks are termed interference tasks. Detailed analyses of experimental distractors show that age differences become small, when the participant knows exactly where to focus his attention.

Divided attention allows the conduction of multiple tasks

Divided attention can easily be realised in experimental settings and by giving multi-tasking instructions. Most simulators require division and switching of attention.

Even standardized tests of divided attention need a complex set-up with different reaction options. Thus basic psychomotor functions are required and age-related changes in psychomotor functions affect the performance scores.

Tests on divided attention are well investigated, because of the common use in traffic-psychology. Most tests work with multiple reactions. Divided attention is necessary for complex simulator situations (e. g. flight simulator). One has to concentrate on various numbers of visual and acoustic stimuli which appear simultaneously and without former warning. Persons have to react by using hands and/or feet.

Aged persons should show additional decrements in dual tasks compared to single tasks if their capacity is lowered. In accordance with this view, Craik and McDowd [33] showed disproportional decrements for complex dual tasks with increased age. This effect does not appear with less complex tasks and is dependent on practice [34].

Shifting of attention

The switching of attention from one input to another is an additional important process, which shows age related decrements in a couple of studies. The age-related decrement is enhanced if the task taxes executive functions like response selection [29]. The rate of shifting attention between different sources shows a clear-cut reduction with age [35]. The assessment is quite similar to divided attention; only the instructions are changed.

Controlling for perceptual slowing factors can reduce age effects [36]. Age differences in shifting attention diminish if valid cues for the shifts of attention are available [37, 38]. Again age differences become more reliable for more demanding tasks like double tasks in a driving simulation.

Automaticity

Automaticity is not a facet of attention, but an important moderator between attention and performance. Action in highly practised tasks can become less and less attention demanding. Highly practised actions are generated automatically in a given condition (e. g. switching gears while accelerating a car).

Automatic processes, which are acquired in young age, seem to be preserved to old age without substantial performance decrements until peripheral motoric functions are fading. In these circumstances prior automatised functions will start to require attentional control again. Thus, active attentional control of prior automatic processes is necessary to perform the action without errors in old persons. This is necessarily related to marked performance declines. The acquisition of new automatised functions is impaired or at least prolonged for aged persons, especially if visual search is part of the activity [39] or new complex motor control has to be established. The problem of automation demonstrates one of the close links between psychomotor performance and attention. Note that in many applied contexts automation of repeated action might be impaired in older subjects due to the fact that old ways of work have to be inhibited.

Arousal

The decline in wakefulness or "arousal" when becoming sleepy or when doing monotonous work is a major reason for attention-based errors and performance declines. With decreased arousal attention becomes less focused and problems with vigilance occur. On the other hand over-arousal and stress lead to a narrowing of attentional focus, a reduction in attention span and to problems in dividing attention. With increasing age we find marked changes in psychophysiological arousal systems, mostly in the direction of under-arousal. Most prominent are changes in sleep-wake regulation and changes in sleep patterns. The reduction in recovery due to non-optimal sleep patterns is accompanied by reduced daytime activation at least in resting conditions. Thus arousal is a potential moderator of attention and psychomotor performance in aged subjects, which is also directly dependent on nutritional factors (e. g. "post-lunch dip").

Psychomotor processes

Neuroanatomical background

A brief look at the neuroanatomical changes with increasing age especially in brain regions that are related to motor control and considerable changes in neurotransmitter systems in motoric brain systems leads to the hypothesis of large psychomotor changes with age. Dopamine neurons in basal ganglia decline 5–10 % per decade [40], dopamine receptors are reduced up to 50 % in the brains of aged persons [41]. Changes in peripheral muscles and especially changes in the peripheral muscle innervation and activation patterns lead to qualitatively different motor activity in the aged [42, 43].

Psychomotor functions cover a broad range of morphologically and functionally different phenomena. Functions range from highly automised gross motor activities like walking to highly skilled fine motor skills like knitting or running a computer program by highly skilled, precisely located mouse clicks. In the early decades of experimental psychology it could already be shown that skill learning and motor performance accuracy suffer from increasing age, especially when unfamiliar tasks are used [44]. Following an object manually (tracking) shows clear-cut age deficits in many studies [45]. Cognitive skill learning also shows age-related impairment.

Execution time for complex nonverbal tasks shows clear-cut impairments with growing age and has been proposed as a psychological age marker [46]. Note that age effects in simple reaction time tasks can be diminished to zero, if factors like novelty, stimulus quality etc. are excluded. Complex stimuli and especially response selection show age-related impairments in nearly all studies. Older subject show marked difficulties in inhibiting previously learned automatic processes [47]. This corresponds to the cue inhibition problem in attentional tasks and is well supported by brain imaging studies, which show marked differences in frontal/prefrontal cortical areas and in frontal lateralisation. These brain regions are centrally involved in inhibitory behaviour control.

Peripheral factors

The evaluation of psychomotor performance has to take into account that not only the central regulation changes with age but also local innervation patterns and muscle strength are changed [42]. New psychomotor tasks with sufficient difficulty show an impaired performance of aged groups even after extensive practice [43]. Changes in innervation of motor neurons in the spine lead to problems in keeping a high torque level for aged persons and the changed innervation pattern causes problems in smooth well-timed and well-powered movement and grip. Nevertheless some of the problems can be counteracted by physical training [48].

Finally, motor control shows clear cut changes in aged persons. Older persons have to rely stronger on practice and visual control as proprioceptive feedback is considerably impaired. Age-deficit is partly compensated if "top down" control is increased due to preparation or self-organisation of movement. Together with slowed sensory information integration aged persons perform normally far below young subjects if corrective adjustments become necessary. Another feature of adult motor activity is the development of a deficit in adjusting grip force to the task at hand. Older persons often show excessive grip force and thus excessive safety margins in grip strength [49].

Motor time

Response time to a simple stimulus can be separated into three components: signal detection, central processing (e. g. response selection) and the time required for the motor response (e. g. time to reach the reaction button). As a consequence of motor impairment response time is increased partly due to increases in motor time. Movement time in simple reaction time experiments shows age related changes, which parallel the reaction time curve, thus adding up to a total response delay.

Fozard et al. [50] conducted a longitudinal study with a larger sample, which was tested in two-year intervals (Baltimore Longitudinal Study). They estimate that simple reaction time increases about 0.5 ms/year. Young–old differences can even be increased by longer preparation times, an indication that problems in maintaining fully prepared reaction patterns increase with age. Further amplification of age-related increase in reaction time can be observed with increases in alternatives, indicating prolonged decision times for aged persons [51]. In a simple reaction time experiment Rabbitt [52] enhanced the number of irrelevant perceptual cues and the number of response alternatives. The performance of older SS was especially affected by the increase in perceptual cues. These results indicate a close interplay of age-related changes in attention, central processing and psychomotor performance.

Welford [53] gives a figure of an about 30 % increase of movement time for older adults compared with young persons, and Stelmach, Goggin, Garcia [54] found differences close to 70 % increased movement times in a simple point to point movement task. There is a tendency of increasing age differences with increased movement difficulty. Especially movement amplitude affects older persons. With increasing movement difficulty aged persons tend to give more weight to precision of the movement, which goes hand in hand with reduced speed in many instances (i. e. switching the speed-accuracy trade-off towards increased accuracy) [55].

Speed of movement has repeatedly been used as an age indicator. Again, for "easy" tasks with sufficient exposure time of stimuli age effects can drastically be reduced. Another point, which should be mentioned again, is the striking increase in inter-individual variability for older persons. Practice, training and high skills as well as physical fitness moderate age effects. Aged persons with high physical fitness outscore sedentary younger individuals as reported by Spirduso [56]. Physical training can compensate age-related declines. Note that physical fitness has an overall positive effect on cognitive functioning, attention and performance in older persons [21].

Assessment of attention and psychomotor functions

Different approaches of neuropsychological assessment

The assessment of deficits in cognitive functions has a long tradition within neuropsychological testing. Two approaches have been proposed. The first approach tries to assess the performance profile. Tests for different functions are evaluated against norms and depicted in a profile that reveals strong and weak points in the performance profile. Based on this approach one can try to find common factors in the tests (like speed of information processing) and thus characterize age-related changes in psychomotor performance or attention. This "macro-approach" has been used frequently in studies of nutrient effects on attentional functions in aged SS. A closer look at age-related changes in attention and especially in complex psychomotor functions shows that the field is quite complex and we even find qualitative changes. One problem common to most studies with test profiles suffer from the fact that test performance requires a set of psychological functions, which can hardly be separated from test performance measures. In these instances the psychometric test approach should be complemented by experimental functional analyses, which try to elaborate which psychological functions contribute to the observed deficits and which mechanisms are used to buffer or compensate for age-related deficits. The process-oriented "microanalysis" tries to follow the information processing steps necessary for performance in a certain test and tries to identify the deficits in the various steps in the information processing system. This approach is used in cognitive psychology, and in functional neuropsychological testing. The basic question in this approach is "How can we compensate for deficits by different ways of information processing and/or function substitution".

The functionally oriented micro-analytical approach plays an important role for the understanding of age-related changes in attention and psychomotor performance and is recommended for future research on the role of nutrient factors for age-related attentional and psychomotor deficits.

Overview across tests for attention and psychomotor functions

According to the attentional and psychomotor processes discussed above there are several tests, which are listed in Table 1.

Psychometric tests and tests from test batteries like the cognitive drug research test battery or the Nuremberg Age Test Inventory or from neuropsychological batteries like the Luria-Christiansen Test Battery or the Halstead-Reitan Test Battery are summarized in Table 1a.

The tables provide the tests, available data on the reliability of the tests, authors of German and English versions, and a brief description of the test procedure. Reliability is a statistical figure, which indicates the precision of measurement of psychological tests. The figure ranges between zero and one. One indicating 100% proportional inter-individual differences with repeated measurements and zero indicating total non-concordance. For a performance test a value above $r = 0.8$ can be considered as satisfactory. Reliability is a necessary but not a totally sufficient condition for psychological tests. In addition one has to prove that the tests assess the functions which it claims to do (validity). Thus a test on selective attention should measure this function and not memory or psychomotor performance. Some of the tests given in Table 1a assess specific facets of attention while others give a more or less global measure, without reference to a specific attentional function. Some of the more specific tests have been described in section 2. Tests that show a high proportion of overlap between attention and psychomotor aspects during response execution are given separately in Table 1b. Highly reliable tests are available as can be seen in Table 1b.

Tests on psychomotor performance are listed in Table 1c. Changes in psychomotor performance have found a broad interest in neuropsychology and pharmacopsychology. Thus a broad range of psychometric tests and experimental paradigms exist.

Whereas the tests mentioned above focus on attention the main target of psychomotor performance is the motoric reaction. One common aspect of these tests is measurement of response time and accuracy of movements.

Experimental approaches start with simple tapping and aiming exercises, cover specific kinetic and kinematic studies with electromyographic recordings, assess posture and complex movement or give specific psychomotor task in a simulator (e.g. driving simulator). Movement with differently distanced and differently sized targets are used to assess precision of movement and its relation to movement time. To separate motor time in reaction time assessment a "rest-button" for the dominant index finger is used in most reaction time experiments to separate the time to start the reaction and the motor time to hit the correct response button.

Table 1a Attention

Test	Reliability	Author(s)	Brief description
Digit Span	0.65	Wechsler, D.	repetition of digits
Attention capacity test		Brickenkamp, R.	cross out letter d with 2 lines; number of correct/incorrect indentations
Bonn Concentration Test	0.79 –0.82	Fay E., Meyer M.	computer-aided programme, ability of concentration
Bourdon Test	0.88–0.92	Bourdon, B.	cross out letters or figures, number of correct/incorrect indentations
Cognitrone (Computerized match to sample)	0.51 –0.98 (split-half)	Schuhfried, G.	4 submittals 1 task field, figure congruity
Face Name Associations Test	0.91 und 0.93 (30er Version) 0.70 und 0.81 (10er Version)	Kessler, J., Ehlen, P., Halber, M., Bruckbauer, T.	recognize faces and names: face – name; name – face; finding name out of targets; finding face out of targets
Facial recognition test	need to be evaluated	Benton, D.	recognize faces out of a series of faces
Field Marking Test	0.95	Hentschel, H.	find target figures
Figure Test	0.60		recognize abstract figures
Frankfurt Attention Inventory	0.85–0.91	Moosbrugger, H., Oehlschlaegel, J.	find target-figures, underline the item-row, emphasise target figures by marking
Geriatric Concentration Test	0.89–0.94	Gatterer, G.	recognize a figure; Speed, number of correct recognition, number of errors
Judgment of line orientation	0.89 –0.94 (split-half)	Benton, D.	identifying lines that match the angle of 2 incomplete lines
Phoneme discrimination		Benton, D.	recognize sounds (same or different sound)
Symbol Digit Substitution Task		Royer, F. L.	
Test battery for Attentional Performance	0.81 –0.97	Zimmermann, P., Fimm, B.	simple reaction-time paradigms, visual or acoustic stimulus
Colour Word Test (STROOP)	0.74 –0.83	Bäumler, G., Stroop, J. R. (1935), Golden, C. J. (1978)	reading colour-words printed in black, naming the colour of colour-bars, naming printing ink of colour-words
Concentration Calculation Test		Haensgen, K. D.	arithmetical problems, time pressure (computer based)
Continuous Attention	0.76–0.87	Schuhfried, G.	find targets (various numbers of triangles (peak down)) out of other triangles (peak up); number of correct/incorrect namings, reaction time, number of missings
Digit Symbol Substitution Test	0.89 –0.97		refer numbers to symbols
Digits forward/backward	0.64		repetition of numbers
Numerical Squares	no comments		numbers 1 to 36 are jumbled up (background of numbers – different colours), naming the colours from 1 to 36 (computer based)
Sentence repetition test		Benton, D.	repetition of sentences
Sentence Repetition Test	0.81		repetition of sentences
Signal Detection	0.74–0.85	Schuhfried, G.	points distributed on screen, finding squares (computer-based); detection time, correct/incorrect reaction, missings
Speed Selection Test	0.89 –0.92 (healthy) 0.76 –0.79 (clinically)	Gaal, L.	detection of target-bar; reaction time (computer-based)
Test battery for Attentional Performance	0.81 –0.97	Zimmermann, P; Fimm, B.	alertness: reaction – symbol (with or without an acoustic information) (computer-based)
Vigilance Test	0.91 –0.97	Schuhfried, G.	points (arranged as a circle) distributed on screen – lighted up successively, target – omission of 1 point (computer-based)
serial searching of digits		Abels, D.	cards with numbers, target – "43" "63" or "43 and 63", processing-time

Table 1b Attention related psychomotor coordination

Test	Reliability	Author(s)	Brief description
Peripheral Perception and Tracking Measure	0.95 –0.96	Bukasa, B., Wenninger, U.	central task (holding a bar in the middle of a dynamic field) and peripheral perception task (light stimuli – field of vision marginally) (computer-based)
Reaction and Movement Time Test	0.95 –0.98	Gediga, G., Schoettke, H.	reaction on targets on screen with pushing or unclasp a key – various conditions of complexity
Vienna Determination Test	0.99–1.00	Schuhfried, G.	reaction on visual/acoustical signals, pedals and keys
Line Maze Test	0.90–0.91	Bukasa, B., Wenninger, U.	following 1 out of 9 lines with eyes, time pressure
Line Persecution Test	0.96 –0.98	Wagner, M.	following lines with eyes and naming the number printed at the end of the line
Trailmaking	0.89 –0.98	Reitan & Davison	conjoining numbers/digits and letters
Vienna Determination Test (complex serial reaction time test)	0.99–1.00	Schuhfried,–Fa-Dr-G.	reaction on visual/acoustic signals, pedals and keys

Table 1c Psychomotor functions

Test	Reliability	Author(s)	Brief description
Developmental Test of Visual Perception – Adolescent and Adult	empirically established reliability		6 subtests: Copying, Figure-Ground, Visual-Motor Search, Visual Closure, Visual-Motor Speed and Form Constancy; measures different but interrelated visual-perceptual and visual-motor abilities
Motor Performance Series	0.63 –0.86	Schoppe	arm-hand-consistency, wrist-finger-speed, precision of arm-hand-motion, speed of precise arm-hand-motion, skill of hand by manipulating big objects, skill of fingers by manipulating big objects, psychomotor coordination – uniform motion
Visuo-motor Coordination Assessment Procedure	no comments	Moeller, A.	persecution of lines or motions, various types of tracking tasks (computer-based)
tube-figures		Stumpf, H., Fay, E.	cubes with hose-figures inside – finding the right cube (presented from another side) out of a number of items
Finger-Oscillation test		Reitan & Davison	finger tapping as quick as possible in 10 sec.
Purdue Pegboard test		Klove & Matthews	putting metal pieces upright into slots
Maze Test G	0.77 –0.82		way out of a labyrinth

Hypotheses on age related attentional and psychomotor deficits

General slowing hypotheses

The general slowing hypotheses received a great amount of support from studies with different psychometric testing procedures. Controlling for changes in speed attenuates all other cognitive performance differences between young and old groups [57]. Perceptual speed seems to be one of the most important factors. Thus, the general slowing hypothesis has to account for impairments in peripheral perceptual systems. With increasing age the senses show a loss in performance. In accordance with this problem, declines in visual attention are reduced if the visibility of cues is increased. Another feature of performance with increasing age is that speed is reduced in many instances, while the number of correct responses shows no effect or even a reversed effect. This indicates that the speed accuracy trade-off is often changed towards increased accuracy for older subjects. Less speedy/impulsive and more cautious/error free behaviour with increasing age might partly be an expression of increased experience and wisdom (due to high costs of errors) and not only a "shift" in speed/accuracy trade-offs due to reduced speed with increasing age.

Finally a decrease in speed of response selection and execution might contribute to an age-related performance decrement in attentional tasks.

Deficit in inhibition hypothesis

Attentional deficits with increasing age can be demonstrated in experiments in which cues have to be ignored actively. Examples are reversal of the meaning of cues or tasks in which a prior response has to be suppressed. The Stroop task requires active inhibition of an informational component. A colour word is written in a different colour and the colour of the letters has to be named. This task shows consistent age-related decrements, which cannot be explained by the general slowing hypotheses [58].

The "deficit in inhibition" hypothesis was repeatedly used to explain age-related performance decrements in a broad range of performance areas including declines in motor skills. The inhibition hypothesis explains age-related attentional changes by a reduced signal-to-noise ratio for aged and problems in inhibiting non-relevant cues. This hypothesis explains the fact that age effects on performance are often diminished in simple or highly skilled tasks, while they appear in complex choice reaction tasks, in tasks with degraded informational input and in tasks involving background activities.

Reduced working memory capacity hypothesis

Alternatively one can view age-related declines in attentional tasks as a sign of reduced spare capacity in the working memory. Traffic accidents increase with age not in a linear fashion, but especially in high complexity situations like left turns (right turns in UK). Left turn simulator errors of aged participants could be reduced by additional cues indicating right of way information. Deficits in inhibition of distracting information, problems in switching attention in complex situation and/or missing spare capacity explains the result of McKnight and McKnight [59] that marked age differences in a simulator appeared during additional "cell phone"-conversation and not in the control condition.

Attentional and psychomotor changes due to selected nutritional variables

Table 2 gives an overview across selected empirical results on changed attentional and psychomotor process for aged persons (Table 2a) and younger persons (Table 2b). The following sections summarize the basic results.

Caffeine

For younger samples a broad range of performance measures show clear-cut effects of caffeine on attention and psychomotor speed. Even after separating effects into possible deprivation relief effects and deprivation unrelated effects an overall positive picture of short term effects from caffeine on continuous performance tasks like serial letter cancellation, serial arithmetic, choice reaction time up to simulator performance could repeatedly been shown [60].

These results as well as considerations on the working mechanisms of caffeine lead to the hypotheses of positive counteracting effects of caffeine on age-related attentional and speed-related psychomotor deficits (as long side effects like rise in blood pressure and changes in sleep can be tolerated).

Correlational studies

Jarvis [61], Johnson-Kozlow et al. [62], and Hameleers et al. [63] related self-reported caffeine consumption to test performance in a series of psychometric tests in two quite large samples. While Hameleers et al. only reported improved long term memory and faster locomotor speed with high caffeine consumption the study of Jarvis [61] reported reduced simple and reduced choice reaction time together with improved memory and visuo-spatial reasoning with increased caffeine consumption. These authors report positive effects especially for the older SS. Johnson-Kozlow separated men and women, she reports clear-cut association between improved test performance and caffeine consumption in a broad range of tests only for women below 80 years of age. For men and for women beyond 80 the correlation between performance and self-reported caffeine consumption remained positive but was low and statistically nonsignificant. No correlations were found for decaffeinated coffee. Rogers and Denoncourt [64] conclude cautiously from their review that despite some evidence for positive effects of caffeine on performance indications of specific compensation of age-related deficits are rare and thus side effects and the problem of separating withdrawal relief [65] and positive effects make it difficult to come to an all in all positive conclusion as far as caffeine, attention and psychomotor performance are concerned. Van Boxtel et al. [66] conclude from a large Dutch longitudinal study that the positive correlation between caffeine consumption at baseline and increased psychomotor speed six years later for the older participants does not give convincing support for the idea of counteracting age-related declines in performance by caffeine.

Experimental studies

Experimental studies all in all show positive effects of caffeine and psychomotor performance, with only weak evidence for specific age-related positive effects.

Lorist et al. [67] could demonstrate positive effects of 250 mg caffeine in a placebo-controlled study for young and old adults in selective attention, reaction time and increased amplitudes in brain-evoked potentials for perception and attention-related components. For a late

Table 2a Empirical studies on attention psychomotor performance and selected nutritional factors in aged persons

Author, year	Subjects	Design	Drug/conditions	Measures, tests	Results
Hameleers P. A., et al., 2000	1875 adults; 24–81 years	Laboratory conditions	Caffeine	Multiple regression analysis with control for age, sex, socio-demographic variables, and substance use.	Habitual caffeine consumption was significantly related to better long-term memory performance and faster locomotor speed. No relationships between habitual caffeine consumption and short-term memory, information processing, planning and attention as measured with the Stroop Test. No difference in sensitivity to caffeine intake between different age groups.
Jarvis M. J., 1993	9003 adults	Cross-sectional survey	Caffeine	Tests of simple reaction time, choice reaction time, incidental verbal memory, and visuo-spatial reasoning, self-reports of usual coffee and tea intake	Dose-response trend to improved performance with higher levels of coffee consumption for all four tests ($P < 0.001$ in each case). Higher levels of tea consumption improved performance in simple reaction time ($P = 0.02$) and visuo-spatial reasoning ($P = 0.013$). Estimated overall caffeine consumption showed a dose-response relationship to improved cognitive performance ($P < 0.001$ for each cognitive test, after controlling for confounders). Older people appeared to be more susceptible to the performance-improving effects of caffeine than were younger persons.
Johnson-Kozlow M., et al., 2002	890 women (mean age of 72.6 years) and 638 men (mean age of 73.3 years)	Correlationed study	Caffeine	Cognitive function: 12 standardized tests, lifetime consumption and current coffee consumption: questionnaire	Higher lifetime coffee consumption in women was associated with better ($p \leq 0.05$) performance on six of 12 tests (trend ($p \leq 0.10$) on two other cognitive function tests). Caffeinated coffee intake was associated with better performance on two tests ($p < 0.05$) (with a trend ($p < 0.10$) on one other test). Among women aged > 80 years, lifetime coffee intake was non-significantly associated with better performance on 11 of the 12 tests. No relation between coffee intake and cognitive function among men or between decaffeinated coffee intake and cognitive function in either sex.
Kaplan R. J., et al., 2000	10 men and 10 women (60 to 82 years)	Placebo controlled experimental study	50 g carbohydrate as glucose, potatoes, or barley or a placebo	Plasma glucose and serum insulin	Difference in plasma glucose after food consumption [glucose > potatoes > barley > placebo ($P < 0, 03$)] did not predict performance. Performance did not differ with consumption of the different test foods, baseline score and beta cell function correlated with improvements in immediate and delayed paragraph recall for all 3 carbohydrates (compared with placebo); the poorer the baseline memory or beta cell function, the greater the improvement (correlation between beta cell function and improvement in delayed paragraph recall: $r > -0.50$, $P < 0.03$). Poor beta cell function correlated with improvement for all carbohydrates in visuomotor task performance but not on an attention task.
Kaplan R. J., et al., 2001	11 men and 11 women (61 to 79 years)	Placebo controlled experimental study	300-mL drink containing 774 kJ as pure protein (whey), carbohydrate (glucose), or fat (safflower oil) or a nonenergy placebo.	Cognitive tests were administered 15 and 60 min after ingestion of the drinks. Plasma glucose and serum insulin concentrations.	Only the carbohydrate drink increased blood glucose ($P < 0.0001$). Compared with the placebo, all 3 macronutrients improved delayed paragraph recall (PR) ($P < 0.001$) and improved or tended to improve immediate PR ($P < 0.04$) 15 min after ingestion. Carbohydrate improved Trail Making Test performance at 60 min ($P = 0.02$) and tended to improve Trails at 15 min ($P = 0.04$) and PR at 60 min in men. Carbohydrate and fat improved or tended to improve performance on Trails at 15 and 60 min in subjects with poor baseline scores ($r > -0.41$, $P < 0.03$), fat tended to improve attention at 60 min ($P < 0.05$), and protein reduced the rate of forgetting on the PR at 15 min ($P = 0.002$).

Table 2a *Continued*

Author, year	Subjects	Design	Drug/conditions	Measures, tests	Results
Kennedy D. O. & Scholey A. B., 2004	1. study: 30 subjects, 2. study: 26 subjects; adults	Double-blind, placebo-controlled, cross-over study	1. study: two drinks (on 2 days) containing carbohydrate and caffeine (68 g/38 mg; 68 g/46 mg, respectively) and a placebo drink. 2. study: a drink containing 60 g of carbohydrate and 33 mg of caffeine and a placebo drink	10-min battery of tasks (2-min versions of Serial 3s and Serial 7s subtraction tasks), 5-min version of the Rapid Visual Information Processing task (RVIP), rating of 'mental fatigue'	All three drinks improved accuracy of RVIP performance. The drink with the higher level of caffeine in first study and the active drink in the second study resulted in lower ratings of mental fatigue.
Kennedy D. O., et al., 2001	20 adults	Placebo-controlled, double blind, balanced, crossover design.	320, 640, and 960 mg of the combination of Ginkgo biloba and Ginseng, and a matching placebo (seven-day wash-out period between treatments).	Mood and aspects of cognitive performance ("quality of memory", "secondary memory", "working memory", "speed of memory", "quality of attention" and "speed of attention")	Dose-dependent improvement in performance on the "quality of memory" factor for the highest dose (this effect was differentially targeted at the secondary memory rather than the working memory component). Dose dependent decrement in performance of the "speed of attention" factor for both the 320 and 640 mg doses.
Kennedy D. O., et al., 2001	20 adults	Placebo-controlled, double-blind, balanced, crossover design.	200, 400, and 600 mg of G115, and a matching placebo (with a 7 day wash-out period between treatments).	Cognitive Drug Research computerised assessment battery: mood and four aspects of cognitive performance ("Quality of Memory", "Speed of Memory", "Quality of Attention" and "Speed of Attention")	Significant improvement in "Quality of Memory" and the "Secondary Memory" factor at all time points following 400 mg of Ginseng. The 200 and 600 mg doses were associated with a significant decrement of the "Speed of Attention" factor at later testing times only. Subjective ratings of alertness were reduced 6 h following the two lowest doses.
Loke W. H., 1988	95 adults	Double-blind study	0, 200 and 400 mg of caffeine		Caffeine, in general, showed non-significant effects on cognitive, learning, and memory performance, except: 200 mg caffeine facilitated performance on the relatively more difficult cancellation (addition and multiplication) tasks than the digit cancellation task. Caffeine decreased boredom and relaxation, and increased other ratings of subjective moods–anxiousness, tenseness, and nervousness. High-to-moderate users of caffeine recalled more words than low users.
Lorist M. M., et al., 1995	30 adults	Placebo controlled experimental study	250 mg caffeine or placebo	Event-related potentials (ERPs) and reaction time (RT).	Caffeine improved performance and increased the amplitude of the N1, N2b, and P3b, in both young and old subjects.

Table 2a *Continued*

Author, year	Subjects	Design	Drug/conditions	Measures, tests	Results
Rees K., et al., 1999	48 subjects (2 groups: 20–25 and 50–65 years)	Double-blind parallel group design	250 mg caffeine or placebo	Psychomotor, cognitive and subjective tests.	After placebo, performance and alertness improved in the younger group but declined in the older. Improvements in psychomotor performance and cognitive functioning in both groups after caffeine, particularly in offsetting declining performance over time in the older subjects. Subjective improvements in alertness because of caffeine. One factor to emerge was that on most assessments older subjects were better earlier in the day whereas in younger subjects performance did not show the same magnitude of decline throughout the day.
Schmitt J. A., et al., 2003	16 men and women (45 to 60 years) and 14 adults (60 to 75 years)	Cross-over design	100 mg caffeine	Cognition, performance, memory, attention	Caffeine did not affect short-term memory span or speed, long-term memory retrieval functions or focussed attention. It is proposed that in middle-aged and elderly subjects cognitive effects may occur predominantly at higher caffeine dosages.
Smit H. J. & Rogers P. J., 2000	23 subjects; 18 to 56 years	Double-blind, within-subjects study	0, 12.5, 25, 50 and 100 mg caffeine	Test battery: long duration simple reaction time task and a rapid visual information processing task; mood questionnaire (including also an item on thirst).	Effects on performance and mood confirmed a psychostimulant action of caffeine. All doses of caffeine significantly affected cognitive performance, and the dose-response relationships for these effects were rather flat. Effects on performance were more marked in individuals with a higher level of habitual caffeine intake, whereas caffeine increased thirst only in low caffeine consumers.
Streufert S., et al., 1995	25 managers	Double-blind cross-over design	Caffeine	Managerial effectiveness; Caffeine Withdrawal Questionnaire: discomfort upon deprivation.	Systolic blood pressure increased during "normal" caffeine consumption levels but fell quickly and remained lower during deprivation. Several measures of managerial performance indicated decreased effectiveness upon caffeine deprivation. Cognitive effectiveness (during complex task performance) was diminished. A measure of strategic performance which requires a relatively high level of cognitive effort showed no impact of caffeine deprivation.
Swift C. G. & Tiplady B., 1988	6 young subjects, 6 elderly	Two-period crossover study	200 mg caffeine or placebo	Psychomotor tests and visual analogue scales.	The objective tests showed a significant increase in tapping rate in the young, while the elderly showed improved attention, faster choice-reaction time, and greater body sway on caffeine. The visual analogue scales showed that the young subjects felt more alert, calmer, more interested, and steadier on caffeine, while no significant changes were seen in the elderly.
Van Boxtel M. P., et al., 2003	1376 subjects (reassessed); 12 age levels ranging from 25±1 to 80±1 years	Correlationed study	Caffeine	Correction for demographic characteristics, baseline performance and health status.	Small significant associations between the overall estimated caffeine intake at baseline and the 6-year change in complex motor speed. The earlier found association between caffeine intake and verbal memory performance was not apparent in this longitudinal study.

Table 2a *Continued*

Author, year	Subjects	Design	Drug/conditions	Measures, tests	Results
Wesnes K. A., et al., 2000	256 subjects; 38 to 66 years	Double blind, placebo-controlled study	60 mg of a standardized extract of Ginkgo biloba (GK501) and 100 mg of a standardized extract of Panax ginseng (G115)	Selection of tests of attention and memory from the Cognitive Drug Research computerised cognitive assessment system; questionnaires about mood states, quality of life and sleep quality.	The Ginkgo/ginseng combination was found significantly to improve an Index of Memory Quality. This effect represented an average improvement of 7.5 % and reflected improvements to a number of different aspects of memory, including working and long-term memory. This enhancement to memory was seen throughout the 12-week dosing period and also after a 2-week washout.
Yu G., et al., 1991	20 elderly subjects	Double-blind crossover experiment	250 mg caffeine or theophylline and placebo	Psychological test performance	Performance on the continuous attention task showed a significant improvement compared with placebo with both active treatments. Performance with caffeine was significantly better than with theophylline. Mean error index scores (normalised AUCs) were: placebo–0.130; caffeine–0.083; theophylline–0.093. Subjective ratings showed that subjects felt significantly more alert on caffeine than on either theophylline or placebo. Subjects also rated themselves as more energetic and interested on caffeine than on placebo. Plasma concentrations of caffeine were lower than those of theophylline at 2 h post-drug.

attention-related component in the evoked potential (P3b) a specific compensation of age-related defects could be obtained.

Similar results were obtained by Rees, Allen and Lader [68], who assessed the effects of 250 mg caffeine on psychomotor and cognitive performance (and subjective state) in younger [20–25] and older [50–65] subjects in a double blind placebo controlled experiment. Both groups showed improved performance due to caffeine, for the older group declines in performance over time were specifically compensated. In addition the results of Rees et al. suggest that age differences were attenuated early in the day and increased in the afternoon.

Smit and Rogers [69] conduced a double-blind dose response study with repeated measure in a sample with a large range in age [18–56]. Their measures included prolonged simple reaction time and a visual information-processing task. Positive effects were more marked for the older group, which was the group with higher habitual caffeine consumption at the same time.

Richardson et al. [70] showed dose response related beneficial effects for younger (20–35 years) and older participants (55–84 years) dependent on trials. Across trial blocks, in a simple reaction time task, increases in reaction time were significantly reduced by caffeine in a dose response related way. Effects were similar for the aged and young groups.

Schmitt et al. [71] could not replicate positive caffeine effects in two groups of older adults [45–75] with 100 mg caffeine. As far as psychomotor performance is concerned psychomotor speed is increased by caffeine in most studies, while measures of hand steadiness indicate a decrement in precision [Richardson et al. 70]. Positive effects on attention and choice reaction time were obtained by Swift and Tiplady [72] for 200 mg caffeine in a placebo controlled cross-over study and by Yu et al. [73] for a sample of elderly persons with 250 mg caffeine on a continuous attention task.

Thus experimental studies on caffeine indicate short term benefits in attention and psychomotor speed of caffeine for higher doses of caffeine, which can be viewed relatively independent of age. The absence of a specific positive effect on the performance of older subjects does not imply a missing effect for older persons. The fact that substances like caffeine show comparable effects for younger and older persons will allow older persons to use nutrition functionally to optimize cognitive functions and/or to compensate their age-related problems (cf. [27]).

Ginseng

Ginseng root extract is a frequently used herbal food supplement, which shows positive effects on mood and memory, while effects on attention and psychomotor

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Table 2b Empirical studies on attention psychomotor performance and selected nutritional factors in young volunteers

Author, year	Subjects	Design	Drug/conditions	Measures, tests	Results
D'Angelo, L. et al., 1986	16 men young volunteers	Double-blind study	A standardized preparation of Korean ginseng (G 115; 100 mg twice a day for 12 weeks) vs. identical placebo capsules	Various tests of psychomotor performance	Effect of G 115 relative to baseline performance in attention, processing, integrated sensory-motor function and auditory reaction time. End performance of the G 115 group was superior statistically to the placebo group only in mental arithmetic. No difference between G 115 and placebo was found in tests of pure motor function, recognition and visual reaction time. No adverse effects.
De Valck, E. & Cluydts, R., 2001	12 subjects; 20 to 25 years	Latin square design	300 mg slow-release caffeine or placebo	Driving performance: twice by a 45-min driving task on a simulator; subjective sleepiness/alertness and mood were assessed four times: Stanford Sleepiness Scale (SSS) and Profile of Mood States (POMS).	After 4.5 h as compared with 7.5 h TIB lane drifting was significantly higher, in the placebo condition at 13.00 h, accident liability increased after partial sleep deprivation. Subjective sleepiness was higher in the 4.5 h TIB group. Caffeine intake gave rise to a signific decrease in lane drifting and after partial sleep deprivation (PSD) it led to a smaller speed deviation and accident liability.
Dimpfel, W. et al., 1993	10 men healthy young	Placebo controlled study	Single oral doses of 200 mg and 400 mg caffeine (under resting conditions and while performing a concentration performance test)	Computer Aided Topographical Electro-Encephalometry System: EEG	Administration of 200 mg and 400 mg caffeine in the relaxed state effected the decrease in spectral power in the theta and alpha ranges. The concentration performance test without caffeine effected decreases in power in the alpha range in frontal to parietal cortex and enhanced theta power in frontal and occipital regions and the alpha power in occipital cortex. The caffeine-dependent decrease in theta power and the decrease in delta power seen under relaxation conditions after 400 mg are not observed during the concentration performance test in the presence of caffeine.
Engels, H. J. et al., 2001	24 active women	Double-blind	Ginseng (400 mg per day of G115) or placebo treatment to their normal diet for 8 weeks		No significant difference between the ginseng and placebo study groups for the variables peak anaerobic power output, mean anaerobic power output, rate of fatigue, and immediate postexercise recovery heart rates ($p > 0.05$).
Fischer, K. et al., 2002	15 male students; mean age 26.3 years	Repeated-measures, counter-balanced cross-over design	Test meals consisted of three carbohydrate to protein ratios, i. e. a carbohydrate-rich (CHO [4:1]), balanced (BAL [1:1]), and protein-rich (PRO [1:4]) meal	Measurement of short-term changes in mood states, objective cognitive functions, blood parameters, and indirect calorimetry.	Accuracy in short-term memory was best after the PRO [1:4] meal concomitant to the least variation in glucose metabolism and glucagon to insulin ratio. Attention and decision times were transiently improved within the first hour after the CHO [4:1] meal, after the first hour the BAL [1:1] and PRO [1:4] meal resulted in improved performance. Reaction times of a central task were fastest after the BAL [1:1] meal concomitant to the highest overall tyrosine (Tyr) to LNAA ratio.
Foreman, N. et al., 1989	32 men	Placebo controlled study	Drinks containing either no caffeine, 125 mg caffeine or 250 mg caffeine	3 tasks: 1) free recall of supraspan word lists, 2) a response time (pointing) task and 3) a numerical Stroop task	No significant group differences on the recall task or in response times, subjects having the higher caffeine dose were seriously impaired on the Stroop test, making particularly slow responses.

Table 2b *Continued*

Author, year	Subjects	Design	Drug/conditions	Measures, tests	Results
Kanarek, R. B. & Swinney, D., 1990	Young volunteers	Experimental study	1. Experiment: calorie-rich snack was a confectionery product, 2. Experiment: snack was fruit-flavoured yogurt.	Four cognitive tasks: digit span recall (forward and backward), arithmetic reasoning, reading, and attention.	In both experiments: subjects were better in the backward digit span test and in the attention task after consumption of the calorific snack than when they had consumed the diet soft drink. Experiment 2: subjects solved significantly more arithmetic problems and solved these problems in significantly less time after eating a fruit-flavored yogurt than after consuming the diet soft drink.
Lorist, M. M. et al., 1994	Young volunteers	Double-blind study	200, 50 mg caffeine or placebo	Behavioral measures: event-related potential (ERP) measures	Subjects reacted faster in the caffeine condition. Caffeine enhanced the N1 and the N2b components. Selection of relevant information apparently was more adequate in this condition. Search negativity was not affected by caffeine. Caffeine effects on the P3 elicited by target letters were more pronounced in the fatigued than in the well-rested subjects, indicating that the effects of caffeine are dependent on the state of the subject.
Magill, R. A. et al., 2003	Young male	Placebo controlled experimental study	Tyrosine 150 mg/kg, caffeine 300 mg/70 kg, phentermine 37.5 mg and D-amphetamine 20 mg or placebo.	Visual scanning, running memory, logical reasoning, mathematical processing, the Stroop task, four-choice serial reaction time, time wall take, pursuit tracking, visual vigilance, Trails (B) task and long-term memory.	Performance decrements with sleep deprivation occurred in visual scanning, running memory, logical reasoning, mathematical processing, the Stroop test, the time wall test, tracking and visual vigilance. Improvements with medication following sleep deprivation were seen in running memory, logical reasoning, mathematical processing, tracking and visual vigilance. D-amphetamine and tyrosine improved performance on several tests.
Mitchell, P. J. & Redman, J. R., 1992	6 men 19 women	Placebo controlled experimental study	4 mg/kg caffeine or placebo	Performance: Short term memory (STM), mental arithmetic (MA), reading comprehension, serial search (SS) and verbal reasoning (VR); caffeine consumption questionnaire.	Reading comprehension was affected by time of day, while caffeine improved performance on all mental speed-related tasks. High caffeine users performed more poorly than other groups on the verbal reasoning task. Several interactions between the three independent variables were observed on a number of tasks, supporting the contention that different processes underlying various types of cognitive performance are differentially, and often jointly, affected by caffeine, time of day and user history.
Mucignat-Caretta, C., 1998	Young male and female volunteers	Placebo controlled experimental study	Caffeine-containing energy drink, no drink or a placebo.	Reaction times task and a go-no-go reaction times task.	The effect of drink was apparent only for females performing the go-no-go task. There is a mild effect due to the drink (but not to the placebo) when the task requires a certain degree of cognitive processing.
Scholey, A. B. & Kennedy, D. O., 2004	20 young adults	Randomised, double-blind, balanced, five-way crossover design	250 ml drinks containing 37.5 g glucose; 75 mg caffeine; ginseng and ginkgo biloba at flavouring levels or a placebo	Cognitive performance: Cognitive Drug Research assessment battery; mood, heart rate and blood glucose levels were also monitored.	Compared with placebo, the whole drink resulted in significantly improved performance on “secondary memory” and “speed of attention” factors. There were no other cognitive or mood effects.

performance are mixed especially with respect to acute/chronic administration [74]. Vogler et al. [75] reported mixed results. Scholey and Kennedy (2002) [76] conclude from their review that Ginseng shows selective effects (especially on memory), and only small doses seem to be beneficial.

Experimental studies

Kennedy and coworker used the cognitive drug research test battery [77] in a series of experimental studies. Kennedy et al. [78, 79] report positive effects on memory and adverse effects on attention related tests of their cognitive drug research test battery for acute administration of ginseng in two independent studies. Positive Memory effects were replicated by Wesnes et al. [80] for a chronic administration of Ginseng.

Experimentally controlled chronic administration of Ginseng (100 mg, twice a day for 12 weeks) positively changed attention, sensory-motor function and reaction time of D'Angelo et al. [81]. But only mental arithmetic showed a significant between-groups effect to placebo.

Sorensen and Sonne [82] found statistically significant positive effects of 8 weeks of 400 mg daily Ginseng on some of their tests (Wisconsin Card Sorting Test, peak auditory reaction time).

Scholey and Kennedy [83] used a drink composite with caffeine, glucose and ginseng with performance improvement both on memory and attention-related subtests for young subjects. This effect can either be due to caffeine, glucose, ginseng or one of the optional interactions. Ginseng-effects tend to be dose-dependent. Reay, Kennedy, Scholey [84] provide evidence that the dose dependent effects might be due to the fact that Ginseng modulates glucose levels. They discuss cellular glucose uptake enhancement as a possible mechanism of performance improvement. In addition effects of acute and chronic administration have to be considered.

Glucose

Experimental studies

Systematic investigations on the role of glucose and/or proteins show evidence for generalized positive effect of glucose on cognitive functioning including positive effect for people above 50 years of age. Thus, Benton et al. [85] report positive effects not only for memory but also for attentional tests. Support for these results stems from Fischer et al. [86], who report positive effects of meals with different carbohydrate/protein-ratios on attention and decision times for a carbohydrate rich meal in a non-aged sample. Similarly Kanarek and Swinney [87] found positive effects in digits backward and attention after a high caloric snack. Kaplan, Greenwood, Winocur, and Wolever [88] used a "breakfast"-design (carbohydrate, fat, protein, placebo) counterbalanced and showed that not only memory but also attention (visual attention, trial making A) and psychomotor function was improved by "energy" in healthy aged adults. Effects were larger for low baseline in energy level and turned out to be significant especially for males. (Report includes description of TMT A/B), and additional attention test (watching TV-spots with certain tasks) was used.

Kennedy and Scholey [89] tested combinations of caffeine and carbohydrate in young adult subjects and showed improvement in an attention-related rapid visual information-processing task.

Correlational studies

A few studies have shown that poor glucose regulation is associated with poor performance in cognitive tests. A correlation of beta cell function of aged adults with improvements in memory and visuomotor performance (and not for attention) has been reported by Kaplan et al. [90] for three conditions of carbohydrate, which were administered before testing.

Messier et al. [91] divided their sample of aged persons [55–84] into a group of sufficient and a group of poor glucose tolerance and showed that impaired glucose tolerance is associated with performance decrements in memory, attention and psychomotor functions) especially for the older participants (above 72 years). Decrements could only partly be compensated by glucose administration.

All in all glucose and glucose regulation have impact on attention and psychomotor performance, but effect sizes in memory are far more pronounced.

Moderating and mediating factors

A striking result is the increased variance in performance data with increasing age. This indicates that performance decrements are related to a large range of mediating and moderating factors, which might prove to be interesting candidates (or lead the way to biopsychological mechanisms) for counteracting age related performance decrements.

Illness and physical fitness

Increasing chronological age is accompanied by a marked increase of physical complaints. Vercruyssen et al. [3] report that as much as 86 % of the American population over 65 suffer from one or more chronic disease conditions. Bashore and Goddard [92] review studies, which indicate a marked improved performance in physically fit elderly. Physical training and practice increased performance on a variety of tasks. Spirduso [56] showed that aged joggers performed as well as college students on simple reaction time tasks and on choice reactions. Szafran [93] compared the effects of cardiopulmonary status and age of pilots on performance on a set of laboratory tasks. He concluded that fitness is much more important for performance than chronological age. Recent studies showed that even participation in a physical training program can positively change cognitive performance [21]. These results indicate that chronological age is a difficult variable or a "fickle mistress" as Birren and Fisher [2] stated.

From a methodological point of view the problem of physical illness and psychological state (e. g. depression) has to be controlled in studies of age effects and performance changes with increasing age. In addition older persons have an increasing probability to experience events which are prone to neurological dysfunctions such as accidents, environmental toxins, general anaesthesia, medication etc.

The fact that we do not know much about the performance level of the "healthy survivor" in their young days as long as we rely on cross-sectional data constitutes a methodological problem, which can only be accounted for in developmental long-term studies.

Increasing variance with increasing age indicates that age-related changes have a high amount of variability and thus are a good candidate for improvement by changing lifestyle and nutrition. Gale, Martyn and Cooper [94] revealed a substantial correlation between vitamin C status, improved cognitive performance and reduced mortality in their analysis of a nutritional survey in Great Britain. Houston et al. [95] attribute the association between high physical activity and the higher incidence of food supplementation in elderly to a "cluster of health behaviors" in subsamples.

Finally claims for functional foods emerge from the fact that a broad range of drugs have negative side effects on attention and psychomotor performance, which might be counteracted by appropriate nutrition (as long as main effects remain unchanged).

Practice

Practice is one of major ways to reduce or diminish age differences in attention demanding tasks and especially in psychomotor functions. Knowledge grows with increasing age and is often used to compensate for age related deficits. Experience buffers compensate or even reverse age differences in performance [96]. One mechanism of compensation for slower information processing is looking farther ahead and thus preparing properly [97].

Predictability

In visual search tasks performance can be improved by information on the appearance of the targets. Amount of improvement in visual search tasks by predictability seems to be similar for young and old subjects; some results support the hypotheses that older SS with impaired perceptual functions tend to profit a little more [98].

Bottom up and top down processes

Attentional and psychomotor changes can be assessed by simple tests as depicted in Table 1a. Nevertheless reduced performance in complex situations is often attributed to changes in attention and psychomotor functions. In complex situations knowledge and experience may play an important role. Birren and Fisher [2] conclude from their review on empirical evidence that knowledge-related performance, especially language-based tests, are far less affected by age than simple reaction time or other simple tests. An interesting example has been provided by Kline et al. [99]. The performance in detecting traffic signs correctly was compared for (n = 12) young (mean age 24 years) and n = 12 older subjects (mean age 62 years) and different conditions of visibility. The superior performance of the younger group in good visibility conditions was much more affected by reduced acuity than the performance of the aged group resulting in better performance (quicker and more correct responses). This was true for novel and non-novel signs. This can only be explained by different strategies to cope with reduced acuity based on experience and knowledge of the older persons.

Thus the notion that speed-related fluid intelligence decreases with age, while knowledge-related crystallized intelligence is kept or even positively developed with age finds its corresponding results even in simple perception tasks.

Age differences in suboptimal conditions

The above-mentioned result from Kline et al. [99], and other recent studies show repeatedly that age deficits and effects of suboptimal (e. g. ambient) conditions interact in the direction of a loss of superiority due to early age, if the quality of stimuli is reduced below the optimal perceptual conditions for the younger group. On the other hand high stimulus intensities may help to reduce age-related performance deficits, which are due to perceptual deficits of the older persons. Following the deficient inhibition hypotheses the salience of the stimuli will help aged persons to show appropriate performance.

Conclusions

Attention and motor performance like other cognitive or cognitively determined functions tend to show age-related performance deficits. Age-related changes show a striking variability, with superior or unaffected performance in some aged subjects and quite large deficits in others. The deficits are easy to demonstrate in cases where age-related reductions in peripheral perceptual functions (hearing/vision), age-related problems information processing (e.g. difficulties to switch to new tasks and inhibit old or alternative reaction tendencies, age-related memory problems) and age-related changes in peripheral motor system cumulate. On the other hand if age-related peripheral problems are compensated or ruled out by the experimental setup performance distributions of old and young groups overlap considerably even in tasks which do not profit from higher experience and knowledge of the older group.

The most important factor seems to be the bio-psychological state of the subjects. This is of high importance for lifestyle variables and nutrition as it is empirically well supported that factors which improve attention and psychomotor performance in young subjects also work for the older groups (at least if there are no clinically relevant deficits) in most instances. Sometimes the effect is even more prominent in aged groups, due to the fact that younger subjects already show very high performance in standard states.

Thus, one can conclude that nutrition like physical fitness can help to counteract age-related degradation of performance by generally improving the biopsychological state of the subject. In addition an improvement of brain metabolism, counteracting oxidative stress effects in brain tissues and providing optimal neurotransmission will allow older subjects to follow the way of healthy aging especially to optimize and compensate deficits.

Acknowledgements This work was commissioned by the Nutrition and Mental Performance Task Force of the European branch of the International Life Sciences Institute (ILSI Europe). Industry members of this task force are Coca-Cola Great Britain and Ireland, Masterfoods, Kraft Foods R&D, Inc., GlaxoSmithKline, Danone Vitapole, Nestlé Research Center, Unilever and Südzucker AG. For further information about ILSI Europe, call + 32 2771.00.14 or E-Mail: info@ilsieurope.be. The opinions expressed herein are those of the authors and do not necessarily represent the views of ILSI and ILSI Europe.

The authors would like to thank Dr. Tomporowski (University Georgia, USA) and Prof. Scholey (Northumbria University, UK) for their useful comments on the manuscripts.

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