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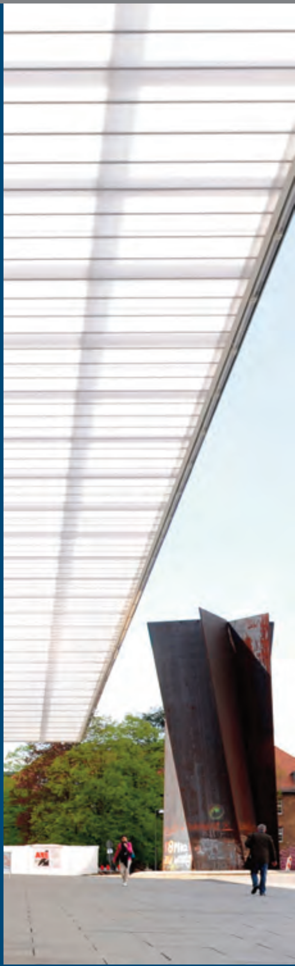
Verleihung der Ehrendoktorwürde der Philosophischen Fakultät III Empirische Humanwissenschaften der Universität des Saarlandes an Herrn Prof. Fergus I. M.Craik, Ph.D



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Universitätsverlag des Saarlandes
Saarland University Press
Presses Universitaires de la Sarre

Prof. Fergus I. M.Craik, Ph.D

Verleihung der Ehrendoktorwürde der Philosophischen Fakultät III Empirische Humanwissenschaften der Universität des Saarlandes an Herrn Prof. Fergus I. M.Craik, Ph.D am 11. September 2013

Conferral of an Honorary Doctorate for Prof. Fergus I. M. Craik, Ph.D. by the Faculty of Social and Applied Human Sciences of Saarland University

September 11 2013

Universitätsverlag des Saarlandes
Saarland University Press
Presses Universitaires de la Sarre

Postfach 151150, 66041 Saarbrücken

Herausgeber	Der Universitätspräsident
Redaktion	Universitätsarchiv
Vertrieb	Presse und Kommunikation der Universität des Saarlandes 66123 Saarbrücken

ISBN 978-3-86223-211-6
URN urn:nbn:de:bsz:291-universaar-1517

Satztechnik: Julian Wichert
Fotos: Jörg Pütz (Umschlag)
Druck: Universitätsdruckerei

Inhalt

Axel Mecklinger

Laudation

Dear Vize President, dear colleagues, students, dear attendees,

it is a great honor and pleasure for me to pay homage to Professor Fergus Craik. He definitely is one of the leading international researchers in the field of human memory and aging, His influential and exhaustive work has led him to become an internationally much acknowledged scientist in the field of Cognitive Psychology. Professor Craik was born in Edinburgh, Scotland, in 1935. He first studied medicine at the University of Edinburgh. However, as he stated it in an autobiographical sketch, his enthusiasm for medical science was significantly damped when he realized that he had to learn a couple dozen afferent and efferent connections of the kidney.

Luckily, he then switched to Psychology and received his Bachelor in Psychology in 1960. Professor Craik then spent five years as a graduate student at the University of Liverpool. During this time, he began conducting experiments on age-related changes in attention and memory and received his Ph.D. from the University of Liverpool in 1965 with a thesis entitled “Age differences in confidence and decision processes”. In 1965, he accepted a position at the prestigious Birkbeck College in London.

Two years later, he took part on a conference on memory in Cambridge at which he met some of the major memory researchers of the time: Donald Norman, Donald Broadbent and Endel Tulving. It is not exaggerated to say that attending this conference changed his life: Invited by Endel Tulving, he spend one year as a Visiting Associate Professor at the University of Toronto (1968-69). He took up a position as an Associate Professor of Psychology at the University of Toronto in 1971 and has been at the University of Toronto since. He was granted tenure in 1972, became Full Professor in 1975 and was appointed to the Glassman Chair in Neuropsychology in 1996. In 2000, he became a Senior Scientist at the Rotman Research Institute. It is nice to see from his bio sketch that Gus Craik’s scientific work was stimulated by the rationally based culture in Britain as well as the empirically based scientific culture in North America and its supportive attitude to research.

Let me briefly highlight his main scientific contributions:

During his early research years in Toronto, Gus Craik developed **the levels of processing framework,** which has become one of the most influential concepts in memory research. The guiding principle of this framework, namely that the nature of a memory, including the likelihood that it will later be remembered, depends upon the qualitative way in which the event was initially processed, has become a standard in modern cognitive text books and is so widely accepted in cognitive psychology and cognitive neuroscience that – as Professor Lindenberger noted in his laudatio "… later generations of researchers may not even recognize that it represents a major departure and advancement from earlier theories of cognition when it was originally proposed by Craik and Lockhart in 1972" (page 2). I am belonging to this generation.

Developed in the early seventies, the levels of processing framework also set the ground for Professor Craik's influential conception of cognitive aging. Bridging the gap between research on attention and aging, Gus Craik postulated that aging is associated with a reduction of attentional resources that can be allocated to information processing.

There are two important implications here: First, when processing resources are curtailed in young adults (for example by performing two tasks simultaneously) the resulting pattern of memory performance is observably equivalent to that of older adults performing a memory task under full attention conditions. Second, cognitive aging is not a general impairment of encoding and retrieval processes. Rather, older adults' deficits can be compensated by environmental support that enables self-initiated processes at encoding and retrieval. This latter notion not only means good news for elderly and those who are approaching this age range. The environmental support view has also stimulated more than two decades of research on the characteristics and suitability of supplies during normal and pathological aging, but most notable is the fact that it has continued to stand the test of time and remains more than compatible with current views on age effects on memory.

Gus Craik's research merits are not restricted to these fundamental contributions to the understanding of the functional architecture of attention and memory and its modulation in old age. He has always been interested in the neural mechanisms underlying behavior. Stimulated by the foundation of the Rotman Research Institute in the late 1980s and the emergence of neuroscience techniques such as PET or fMRI, Gus Craik has become a world leading cognitive neuroscientist, with the mission to study normal and pathological aging and the role of the frontal lobes in memory and attentional control. As he notes at the end of his autobiographical sketch, and not without a degree of self-depreciation: "I am getting involved in the exciting new world of neuroimaging. Perhaps my early medical school training will come in useful after all".

Gus Craik has published more than 180 articles in peer-reviewed journals, 65 book chapters and co-edited 11 books. His seminal and highly influential article together with R. Lockhart on levels of processing has been cited more than 3836 times to date and his entire scientific work receives an extremely high rate of 373 citations per year with more than 1000 citations in 2012 alone. Gus Craik served (and still serves) as Editorial Board member or Consulting Editor in more than 15 scientific journals.

Of course, Gus Craik's contributions to cognitive science have been honored in multiple ways. I will not go in all details here, but he is a fellow of both the Royal Society of Canada and the Royal Society of London. He received the "Distinguished Contribution Awards from the Canadian and American Psychological Associations. In 1992, he won the "Irv Acenberg Award from the Rotman Institute. In 2009 he received the "Norman Anderson Lifetime Achievement Award" of the Society of Experimental Psychologist and Gus already holds two honorary doctorates: Docteur Honoris Causa, University of Bordeaux 2 (2006) and the Honorary Doctor of Science in Social Sciences from the University of Edinburgh.

As a testimony to his excellent teaching capabilities, he has mentored more than 35 graduate and doctoral students and has supervised more than 30 postdoctoral fellows: His merits in teaching and mentoring were honored as well: He received the outstanding teaching award of the University of Toronto in 1996.

Gus Craik is an exceptional and outstanding scientist whose work still has an enormous impact on researcher in the fields of memory, attention and cognitive aging today. As noted by Ulman Lindenberger in his laudatio "Fergus I.M. Craik has been the leading theoretician and experimentalist at the intersection of research on memory and aging for decades. He is one of the most visionary, eminent, influential, and independent minds in cognitive psychology" (p. 1) and "Fergus I.M Craik's contributions to science have served as heuristics and guideposts for several generations of researchers and continue to do so up to the present days" (p. 3). He has received major inspirations from outstanding colleagues in the field like Donald Broadbent, Gregory Miller, Anne Treisman, Endel Tulving and Brenda Milner.

Introducing a hierarchical view to the encoding aspect of memory was ground breaking at the time, as was the conceptualization of cognitive aging on the dimension of environmental support and self-initiated processing. By this, Gus Craik has pioneered new and intriguing approaches to memory and cognitive aging that stimulated research of several generations of cognitive neuroscientists. Gus Craik is also a genuine and valuable friend and colleague and is most deserving of an honorary doctorate from Saarland University.

Fergus I. M. Craik

Aging and Memory: A Processing Approach

First I would like to say how grateful and honoured I am to be receiving the degree of Doctor Honoris Causa from Saarland University. Although I have lived and worked in Canada for over 40 years, I still think of myself as European—I was born in Edinburgh, and lived in Scotland and England for 35 years before moving to Canada—and it means a great deal to me to receive an honorary degree from a major European University. In addition, I have a number of good friends who are associated with the Department of Psychology here at Saarland University and it is extremely gratifying for me to know that they think enough of my work over the years to honour me in this splendid way. So I would like to convey my grateful thanks to the President, the Faculty Board and my colleagues here in Saarbrücken for their kind hospitality and for this great honour.

A processing approach to memory and cognition

In this essay I will review some of the work I have done over the years in an attempt to understand the changes in human memory that take place from young adulthood to old age. I am an experimental psychologist by training, so the work and ideas I will describe are at the level of experience and behaviour rather than at the levels of brain function or molecular changes, although I will make occasional speculative references to how changes in mental function may relate to underlying changes in the brain. As the title states, I take a 'processing view' of memory and cognition. Basically, this means that I think of memory processes as *activities* of the mind and brain rather than as structural entities. When we experience an event for the first time the various sights, sounds, smells and other senses evoke complex patterns of activity in the brain. These sensory patterns are interpreted in terms of our previous experiences, and the resulting perceptual and conceptual activities are gradually 'consolidated' over time to form structural records whose correlates are presumably molecular changes in neurons and their interconnections. In my view, the learning or 'encoding' aspects of memory are nothing more than those initial perceptual and conceptual processes, and memory retrieval consists essentially of the attempt to reinstate the same pattern of perceptual/conceptual processing that took place during initial encoding. In this scheme, then, remembering is a form of perceiving rather than a separate 'mental faculty.' What we lay down as memories will depend on what we attend to and the level of meaningful interpretation that we apply to our perceptions. Successful retrieval of the original event will demand on how well and how fully the original patterns of neural activity can be reinstated. In turn, successful reinstatement will depend on such things as being in the same physical and mental context at encoding and retrieval. The same context at retrieval evokes part of the initial complex of neural activity, and we assume that the brain has an inherent tendency to carry out 'pattern completion' processing on partial representations of well encoded previous experiences, and so reinstate the original pattern to some extent at least.

Memory and aging

Memory loss is one of the most frequent complaints of people as they age, although there are wide individual differences in the amount of age-related loss, and also substantial differences depending on the type of memory used in a particular situation. The experiments carried out in my laboratory over the years have attempted to illustrate these differences and provide a coherent account of them in terms of the processing notions described earlier. With regard to differential age-related losses as a function of different memory tasks, what we and others have shown is that age decrements are substantial in tasks involving episodic memory, working memory, source memory and prospective memory. Episodic memory is the label for remembering events that occurred anything from minutes to years ago; it is memory for personal experiences as we normally think of it. Working memory refers to information held in conscious awareness especially if we carry out some operation—like mental arithmetic—on the material we are holding. Source memory is the ability to remember where and when some event occurred or the circumstances in which we learned some new information. It is obviously possible to remember a fact, but be unable to recollect where and when we learned the fact. Finally, prospective memory is remembering to carry out an intention at a future time, either when some event is encountered (e.g., conveying information to a friend when you meet her) or after some specified time (e.g., "I must phone my wife in 30 minutes"). These types of memory all show substantial losses and inefficiencies in older adults.

On the other hand some memory tasks are performed almost as well by individuals in their 70s and 80s as by those in their 20s and 30s. Such tasks include recognition memory, procedural memory, and memory for facts and accrued knowledge—referred to as 'semantic memory' by cognitive psychologists. Recognition memory involves re-providing items or events to the experimental participant; for example "which of these 40 words are the 20 words that I recently had you learn?" The task thus differs from a recall task in which the participant is simply asked to recall the 20 works without any hints or reminders. Procedural memory refers to remembering some mental or physical skilled procedure such as skating, driving a car, playing a musical instrument or playing chess. Success at these tasks does not require that you remember where and when you learned the skill, only that you are still able to perform the task successfully. Similarly semantic memory—remembering a body of learned knowledge—does not require memory for the time and place of original learning but simply error-free access to the facts themselves.

One way that I have characterized differences between these two classes of memory tasks is in terms of the degree of 'environmental support' that each task involves. The idea here is that aspects of the current context, or aspects of the task itself, can help to re-instate the appropriate pattern of mental and neural processes at the time of retrieval. So if a learned item is re-presented in a recognition test it helps to drive the system back into the same configuration that it held during the encoding process. Similarly, remembering details of an earlier event is aided by returning to 'the scene of the crime.' On the other hand, it is clearly possible to remember events in contexts far removed from the original happening—we can reminisce about childhood episodes or recent vacations in our present-day living rooms. I have suggested that this aspect of remembering relies on 'self-initiated activities' (Craik, 1983), and that such self-initiated processing helps to bootstrap the system into the configuration that yields the experience of confident remembering. Thus, as many people have suggested, memory retrieval is a process of reconstruction and in my view the processes of environmental support and self-initiated activities play complementary roles in achieving this reconstruction. It follows that as environmental support increases, there is less need for self-initiated processing; the two sources of support trade off against each other.

With regard to aging, my suggestion is that self-initiated processing becomes progressively more difficult to accomplish as a person grows older, and therefore older adults must rely progressively more on environmental support for successful remembering. The age-related difficulty with self-initiation is attributed to age-related inefficiencies of frontal lobe functioning (e.g., Stuss & Benson, 1986). It is well established that the frontal lobes are among the earliest brain regions to suffer the negative effects of aging (Raz, 2000). The suggestion, then, is that the memory tasks performed poorly by older adults, especially unaided recall of episodic memories, recollection of the source of factual information, and prospective remembering at a later time, are all tasks that are not well supported by the external environment and therefore require substantial amounts of self-initiated activity, which older adults find more difficult to carry out. These interrelations are shown schematically in Figure 1. Success at a particular memory task is held to reflect interactions among attributes of the person, the task and the environment.

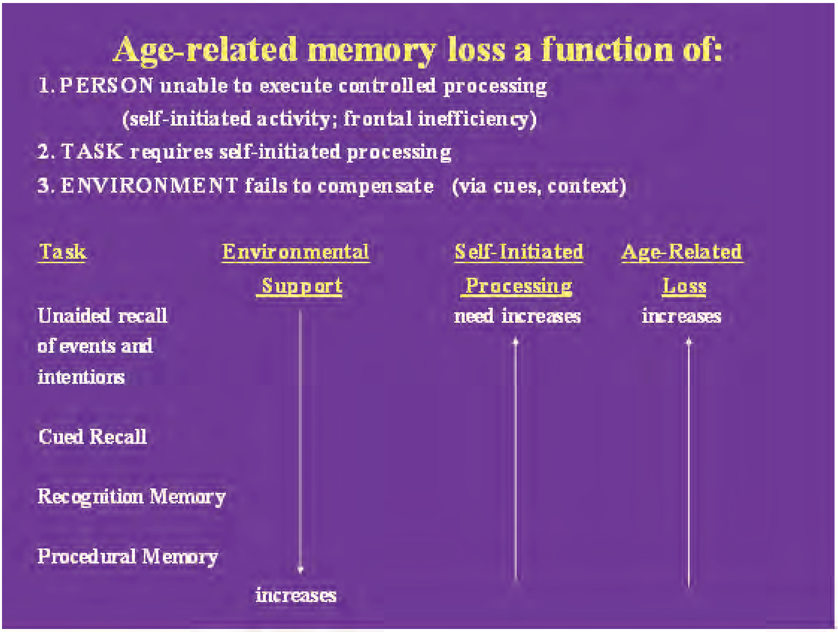

Figure 1. *Hypothetical scheme illustrating the complementary relations between self-initiated processing and environmental support. As memory tasks require more self-initiated processing the age-related loss in performance increases. Reprinted with modifications from Craik (1986).*

I do not argue that an age-related decrement in self-initiated processing is the *only* factor leading to memory problems in older adults, but I believe it is one of the main causes of such problems. There are other well-documented age-related changes in cognitive functioning—for example general slowing of mental processing (Salthouse, 1996), decreased inhibitory control (Hasher &

Zacks, 1988), less effective formation of associations (Naveh-Benjamin, 2000) and a postulated decline in processing resources, the ‘mental energy’ needed to perform cognitive operations (Craik & Byrd, 1982). A full understanding of why memory performance typically declines with age will therefore depend on a more complete understanding of each of these factors, how they interact, and how they are related to parallel changes in brain structure and function.

These ideas have recently been endorsed and extended in an article by Lindenberger and Mayr (2014). They agree that older adults rely more on the external environment during memory retrieval, but point out that this greater reliance on environmental support applies also to other cognitive processes—those involved in perception, learning and action management, for example. The authors also comment that this greater age-related dependence on environmental support comes at a cost—a loss of internal control. The individual is more at the mercy of variations in appropriate environmental input to guide optimal cognitive operations. Whereas I have talked in terms of the environment playing a greater role in ‘deploying attentional resources,’ Lindenberger and Mayr suggest instead that increased environmental support helps older adults establish and maintain cognitive representations. In general, whereas younger adults are able to rely on frontal brain processes to provide ‘self-initiated’ or internal control, older adults lose this ability to some degree and must therefore rely more on the external environment to provide control of cognitive operations. In many ways this age-related reversion of control to the environment reverses a general evolutionary trend for control of behaviour to become progressively more internalised in higher organisms. That is, the behaviour of simpler organisms is often triggered or guided by external stimuli, whereas the behaviour of more evolved species is increasingly controlled internally. In this sense then the processes of human aging force older adults a notch down the evolutionary ladder!

As one example of greater perceptual control in younger than in older adults, Lindenberger and Mayr (2014) cite a study by Passow and colleagues (2012) in which younger and older adults were presented with pairs of syllables dichotically—that is, one syllable to each ear simultaneously over headphones. The stimuli consisted of voiced versus unvoiced syllables (e.g., /ba/ versus /pa/) and the participant reported which syllable was heard. Perceptual saliency was manipulated by varying loudness on each ear separately, and attention was manipulated by directing participants to attend to either the right ear, the left ear or to both ears equally. The basic result was that detection and report of a particular syllable depended first on the relative loudness of that syllable compared to its simultaneously presented paired stimulus. However, young adults could override this effect of perceptual saliency to some extent by deliberate attention to the softer syllable whereas older adults did not show this effect; for them, performance was determined almost exclusively by relative loudness of each stimulus—that is, by external control.

Experimental evidence

Work in my lab has documented differences in memory and attention between younger adults, typically in their late teens and early 20s, and older adults in their 60s and 70s. The purpose of the experiments we have conducted has mainly been to accrue evidence relevant to the related ideas that older adults have fewer processing resources (less attentional capacity) and also are less able to carry out self-initiated activities as described above. Two early experiments in this series are one showing greater age-related differences in recall than in recognition memory and one showing that older adults are less able than their younger counterparts to remember the source of newly learned factual information. In the first study (Craik & McDowd, 1987), participants attempted to either recall or recognize words while simultaneously performing a choice reaction-time (RT) task. The idea here was that performance on the RT task provided a measure of the attentional capacity needed to carry out the memory retrieval task; a more effortful retrieval task would cause more slowing on the RT task. The results showed first that there was a greater drop in performance between the younger and older groups in recall than in recognition, in line with the idea that unsupported recall requires more self-initiation than does recognition memory, and that older adults are less able to muster such processing abilities. Second, recall slowed the simultaneous RT task more than recognition did suggesting that free recall requires more attentional capacity than recognition. And third, slowing of the RT task was especially marked for the older participants showing that 'resource costs' (the mental effort of recall) were heavier in older adults. These results thus provide some evidence in favour of the notions that self-initiated processes are less effective and more costly in terms of attentional capacity in older than in younger adults.

A further study by McIntyre and Craik (1987) explored the hypothesis that source memory is impaired in older adults. We tested younger and older adults with 30 trivia questions about Canada. Participants attempted to answer the questions—which were rather obscure facts—and were then given the correct answer. One week later the same participants were given 60 trivia questions to answer, the original 30 plus 30 new, easier questions. On this second occasion, participants answered each question if they could and were also asked where they had first learned the fact. The interesting aspect of the results is the proportion of facts that participants did *not* know on the first occasion that were correctly sourced to the first testing occasion. Of the items that participants did not know on Week 1 but answered correctly Week 2, the proportions whose source was attributed to the first occasion was 0.89 for younger adults and 0.56 for older adults, a highly reliable difference. This inability to remember the source of learned material has been referred to as ‘source amnesia’ and is attributed to impaired functioning of the brain’s frontal lobes (Schacter, Harbluk & McLachlan, 1984). So the results just described provide further evidence that an age-related decline in frontal lobe efficiency may be associated with problems in remembering contextual details of events, even when the central facts are remembered by the same people.

A study by Naveh-Benjamin, Craik, Guez and Kreuger (2005) was carried out to assess the processing costs associated with encoding and retrieving, and to check on the idea that processing resources are limited in older adults. Participants learned a set of arbitrary word pairs (e.g., donkey-wallet, harbour-picture) and were later tested by presenting the first word and asked to recall its paired associated word (e.g., donkey- ?, harbour- ?). The experiment thus provided a measure of associative memory which is known to be especially vulnerable to the aging process (Naveh-Benjamin, 2000). Processing costs were measured by giving participants a second task to perform while they were either learning (encoding) or retrieving the word pairs. The word pairs were presented auditorily for learning and retrieval, so the secondary task was a visual one in order to reduce simple interference effects. The task involved tracking a visual target (an asterisk) that moved randomly around a monitor screen in front of the participant. The screen also showed a white dot that could be moved by the participant by means of the computer mouse. The tracking task was therefore to keep the dot as close as possible to the asterisk as it moved around the screen. A computer program measured the distance between the dot and the asterisk from moment to moment, and the idea was that this distance would remain small as long as the participant was able to attend closely to the tracking task. When the participant was required to learn or retrieve word pairs at the same time however, this diverted some attention (processing resources) from the tracking task, and the average distance between the dot and the asterisk increased. Each participant carried out the tracking task under full attention conditions, and also when it was combined with either encoding or retrieval. The *difference* between a person’s tracking performance under full attention and attention shared with encoding or retrieval thus served as a measure of the attentional resources dedicated to the memory task. That is, the increase in the dot-asterisk difference from the task performed alone and performed simultaneously with learning or remembering gave us a measure of the ‘processing costs’ associated with encoding and retrieval.

The results for younger and older adults are shown in Figure 2. The vertical axis shows the average difference between baseline performance of the visual tracking task (task done alone) and performance of younger and older adults when the task is performed simultaneously with encoding or retrieval. Greater differences between baseline and encoding or retrieval were interpreted as showing that the memory task demanded more processing resources for its completion. The horizontal axis in the figure represents the 6-sec. intervals that were used both to encode and to retrieve each word pair. The figure shows that young adults consumed relatively small amounts of processing resources during both encoding and retrieval—the average increases from baseline to memory task are quite slight, especially after 4 sec.

Figure 2. *Processing costs for older and younger adults during encoding and retrieval of word pairs. The vertical dimension indicates the difference in tracking performance between baseline (tracking task alone) and the tracking task performed simultaneously with encoding or retrieval. The horizontal dimension indicates time in milliseconds for encoding or retrieval processing. Greater differences reflect larger processing costs. Data from Naveh-Benjamin et al. (2005).*

Processing costs for older adults were substantially greater however, especially during retrieval. Another way of interpreting the results is that older adults have a smaller pool of available processing resources, and thus performance of the encoding and retrieval operations has a greater deleterious effect on performance of the visual tracking task. The experiment thus provides further support for the ideas that available processing resources decline with age, that memory encoding and especially retrieval operations require processing resources to run them off, and that this combination is one reason for the declining memory performance of older adults.

Reducing the age-related decrement in memory

If memory problems in older adults are attributable in part to difficulties with self-initiated processing, it should be possible to demonstrate a reduction in the typical age-related memory decrement by reducing the need for self-initiated processing in specific tasks. Following the scheme shown in Figure 1, this can be done by 'repairing' the quality of encoding and retrieval processes by the greater provision of environmental support and perhaps by other means. I will conclude this brief run through work from my lab with some illustrations of how this has been achieved.

In a series of studies with Astrid Schloerscheidt we varied environmental support by reinstating the context of presentation in varying degrees. The stimuli for the study (Craik & Schloerscheidt, 2011) consisted of either the names of objects or pictures of objects presented on the background of a pictured scene. Thus either the names of objects such as 'guitar, angel, brush, pipe' or pictures of these objects were superimposed on unrelated scenes such as a woodland scene, a market place, a kitchen, a beach scene and so on. Names were presented in one half of the study and pictured objects in the other half; different groups of young and older adults participated in the two halves. The names or pictured objects were presented in framed boxes and superimposed arbitrarily over some part of the scene, obscuring approximately 1/16 of the scene. Participants were instructed to learn the names (or objects) and also which name or object was presented with which scene. For the name version 12 words were paired with each of 10 different scenes, so 120 word/scene combinations were presented altogether; each word was different, but the 10 scenes were each used 12 times. For the object version exactly the same design was used; so 12 pictured objects were paired with each of 10 different scenes, again making 120 combinations.

The memory test was recognition of the original words or pictured objects, and we varied the degree of context reinstatement by re-presenting the name or pictured object either on its *original* scene, a different scene that had been used with other stimuli ("*switched*"), on a blank background ("*none*"), or on a *new* scene that had not been shown during the original presentation. Our idea was that the closer the background scene context was to the original presentation, the better recognition would be. In the test a number of completely new names or pictures of objects were also included as distractor or lure items; participants had to decide on each test trial whether the word or pictured object was 'old' or 'new'—regardless of its current background context. With regard to aging, our expectation was that the age difference in recognition memory would be smallest in the condition involving re-presentation of the original context, and be progressively greater as context reinstatement declined from *original* to *switched*, *none*, and *new*.

The results are shown in Figure 3; the left-hand panel shows results when names were used and the right-hand panel shows data from the pictured objects. In both cases, the probability of recognition for younger and older adults is shown as a function of context reinstatement. For names/words on the left, recognition performance for older adults increases progressively from *new* to *none* to *switched* to *original*. That is their performance increased to the extent that the original context was re-provided. For younger participants, performance was also best with the original context, although in this case performance did not decline further from *switched* to *new*. Notably, the age-related decrement was least for the original context. When the stimuli were pictured objects, surprisingly the older adults now performed at least as well as their younger counterparts, and now the degree of context reinstatement had little effect on level of performance. We interpret this result to show that pictures drive a very good encoding of the stimulus, and that little further 'mental elaboration' is required, although such elaboration is beneficial for names. Further, we conclude that names are elaborated by younger adults but less so for older adults. Overall, the experiment demonstrates that recognition memory is enhanced both by richer stimuli (pictured objects vs. words) and by context reinstatement. Older adults rely more on such external sources of enhancement and when both sources are present the age-related decrement in memory is abolished.

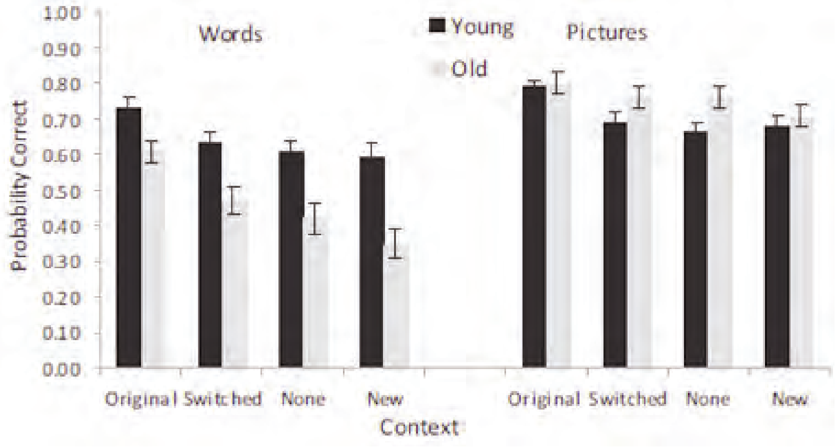

Figure 3. *Recognition of names and objects as a function of age and context reinstatement. Reprinted from Craik and Schloerscheidt (2011).*

A second study making similar points was reported by Troyer, Häfliger, Cadieux and Craik (2006). This experiment (Troyer et al., 2006, Experiment 1) made use of the levels-of-processing notions proposed by Craik and Lockhart (1972) and illustrated by Craik and Tulving (1975). The basic idea is that memory is strongly influenced by the type (or 'depth') of processing carried out at encoding; deeper semantic processing is associated with much better subsequent memory than is shallow perceptual processing of the same event. A further ideas is that memory is a function of the type of processing carried out, regardless of the person's intention to remember the information later (Craik & Tulving, 1975). This principle becomes important when dealing with individuals (like older adults) who have trouble encoding events in a memorable way; giving such individuals a task that will induce deep processing automatically is an example of environmental support used at encoding as opposed to retrieval.

The study reported by Troyer and colleagues examined younger and older adults' ability to learn and recall proper names. We took 32 surnames from a local telephone directory and arbitrarily designated each name *Mr.* or *Mrs.* The 32 names were divided into four lists of eight names each. Participants were instructed that one set of eight names was to be learned, and that memory for these names would be tested later. The other names need not be learned but they would be asked a specific question about each name as it was presented. Following the techniques of levels of processing experiments the types of question (or instructions) were a) state the first letter of the name, b) generate a word that rhymes with the name, c) provide a definition or association to the name, or d) learn this name for a later test. The questions a, b, and c thus induced physical, phonemic and semantic processing respectively, and we expected these types of processing to be associated with progressively higher levels of memory. The intentional 'learn' condition will be associated with a memory level reflecting the type of processing carried out spontaneously by the participant, and we expected that younger adults would do better than older adults in this condition. The four types of processing were mixed randomly throughout the 32 learning trials; each word and question was exposed for five seconds, and there was an interval between this learning phase and the memory tests. The two tests given were first 'free recall' in which participants were asked to recall *all* 32 names, not just the 8 'learned' names, and second, a recognition test in which the original 32 names were mixed with 64 new names; the participant's task was to indicate the original 32. Our thinking was that the recall test requires considerable amounts of self-initiation and would thus show a large age-related decrement for the words designated 'learn.' This decrement might be reduced for the 'incidentally' processed items, however, with those associated with semantic processing being recalled more often than those associated with physical or phonemic processing. Following arguments presented earlier we expected the age decrement to be even less in the recognition test, given its greater degree of environmental support.

The results are shown in Figure 4, with name recall on the left panel and name recognition on the right. For recall, younger adults outperformed older adults, especially in the free learning condition where the young group recalled more than twice the number recalled by older adults. The recognition test yielded a very different pattern. Now the *same* older adults recognised more items than the young adults for all except the intentionally learned items. Our interpretation is that by supporting encoding processes by means of specific question types, and supporting retrieval processes by means of a recognition test, the need for self- initiation is substantially bypassed, and older adults perform as well as younger adults. Does this result mean that memory processes in older adults are 'really' just as good as those in their younger counterparts? Unfortunately, no. The age-related loss of self-initiated processing is real and pervasive in most real-life memory situations. Additionally there are other problems that are briefly discussed in a final section.

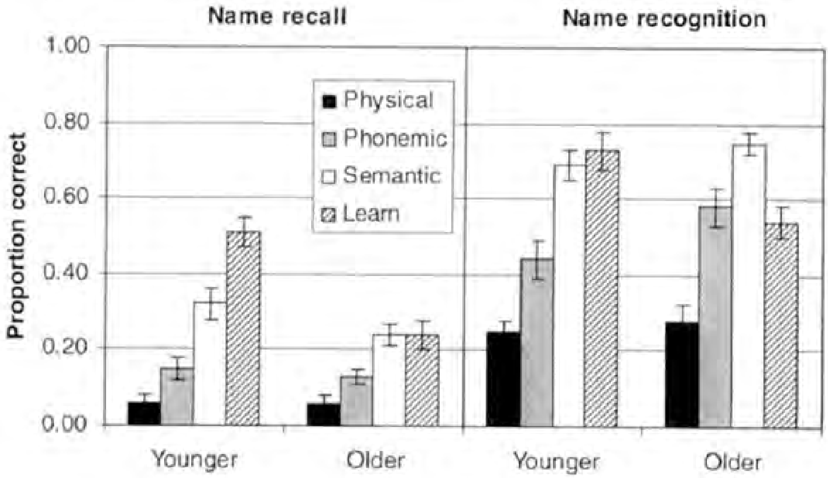

Figure 4. *Proportions of correct name recall and name recognition as a function of age and type of processing at the time of learning. Reprinted from Troyer et al. (2006).*

Conclusions

In this essay I have presented a short account of some of the experimental work I have done over the last 40 years or so to understand the nature of age-related changes in human memory. I take a 'processing' view of memory and cognition, arguing that encoding and retrieval processes should be thought of as activities of the mind and brain as opposed to memory being considered as 'an object in the head.' Of course, *some* structural changes must underlie our stores of knowledge and episodic memories of past events, but my point is that these molecular changes have no cognitive or experiential correlates. They can certainly be described in physiological and biochemical terms, but the processes of memory encoding and memory retrieval—like attending, perceiving and thinking—are cognitive operations that must be studied while they are happening.

With regard to age-related changes in memory, I first pointed out that such age-related decrements are typically greater in such tasks as free recall, memory for source and prospective memory, while being comparatively slight in recognition memory, semantic memory for facts and procedural memory. My argument is that the tasks that do show reductions in older adults are often tasks that are poorly supported by external cues and therefore require substantial amounts of 'self-initiated activity' to be successful. In turn, it seems likely that this age-related reduction in self-initiated activity is attributable to less effective functioning of areas of the frontal lobes. This part of the brain does show substantial deterioration in the course of aging (Raz, 2000), and specific areas have been linked to decrements in initiation and in cognitive control (see e.g., Stuss & Levine, 2002).

Other researchers have made the case for different factors being associated with age-related memory losses, and it is highly likely that the final picture will include a number of different causes, some of which may be related to a drop in self-initiated activities. The proposal that older adults exhibit poorer cognitive control (e.g., Jennings & Jacoby, 1993) is clearly related to my suggestion that older individuals have a greater need for environmental support; cognitive control is also generally regarded as a frontal function (Stuss & Levine, 2002). The notion of an age-related inhibitory deficit (Hasher & Zacks, 1988) is also similar to the idea of poorer cognitive control, although Hasher, Zacks and their colleagues have typically stressed the increase in interfering information that arises as a consequence of inefficient inhibition of unwanted material. Salthouse (1996) has illustrated the undeniable fact that mental processes slow with age, and has suggested ways in which this slowing may affect memory. Finally, Naveh-Benjamin (2000) has shown that older adults have a particular problem with associative information—linking names to faces for example. Unlike some other problems of aging, the decrement in associative information may be attributable to medial-temporal regions of the brain, especially the hippocampus.

A final theory of age-related changes in memory is therefore likely to embrace a number of ideas at the level of cognitive psychology and also a number of structures and processes at the level of brain anatomy and physiology. This greater knowledge will enable us to understand memory pathologies more fully and may hopefully provide us with techniques and devices to compensate the cognitive losses that accompany aging.

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ISBN: 978-3-86223-211-6