How Do They Do It? Delving Into The World Of An Aging Medical Expert

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Abstract

It is well established that there are declines in basic cognitive functions associated with aging. However, for individuals with extensive knowledge in a particular domain (e.g. experts), there does not appear to be age-related limitations in performance. Although expert performance relies on certain fundamental cognitive processes, such as information processing and memory capacity, the strategy with which an expert maintains a high level of functioning in his/her domain may be altered. One may view this alteration as a sign of compensation for age-related limitation, or one may deem that this alteration of strategies is due to the natural course of extensive practice in the field. The aim of this paper is to explore diagnostic reasoning processes in an aging medical specialist. Specifically, this study explores what aspects of performance approximates that of a younger expert, and what aspects deviate from the current model of expertise in medicine.

Introduction

Rapidly expanding medical knowledge, improvements in general nutrition, hygiene, education and public sanitation has contributed to the health and longevity of our population. Consequently, as a higher proportion of people continue to live longer lives, interest in the aging process has sparked a flurry of research delineating many physiological, psychological and cognitive effects associated with advanced age (Birren & Schaie, 1985). For instance, aging has been shown to affect basic cognitive functions, such as working memory (WM) capacity and rate of information processing (Verhaeghen, Marcoen & Goossens, 1993). However, there is evidence to support the claim that more complex cognitive functioning, such as reasoning and problem-solving abilities, do not appear to show the same magnitude of age related limitations (Charness, 1985). Furthermore, as professionals maintain interest in their fields well into their 60's, 70's, and beyond, research has been conducted to characterize and understand competent expert performance as a function of aging. Findings indicate that many aging individuals continue to function at a remarkable level of proficiency, especially in domains where the individual has extensive knowledge (Charness, 1985). This is especially true in areas where new information is quickly accumulating, such as medicine, requiring current practitioners to improve their medical knowledge and professional competence as they continue to practice medicine at advanced ages.

As was mentioned earlier, accuracy or successful performance in an individual's domain of expertise may not necessarily decline as one gets older (. However, declines in memory tasks, such as recall ability and WM capacity, is apparently related to age. Therefore, this exploratory study seeks to investigate whether working memory capacity and decreased efficiency in retrieval of stored information of an aging medical expert constrains performance. If not, then what possible mechanisms are there which "compensate" or "bypass" the apparent limitations?

Expertise and Aging

Studies investigating performance of aging experts are able to demonstrate differences in performance between aging and younger individuals primarily when subjects are tested *outside* their area of expertise. These differences demonstrate that older individuals are slower in learning a new task and have poorer memory for recall (rather than recognition) of items. Studies looking at aging and expert performance *within* their area of expertise have come to somewhat different conclusions. Namely, that expert skills *within* their domain of specialty are maintained at advanced ages. It seems that something about extensive knowledge in an area either prevents or protects individuals from age related declines, enabling them to continue functioning at amazing levels (Shimamura et. al., 1995).

Investigations of the recall of chess piece positions of both young and old expert and novice chess players indicated that performance on the chess position recall task was dependent upon both the age and the skill (level of expertise) of the participant (Charness, 1985). Charness found that expert chess players as a group recalled more chess positions than the novice chess players. However, older players (greater than 55 years) in either group (novice or expert) did not recall as many chess piece positions as their younger, skill-equivalent counterparts.

When Charness compared the performance of these chess players in a game, he found skill, not age, to be a determining factor. So, although the older players had poorer recall scores, this did not interfere with their ability to play well. Skill level was found to be a better predictor of a successful player, regardless of age and related impairments.

Working Memory and Aging

WM is defined as "a system for temporarily holding and manipulating information as part of a wide range of essential cognitive tasks, such as learning, reasoning and comprehending" (Baddeley, 1990, p. 67). WM capacity has been shown to decline with age (Kausler, 1985; Craik, 1994), but experience with a particular task may potentially improve the efficiency of the WM system (Salthouse, 1985). This proposed efficiency may be evidenced as the ease with which facts and information can be retrieved from long-term memory (LTM) stores.

Studies of aging on WM have demonstrated that older adults are unable to perform as well as younger adults on conventional free recall tasks. But, performance on these free recall tasks is highly influenced by factors such as instruction, context, and prior knowledge. Craik (1994) explored the effects of these types of "environmental support" on the performance of older and younger subjects on a free recall task. He concluded that "the negative effects of aging can be somewhat ameliorated by the provision of appropriate environmental support" (p.158).

Medical Expertise

The diagnostic reasoning strategies of novices, intermediates and medical experts have been well documented (Schmidt & Boshuizen, 1993; Patel, Arocha & Kaufman, 1994). Novices are beginner medical students, whereas intermediates are advanced medical students and/or residents, who have knowledge of a particular field of medicine but they do not have extensive clinical experience (Patel & Groen, 1991). The common findings are that novices process information at a superficial level, and therefore search strategies into possible etiologies and diagnoses are quite limited. Conversely, intermediates engage in extraneous search, and they provide extensive elaborations in explaining a patient's symptomology (Arocha, Patel & Patel, 1993). However, medical experts' knowledge is "finely tuned" so that they are able hone in on critical items and to filter out irrelevant information, preventing an extensive search (Patel, Arocha & Kaufman, 1994). They very efficiently recognize, focus and elaborate on the essential components of a patient's health profile, due to their comprehensive knowledge as well as their history of clinical exposure/experience. Typically, medical experts conduct what is referred to as a situational assessment (Klein & Calderwood, 1991), where the formulation of an accurate diagnosis depends on understanding the details, parameters and circumstances under which the patient currently manifests his/her symptoms. This was found to be a key elaboration before a diagnosis is usually provided relatively early on (Kushniruk, Patel & Fleiszer, 1995) Finally, a last characteristic of expert performance is the high level of accuracy and intricate comprehension of the patient's condition and diagnosis.

Aging and Medical Expertise

There has been little attempt to examine the diagnostic reasoning process in aging medical specialists. However, Patel & Arocha (1997) investigated some implications that the development and maintenance of medical expertise have on aging medical experts, although age-related measures were not directly investigated. Therefore, the focus of this study was to advance an attempt at a qualitative examination of possible cognitive changes associated with aging in medical specialists. We wanted to characterize the performance of two outstanding individuals in a task *within* their specialized domain. Further, we wanted to look at processes that are required for successful medical problem-solving and decision making, which may potentially be immune to the effects of aging. These include A) degree of situational assessment B) ability to distinguish relevant and irrelevant clinical findings and C) diagnostic accuracy. Other cognitive characteristics needed as basic support for the expert strategies, which are believed to be affected by the aging process, were also investigated. These include D) speed of information processing/efficiency of retrieval, which determines the amount of time it takes to diagnose, and the facility with which one has immediate access to acquired knowledge store in memory and E) WM capacity, which allows one to keep track of patient details, goals and hypotheses while formulating a diagnosis. Ultimately, we wanted to examine whether an aging physician utilizes different problem-solving (diagnostic) strategies to maintain a high level of performance, when faced with basic cognitive limitations associated with aging.

Methods

Subjects

Two subjects were carefully selected to participate in this study. A top cardiologist, aged 70, who is a pioneer in his field, and published the first article on "cardiac tamponade" in *The New England Journal of Medicine,* was chosen because of his specialized expertise in the domain, extensive clinical experience and track record. The senior cardiology resident, aged 35, was in his fifth year of residency, highly recommended for this study by his supervisors because of outstanding performance during his training, and his continual effort in the field. We wanted to collect rich and in-depth data on the performance of two very talented and competent individuals who differed in age, clinical experience and expertise.

Procedure

Clinical Problem An actual clinical case, modified in textual form by a team of specialists, was developed with the aid of an independent cardiologist. The problem, used in other studies, and elaborated in detail elsewhere (Patel, Groen & Arocha, 1991), describes a man who was diagnosed as having Pericardial Effusion with Pre-Tamponade. This is a condition in which there is compression of the heart produced by the accumulation of fluid in the pericardial sac, to the extent that the normal expansion of the heart is prevented. The actual diagnosis is comprised of two parts. 1) Pericardial Effusion, which is relatively "easy" to identify, and 2) Pre-Tamponade, which is a serious condition and rather difficult to identify. The written case was presented in three sections, one per page: History, Physical Examination, and Lab Results. Subjects were asked to read the cardiology case while "thinking aloud". They were then required to provide a diagnosis, to recall the case (without looking at it), and to explain the underlying pathophysiology of the problem. The subjects' responses were audiotaped, transcribed, then analyzed using proposition analytical techniques.

Working Memory Span Test This task involves reading a series of sentences, one at a time, with the goal of recalling the last word of each sentence after the series is over. This task interferes with the subject's ability to rehearse the words by requiring that the next sentence be read immediately after the previous one. Subjects move on to harder levels (increased number of sentences per series) until they are unable to recall most of the words. This ceiling is thought to represent the subject's Working Memory Capacity, the reading span score. This task is constructed so that one can attain a maximum reading span score of 6 words.

Data Analysis

We utilized propositional and semantic analyses, which enabled us to represent diagnostic dialogues into semantic representations and directionality of component reasoning strategies (Patel & Groen, 1991; Ericsson & Simon, 1984). These analyses were conducted to aid in the examination of A) degree and timing of situational assessment B) relevant and irrelevant clinical findings C) diagnostic accuracy and completeness. These measures were chosen because they represent critical characteristics of expert performance in medicine. Further analysis included quantifying the D) the efficiency (speed) of problem-solving and E) the capacity of working memory using the Reading Span Task (Just & Carpenter, 1992). Selection of these measures enabled us to look at already established measures believed to be affected by the aging process.

Results

Situational Assessment

A situational assessment involves clarification and identification of the state of a decision problem, for example, requesting additional information on key details, or reviewing and interpreting data. This is an example of forward-directed, or data-driven reasoning, an indicator of expert performance. It is important to note that situational assessment involves a thorough understanding of the entire clinical picture, rather than simply determining the urgency of the situation, and acting on it. One must take into account all critical factors *before* an action is chosen. For example, responding to an urgent infection might entail antibiotic treatment, however, a thorough situational assessment might reveal an allergy to a common antibiotic. Thus, one can see the importance of a deep understanding of the entire clinical picture, rather than a quick response lacking sufficient information. The following excerpt illustrates that the older expert requested further information, and described what he would do next. He was reluctant to provide a definite diagnosis even two minutes into the task (compared to 20 seconds with the resident), until he understood more (read on).

> *"Now there are other possible things which you go straight into, trying to see if it goes on fitting. I am not going to tell you all the other things that it might be. You bear them in mind.....[LATER] I would surely want to know how he was breathing. I presume he was breathing rapidly....probably 20-25 a minute....The reason I want to know that is that a Pulses Paradoxis of 12mmHg is unimportant if you are breathing hard, but if he's breathing quietly at 12 a minute, then you would be alerted for probably a pericardial involvement."*

The resident began by elaborating some of the differential diagnoses, going into detail as to why each should be considered, rather than collecting more information on this patient. Contrasted to the directionality of the expert, the resident engages in backward-directed, or hypothesis-driven reasoning, seeking text information to justify the hypothesized diagnosis. Further, the resident stays at the level of *explaining* why clinical facts (symptoms) exist, rather than evaluating whether a particular fact is relevant, and what additional information is required. The passage below highlights how the resident sticks to the data, and rather prematurely proposes a diagnosis, some 20 seconds after commencing the case, evidencing a lack of adequate situational assessment.

> *"So he's got what sounds like orthopnea, which may be secondary to myopathy or some disease of the muscle like from alcohol, or maybe secondary to coronary artery disease...[LATER]* Pulsus paradoxicus 12 mmHg; *So just on the borderline of being significant. Paradoxical pulse is what you should be concerned about. Pericardial effusion with some tamponade. Although if he has a primary lung problem, I could explain the Paradoxis one, and you could have mild Pulsus with congestion."*

Relevant and Irrelevant Clinical Findings

The resident judged many more text findings/observations to be relevant to the diagnosis than the expert did. The expert used 7 text findings/observations to support all 6 subdiagnostic hypotheses, whereas the resident mentioned 18 text findings/observations, more than double the amount generated by the expert. In other words, the expert successfully recognized not merely the relevant observations, but the *critical* ones in the determination of the correct diagnosis, making his strategy a more efficient one. Further, the resident concentrated on supporting 1 subdiagnostic hypotheses with the majority of the 18 text findings (72%), leaving the other diagnostic components effectively unaccounted for. Essentially, the resident *over-supported* the diagnosis of Pericardial Effusion, spending a considerable proportion of his time confirming this one subdiagnostic hypothesis.

Diagnostic Accuracy

Six subdiagnostic hypotheses (associated health problems) are needed to reflect complete diagnostic understanding of the case. The six associated health problems included Ischemic Heart Disease, Left Ventricular Failure, Right Ventricular Failure, Pericardial Effusion, Pericardial Tamponade, and Hepatic Congestion. The final diagnosis is Pericardial Effusion with Pre-Tamponade. The expert mentioned all 6 subdiagnostic hypotheses, and provided the final diagnosis in the diagnosis section. The resident failed to mention the subdiagnosis of Hepatic Congestion. When prompted for a final diagnosis, the resident stated Pericardial Effusion, but did not qualify it with Pre-Tamponade, essentially missing this urgent and serious condition.

In addition to the resident providing an incomplete diagnosis, he also made errors in understanding the case, and there were some self-contradictions. The errors he made were a) stating that the liver was not congested, when in fact it was; b) stating that there was a right pleural effusion, where there was none; c) he incorrectly recalled that the patient drinks alcohol more recently, whereas it was stated that the patient began drinking less. Finally, the resident d) suggests that this is not a case of hypothyroidism, yet in concluding, he is uncertain about this and suggests testing for this condition.

Efficiency (Time)

The overall amount of time spent on the clinical case was 11 minutes 20 seconds for the resident and 23 minutes 40 seconds for the older expert. Although the task was not time constrained, it is important to note that the older expert took twice as long as the resident. Also, the expert spent more time in the diagnosis section than any other section (almost 7 minutes, approximately one third of the total time), which indicates that he places the most importance in this section.

Reading Span WM Task

The resident performed better than the expert on the Reading Span Memory task. Scores are determined by the level at which one cannot continue to recall the last words in a series of sentences. The resident achieved a score of 4, whereas the older expert attained a score of 3.5. According to the categorization used by Just & Carpenter (1992), the resident obtained a *high span* (4 up to a maximum of 6 words) WM capacity, whereas the expert cardiologist achieved a *medium span* (3-3.5 words) WM capacity.

Discussion

The purpose of this study was to investigate optimal performance of prominent medical professionals during a challenging and realistic task, and to explore age-related differences in the formulation of a diagnosis. The findings suggest a relationship between potential declines in WM capacity and highly organized knowledge increases for experts in their subspecialty.

Situational Assessment

Subjects focused on different clinical findings, illustrating different schema representations of the problem. Patel, Arocha & Kaufman (1994) write that "schemata, which are built up as a function of experience within a domain of expertise, guide a subject to key elements in a problem and serve to filter out irrelevant information" (p. 21). The schema is revised and altered as new information about a situation is realized (Kleine & Calderwood, 1991). Thus, situational assessment proves essential in determining which details are important to hone in on and to clarify. It appears that the resident's schema is not as well developed or elaborated as the expert's, for he utilizes many more text findings than the expert, indicating that he relies on given information to make a diagnosis, rather than interpreting then seeking key additional clarifications.

Separating Relevant and Irrelevant Clinical Findings

A characteristic quality of experts is that they quickly and efficiently recognize patterns in their domain of expertise, crystallize the decision problem, and are able to effectively distinguish between relevant and irrelevant details with respect to their goal (Patel, Arocha & Kaufman, 1994; Patel, Groen & Frederikson, 1986). In contrast, intermediates amass vast amounts of information, but lack expert experience which facilitates the efficient organization and filtering of this information (Patel, Arocha & Kaufman, 1994). The efficient organization of information allows the expert to 1) select relevant and critical clinical information and 2) to "chunk" this information into related units to be stored in memory. So, it appears that this resident processed information as an intermediate does, deeming almost everything to be important. For the expert, because his knowledge base is efficiently organized, a few select propositions is all that is required for complete and accurate understanding of the case.

Diagnostic Accuracy and Completeness

The expert cardiologist demonstrated superior knowledge of his field, by providing all the essential subdiagnostic hypotheses critical to understanding the case, and by providing the complete final diagnosis. The resident, however, was only partially accurate, for he did not provide a complete diagnosis. He neglected to mention Pre-tamponade in his final diagnosis, indicating that he was unaware of the real urgency of the patient's medical condition. There were also several errors generated by the resident. These differences may be partially explained by the impact that years of clinical experience have on medical performance. However, one cannot "learn" clinical exposure, one has to experience it. The expert has acquired many years of clinical experience, and this is illustrated in his ability to correctly diagnose and explain a very complicated clinical problem in his domain.

Efficiency (Time)

One theory of aging proposes that declines in cognitive performance can be attributed to slowing in the rate of information processing (Brewer, 1987). However, practice can maintain the performance of older experts at high levels, *only if* the task is self paced. This means that an older expert may be penalized if a time limitation were imposed on him/her. Therefore, an important measure of rate of information processing is the time it takes a subject to complete a given task. The cardiology problem required that the subject read the case at his own pace, while "thinking aloud" as he went along. The fact that the older expert took longer may represent a number of possible explanations, including that this may be a strategy to (inadvertently or not) stall for time. Perhaps while he was thinking aloud, the expert may be searching to obtain or link information from WM to LTM, where organized knowledge is stored. Anecdotally, encounters we all have had with older adults and relatives support the notion that older adults sometimes remember information quite a while after it was requested - even as much as several days later.

Working Memory Capacity

The expert was found to have a *medium* WM capacity, indicating a smaller, more limited, WM capacity than the resident, who is categorized as having a *high* WM capacity. Craik (1994) has argued that "age related changes in performance are extremely variable" (p.155). Because this study investigated WM capacity in two subjects, the possibility arises that the expert may be atypical in that he may not exhibit as marked a decline in WM capacity as one would expect in an older individual, although, again, the expert is an active researcher and clinician, and therefore continues to "exercise" his WM capacity, perhaps protecting him from typical age-related declines. Also, the Reading Span task was not time constrained, for the subjects were permitted to read at their own pace. This may partially explain why the expert's and the resident's performance were both good.

Conclusions and Implications

Different strategies in diagnostic reasoning may be employed by individuals in order to counteract cognitive declines related to the aging process. It is the characterization and understanding of these hypothesized mechanisms that may provide valuable tools to help combat the effects of aging on certain cognitive measures. For example, an older expert physician may find it increasingly difficult to keep track of details regarding a patient's symptoms, exam, and lab results. He/she may find it helpful to use memory support systems and diagnostic aids, such as a portable data entry terminal, or a computerized patient record, to store the particulars of each patient, which can be quickly and easily accessed when required.

This study provides an initial framework from which future studies focusing on the diagnostic strategies of aging medical experts can be built. We have begun to develop a theoretical and methodological framework for studying the effects of aging on medical expertise. Future research endeavors should elucidate the mechanisms under which expertise is maintained at advancing ages. Specifically, one proposed mechanism is that decreases in WM capacity is *compensated* by increased knowledge and experience. Another mechanism suggests that organization of knowledge is the result of years of practice, rather than simply a strategy to make up for basic cognitive limitations associated with aging.

It is our view that this issue is likely to be of considerable importance if we want to capitalize on utilizing the vast experience and knowledge of expert medical professionals as they approach their retirement years.

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