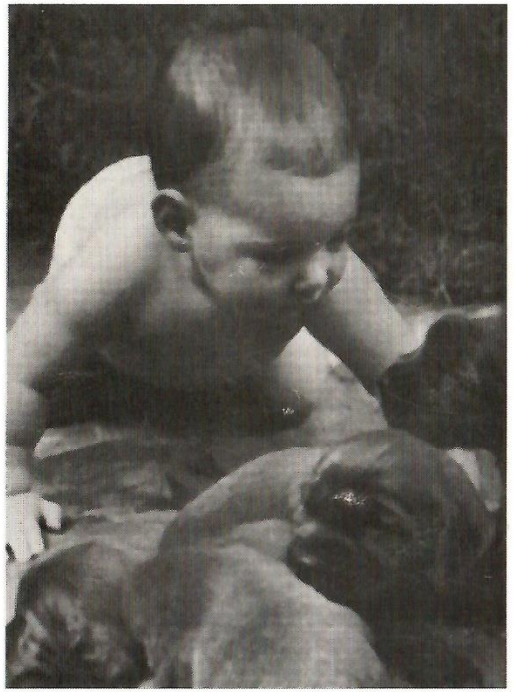
Oana Benga Mircea Miclea

DEVELOPMENT AND COGNITION



Presa Universitară Clujeană

Oana Benga, Mircea Miclea
DEVELOPMENT AND COGNITION

Production supervisor: Daniel Paul

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This volume was published with the support of The Open Society Foundation for Romania, "East-East" Program

Babeş-Bolyai University
Cluj University Press
Director: Horia Cosma
Gh. Bilaşcu 24
3400 Cluj-Napoca
ROMÂNIA
Tel.: (+40)-64-405.300, int. 167
Fax: (+40)-64-191.906

ISBN 973-8095-82-4

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DEVELOPMENT AND COGNITION

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Editura Presa Universitară Clujeană
Cluj-Napoca
2001

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ACKNOWLEDGEMENTS

This volume is based on lectures and seminars presented at the International Workshop "Cognitive Development and Education", September 6-12, 2000, organized in Cinciş, Romania by the Department of Psychology, Babeş-Bolyai University, Cluj-Napoca, Romania and the Association of Students in Psychology from Transilvania (ASPT). The workshop as well as the present book were generously supported by the "East-East" Program of The Open Society Foundation for Romania.

We want to thank for their efforts to those "key" people from ASPT who made the international workshop not only possible, but also highly attractive even for our foreign guests. It was very rewarding to work with them and they have proved once again the quality of students in Psychology from Babeş-Bolyai University.

We also are grateful to our foreign colleagues from France, Bulgaria, Spain and Slovakia for their exciting presentations and for the interesting papers provided for this volume.

In the same time, many thanks to our colleagues from the Department of Psychology Cluj-Napoca that contributed to the workshop and helped in the writing of this book.

The valuable contributions of participants - students from Latvia, United Kingdom, Belgium and Russia, as well as those of Romanian students from the universities of Iaşi, Bucharest, Timişoara and Cluj-Napoca - raised the quality of the workshop, but also inspired many of us in the final preparation of the papers.

Last but not least, many thanks to all who have worked so hard in realizing this book. We think their efforts are worthy.

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COGNITION, CULTURE AND COMPUTERS IN CONTINUOUS EDUCATION

Maia Dimitrova

This chapter is an attempt to summarize some of the current knowledge about the complexity of cognitive processing within the new "natural context" of learning – the computers. Computers are viewed as much more flexible devices for understanding, modeling, guiding and prompting the learner, than it is generally assumed. In order to be efficient educational tools, they have to accommodate both the general and the specific phenomena of learning as revealed by research on human cognition. Interacting with the computer is in essence a process of continuous education where developmental, cultural and cognitive aspects "blend" to create an educational system of mutual understanding and adaptation for the learners to gain confidence in their knowledge about the world and about themselves.

INTRODUCTION

Continuous education is a life-long process of knowledge acquisition, representation and utilization. Until recently, there was a lag between learning of new skills (i.e. education) and the application of the acquired skills (i.e. real life and work) on the time scale of the individual life. The situation has dramatically changed to life-long education and on-line application of new skills via the presence of computers in people's lives from childhood to very old age. The interaction with the computer can be viewed as an educational system with the ability of the interface to teach, coach, guide, direct, prompt and feed back (e.g. Papanikolaou, Magoulas & Grigoriadou, 2000; Dimitrova, Boyadjiev & Butorin, 2000). Moreover, computers are in principle capable of exhibiting behaviours of social support

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such as, for example, "empathy" to the learner, which is also becoming a developmental issue, especially for impaired people and children with disabilities.

The current level of development of the computer technology provides an incredible chance for immediate application of theoretical knowledge in practice and its verification by the design of a variety of user interfaces appropriate for any age, culture, knowledge and skills level. Thus, cognition, culture and computers are viewed as three equipotential aspects of continuous learning within the current view that education and technology should be for all people according to their individual - differences, preferences and needs.

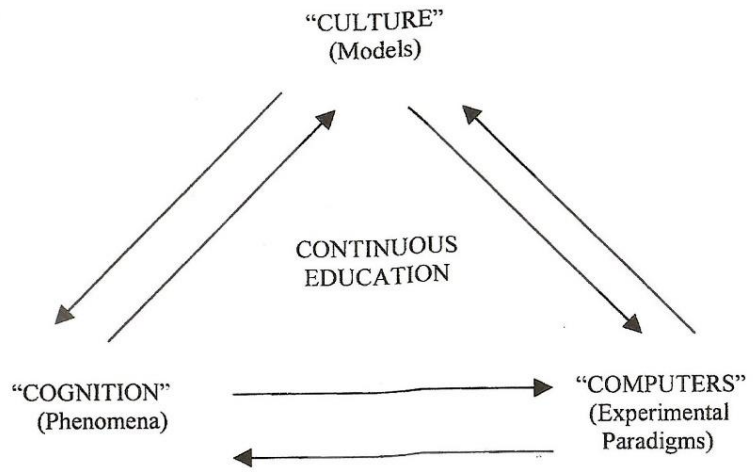


Figure 1. *The interaction of the three aspects of continuous education constitute the friendly "natural" environment for efficient learning*

This structure of the interaction of the three components of continuous education bears resemblance to the more traditional structure of methodology in cognitive research. The label "Cognition" represents the phenomena under study in an experimental setting, the label "Culture" in a specific sense relates to the existing knowledge about the studied phenomena presented by current theories and models, being in a way "culturally flavored". The label "Computers" is used as a "substitute" to experimental paradigms or designs, by being mediators and communicators

of relevant information and knowledge assistance, and which are often built to generate tasks and dialogues to the users and to accumulate measured responses for system adaptation.

The nature of the human-computer interaction process is heavily dependent upon the user's memory and on dynamic cognitive processing. The cognitive ecology of the interface is becoming the dominant aspect of interface design, development and adaptation to suit the purposes of educating people of all ages, abilities, needs and preferences. These have to be built on the grounds of most recent knowledge from the cognitive and developmental sciences. From such a perspective the following issues are set as a framework for understanding and enhancing cognition in the new "natural" context of continuous education – learning with and from computers:

- Rehearsal systems in cognition. Transient processes. Cultural considerations.
- Interfering systems and composite traces in cognition. Educational implications.
- Function distributedness and specialisation. Local and global models. Computational aspects.
- Incidental and intentional learning. Event representation and learning in natural contexts.
- Computer modeling and adaptation to individual learners. Continuous education and cognitive support in human-computer context.

REHEARSAL SYSTEMS IN COGNITION. TRANSIENT PROCESSES. CULTURAL CONSIDERATIONS

Rehearsal systems. The rehearsal systems in cognition are the functional structures of immediate cognition. They are multiple, rather than single, modality specific, and involve translation from one into another. In human-computer context the following are of great importance – articulatory based on the phonological loop for the verbal material, spatio-visual for the graphical, pictorial and 3-dimensional presentation, tactile and motor for the mouse and keyboard control, etc. The goal of the rehearsal systems is to capture, maintain, understand and preserve the studied material, i.e. for the learner to acquire new knowledge. Rehearsal is the basic mechanism of new knowledge acquisition. Rote ("maintenance") rehearsal ensures that the newly introduced item is being kept for a certain time in the cognitive system so that it is available for the analysing systems to "deeply process" its contents and features, incorporate it and integrate it

with the existing knowledge structures. It is well known from extensive research that simply repeating the items may not lead to better learning and remembering unless deep-processing systems are involved in the rehearsal process (e.g. Glenberg, Smith & Green, 1977).

The complex nature of the "front-end", immediate or "short-term" cognition has been, perhaps, best revealed by theory of working memory (Baddeley, 1990). The working memory, according to his theory, consists of a phonological loop, a spatio-visual sketchpad and a central executive. The phonological loop is a rehearsal system for articulatory information. It includes several systems such as the auditory system, speech perception and articulation systems, including the motor component of speech. Baddeley and co-workers have shown that the "inner speech" plays a role in the rehearsal process and that the spoken duration is an important determinant of the words that are to be rehearsed. One of the most notable features of the "phonological loop" concept is that it gives time constraints on the introduction of new material at a micro-level of cognition. In one study it was shown that the number of words that can be rehearsed in a unit time is related to their spoken duration in a unit time. The number of words that can be produced immediately after their presentation depends on how many of them can be read in approximately 2 seconds and the dependency is linear (Baddeley, Thomson & Buchanan, 1975). This is a finding with very important implications for education in both pedagogical and human-computer settings. Thus, if a new concept is introduced to the learners, at least 2 seconds have to be allowed for the rehearsal system to include it into the loop for efficient rehearsal, understanding and further remembering. This is especially important when teaching children. In user-computer context the 2 second limit for novel items (messages, commands, concepts, etc.) should be incorporated in the systems for generating the dialogue to the user.

Although a dichotomy has long been assumed (explicitly or implicitly) between the rehearsal systems as some "shortly-lived" memory and the long-term retention of knowledge, evidence supporting the 2-second boundary for efficient learning can be also found in paradigms traditionally employed in studies of long-term memory. In experiment 1 of a study of Jones (1982) subjects studied a visually presented list of 50 pairs of words where the presentation time of each pair was 3 seconds. The employed experimental paradigm was cued-recall. At test, the level of performance was 0.098. In experiment 2 the list was shortened twice to 25 items to avoid the observed floor effect in experiment 1. This increased the level of performance twice to .18. In a subsequent study with the exactly the same stimulus set as in experiment 1 (50 pairs) (Dimitrova, 1994) the pattern of

results was replicated at the level of .093. In experiment 2 the study time was increased to 5 seconds for a pair of words in both conditions of study – intentional and incidental learning. This increased the level of performance twice to .175 and .125, respectively. Moreover, this level of recall in the intentional and incidental learning tasks did not differ significantly. It seems that the 2-second boundary is of crucial importance for the visual (reading) to articulatory (rehearsing) translation process of learning of words and concepts. This observation can be taken as evidence in support of the working memory theory of Baddeley and the importance of the time spacing of learning at this micro-level of cognition. Working memory processing involves a great deal of *interiorised* cognitive activities and the time limit is an essential component in learning.

Although the three main components of the working memory system forwarded by Baddeley have usually been considered together, the proposal here is that the rehearsal systems are best exemplified by the phonological loop and refer to systems of other modalities like visual, tactile, etc. to the extent that it involves time constraints, repeated reinstatements and translations from one system to another. An example of visual rehearsal can be trying to learn the spelling of a foreign word by imagining it letter by letter, or tactile – trying to learn it by typing it several times. The basic findings about the spatio-visual slave subsystem of working memory is considered as an example of a type of transient memory proposed by Anderson (1995).

Transient processes. Transient processes participate in working memory learning activities, but their direction is slightly different. The main goal is not so much the intention to permanently store the studied material for later test, but mainly to perform the current task efficiently. In this sense, the main function is a kind of monitoring, or *exteriorised* cognition. It was shown by Baddeley that retention of an image after performing a mental imaging task can be dramatically impaired by a concurrent visual tracking ("monitoring") task (Baddeley et al., 1975). The cognitive activity performed by the spatio-visual "sketchpad" of the working memory system is a transient process more oriented towards efficient immediate performance than to long-term remembering of the mentally manipulated items. An important finding is that this slave system is rather spatial than "simply" visual. In a subsequent series of experiments it was shown that the remembering of the generated mental image is impaired by spatial "monitoring" tasks like trying to determine the location of a sound while blindfolded. On the contrary, no image disruption was observed when the concurrent task was to observe the brightness of a screen while performing a

mental imaging task (Baddeley & Lieberman, 1980). This has a direct implication for the design of the computer interface where graphical or 3-D representations are more salient to the user, whereas attentional processing is less sensitive to the visual background like brightness or colour.

Cultural considerations. The discovery of the phonological loop has had an important implication to show that verbal aptitude tests for children from different cultures (e.g. Welsh & English) have to be equated on the basis of the spoken duration of the included words (Ellis & Hennelly, 1980). After doing this, it turned out that there were no differences in verbal abilities between children of the same age from the Welsh and the English communities, only the used words were of different length. Similarly, computer users often interact with software, which generates messages and dialogue in a language, different from the user's native language. Efficient interaction to a great extent depends on the ability of the user to understand and accommodate the largely technical semantics of the generated messages and should be appropriately spaced over time (e.g. Larson & Czerwinski, 2000). Investigations from user-computer interface studies have also revealed that users from different nations are sensitive to culturally provided specific signs by the interface, like facial expressions or gestures of synthetic images of people, characteristic of their nationality, rather than abstract signs of form and colour (e.g. Andre, 2000). This is in agreement with the working memory theory for "immediate" cognition.

INTERFERING SYSTEMS AND COMPOSITE TRACES IN COGNITION. EDUCATIONAL IMPLICATIONS

Interfering systems and composite traces in cognition. A natural tendency of human cognition is to integrate old and new knowledge in complex structures. Whenever a new material is introduced, the first performed check is for its familiarity. It is claimed here that this is a very fast and automatic process and that its outcome triggers different strategies for further processing. Low familiarity items are more likely to be elaborated separately, whereas high familiarity items are more likely to be incorporated in familiar previously acquired broader schemas or contexts. Numerous investigations on everyday memory (eyewitness testimony, flashbulb memories, etc.) in both realistic and laboratory settings have shown two main phenomena. First, dramatic confusions for high familiarity images to be reconstructed like faces and objects (cars, tools, etc), and, second, exceptional level of inclusion of nonexisting, but familiar details in

subsequent reports of a dramatic event with the increase of the level of familiarity of the memory about the event (e.g. Loftus, 1979, Davies, Ellis, & Shepherd, 1981, Neisser & Harsh, 1992). Thus, the cognitive system spontaneously "blends" the memories, generalizes across contexts and leaves *composite traces*. This is most evident in situations of single-trial learning, incidental learning and implicit learning tasks. These are all present in human-computer interaction.

For low familiarity items the "spontaneous reaction" of the cognitive system is to try and elaborate the item *itself*. The elaboration involves multiple generations of previously stored knowledge in an attempt to accommodate the novel item within existing structures. This is a temporary process and lasts until the item becomes "familiar enough". During this process, the "distinctiveness" of the item remains its characteristic feature.

In general, two different forms of spontaneous learning can be distinguished depending on the nature of the studied material – deep, "conceptual" elaboration of low familiarity items and spontaneous access to well-consolidated "gestalt-like" structures for high-familiarity items. They can be revealed by two forms of a so-called "familiarity-based automatic retrieval". The implication is for introduction of new systems, which have to be as much distinctive as possible in their novel features and general in their similarity to previously learnt ones.

Educational implications. The distinction of kinds of familiarity-based automatic processing in cognition can help resolve the proactive and retroactive interference effects, frequently observed in education. The proactive interference observed when subjects study lists of words can be operationally defined as retention being a decreasing function of the number of previously learnt similar lists of words. Thus, learning of new lists of words is a negatively accelerated function of the level of familiarity of the learning task. Distributed practice is in essence the manipulation of the novelty aspects of the learning situation and has been shown as an effective strategy in education.

The observed retroactive interference of a previously learnt list of words can be defined as retention being a decreasing function of the number of "intermediate" lists. This process can be understood as "fitting" the interfering items into the composite trace. It was shown that the observed effect of retroactive interference is due to loss of entire categories rather than random items and can be retrieved if cued with the name of the category (Tulving & Psotka, 1971).

The existence of the interfering systems and composite traces in cognition can be understood from an efficiency perspective – to acquire,

process and recollect knowledge in a fast, "storage-and-cost effective" way. The important information is preserved and the "unnecessary" details are gradually removed. Connectionist frameworks of distributed knowledge over numerous processing units quite parsimoniously represent this view (e.g. McClelland, McNaughton & O'Reilly, 1994).

FUNCTION DISTRIBUTEDNESS AND SPECIALISATION. "GLOBAL" AND "LOCAL" MODELS. COMPUTATIONAL ASPECTS

The issue of the universality of cognitive functioning relates to the issues of the dichotomies proposed by current theorists in relation to the kinds of system(s), process(es) and structure(s) of human memory as they are revealed by various measures of retention. A universal function is assumed to perform in a similar manner across various tasks assumed to represent possibly different processes. In this sense a universal function is characterised by its *distributedness*. For example, if a model proposes similarity between two processes, for example, recognition and recall, it emphasises some universal aspects of the retrieval process and can be assumed as a *global model*. If, on the contrary, the model aims at explaining the distinctions between processes, it deals with function *specialisation* and can be called a *local model*. The following sections present three models for recognition and recall -- a global model, a local model and a combination of the two. It is shown that both function distributedness and specialisation participate in cognition.

A "local" model of recall

A quantitative model of recall was proposed by Bahrick (1970). In his experiment subjects studied lists of pairs of words such as *time* - BLUE. At test they were given the first member of the pair as cue for recall. Immediately after this test, subjects were given, together with the cues, prompters to help recall the targets they had failed on the previous test. The prompters were taken from one of 4 categories. Each category represented a different level of preexperimental association between the prompter and the target. Thus the following prompters were given for aiding the recall of BLUE - *velvet* (.03), *grey* (.10), *green* (.28) and *azure* (.58). The preexperimental association strength presented in the brackets was obtained from a separate group of subjects that were instructed to produce as many free associates as possible of the target. A third group of subjects was given

a recognition only task. According to Bahrick's model the probability of successful recall is a product of retrieval probability and recognition probability, i.e.

$$P(Rc) = P(Rt)P(Rn),$$

where P(Rc) is the probability of recall with the aid of a prompter, P(Rt) is the probability that the target item will be among those retrieved (generated) within the allowed retrieval time (20 sec), and P(Rn) is the probability of successful recognition given the target that has been generated (Bahrick, 1970). The model was successful for predicting the observed probability of recall for all four levels of prompter-to-target association strength.

Bahrick's model was consistent with the approach to modeling the recall process as involving recognition as a second stage of the retrieval process, the dominant approach at that time (e.g. Kintsch, 1978, Anderson & Bower, 1972). Two basic assumptions underlie the model, first, that recall is not possible without an undergoing recognition stage, and, second, that recall cued by unrelated studied words is always mediated by the generation of strong associates of the target even if they were not presented in the study list.

Thomson and Tulving (1970), on the other hand, provided evidence that weak associates can be more effective cues if they were present at study than strong extralist associates of the targets. For example, *train*, if paired at study with BLACK, was more effective for recall of BLACK than the nonstudied extralist strong associate *white*. This finding was interpreted in terms of the proposal by Tulving and colleagues of an Encoding Specificity Principle, formulated as: "In its broadest form the principle asserts that only that can be retrieved that has been stored, and that how it can be retrieved depends on how it was stored" and, further: "...the effectiveness of retrieval cues depends on the properties of the word event in the episodic system. It is independent of the semantic properties of the word except insofar as these properties were encoded as a part of the trace of the event" (Tulving & Thomson, 1973, p. 359).

These two studies illustrate two theoretical approaches to modelling recall with respect to the issue of how information is stored in memory. One of them assumes retrieval of an item from its cue as mediated by access to a higher order structure, e.g. a "schema" (Ross & Bower, 1981) that has emerged from processes of organisation and abstraction. The second approach considers the possibility that items in memory are connected directly to each other comprising individual structures called "fragments" (e.g. Jones, 1978b, 1984b). Successful retrieval emerge through the so called

"orthogonal cued recall" because the components of the fragment are assumed independent from each other (Jones, 1978b). The experimental studies within these theoretical frameworks revealed the dual nature of the process of recall, namely, a) recall as an elaborate process of recovery of information from memory (generation) and decision making about its appropriateness to be produced as a response to the cue, and, b) recall as a simultaneous, automatic access to the needed appropriate information.

Retrieval independence in recognition and recall – a "global" model

Recognition failure phenomenon

The theoretical debate about the mechanism(s) of retrieval from memory sharpened with the discovery of the "recognition failure function" (Tulving & Wiseman, 1975). The recognition failure function was suggested to account for the phenomenon of recognition failure, first described by Tulving and Thomson (1973). Subjects studied lists of paired words (A-B) having been informed that they would be subsequently tested for recall of B with A as a cue. An example is the pair *door*-RED. Following the study trial the subjects performed a free association task in which they produced several associates to extralist cues, for example to the word *colour*, a frequent response to this being RED. These protocols served later on as recognition tests. The subjects were asked to circle the generated words they remember from the study list, resulting often in the failure of RED to be recognized as studied before. However, on a subsequent recall test the cue *door* was effective to retrieve RED. This phenomenon was called "recognition failure of recallable words" and was later replicated in various experimental settings (see Tulving 1983 for a review). The experimental paradigm has undergone some change and nowadays it refers to any experimental situation in which memory is tested first for recognition of the targets in the absence of the cues and, after that, for recall in the presence of the cues (e.g. Bryant, 1991; Gardiner, 1994; Tulving, 1983).

The finding that recall can emerge in a somewhat direct way, avoiding the recognition stage, posed a problem to the generation-recognition theories that assumed recognition is always easier (since it is a unistage process of computing the degree of match between the item-to-be-recognized and the trace in memory) and that recall is more difficult (since it is a two-stage process, depending, first, on the success of the generation process, and, second, on the success of the recognition process) (Bahrick, 1970; Murdock,1982, 1993). Instead, Tulving and colleagues (e.g. Flexer &

Tulving, 1978, 1993) suggested that both recall and recognition are unistage processes of mapping the cue to the stored episodic trace and that retrieval success depends on the degree of correlation between the cue and the trace. In recognition the cue was assumed to be a nominal copy of the target and in recall the cue was represented as the word that has been associated with the target during study. Thus both recognition and recall can operate (nearly) independently of each other. In order to describe the empirical finding of a relation of "quasi independence" Tulving and Wiseman (1975) suggested a quadratic function, called the recognition failure function.

Recognition failure function

Tulving and Wiseman (1975) plotted the conditional probability of recognition of recalled items against the overall recognition hit rate from 89 conditions (33 experiments) and found out that the magnitude of recognition failure is an orderly monotonic function of recognition level. They suggested that the following quadratic function with only one constant c provided a good approximation to the empirical data:

$$P(Rn|Rc) = P(Rn) + c[P(Rn) - P(Rn)^2] \quad (1)$$

where P(Rn|Rc) is the probability of recognition given recall, P(Rn) is the probability of recognition, and c is a constant. The function provided best fit with the data at $c = 0.5$.

To explain the moderate degree of dependence between recognition and recall Flexer and Tulving (1978) suggested the so-called "*goodness-of-encoding hypothesis*". According to their hypothesis a unique trace relating the cue and the target is stored at study ("trace identity assumption"). The recognition cue and the recall cue access the stored trace. The variation in "goodness of encoding" is responsible for the positive deviation from the line of stochastic independence. The second crucial assumption was the "retrieval independence assumption". The trace and the cues were represented as arrays of features. Retrieval independence results from the uncorrelated nature of the cues (see also Metcalfe, 1991): the higher the degree of overlap between the cues the higher the degree of dependence between the retrieved items for recognition and recall.

Exceptions to recognition failure

a) Maintenance vs. elaborative encoding of the A-B pairs

In Begg's (1979) Experiment 1 subjects were allowed 10 sec to study each pair. Half of the subjects were given the task to repeat the pair aloud as often as possible in the time allowed. The other half of the subjects had to

list words meaningfully relating the members of the pair. The results show high degree of dependence between recognition and recall for the maintenance condition and complete independence for the elaborative condition. Begg (1979) interpreted the results in terms of his "vandal" theory, according to which recognition failure as a moderate dependence between recognition and recall occurs because of trace loss from study to test. Disappearance of items from memory due to trace loss reduces the overall probability of recall but leaves the conditional probability of recognition given recall unchanged. Trace loss is less likely to occur if the encoding conditions enhance the memorability of an event (the strength of its trace) as in situations of elaborative rehearsal of the study material. In this case retrieval occurs independently for recognition and recall because of the richness of the trace. Whenever the encoding conditions foster trace loss as in the case of rote repetition, an impoverished trace is accessed at retrieval, leading to greater dependence between recognition and recall (Begg, 1979).

b) Associative asymmetry between the cue and the target

Fisher (1979) varied the preexperimental degree to which one member of the pair can elicit the other. He used a set of cue-target pairs with asymmetry in the direction of the associative strength between the cue and the target. Thus, when the direction was from cue to target, recall was enhanced and the empirical value for recognition given recall was slightly below the value expected by the function. When the direction was from target to cue, recognition but not recall benefited and, in addition, the value was well above the prediction of the function. This outcome was replicated with the same stimulus words in a series of experiments by Horton and Pavlick (1993a; 1993b, 1993c). These results were interpreted by Hanley (1984) and Horton and Pavlick (1993b; 1993c) in terms of the theory of recognition advanced by Mandler (1980) and his colleagues (Rabinovitz, Mandler & Barsalou, 1977). According to Mandler's theory two different processes are involved in recognition - recognition based on familiarity and recognition based on retrieval. Recognition based on retrieval of contextual information (e.g. backward retrieval of the cue word) is assumed qualitatively different from retrieval involved in cued recall, so they were expected to be uncorrelated.

c) Levels of processing and semantic relatedness effects on recognition failure

Bryant (1991) tested two variables influencing the magnitude of deviation from the recognition failure function - levels of processing and

semantic relatedness. The outcome of his Experiment 1 was that deviations from the function in the direction of higher dependence between recognition and recall were found when subjects performed structural ("Are the words printed in the same lettering case?") or phonemic tasks ("Do the words rhyme?"), but not in the condition when they performed semantic tasks ("Are the words meaningfully related?"). Tasks requiring deep (meaningful) processing were more likely to lead to subsequent retrieval independence than tasks oriented towards shallow (perceptual) processing of the studied pairs of words.

In Bryant's (1991) Experiment 2 the effect of a second variable - the degree of preexperimental association (semantic relatedness) between the cue and the target was investigated. For all three levels - non-associates, weak associates and strong associates - it was found a deviation from the function, although in the former two cases it was much bigger than in the latter case. The results were interpreted in terms of the existence of a boundary condition for recognition failure to occur. This boundary condition was defined as the integration of the cue-target pair during study, the so called "first boundary condition for the law to hold" (Nilsson, Law & Tulving, 1988). To the extent that the study conditions favor the integration of the studied pair retrieval independence is to be expected (Bryant, 1991). A similar interpretation, however, has been previously suggested by Hanley (1984) as supporting the generate-recognize view on recall.

d) Recognition failure of common and unique names recalled from semantic memory.

Muter (1978, 1984) and Neely and Payne (1983) provided evidence that recognition and recall of famous common names from semantic memory, for example, "Maker of the first U.S. flag: Betsy.....(Ross)", conform to the recognition failure function initially proposed to describe a regularity of retrieval from the episodic (but not semantic) memory. In Muter's (1984) experiment a condition of recognition and recall of unique famous names was added. Subjects had to recognize first common and unique famous names and then to try and recall them by providing with information about their lives as cues. An example of an unique name was: Nobel prize winning physicist: "Madame.....(Curie)". Virtually no recognition failure was observed for unique famous names. Those unique names that were successfully recognized were successfully recalled as well. This finding was interpreted in terms of the theory proposed by Jacoby (1983), holding that all the memory consists of traces of episodes including those memories referred to as general knowledge. Recognition of a famous name can fail if only examples of nonfamous persons with this name are accessed at retrieval (Muter, 1984).

However, as pointed out by Neely (1989) the assumption of similarity between retrieval from episodic and semantic memory cannot be made without direct comparison between performance on an episodic and semantic memory task. Nilson, Law and Tulving (1988) gave subjects the episodic task of studying unique famous names and unique geographic names. The results conformed to the recognition failure function. Testing subjects on recognition of famous unique names without prior study is in fact a test of the general knowledge of the subject about this person. As a result, the retrieval conditions for recognition and recall are basically the same, so recognition failure is unlikely to occur. This constitutes the second boundary condition for the function to hold defined by Nilsson, Law and Tulving (1988), i.e. the experimental paradigm should ensure that the retrieval conditions for recognition and recall are independent.

Encoding specificity vs. generation-recognition theories

As mentioned earlier, within the encoding specificity framework recall is assumed to proceed by a single stage direct access ("ecphoric") process (e.g. Tulving, 1983) the outcome of which is determined by the quality of the trace that is accessed at test. This process is assumed to be almost independent of the recognition process, being also a unistage process of matching the nominal copy cue of the target item to the trace. The basic problem with the "encoding specificity" account of recognition failure comes from the numerous exceptions to the recognition failure function reported by researchers for the last two decades that question its generality. In particular, difficulties arise with the explanation of semantic memory blocking of episodic retrieval. For example, in the experiment of Kato (1985) subjects studied pairs of unrelated words and then were tested for recall cued by the first member of the pair only and by the additional provision of a fragment of the target word. For half of the words, there was no semantic competitor for the target, for example, "clock-dollar". The other half of the targets had semantic competitors, for example for the study pair "nurse-dollar" the semantic competitor of the target was "doctor." At retrieval, the level of recall of "dollar" cued by "nurse" was comparable to the level of recall of the same target cued by "clock". The additional provision of the fragment sharply increased the level of recall of "dollar" in response to "clock-do___r", but not to "nurse-do___r". Instead, subjects produced more semantic memory intrusions such as "doctor". Encoding specificity would have expected enhanced retrieval with the provision of more contextual information from the study episode.

The alternative "generate and recognize" models have attempted to accommodate the recognition failure data by postulating two different mechanisms for recognition decisions in terms of low/high criterion setting (Kinstch, 1978), in terms of familiarity/retrieval based decisions (Mandler, 1980), or in terms of fluency of the generation process (Jacoby & Hollingshead, 1990). The various generate-recognize theories share the view that, first, recall emerges from a generation process that is independent from recognition (Bahrick, 1970), and, second, the targets produced at recall that fail to be recognized come from a process, operating *within* generation. The basic problem with the "generate and recognize" models is to accommodate the distinction provided by Bartlett (1932) and cited by Jacoby and Hollinshead (1990) between "reconstructive" and "reproductive" memories, viewed by the authors as reflecting influences of memory for an earlier event on generation processes and on the additional second-stage recognition process, respectively. They applied this framework to test directly performance on recognition (explicit test) after stem completion (implicit test). The subjects failed to recognize some of the earlier presented items although they were successful in completing them. The dual-mechanism framework, proposed by Jones (1982, 1983, 1987) seems more plausible to account for these findings because it employs a direct access mechanism for retrieval of items that subjects fail to recognize.

Dual-mechanism theory of recall

The dual-mechanism theory of recall postulates the existence of two routes to memory - one based on direct access, and a second based on generation and recognition (indirect access) (Jones, 1978a, 1982, 1983, 1984a, 1987; Jones & Gardiner, 1990). Direct access is assumed to operate over intrinsic knowledge that relates the target word to the context in which it has been initially encoded (cue-target feature overlap for cued recall or list context for free recall). The direct access route was conceptualized within the fragmentation model (e.g. Jones, 1978b, 1984b). Retrieval via the indirect route proceeds by generating target candidates by means of extrinsic knowledge that is unrelated to the study context and their subsequent recognition on the basis of intrinsic knowledge. To represent the indirect route Jones applied the straightforward model proposed by Bahrick (1970). Recall is thus viewed as a multistage process consisting of two different retrieval mechanisms. Direct access is assumed to be independent of recognition whereas the indirect access is completely dependent upon recognition (Jones, 1978a, 1982).

The general probabilistic form of the model was given as

$$P(Rc) = P[D \cup (G \cap Rn)], \quad (2)$$

where D, G and Rn denote direct access, generation and recognition, respectively (Jones, 1983, 1987). The general expression for the probability of joint recognition and recall was represented by

$$P(Rn \cap Rc) = P[Rn \cap (D \cup G)]. \quad (3)$$

The dual-mechanism theory was formalized by making the assumption that the two retrieval routes operate independently. The overall probability of recall was given by

$$P(Rc) = P(D) + P(G)P(Rn) - P(D)P(G)P(Rn), \quad (4)$$

where P(D) is the probability of direct-access recall and P(G) and P(Rn) are the independent probabilities of generation and recognition, respectively (Jones, 1982). It was shown by Jones (1978a, 1982) that according to the dual-mechanism theory the probability of joint recognition and recall can be represented by

$$P(Rn, Rc) = P(Rn)[P(D) + P(G) - P(D)P(G)]. \quad (5)$$

It was proven by Jones (1978a, 1983, 1987) that it is possible to derive the Tulving - Wiseman function from the generalized form of the model and it was shown that the two functions are identical when $c = P(G \cap D')/P(Rc)$, where D' denotes the probability of failure to directly access the target. The original derivation of the dual-mechanism theory was successfully applied to a wide range of recognition failure data (105 sets of data from experiments in the recognition failure paradigm, see Jones, 1978a for details). As pointed out by Begg (1979), the dual-mechanism theory predicts that the probability of generation increases with the overall level of recall. This prediction turned out to be correct for the case of recognition failure when recognition targets and recall cues are identical (Jones & Gardiner, 1990). The theory was also correct in predicting the relationship between recognition and recall in Begg's experiment when the type and processing (rote vs. meaningful) and type of study words (all possible combinations of concrete vs. abstract and rare vs. common) were manipulated (Jones, 1980b).

The experimental paradigm

The experimental paradigm proposed by Jones (1982), allowed for direct manipulation of the hypothesized contributions of the two recall routes. Subjects study lists of apparently unrelated cue-target pairs of words such as *liar*-TRAIN. After a distracter task their memory is tested first for recognition and then, after another distracter task - for cued recall of the targets. Two different instructions were given for the recall task. Half of the subjects (the control group) were given standard instructions for cued recall. The other half of the subjects (the experimental group) were informed that the reverse reading of the cue words produced a new word that was related to the target word (e.g. *liar* yields "rail" for TRAIN). All of the cue words were the so-called "heteropalindromes", i.e. meaningful words at forward and backward reading (Jones, 1980a). The basic finding consistent with the predictions of the dual-mechanism theory was that the introduction of the generation component at the *retrieval* stage but not during encoding significantly enhanced recall. The particular formalization of the model for joint recognition and recall yielded a good fit between theory and data for the experimental condition when overall recall results from the contributions of both routes.

Summary

The recognition failure function was initially proposed as an empirical law of operation of retrieval from episodic memory as a functionally distinct memory system (e.g. Tulving, 1983). It emphasized the importance of the reinstatement of the context of the learning situation (e.g. Humphreys, Bain & Pike, 1989; Tulving & Thomson, 1973).

The critiques of recognition failure, on the other hand, insisted that words have various meanings (or senses) and it is very difficult to tell what aspect of the word would be retrieved at test - general knowledge, individual experience or a context of its recent occurrence (Jones, 1979). This unpredictability, in their view, is expressed in the relation of "near" independence between recognition and recall. As it is evident from the overview of the exceptions to the recognition failure function, knowledge from semantic memory does play a role in retrieval from episodic memory and to a certain extent predetermines the boundaries of validity of the function. The dual-mechanism theory has been successful in accounting for both aspects of the problem of the moderate degree of retrieval independence between recognition and recall (boundary conditions and role of retrieval from semantic memory) by postulating two different mechanisms of recall - direct access and generation-recognition. It seems,

however, that the biggest difficulty in explaining the exceptions to recognition failure for any of these approaches - encoding specificity, generate-recognize or dual-route to memory - is related to the account of strong dependence between recognition and recall after the subjects studied lists of semantically unrelated pairs of words.

The phenomenon of recognition failure has its importance for education both in "classroom" and in human-computer settings and should not been neglected. As it is shown in the above analysis, it reveals a "clash" of processing of novel and familiar aspects of the studied items, and is best accounted for by a combination of a global and a local model as proposed by the dual-route to memory theory of Jones. It seems that research on learning from and with computers may help understand more deeply the nature of the phenomenon and its educational implications.

INCIDENTAL AND INTENTIONAL LEARNING. EVENT REPRESENTATION AND LEARNING IN NATURAL CONTEXTS. LEARNING FROM AND WITH COMPUTERS

It has been long assumed that the depth of processing is the more influential learning factor than the intentionality to learn. This has been revealed in paradigms of single testing and is considered a robust finding. In view of the forwarded here assumption of the "temporiness" of some aspects of long-term learning, it is hypothesized that deep processing in intentional and incidental learning may have similar "immediate" results, but different subsequent outcomes. Intentional learning of pairs of unrelated words as opposed to incidental learning of the same words is viewed as involving to a much greater extent multiple generations of semantic mediators in the attempt to memorize the unrelated study material, resulting in a higher relative contribution of the generation component of the recall process. This is revealed at a "follow-up" stage of testing rather than at immediate single-trial test. In an experiment of Dimitrova (1994), the "dual route to memory " experimental paradigm of Jones (1982) was employed in two conditions – intentional and incidental. The results showed similar "immediate" performance and different subsequent results. The experiment is described in the following section.

A study of the intentional vs. incidental learning in a "Recognition Failure" experimental paradigm

The incidental vs. intentional manipulation is traditionally used to measure the influence of conscious retrieval strategies in recognition and

recall (e.g. Estes & Da Polito, 1967; Greenwald & Johnson, 1989) as well as in studies of forms of memory impairment in amnesia (e.g. Shimamura & Squire, 1984). Gardiner and Java (1993) reported a study of Carter (1991) in which incidental vs. intentional learning manipulation affected the level of "remember" responses but not the level of "know" responses in a recognition memory task thus affecting the overall recognition performance. The result was interpreted in terms of differential influence of conscious awareness of the past episode. "Remember" responses were associated with reinstatement of the context of encoding, whereas "know" responses were accompanied with feeling of familiarity (Gardiner & Java, 1993). The result was obtained after a single-word study task. Whenever cue-target pairs of words are studied and the targets are subsequently tested for recognition, however, "remember" outcome would apply to the whole pair whereas "know" outcome would refer to the target itself. Remembering the pair as a whole in some cases would imply directly accessing it and in some occasions would result from generation and recognition. It is hypothesized that the incidental vs. intentional study manipulation would affect the "ease" of generation of the target as well as its recognition that are more dependent on conceptual elaboration (Tulving & Schacter, 1990).

A point to be mentioned is the nature of the incidental task for paired associate learning. Simply reading the pairs is ambiguous since it can lead to big variation in subjects' motivation, i.e. they could be either inattentive, or suspecting subsequent testing. In order to ensure that the subjects elaborate on each pair they were given the task of rating the ease of combining the two words into a meaningful sentence. This task has been previously employed as incidental by Dyne, Humphreys, Bain & Pike (1990). On the other hand, according to a level-of-processing account (Craik & Lockhart, 1972) the task requires deep processing. As a consequence, two tasks requiring deep processing are compared. It should be noted that the choice of tasks was also made on the basis of the study of Roediger, Weldon and Stadler (1987) described by Neely (1989). They found that the level of processing manipulation did not interact with motivational factors related to the test instructions following intentional and incidental tasks.

Method

Subjects. Thirty undergraduate and postgraduate students from different courses from the University of Warwick participated in the experiment. Subjects were tested individually or in small groups (up to 3) and assigned randomly to one of two groups - intentional and incidental. Each group consisted of 15 subjects.

Materials. The stimulus material used was identical with that employed in Jones' Experiment 1 (1982) and was a list of 50 seemingly unrelated pairs of words. An important characteristic feature of the stimulus material is that the cue words were heteropalindromes (Jones, 1980a), i.e. meaningful words at forward and backward reading. Examples of such cues are *liar, time, nib*, presented with TRAIN, RADIATION, RUBBISH as the corresponding targets, respectively. A post hoc word frequency check revealed that 17 of the target words were low frequency (1-10 per million), 15 were medium frequency (10-50 per million) and 14 were high frequency (more than 50 per million) according to Francis and Kucera (1982) norms. The ordering of the study pairs was random in respect to the frequency of the targets. The booklets contained instructions for three successive retention tests - recognition, recall with studied unrelated cues and recall with both studied unrelated and nonstudied related cues.

Design and procedure. The design was 2 X 3 with repeated measures on the second factor. The between subjects manipulation was type of instructions (intentional vs. incidental), and the within subjects manipulation was type of retention test - recognition, single cue recall with studied unrelated (SU) cues and dual cue recall where nonstudied related (NR) cues were added (i.e. SU plus NR cues). The subjects from the intentional group were given exactly the same study instructions, interpolated activity, recognition and recall task as the control group in Experiment 1. One difference in the study procedure was that the time for studying each pair was increased from 3 to 5 sec. A second change in the procedure was that confidence rating of the responses was introduced for the recall tasks. Subjects had to rate their confidence in the accuracy of each recalled word on a five-point scale from 1 ("guessing") to 5 ("certain"). The timing of the test procedure was self-paced. To make the upper response time limit equal in both experiments the experimenter ensured that it did not take more than 16 min 40 sec (i.e. 50 items X 20 seconds per item) to accomplish each recall task. Data only from subjects that *never* guessed about the palindromic nature of the cues was included in the analysis.

For incidental learning the second group was given a sentence judgement task. They received a 2-page booklet first. The subjects read that this is a study of the relationship between words. They were asked to assess on a 4-point scale how easy they find it to combine the two words from each cue-target pair into a meaningful sentence. The scale range was from "very easy" (4) to "very difficult" (1). The subjects were also told that they would have 5 sec on each pair. After they finished the sentence judgement task the booklets were collected. A second booklet was delivered with the first set of arithmetic tasks on the front page with the instruction as soon as they

received this booklet to start solving the problems. After one minute they were interrupted and told to turn over. Next followed exactly the same three retention tasks as in the intentional learning group. After the test the subjects were asked whether they deliberately studied the word pairs in expectation of a subsequent memory test while they performed the sentence judgement task. Two subjects reported that they knew it was a memory test and were replaced by two new subjects (who afterwards gave a negative answer). The subjects were asked not to discuss the experiment with potential subjects.

Results and Discussion

Retention following intentional vs. incidental learning. The means for the three retention tests in both groups are given in Table 8.

Table 1.
Mean Proportions Correct on Three Successive Retention Tests

	Recognition	Recall 1 (SU cues)	Recall 2 (SU plus NR cues)
Intentional	.468	.175	.325
Incidental	.326	.125	.197

Repeated measures 2X3 ANOVA revealed a significant main effect of type of study task (intentional vs. incidental learning), $F(1, 28) = 6.826$, $MSe = .038$, $p = .014$ and main effect of retention test (recognition, single-cue recall and dual-cue recall), $F(2, 56) = 57.268$, $MSe = .008$, $p < .000005$. The lack of interaction between these two factors reveals parallel effects of study task over retention, $F(2, 56) = 2.249$, $MSe = .008$, $p = .115$. Pairwise post hoc (Tukey) comparisons revealed significant difference between groups for recognition ($p < .0005$) and for dual-cue recall ($p = .001$), but not for single-cue recall ($p = .13$). The finding of a lower level of recognition performance after incidental than after intentional learning is in agreement with similar findings (e.g. Gardiner & Java, 1993). There was no significant difference between the level of Recall 1 in the two groups of subjects.

Recall. A separate ANOVA on recall-only scores revealed a small, but significant main effect of type of task $F(1, 28) = 4.240$, $MSe = .028$, $p = .049$, a highly significant main effect of cueing (single vs. dual), $F(1,28) = 43.604$, $Mse = .004$, $p < .000005$, as well as a significant interaction

between these two factors, F(1, 28) = 5.232, p = .0299. As expected, the dual cueing is less efficient in the incidental learning condition, resulting in a relatively small increment in performance. The observed low degree of nonindependence between recognition and recall in the case of incidental learning of the cue-target pairs is in support of the hypothesis that the relative contribution of generation is higher after intentional than after incidental learning.

Stochastic (in)dependence. The contingency analysis revealed a positive relationship between recognition and recall in both intentional and incidental conditions. There was strong dependence in the intentional group, Q = .541 [$X2$ (1, N = 690) = 31.266]. The level of dependence in the incidental group was lower, Q = .472, [$X2$ (1, N = 690) = 5.969]. This is in support of the hypothesis that the incidental vs. intentional learning manipulation affects the contribution of generation, but not of direct access.

Table 2.
Stochastic Independence Analysis of the Intentional and Incidental Conditions in Experiment 2

	Rn-Rc Intentional				Rn-Rc Incidental			
		Recall				Recall		
	+	-		T	+	-		T
Rn	+	86	236	322	+	71	198	269
	-	36	332	368	-	48	373	421
	T	122	568	690	T	119	571	690

X^2= 31.266
Q = 0.541
SD(Q) = 0.077

X^2= 5.969
Q = 0.472
SD(Q) = 0.164

X^2 = 0.157

False recall. These responses were defined as words responded at recall with a confidence rating of 5 (i.e. "certain") which were in fact

incorrect. The mean proportions of falsely recalled items across groups and retention tasks were at a level from 1% to 4% and can be considered of no crucial influence on subjects' performance. There was no significant main effect of type of learning task (intentional vs. incidental), F(1, 28) = 1.155, MSe = .001, p = .292, nor did this factor interact with type of recall (Recall 1 vs. Recall 2), F(1, 28) = .471, MSe = .0008, p = .498.

Probability of correct guessing after intentional and incidental learning. Correct guessing responses were defined as words correctly responded at recall which nevertheless were given a confidence rating 1 (i.e. "guessing"). The level of correct guessing was comparatively low in both groups at .025 and .013 for Recall 1, respectively, and at .081 and .036 for Recall 2, respectively. ANOVA revealed a significant main effect of learning task (intentional vs. incidental), F(1, 28) = 6.375, MSe = .002, p = .018, and of type of recall (Recall 1 vs. Recall 2), F(1, 28) = 26.014, MSe = .001, p = .00002 as well as a significant interaction between these two factors, F(1, 28) = 4.549, MSe = .001, p = .042. The intentional learning task leads to a higher level of correct responses of the kind that subjects would define as mere guesses rather than as remembered from the study episode. The more the retrieval task tolerates generation (e.g. from Recall 1 to Recall 2) the more expressed is this tendency.

Proportion of items that have been remembered in the three retention tests. The proportion of items that were correctly jointly recognized and recalled on both recall tasks in the intentional and the incidental groups did not differ significantly at .087 and .057, respectively, F(1, 28) = 1.313, MSe = .005, p = .262. It can be concluded that the two tasks did not differ with respect to conscious influences over recall.

Effect of word frequency on recognition performance. The main effect of WF was only marginally significant, F(2, 43) = 2.739, MSe = .062, p = .076. The interaction with type of learning task was marginally significant as well, F(2, 43) = 2.763, MSe = .016, p = .074. The only significant effect was the main effect of type of learning task (intentional vs. incidental), F(1, 43) = 9.144, MSe = .016, p = .004. There is some indication that low frequency words are better remembered after intentional than after incidental learning, but this tendency is only approaching significance.

Conclusions

The results of the experiment (within-subjects design) replicated the results of previous studies in a between-subjects design (Jones, 1982, Dimitrova, 1994). The contingency analysis revealed a dependency between recognition and recall for both intentional and incidental learning. The level

of dependency was much higher after intentional than after incidental learning. The intentional vs. incidental manipulation affected recognition and dual cue recall but not single cue recall. The level of false recall was relatively small in both groups. The intentional group produced more correct guesses than the incidental group.

Summary

An interesting finding in the present study is the lack of dissociation of explicit and implicit learning at immediate test and the presence of dissociation later on at retrieval. Whenever the encoding relies on generative processes (intentional learning) there are relatively longer lasting influences than in incidental learning.

Craik, Moskobitch and McDowd (1994) proposed a "non-trade-off" view about the relation between encoding and retrieval. They found evidence that manipulation of one kind of processing (e.g. semantic) does not necessarily impair other kinds of processing (e.g. perceptual). Recollection can emerge either by a fast process of reproduction of a holistic pattern of activation, or by a slow process of reconstruction of the stored trace. In studies of implicit retrieval a "transitive" phenomenon has also been observed when implicitly retrieved items bring about a spontaneously elicited "awareness of the past" (Richardson-Klavehn, Gardiner & Java, 1994).

In connectionist terms the distinction between the processes resembles the dual-mechanism model of retrieval proposed by McClelland, McNaughton, and O'Railly (1994), employing a Hebbian-like system for modeling single-trial learning (and fast retrieval) and a system based on weight adjustment for multiple-trial learning (employing generalization) with the introduced "temporariness" of presence of the teaching pattern in the hypocampal area of the brain.

Learning in "natural" contexts. Learning from and with computers. The "natural" context of learning nowadays is becoming rather an "artificial" phenomenon, because in much of the time it is mediated by computer or "smart" device technologies which are inheritantly designed on the basis of mathematical and logical models of learning. From a human cognition perspective it is mainly based on incidental learning and in most cases the incoming information is deeply processed following the natural tendency of the cognitive system to learn from instances, generalize and translate from one domain into another. It has been shown that memory about autobiographical events obey the general laws of forgetting which

otherwise are revealed in laboratory (e.g. Wagenaar, 1986). Especially in the context of the internet and, for example, on-line news providing systems, the interaction with the computer has become an "autobiographical factor" of learning, remembering, recollection and communication, where cognition is involved with its general and diverse mechanisms. Dealing with problems like the "lost-in-hyperspace" phenomenon, and other problems as well, is becoming an issue of primary importance in the design of user interfaces. Learning frameworks for implementation in interface systems should be proposed on the basis of regularities of cognition for creating friendly "natural" learning environments.

COMPUTER MODELING AND ADAPTATION TO INDIVIDUAL LEARNERS. CONTINUOUS EDUCATION AND COGNITIVE SUPPORT IN HUMAN-COMPUTER CONTEXT

Learning can be viewed as a continuous process of implicit or explicit accumulation of new knowledge that can occur spontaneously or can be set as a deliberate personal goal. Teaching sets a framework to make learning more efficient by giving structure that, in the end, organizes content into procedures of acquired skills. The interplay of spontaneity of learning and control over the process of new knowledge acquisition is especially evident in human-computer interaction (HCI) where users' mental models undergo more dynamic transformations than in activities that are not computer mediated. Common instantiations of the two aspects of learning in HCI, namely explicit and implicit, are the Help systems providing declarative knowledge about *both* content and procedures and Wizard-based systems where learning is acquired via step-by-step instruction *how* to perform a task with a minimum of explanation.

The learning framework emerged as a result of our investigations on cognitive activities (i.e. human operators of technical systems), which users get involved in when they have to communicate with computers in order to perform the task at hand. Data was collected from users performing different computer-generated tasks at various levels of cognitive complexity. These included: reactions to extreme situations, visual tracking tasks, spatial (left-right) coordination, visual-spatial orientation, visual pattern recognition, attention, visual working memory capacity, personality (extroversion/introversion), simple motor reaction tasks and complex motor reaction tasks. The results revealed individual profiles of performance on these tasks that comprise style of human-computer interaction. Adaptive interface can identify and classify these styles via implementation of neural networks (Dimitrova et al., 1997). The post hoc principle component

analysis on the set of the collected data revealed two main components that were labeled "extreme/undisturbed performance" and "visual tracking. working memory capacity".

An important factor influencing user-computer interaction was experimentally revealed and it was labeled "free/normative context of work" has been (Dimitrova et al., 1998). It reflects the finding that when users have the freedom to choose the order in which they have to perform a subset of actions, they perform faster and more efficiently than when the same set of actions are "grounded" in a normatively given larger succession of actions. The proposed framework contains instantiations of these findings from the point of view of learning in user-computer interface.

Dimensions of user cognitive performance

The main revealed dimensions of user cognitive performance in human-computer interaction are:

- Exteriorization/interiorisation of cognitive activities,
- Normative/free organization of learning activities,
- Level of stress/time-pressure accompanying performance.

These dimensions can be assumed to be independent from each other. If the processes of learning and teaching are aspects of a *single* "educational system", the first two dimensions are intrinsic to the educational process whereas the third can be considered extrinsic (although sometimes very influential) and will not be discussed for the present moment. Figure 2 depicts instances from both ends of the two outlined dimensions.

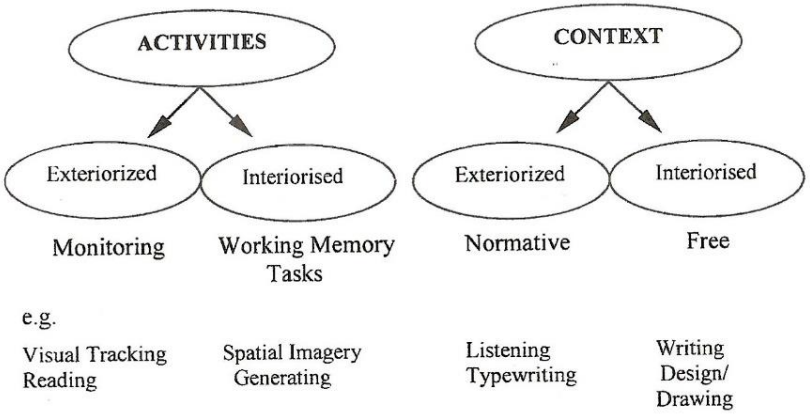


Figure 2. *Instances of exteriorized/interiorised cognitive activities and context*

Cognitive activities in learning and teaching. "Monitoring" denotes cognitive tasks based on visual scanning. Users may have to be alert to deviations of process indicators from normal operation (digital or analog) or may have to scan texts for occurrence of letter and digit patterns. The matching tasks that require "nonsemantic/surface/shallow" processing (Craik & Lockhart, 1972) stand at the monitoring end as exteriorized activities requiring minimum working memory involvement. In contrast, semantic memory tasks like reading, generating word associates, arithmetic operations (i.e. checking correctness of digit multiplication) or sentence processing span a range of increasing involvement of working memory and are placed to the other end of the interiorised cognitive activities. Thus, reading is much less demanding to working memory and relies more on visual scanning, whereas generating word associates involves much more interiorised cognitive activities. Other modalities, like tactile or auditory act in a similar, complex way (Baddeley, 1990).

Cognitive context of learning and teaching. "Normative context of work" here denotes a hierarchy of cognitive operations that have to be performed in order to achieve a certain goal. In the educational context a possible goal can be to acquire knowledge on a given subject. A course module is organized normatively into separate topics, e.g. a Human Memory course may start with "Memory Structure and Processes", followed by "Sensory Memory", "Short-Term/Working memory", "Semantic Organization", "Retrieval/ Forgetting", etc. The organization of the issues within a topic is also fairly normative, although it allows "freedom" in structuring the topic according to the individual style of the teacher/learner. The interaction of the four kinds of cognitive operations involved in learning yields the educational dimension. Thus, in a most "rigid" (non-feedback) educational system learning stands at the one end with exteriorized activities in a strictly normative context and teaching represents the opposite end with interiorised way of presenting new material to students in a "free" context. Figure 3 represents the participation of cognitive activities and context in a non-feedback educational system.

Optimal learning is achieved by constant movement along the learning/teaching and normative/free continuums where feedback provides correction to allow more interactive activities and context by the learning and teaching agents. If a teacher is sensitive to the feedback from the students, it means that s/he is employing monitoring over the process of learning of new material by the students (exteriorized cognitive activity). Very often the successful teacher is described as the one that has "personal style" in this sense. And, at the same time, successful learning is facilitated when the student actively participates by asking questions and generating

ideas (free cognitive context of learning). This can be called "individualized learning". Figure 4 depicts the interaction of the outlined dimensions in an efficient educational system.

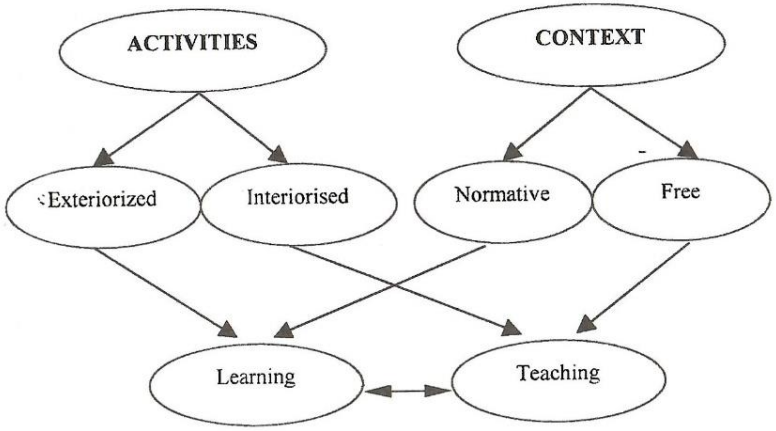


Figure 3. *Participation of cognitive activities and context in teaching and learning*

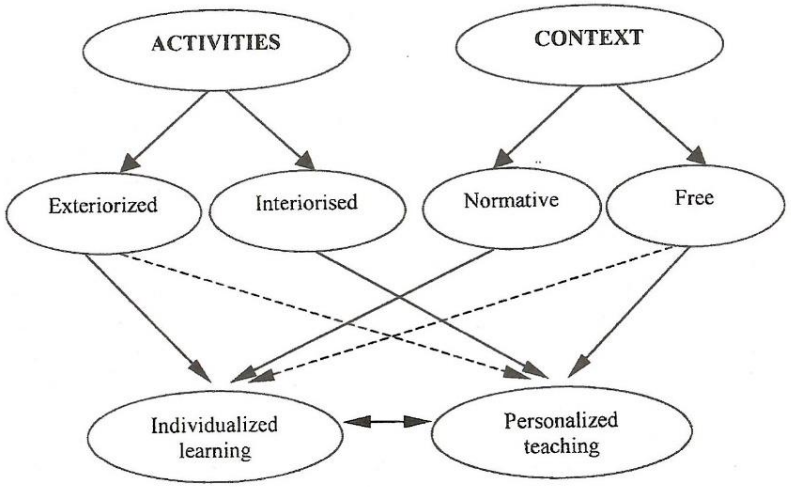


Figure 4. *Participation of cognitive activities and context in efficient teaching and learning*

The aim of this investigation has been to outline factors of efficient learning in order to implement them in computer-based tutoring systems. If the interface is capable of monitoring the individual progress of the learner it can be more efficient in providing the appropriate information based on the learner style of human-computer interaction. Some ideas how to define user style of interacting with a computer within examples of existing computer-based tutoring systems are presented in the next section.

Systems for cognitive support

In the user-computer interface, Help systems can be viewed as based on exteriorized activities (i.e. reading) where the learner can also browse through the system and choose which items to read and in what succession (free context). Wizards, on the contrary, are strictly normative in the succession of operations to be performed. At each step the user makes decisions which options are necessary from a set of specified options, which requires a great deal of interiorised or working memory processing. Figure 5 represents the structure of a system for cognitive support. Systems for cognitive support provide unified generalized knowledge to all users of an application that is available in both declarative (Help-system) and procedural (Wizard) forms. Within the present framework, an interesting architecture emerges from the interaction of the outlined dimensions. The learner is engaged in two distinct, compound cognitive activities based on procedural and declarative forms of knowledge presentation that is provided by the cognitive support system. The first compound activity combines interiorised plus normative cognitions (Wizard-based) and the second combines exteriorized plus free cognitions (Help-system based).

Implications for interactive interface design (systems for personalized support and education). The situation where users have to learn on line in order to perform the tasks at hand can be represented by the case when new software is introduced. For example, users of computer applications and designers of such systems develop dramatically different mental models of the systems they are using although the "building blocks" (the functionalities of the developer kits) are virtually the same. The process of learning about the architecture and functionalities of these systems databases for either class of users differs, too.

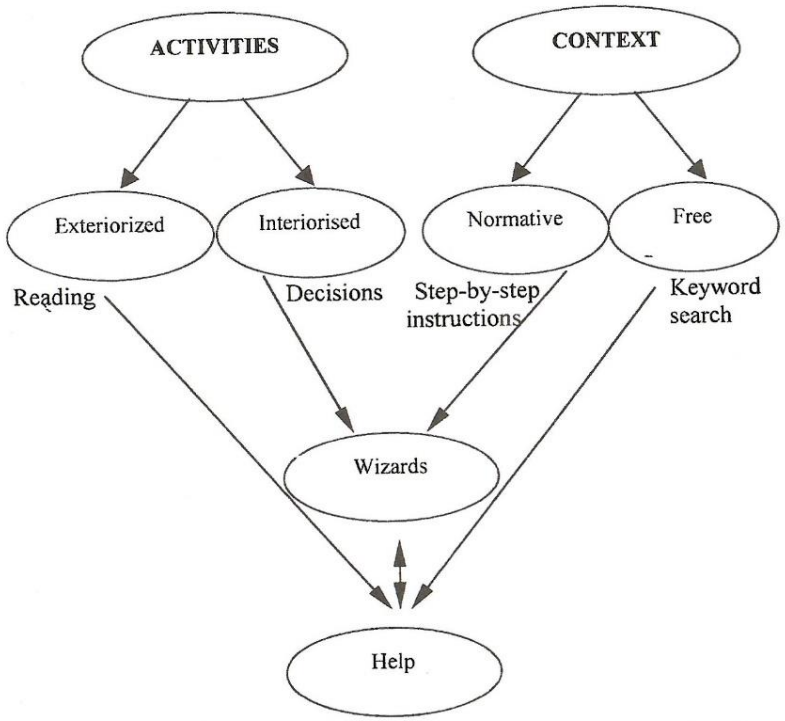


Figure 5. *Participation of cognitive activities and context in computer-based learning via Wizards and Help Systems*

Figure 6 depicts a hypothesis about the type of learning activities for two different classes of users. Depending on type of learning preferences (procedural vs. declarative) application users span a space from normative to monitoring activities, predominantly, whereas designers span a space from free search of necessary information to complete interiorisation (working memory) in cases of skilled performance in design. Similarly, in computer based education, the upper half of the space of activities is more present in monitoring and understanding, whereas the lower one participates more actively in problem-solving and application of acquired skills.

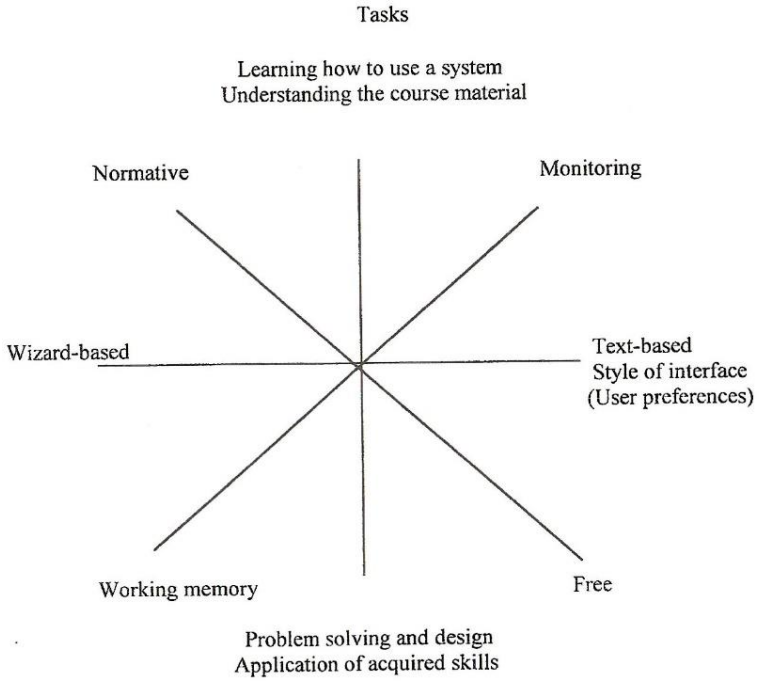


Figure 6. *Dimensions of cognitive performance of different classes of learners in user-computer interface*

Ways to personalize the interface. If users spend more time on Wizards, the are likely to prefer step-by-step instructing in learning how to use a system (prefer learning by practicing first). On the other hand, if they browse in a Help system they are more likely to need more detailed explanation about the system itself (prefer learning by explanation first). If designers spend more time on Wizards, they are likely to be more focused on the functionality of the system and if they spend more time browsing in the Help system, they are more likely to be focused on structure and contents. This hypothesis needs further investigation, especially for different stages of the learning process. The utility of the proposed framework lies in the adopted approach for implementing means for implicit monitoring (and measuring preferences and reaction times) to make inferences about user

style of interaction with a computer-based tutoring system for faster and more efficient access to the relevant information.

Summary

The ability of the interface to switch between declarative knowledge provided by a Help system and procedural knowledge provided by Wizard based systems is a step towards personalisation of the dialogue in user-computer interface that is in essence a process of continuous learning. Methods and means of implicit monitoring of style of user interaction with web-based learning systems can be helpful in designing flexible and efficient computer interface.

Acknowledgements: *The chapter is based on the following sources: a course on Learning and Memory, held for the New Bulgarian University since 1995, research at the Department of Psychology of Warwick University, UK, from 1993 to 1994 and research project on Adaptive User-Computer Interface: Systems for "Personalized" User Support under grant No 809/98 of the Bulgarian Ministry of Education and Science.*

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