Memory & Creativity

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This article is a revision of the previous edition article by Edward Nęcka, volume 2, pp. 193–201, © 1999, Elsevier Inc.

Glossary

Encoding Assigning a specific label to the information that is to be stored in long term memory, in order to make it suitable for storage, retrieval, and further processing.

Long term memory (LTM) A system able to hold a large amount of episodic or semantic information permanently, organized as a network.

Retrieval Activation of the information retained in long term memory, presumably with the use of valid retrieval cues or specific mental strategies.

Storage The intermediate phase of the memory process, which consists in keeping the memorized information in the latent form that potentially allows retrieval and further processing.

Working memory (WM) System responsible for maintaining a restricted number of pieces of information for up to a few minutes; also acts as an information processing unit, responsible for the manipulation of symbols during problem solving and other types of cognitive activity.

Memory is a psychological structure that, apart from its many other functions, takes part in the cognitive mechanism of insight in creative problem solving and determines the specificity of information processing observed among creative individuals. The importance of memory phenomena to understanding of creativity is enormous, for obvious reasons: creativity is an activity of mind, and activities of mind are executed through memory. Therefore, creativity cannot occur without the participation of memory processes and structures. However, psychological theory concerning the relationship of memory to creativity is not well developed, and empirical results are rather scarce. For these reasons, the present article outlines the map of the problem at a very high level of abstraction and with a large amount of speculation. The order of presentation is determined by the stages of memory processes, corresponding to the stages of information processing.

Sensory Memory and Creativity

Stimuli arriving from the external world are first memorized for a short time by two structures: sensory store and short-term store. The sensory store (e.g., iconic memory for images or echoic memory for sounds) holds the information for less than one second. Because of its extremely short duration, the sensory memory is not accessible for introspection, and people usually do not realize that they possess such an ability. Both iconic and echoic memory act at the preparatory stage of stimulus elaboration, thanks to which the next stages are not swamped by a surplus of information.

There is no evidence whatsoever that sensory memory is connected in any way with creative processes or creative abilities. Interestingly, though, the sensory memory may play an important role in perception and appreciation of creative performances, particularly in music, ballet, and visual arts. From the evolutionary point of view, the sensory memory is still mysterious, but it is possible that it evolved in the service of speech perception. An ability to keep in mind sounds that have already disappeared probably allows human beings to perceive spoken language smoothly and rapidly. Without echoic memory it would be perceived as a staccato of separate sounds. Keeping past sounds in mind for a moment makes this process much more efficient. Words are perceived as complex structures rather than sets of unconnected vowels and consonants; therefore they are recognized with enormous speed and efficiency. Moreover, holistic perception of words makes it possible to use prosody and intonation as a means of speech perception and, in consequence, as a means of language comprehension.

This is just a hypothesis but if the reconstruction of adaptive functions of the sensory memory outlined above is close to reality, we could speculate about relationships between echoic memory and music perception, as well as between iconic memory and ballet dancing perception. The same mechanism that makes speech perception speedy and efficient can produce greater appreciation of music (echoic memory) or ballet dancing (iconic memory). One can even doubt whether human beings would invent music and ballet as important domains of creativity if they were not able to perceive sounds and movements smoothly. Production of sounds and structured body movements obviously serve important social ends, such as communication, but these reasons seem insufficient to invent the art of music or dancing. For that, our ancestors had to be able to appreciate esthetic rather than social aspects of sounds and movements, which – according to my hypothesis – would not be possible without the phenomenon of sensory memory.

These speculations lead to yet another hypothesis, namely, that musical abilities (or just being fond of music) are rooted in individual parameters of echoic memory. People who can keep in their echoic memory more information for a slightly longer time may be better prepared to appreciate and understand music when compared with persons characterized by less efficient mechanisms of sensory memory. However, this hypothesis may be difficult to verify because individual differences in sensory memory have not been investigated at all.

Even if such differences really do exist, their range may be very restricted, as it usually is in the case of basic, evolutionarily old, and biologically rooted mechanisms.

Working Memory and Creativity

The short-term memory (STM) store is able to retain information for limited intervals of time, ranging form a few seconds to several minutes. This system is now called *working memory* (WM) because it is responsible for both maintaining pieces of information and manipulating them, which is synonymous with human information processing. Metaphorically speaking, WM is a central processing unit of the human mind, or 'the blackboard of the mind.' Less metaphorically, it is an active part of memory consisting of a number of pieces of information that are either in the state of readiness for upcoming processing or in the state of just being processed. It is unlikely that the central processing unit of the human mind would not take part in the cognitive mechanics of creative processes. Some theoretical models assume such an engagement in an explicit way. There is, however, little empirical evidence about how and to what extent working memory processes affect creativity.

Characteristically, WM is very limited not only in time but also in its capacity, because it is able to manipulate fewer than ten pieces of information (words, numbers, etc.) simultaneously. Short-term memory capacity is traditionally defined as the 'magical' number seven (plus or minus two) but this value is probably overestimated. Recent estimates (e.g., Nelson Cowan's) suggest that working memory cannot retain and manipulate more than four elements simultaneously. Although this is a very small number, people still differ in working memory capacity (WMC), and these differences result in different ability levels. It has been convincingly shown that WMC determines the general cognitive ability level (i.e., intelligence). Unfortunately, no evidence concerning the relationship of WMC to creativity has been obtained, although in some studies both intelligence and creativity tests were used to check this hypothesis.

The difference is probably rooted in the particularity of cognitive mechanisms of intelligence and creativity as two distinct dimensions of human intellect. Intelligence is the ability to tackle convergent, well-defined problems of average complexity and average novelty. Such problems are well described in terms of a number of separate 'chunks' of information, which have to be memorized and manipulated for a short time in order to let the problem solver reach the solution. In other words, an intelligent problem solver has to split the problem into separate portions of information, keep these portions in working memory, and manipulate them in order to achieve a suitable solution. In such cases, the more items a problem solver is able to keep in the short-term store, the more competent he or she is in tests consisting of convergent, well-defined problems of average complexity and novelty. On the contrary, if a problem solver's WM capacity is small by nature, or declines for any reason, he or she inevitably loses some part of his or her intellectual ability, because tasks that are critical for the person's intellectual level may surpass the actual limitations of WM.

Nothing like this seems to exist in the case of creativity. It is usually assessed with tests consisting of divergent tasks of low complexity (e.g., Unusual Uses, Alternative Definitions, etc.), which do not exploit working memory thoroughly. As far as the limited capacity of WM is concerned, such problems may even be regarded as relatively 'easy.' No surprise, then, that creative abilities assessed with divergent thinking tests do not correlate with WMC.

Of course, creativity is not reduced to simply divergent thinking ability, particularly if real creative endeavors rather than basic cognitive skills are taken into account. However, there is no point in looking for the working memory determinants of 'real' or eminent creativity, either. The problems undertaken by exceptionally gifted creators and great achievers are usually divergent, too, but also ill-defined and very complex in nature. In fact, problem finding and problem definition constitute the vital part of creative processes in real life, that is, outside the psychological laboratory. Finding, definition, redefinition, and solution of such problems usually take a lot of time, effort, and motivation, but they do not seem to require extended capacity of working memory. Individual differences in WMC may matter in the case of problems of average complexity, because – for instance – if a problem needs four items to be kept and manipulated in memory, a person with a capacity of four is naturally endowed to tackle such a problem, whereas a person whose capacity is only three is naturally unable to deal with it. But both hypothetical persons are structurally unable to deal with a problem consisting of 100 or 1000 items of information, that is, with very complex, unclear, ill-defined problems that require a creative approach.

This does not mean that such complex problems are unworkable for any human being, whose WM capacity – even relatively large – usually does not exceed four portions of information. Rather rarely, a very complex and ill-defined problem is solved by a very creative individual by means of his or her exceptional capacities, but not necessarily by means of WM capacity, as it seems. Such creative achievements are attainable through specific strategies of problem solving, and through inventive manipulations with problem structure and problem definition. Such manipulations are sometimes referred to as *metacognitive strategies*. For instance, a creative person organizes his or her knowledge of the problem hierarchically: a relatively small number of higher-order, abstract portions of information may contain many lower-order chunks of information, accessible for processing only after having been 'unwrapped.' Another metacognitive strategy used by creative individuals amounts to simplification of the problem structure so that it is workable with WM of limited capacity. However, such manipulations refer to long-term memory processes, mainly selective encoding and 'familiarization.'

There is a paradoxical tension between the structural limitations of WM in terms of the very small number of items that can be effectively maintained and processed, on the one hand, and the requirements of complex and ill-defined problems that are typically undertaken in mature creativity, on the other hand. If 'creative problems' are much too complex for human working memory, no matter how efficient and capacious it is in the case of a given person, how can such problems be solved at all? An interesting solution to this paradox comes from the theory of long-term working memory (LTWM), developed by K. Anders Ericsson and Walter Kintsch. LTWM is conceptualized as a part of long-term store that is activated by retrieving cues maintained in working memory proper. In other words,

WM does not need to retain anything that is directly used in problem solving. It retains only retrieval cues, thanks to which the vital information is quickly and easily retrieved from LTM. Long-term store is not structurally limited, so there is no threat of it being overloaded. And a person must keep in mind only a few hints that make it possible to use a kind of 'highway' between WM and LTM. Ericsson and Kintsch believe that their model accounts for expert performance in a variety of domains, as well as for language comprehension. Since mature creativity is a form of expertise, their model should be explored more thoroughly in creativity studies.

Models of working memory usually assume that this structure shows two aspects: one purely mnemonic and another pertaining to cognitive control. For instance, in the model developed by Alan Baddeley the mnemonic functions are performed by such 'devices' as the articulatory loop and the visuo-spatial scratch pad, whereas the control functions are performed by the central executive, which is described as a 'device' of attention deployment. The dual nature of working memory suggests that creative thinking and creative performance may be determined by efficiency of cognitive control rather than by capacity of working memory understood as the number of 'chunks' that can be memorized for a short period of time. Or, possibly working memory capacity should be defined as an ability to perform mnemonic functions under the auspices of control mechanisms. For instance, switching between tasks is a popular means of investigating cognitive control. It seems that creativity requires switching between thoughts rather than tasks. An ability to switch from one mental activity to another is probably vital for flexibility of thinking and resistance to mental blocks. Such relationships have not been systematically studied, although there are data suggesting that a high level of dopamine increases the strength of cognitive control, reduces switch costs in the task switching paradigm, and improves performance on divergent thinking tasks, particularly if flexibility is taken into account. Creativity probably needs both increased and reduced cognitive control, depending on the phase of working on a problem at hand. Such studies, if performed systematically, should broaden knowledge about the relationship between creativity and working memory.

Long Term Memory and Creativity

Contrary to working memory, long term memory is able to retain information for an unlimited period; it is also assumed to possess unlimited capacity. This does not mean that the human mind is able to remember everything; however, forgetting and other imperfections of memory do not result from the capacity of the LTM store but from other sources, such as interference, inefficient strategies of remembering, etc.

Three basic categories of memory processes define the efficiency of operations in LTM: encoding, storage, and retrieval. These operations, or stages of the memory process, determine the way in which LTM performs its basic functions, including the ones connected with creativity, problem solving, and insight.

Encoding

Information cannot be placed in long-term store without having been encoded. This is an operation analogous to labeling products in a department store or allocating new books to appropriate shelves in a library. Only after the information is encoded can it be stored in memory as a part of related knowledge structures. In most cases, encoding amounts to categorization. For instance, the scene shown in a news headline is categorized as a 'street accident,' a portion of textbook knowledge as 'the quantum theory of particles,' etc. The psychological function of encoding is obvious: it allows assigning the information to the appropriate parts of the LTM store. In this way, it makes it possible to arrange LTM as an organized system of knowledge. It is also a necessary condition for future retrieval, because nothing can be regained from the store without being properly labeled.

Creativity is probably connected with, and affected by, the specificity of encoding in three ways. First, a person can *encode information in a peculiar way*, different from other people. For instance, a child can categorize the animals familiar to him or her into the categories of nice, shaggy, and awesome. This kind of categorization, though illogical and far from what biology offers, probably serves some important cognitive needs of the child. Such categorization is also unusual, different from what the majority of people think about animals and how they classify them. This is probably why small children perceive the world so originally. Children's originality is normally accounted for in terms of their being free from obstacles, conventions, and inhibitions typical of adult life. However, this phenomenon should also be regarded as a manifestation of the unusual way in which children categorize objects, and in consequence as a result of the specific way of encoding information that is stored in their LTM.

In the case of adult creative individuals, the instances of bizarre categorization are probably accompanied by the conventional, 'uncreative' way of perceiving the world. In other words, an adult creative person is able to categorize the world in the 'official,' objective, commonly accepted way, as well as in the unusual, subjective, and personalized manner. This is the second exemplification of how the activity of this stage of LTM operations affects creativity: *alternative encoding*. A person who encodes alternatively is able to take advantage of unusual encoding (making unpredictable associations, discerning similarities, etc.), while still being close to reality and conventions – a phenomenon recognized by Ernst Kris as "regression in the service of the ego." Some techniques of creativity training deliberately focus on the phenomenon of alternative encoding, with the conviction that divergent thinking and unexpected associations are more likely to result from the ability to memorize the same item of information in many different ways.

The third property of encoding found in creative persons is *selectivity*. It is particularly important for the construction of the cognitive representation of the problem. Problems worth creative endeavor are usually too complex and ill defined to be memorized completely and categorized with the use of clear-cut terms. Selection of information is therefore necessary; however, successful problem solvers are able to memorize only the important elements of the problem, while ignoring less important and superfluous ones. Less efficient solvers try to memorize everything, thus being unable to focus on the gist of the problem situation. It is very unclear what the origins and determinants of this ability to encode information in the

selective way are, as well as to what extent it is susceptible to development and training. However, the selectivity with which some people store information in their LTM store inevitably makes them more efficient solvers of complex, ill-defined problems; therefore, it makes them more creative.

Peculiar, alternative, and selective encoding are responsible for creative behavior in many ways. They help people produce original associations, they are responsible for 'perceiving things' differently, and they allow simplification of the structure of excessively complex problems through selectivity of encoding. In many instances, creative behavior is a result of natural, effortless use of specific encoding, although from the observer's perspective it may give the impression of being a result of rather difficult and complex processes. In other words, creative processes are sometimes less 'exotic' than they seem to be from the point of view of somebody who normally does not encode information in a peculiar way.

Creativity also benefits from so called *prospective encoding*, which involves setting up criteria for future acquisition of knowledge that might be relevant to a problem at hand. Careful examination of the problem and its requirements helps establish exact criteria of information needed for the continuation of creative problem solving. Such knowledge may not be available at the moment. but it can be easily acquired upon the appearance of particular learning opportunities. The mental set established by prospective encoding induces highly selective acquisition of knowledge; consequently, it enhances the likelihood of sudden and insightful recognition of new possibilities for dealing with the problem.

Storage

Storage amounts to keeping previously encoded information for a long time. Contrary to naive conceptions of storage, it is an active process, likely to impose unexpected changes on the seemingly dormant information kept in LTM. Three phenomena connected with storage are worth investigation from the creativity point of view: selective forgetting, familiarization, and spontaneous recovery.

Selective forgetting may account for the phenomenon of 'incubation.' According to the classical four-stage model of creative thinking, incubation is a stage of unconscious idea production, following preparation but preceding illumination and elaboration. Modern cognitive approaches do not deny the empirical evidence that the 'incubational' break sometimes helps in the creation of new ideas, although they usually do not accept the notion of subconscious 'incubation' of solutions. It has therefore been suggested that, during the 'incubational' break, people selectively forget superfluous information, particularly the unnecessary elements of the cognitive representation of the problem. The memory preserves only a part of the information that has been gathered concerning the problem: its definition, requirements, and context. After having forgotten a huge part of this information, people are more likely to 'view the problem from a new perspective,' that is, to experience sudden and holistic understanding of the problem, synonymous with insight.

'*Familiarization*' is another term introduced by Herbert Simon in order to account for the phenomenon of 'incubation.' Simon assumed that problems worth creative endeavors are complex and difficult, requiring a lot of time and effort to be solved. During the long process of problem solving, almost all trials seeking a solution are unsuccessful, except the final ones that result in solutions. This does not mean that earlier trials are worthless: their function amounts to 'familiarization' with the problem, that is, making it more and more understandable, clear, and simple. Simplification of the problem structure and definition makes it possible to grasp it with a small number of items of information. This, in turn, makes it possible to manipulate the problem within the system of short-term memory, which has very limited capacity to handle information. In other words, every instance of problem solving relies on the vital operations of working memory, which performs the basic operations of information processing. But in order to be suitable for such operations the problem has to be simplified to a great extent; otherwise, the working memory system is likely to be flooded. Familiarization is a means of making the problem simple enough to be dealt with by the system of working memory. Thus, numerous unsuccessful trials seeking a solution have an important simplifying function, due to which problems originally too complex become more and more workable for the very limited capacity of the memory system.

Spontaneous recovery consists in an increase of the likelihood of recall of information if it is kept dormant for some period of time, compared to the likelihood of recall at the beginning of the learning process. It is assumed that vital information is blocked by other pieces of knowledge, learned more recently or acquired through the learner's conviction of their importance. After some period of time the blocking pieces of information lose their activation, thus yielding access to the previously inaccessible knowledge. It is also assumed that the LTM store becomes more and more organized with time, a process taking place without any intention or effort on the learner's part. Due to such hypothetical processes, people can sometimes remember more information after some time has passed than at the beginning of the learning process – a phenomenon known as 'reminiscence.' These phenomena are important for creative thinking and problem solving because they may be responsible for the elimination of mental sets, blocks, and other obstacles often preventing poeple from attaining original solutions. This is why 'incubational' breaks probably help work out creative solutions, although there are other cognitive mechanisms that operate with similar results (e.g., selective forgetting, familiarization).

Selective forgetting, familiarization, and spontaneous recovery are possible mechanisms of insight, which – according to modern cognitive theories – is basically a memory phenomenon. From the phenomenological perspective, insight is a sudden flash of understanding ('Aha!' response). From the cognitive perspective, however, its mechanisms are probably rooted in operations taking place in long-term memory during the storage phase. However, recognition of such a theoretical possibility requires that storage be viewed as an active, purposeful, and 'creative' phase of LTM operations. Spontaneous changes of the LTM structure during the storage phase do not guarantee that insight will occur and help people solve the problem in a creative way, but without these cognitive operations the phenomenon of insight would be very difficult to account for beyond its purely phenomenological aspects.

Retrieval

Retrieval consists in recalling information previously encoded and then kept in the LTM store. It is the reverse process to encoding, and its efficiency mostly depends on encoding strategies used in the first stage of the memory process.

The main problem of retrieval amounts to *accessibility* of information stored in LTM. Creative ideas are often just recovered from memory, or they result from uncommon combination of stored memories, although they may create the impression of being crafted out of nothing. In other words, a creative idea – or at least the very core of it – remains in the LTM store for a long time, 'waiting' to be noticed and used. The difficulty lies in accessing such an idea or its bud, because it is not kept in memory in its ready-made, easy to retrieve form. If it were like this, it would probably be memorized and retrieved easily by many people; as a result, such an idea would reappear frequently and, by definition, could not be called creative. So, the act of creation consists, by and large, in the use of effective retrieval strategies, through which vital information may be accessed and used in problem solving.

Hence, the problem lies in making already stored information accessible, so that it can take part in the creative process. This aim is achieved in two ways: by the use of appropriate retrieval cues and by the application of effective strategies of search of the LTM store. The *retrieval cue* is a means of decoding information kept in the LTM store, analogous to the operation of taking away an item from the shelf in the real storehouse, library, or other kind of depot. Normally, the information is retrieved from LTM with the use of exactly the same code (e.g., a category or label) with which it was put into the LTM store. These are the instances of the commonplace use of memory, resulting in uncreative behavior. However, the information may be retrieved with the use of entirely new codes, providing that a problem solver is able to recode the items constituting his or her knowledge, that is, to label the pieces of information kept in the LTM store in a new way, different from the initial encoding. Analogical thinking is enhanced in this way, since notions, memorized events, and other pieces of knowledge can be retrieved on the basis of their similarity to other areas of experience. It is a process particularly important for creativity if the analogies and similes are remote and unusual, which means that the pieces of knowledge utilized for the building of the analogy have to be retrieved with cues other than the ones used during the acquisition of knowledge.

As to the LTM *search strategies*, the problem consists in making the search as global as possible. Robert Weisberg suggests that the inability to use previous experience while solving a new problem, a phenomenon frequently described in the literature on mental 'ruts' and other blocks to creativity, may result from 'local' memory search. This kind of search is limited to the narrow, well-defined areas of knowledge stored in the long-term memory, and does not apply to other areas of knowledge, even though these regions could be highly relevant to the problem at hand. A problem solver is unable to use some fragments of his or her knowledge because they are 'too distant' from the areas defined by the problem space, and thus look 'irrelevant' to the problem. Of course, the distance between the knowledge responsible for problem representation and some potentially useful but neglected areas of experience may be superficial or only seem to exist. Furthermore, the boundaries between different fields of knowledge and expertise are usually fuzzy and conventional, sometimes artificial; however, they define the boundaries within which the memory search is normally performed. In consequence, the search is likely to be 'local,' that is, limited to the knowledge base that is directly applicable to the problem being currently solved. In order to make the search 'global,' that is, referring to the whole network of semantic memory and conceptual knowledge as well as to the vast number of episodes stored in LTM, the problem solver has to surpass the between-domain boundaries through analogy, metaphorical grasp, and mostly through the redefinition of the problem statement.

The creative search of memory does not have to be entirely global; sometimes it suffices to make the search less local, that is, less limited to the narrow conceptual boundaries defined by the initial problem statement. Redefinition of the problem statement naturally makes a problem solver more likely to cross the conceptual boundaries, as the newly defined problem requires a new set of information and provokes new associations. However, making the search 'less local' may be a deliberate strategy used by the problem solver, and trained during sessions of creative problem solving, not necessarily preceded by problem redefinition. On the other hand, redefinition of the problem is unlikely to occur without the global (or 'less local') search, because only the truly uncommon information retrieved from memory is able to make people perceive the problem in a fresh way.

Highly creative individuals are more inclined to global memory search than less creative people. The network of semantic memory of creative people is more compound, and thus more apt to make remote, unusual associations. The creative semantic memory is also more likely to be activated as a whole network rather than restricted associative regions if a priming stimulus is presented. The higher the general activation of the semantic network, the more likely it is that a person will perform a global search of the information needed during the problem solving session. Conversely, if the activation is limited to small areas of the semantic network, defined by the routine meaning of the priming stimulus, it is likely that a person will perform only a local search, with all its uncreative consequences.

Conclusions

Obviously, creativity is not just the proper use of one's memory. However, the purely creative phenomena known from the studies of creative problem solving, like insight, analogical transfer of knowledge, or unusual remote associations, probably result from the peculiarity of memory processes. It is therefore justifiable to conclude that the memory of creative individuals differs qualitatively from the memory of less creative people. The quantitative differences (for instance, the sheer amount of knowledge about some topic) are probably less important because there is no evidence that the more one knows the more creative one is. On the contrary, experts are frequent victims of rigidity and mental ruts, unless their knowledge is flexible and creative due to the specificity of its organization.

See also: Analogies; Associative Theory; Cognitive Style and Creativity; Divergent Thinking; Insight; Intuition; Metaphors; Problem Finding; Problem Solving; Remote Associates.

Further Reading

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