Memory, Aging and the Brain

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3 Memory for actions

How different?

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In the early 1980s, several groups of researchers began research on a topic variously called action memory, the enactment effect, and the subject-performed task effect. We take this as the topic of our chapter for several reasons. First, research by Lars-Göran Nilsson and his colleagues has played an important role in this research arena; second, Nilsson's supervisor, Ronald L. Cohen, was one of the initiators and champions of this line of research until his early death; and third, the effect is quite interesting in its own right and is now a central topic in the field.

The study of action memory arose independently among three different groups of researchers in the early 1980s (Zimmer & Cohen, 2001). The first published report was by Engelkamp and Krumnacker (1980) from Saarland University in Germany. They had subjects listen to a series of instructions that described a series of mini-tasks that could be performed in the lab (e.g., break the toothpick, comb your hair, touch your left ear with your right hand, pick up the toy car). All subjects heard the actions described ("pick up the toy car") with intentional learning instructions, but three different conditions were manipulated within subjects. In one condition, students simply heard the commands, in a second condition they heard them and were asked to imagine performing the action described, and in a third condition they were instructed to actually perform the action. During a later test, they were instructed to recall the actions by writing down the phrases that had been presented. The results are presented in the left panel of Figure 3.1. Recall was best after performing the action, next best after imagining performance of the action, and worst when the command had simply been heard. Engelkamp and Krumnacker referred to the superiority of recall following performance of the relevant action as the enactment effect.

At roughly the same time, Ronald Cohen (1981), then working at Glendon College, York University in Toronto, developed a similar procedure. His subjects studied four lists of action phrases either under instructions to listen to them or to perform the actions. He called the experimental condition one of using subject-performed tasks, or SPTs. His finding was perfectly consistent with that of Engelkamp and Krumnacker (1980), as subjects recalled the subject-performed tasks better than those that were merely heard (see the

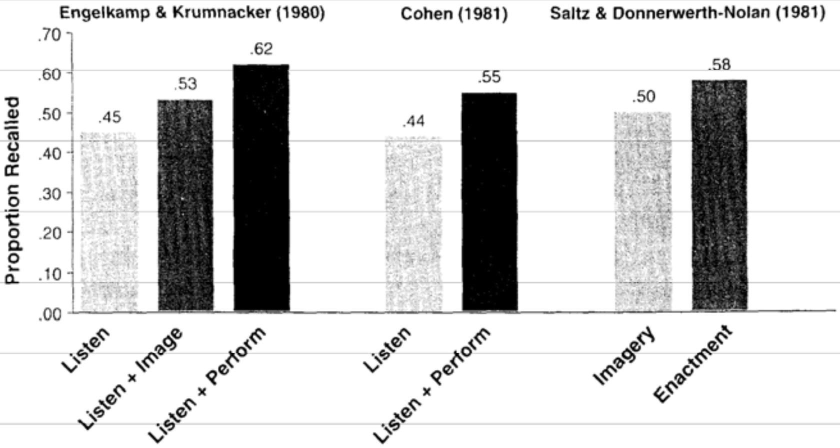

Figure 3.1 Data from three reports in 1980–1981 showing the enactment effect. The bar on the right of each panel shows retention after enactment, whereas the bars on the left show retention after either listening to the commands or listening to and imagining them. (Data adapted from selected conditions of the original papers listed in the figure.)

second panel in Figure 3.1). He called the effect the subject-performed task effect or SPT-effect.

Also in 1981, Saltz and Donnerwerth-Nolan, working at Wayne State University in Detroit, had students remember action statements presented as subject–verb–object sentences (e.g., "The dentist NAILED the sign on the WALL"). For some sentences students actually acted out the stated action, whereas for other sentences the students imagined the experimenter performing the action. (The nature of a secondary task was also manipulated; we report data from only one of two conditions here.) Once again, the basic finding was that when subjects enacted the command stated in the sentence, they remembered the sentence better on a later test than if they imagined the experimenter performing it. (See the right-hand panel of Figure 3.1.) Prior research by Paris and Lindauer (1976) had also shown that children remembered sentences better when acting them out, especially if cued by the implied object of the sentence that had to be inferred, such as *broom* in the case of "The boy swept the floor."

These three studies in the early 1980s were impressive in showing that actions were well remembered relative to verbal statements describing the action. Even more impressively, actions were even well remembered compared to imagined actions, either imaginings of the subjects themselves performing the action or of the experimenter doing so. Imagery has long been encouraged as a beneficial encoding strategy for mnemonic success (e.g., Bower, 1972; Paivio, 1969), so finding that actions speak as loudly as, or even louder than, images and words in terms of mnemonic benefit is especially noteworthy. In addition, using the subject-performed task or action memory paradigm brought more than a whiff of ecological validity to the enterprise of studying human memory. Humans hardly evolved to remember lists of words, tractable as this technique might be in the lab, but surely we must have evolved in part to be able to remember actions we have performed.

Although the findings represented in the enactment effect were powerful, they did not, at first, take the English-speaking world of psychology by storm. Engelkamp and Krumnacker's (1980) paper appeared in a German journal in German, and English speakers are notoriously recalcitrant about reading literature in languages other than their own (although, of course, we expect everyone in the world to know English). Cohen's (1981) paper was published in the *Scandinavian Journal of Psychology* (in English), but again the English and American psychological audience did not (and does not) routinely run across this journal. The Saltz and Donnerwerth-Nolan (1981) paper was published in the *Journal of Verbal Learning and Verbal Behavior*, then and now (under a new name) a dominant North American journal, but they cast their paper as about motor imagery in language (which it was), so their reporting of data showing an enactment effect was not made the central focus. The first author of this chapter was fortunate to hear about the action memory research while on sabbatical at the University of Toronto in 1981–1982, when Ronald Cohen gave a provocative Ebbinghaus Empire presentation on his work. Roediger foresaw a bright future for this research area, because it was new and interesting and the basic technique was easy to carry out (although he did not himself use it until much later; Goff & Roediger, 1998).

Of course, with time, this whole picture changed and action memory became a central focus of study for many people. The study of action memory (or SPT events) became a frequently used paradigm, adding to the arsenal of methodologies that psychologists used to conduct research on learning and memory. Although some researchers saw the paradigm as another useful technique, Cohen (1981) made much stronger claims. In this first paper he asked if principles derived from action memory experiments obeyed the same laws of memory as with standard (mostly verbal) materials. The answer he provided was, by and large, no. Although immediate free recall of SPTs showed a normal recency effect, the primacy effect was absent. In addition, a levels-of-processing manipulation (Craik & Tulving, 1975) did not affect recall of SPT events, unlike with word lists. In brief, Cohen argued that action memory tasks obeyed different laws of memory from those obtained with normal verbal tasks such as word lists.

Since Cohen's original experiments raising this issue, research on action memory has often revolved around the issue of the extent to which the laws of memory are different for subject-performed tasks and, as a corollary, whether the study of action memory is not more ecologically valid than research using nonsense words, words, sentences, prose passages, and the like. We continue this debate in our chapter.

The purpose of this chapter is to review selectively the literature on memory for enacted events and to address the question of generality of findings. Our chapter has several parts. We first outline conditions necessary to establish laws of memory (or any other phenomenon): What characteristics should laws have? Second, we introduce Jenkins's (1979) framework for understanding memory experiments as a useful heuristic to aid our asking whether laws of memory exist. Following Roediger (2008), we conclude that laws of memory have thus far proved elusive and that the claims for laws of memory early in the history of psychology have vanished over time as we have learned more. Rather, findings in human memory (and practically all of psychology) turn out to be highly context dependent. After setting this stage, the main section of our chapter examines research on action memory using the lens of Jenkins's model of memory experiments. Are findings from action memory experiments consistently different from those obtained with other materials? Are there laws of action memory, even if not for more traditional materials? After answering these questions, we briefly consider theories of action memory.

Laws of nature

Philosophers and scientists have written volumes on proper understanding of the laws of nature and what properties a law should have. We will not add much to this verbiage but will cut to what we see as the heart of the matter, using Teigen's (2002) excellent summary (see Cohen, 1985, too). Teigen proposed five criteria for the establishment of a law in science. The first is validity, or the fact of a well-established regularity in nature through many observations. A deterministic law should have no exceptions, whereas a probabilistic law should permit few exceptions. The second is universality, with a law being independent of time and place. Third, true laws take priority over observations – that is, when observations appear to conflict with a law, we tend to doubt the observations. Fourth, the law should have explanatory power by being connected to other general principles. The final property is that the law should have autonomy by being self-contained. It should be encapsulated in a brief description, often a mathematical one.

If we accept Teigen's definition of a scientific law (and we do), then the question becomes: Has the scientific study of human memory produced any laws that meet these criteria? Has the subfield of action memory research produced law-like statements? We turn next to Jenkins's (1979) framework to help us in answering these questions.

Jenkins' model of memory experiments

In 1979 James J. Jenkins wrote a chapter for a volume entitled *Levels of Processing in Human Memory* edited by Cermak and Craik. It was a brief chapter, tucked in towards the end of a long book, and it was a commentary chapter on other chapters in the volume. Despite its somewhat obscure origin, now 30 years in the past, we believe the content of the chapter represents a seminal contribution to the field (see Roediger, 2008). Briefly, Jenkins proposed not a model for memory (we have plenty – probably too many – of those) but, rather, a model for memory experiments. He proposed that the typical memory experiment can be conceived as a constellation of four sets of factors, as portrayed here in Figure 3.2 (which is adapted from Jenkins, 1979). The sets of factors are the types of subjects tested (college students, fifth grade students, older adults, etc.), the types of events that are to be remembered (pictures, prose passages, lists of words), the study or encoding task put to the subject (instructional set, strategies given, settings), and finally the way memory is tested, or retrieval factors (free recall, cued recall, forced-choice recognition testing, and many more).

In a typical memory experiment, Jenkins argued, the researcher is usually only concerned with manipulating one or two factors in this whole constellation. For example, imagine that the researcher is interested in comparing retention of pictures and words (the verbal labels of the pictures) on tests of free recall and yes/no recognition (e.g., Madigan, 1983; Paivio, 1969). Interestingly, the test mode in these experiments is almost always verbal – that is, in free recall, subjects recall the names of the pictures and the verbal labels they saw – whereas in recognition they see the word *elephant* at test regardless of whether they studied its verbal or pictorial representation during study. This basic sort of experiment then would represent at least a 2 × 2 design,

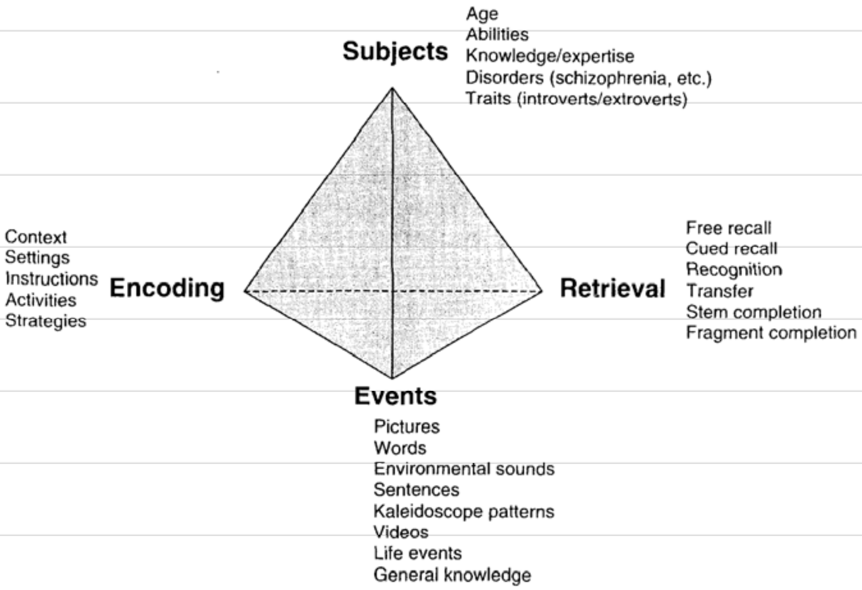

Figure 3.2 Jenkins's (1979) model of memory experiments in which at least four sets of factors are considered. In a typical experiment, only one or two factors are manipulated and retention is usually assessed using a single measure. Many other factors are held constant or allowed to randomly vary. (Adapted from Jenkins, 1979.)

with one factor being type of material (pictures/words) and the other factor being type of test (free recall/recognition). In the typical experiment, the other factors would be held constant or, in the lingo of experimental psychologists, would be control variables. College students are typically used as subjects, and the students are typically given intentional learning instructions before the material is presented.

The outcome of this particular experiment is also well known: pictures are both recalled and recognized better than words, even when the response mode in the recall test is verbal (producing names of pictures and words) and even if the test items on the recognition test are also verbal. That is, even when a nearly exact match occurs between word encoding and recognition testing item (a copy cue: study *elephant*, test with *elephant*), performance is worse than when the pictures are encoded and the test item is the verbal label (study a picture of an elephant, recognize the word elephant). Data from recall and recognition experiments following this basic form are shown in Figure 3.3. The punchline is that the picture superiority effect occurs on both recall and recognition tests with verbal tests. (A thought question for the reader: Can these results be reconciled with ideas of encoding specificity or transfer-appropriate processing? How? Shouldn't arguments favouring a match between encoding and retrieval predict suprior performance in the study word/test word condition relative to the study picture/test word condition?)

Because the picture superiority effect seems to occur with any subjects who

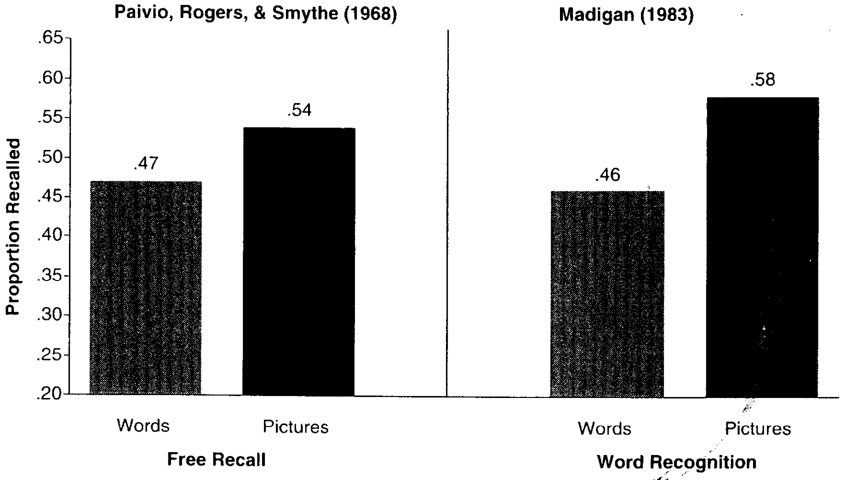

Figure 3.3 The picture superiority effect in recall and recognition experiments. Subjects study easily named pictures or words (the labels of the pictures). They are then tested in free recall (write the names of the pictures and words in any order) or in verbal recognition (recognize the words that represented pictures or words in the study phase). Despite the use of verbal coding on the test, pictures are better recalled and recognized than are words. (Data are adapted from the original reports listed in the figure.)

are fluent in their language and with intentional and incidental learning instructions, it might be thought to be a general law of memory: Pictures are better retained than words. The effect also occurs in between-subject designs (students study and recall or recognize only pictures or only words) as well as within-subjects designs (for one example of a between-subjects experiment showing the picture superiority effect, scc Erdelyi & Becker, 1974).

Nonetheless, any idea of a general law of pictorial materials being universally better retained than verbal materials can be quickly dashed when a factor held constant in the typical experiment outlined above is manipulated. That factor is the nature of the test and cues used on the test. Although the picture superiority effect generally holds in both recall and recognition tests (and, as noted above, even when the test mode is verbal), these are both explicit or episodic memory tests, ones that ask the subject to mentally travel back in recent time and retrieve episodes of pictorial and verbal elements (Schacter, 1987; Tulving, 1972). The pattern can change dramatically when one uses certain types of implicit memory tests. In one class of implicit memory test – data-driven or perceptual implicit memory tests (Roediger & Blaxton, 1987; Tulving & Schacter, 1990) – subjects study words and pictures as in the typical experiment, but then they are tested in a different manner. They are given implicit memory instructions telling them that when they see a test stimulus they should respond with the first item that comes to mind to that cue. (Nothing about conscious recollection is mentioned in the instructions, and researchers often go to some length to disguise the test so as to discourage conscious recollection.) Subjects can be given either word fragments or picture fragments with these implicit instructions to say the first thing that comes to mind to the cue. The measure of interest is priming, or the facilitation of performance on the tested fragments from having studied a relevant picture or word relative to the completion rate in the absence of recent prior study of the element.

In general, results from this type of experiment using perceptual implicit memory tests show exquisite modality specificity, unlike experiments using explicit memory tests. That is, study of pictures produces priming on picture fragments but not on word fragments, whereas study of words produces priming on word fragments but not much on picture fragments (Weldon & Roediger, 1987; see also McDermott & Roediger, 1994; Rajaram & Roediger, 1993). The picture superiority effect disappears – it actually reverses – on a verbal perceptual implicit memory test.

The data shown in Figure 3.4 come from selected conditions of McDermott and Roediger (1994, Expt. 4), where the data shown are priming from pictures or words (i.e., a baseline completion rate of guessing the fragments' identities when they had not been studied has been subtracted out). As can be seen, the picture superiority effect holds on an implicit test with picture fragments, but completely reverses on the primed word fragment completion test. On the word fragment completion test, words produced greater priming than did pictures, in line with the transfer-appropriate processing account of task

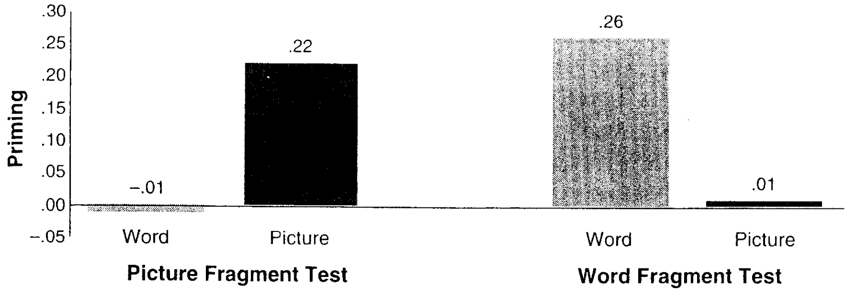

Figure 3.4 Priming on verbal and pictorial implicit memory tests after study of words and pictures. The pattern of priming shows specificity of modality: Prior study of pictures primes picture fragment naming but not word fragment completion, whereas prior study of words has the reverse effect. Baseline (non-studied) completion rates have been subtracted, so the data are priming scores. (Data are adapted from selected conditions in McDermott & Roediger, 1994, Expt. 4.)

dissociations (see Roediger & Srinivas, 1993). One might think that pictures are automatically named when they are presented, but if so this type of verbalization does not lead to priming on the verbal implicit test. (When McDermott and Roediger explicitly told subjects during study to imagine the form of the stimulus – that is, to imagine the written word or the image of the appropriate object – then some priming did occur on the task-appropriate test.) This test-appropriate pattern of results on perceptual implicit memory tests as shown in Figure 3.4 holds with both intentional and incidental learning instructions (Roediger, Weldon, Stadler, & Riegler, 1992) and on a variety of verbal implicit memory tests (Rajaram & Roediger, 1993).

In short, we can confidently say that the picture superiority effect reverses on verbal implicit memory tests. This outcome violates the idea of a general law that pictures are retained better than words. Rather, whether pictures are retained better than words, or the reverse, depends on the combination of study and test conditions used to examine the effect. In this case, the type of test used is critical, but other examples exist. Paivio and Csapo (1973) showed how the picture superiority effect can be reversed even on an explicit test, by manipulating study conditions.

Roediger (2008) examined the issue of whether *any* laws of learning and memory exist. As scientific psychology developed in the late nineteenth and early twentieth century, researchers sought to provide general laws of behaviour that would be like the famous laws of physics and chemistry. Thus, within the realm of learning and memory, Thorndike boldly proclaimed in 1911 that "Two laws explain all of learning." These were the law of effect and the law of exercise. Roediger examined 8 candidate variables that have been said to (or might be expected to) provide lawful relations with retention within the field of the cognitive/behavioural study of human memory. These variables included the effects of repetition, study time, distribution and spacing of practice, generation, retention over time (forgetting), as well as the mirror effect and the picture superiority effect. All these variables have been claimed to provide regular relations with certain types of retention tests. However, when Roediger examined them through the lens of Jenkins's tetrahedral model, each seemingly regular effect of these variables was shown to have important exceptions when other variables were manipulated, as just demonstrated in the paragraphs above with the picture superiority effect.

Roediger (2008) noted that most phenomena studied in human learning and memory are actually highly reliable; perform the same experiment the same way and the same outcome will (by and large) be obtained. The problem for the field in claiming laws is one of generality across the dimensions of Jenkins's (1979) tetrahedron. A highly replicable finding in one set of circumstances will lose its robustness when examined across the four corners of the model (subjects, encoding activities, materials, and types of test). In fact, if anything, Jenkins's model omits one critical variable that greatly matters in learning and memory experiments, as well as in all sorts of cognitive psychology experiments: the nature of the experimental design used (between-subjects or within-subjects). McDaniel and Bugg (2008) have reviewed five important memory phenomena in which results differ depending on the type of design used. Often an experimental effect (e.g., the generation effect, the word frequency effect) will be revealed in a within-subjects design, but the effect may evaporate (word frequency) or even reverse (generation) in a between-subjects design. This design feature is not embedded in Jenkins's framework, but it often matters in experiments, as Poulton (1963) also showed with reaction time experiments (see also, in the realm of animal learning, Bower, 1961). We will discuss the issue of type of design further in the context of action memory experiments.

Are there laws of action memory?

Cohen (1981) argued that laws for the enactment effect, or SPT tasks, were different from those based on standard verbal or pictorial materials. Of course, if Roediger (2008) and, for that matter, Cohen himself a bit later (1985) are right, there may be no general laws of memory to which principles of action memory would represent an exception. However, the enactment effect was not one that Roediger (2008) considered at length in his chapter. We aim to remedy that oversight in the remainder of this chapter by applying Jenkins's model of memory experiments to the enactment effect (see also Nilsson, 2000; Zimmer et al., 2001).

The enactment effect can often be quite substantial, typically ranging from 20–30% (Nyberg & Nilsson, 1995), and, as we will discuss, this effect generalizes across a wide range of subject populations and experimental conditions. Therefore, it seems a good candidate to examine for robustness across other variables. Another purpose of our chapter is to suggest modifications of Jenkins's (1979) model. We have already noted that type of design is one important factor omitted from Jenkins's model. In addition, we suggest that enactment tasks in memory experiments may themselves constitute an independent factor. That is, task enactment does not always fit squarely into the category of either a study/encoding manipulation or an event (materials) factor – it has features of both. When the to-be-learned items are action verbs or phrases, and when subjects are instructed to physically perform the actions or merely to listen to the instruction, this manipulation seems to fit squarely in Jenkins's framework as a study or encoding factor. On the other hand, when subjects are asked to perform actions with real objects provided by the experimenter (e.g., fill a glass), task enactment in this case creates the to-be-learned event, so it seems more like a type of material. Furthermore, in studies that require subjects to perform the to-be-learned actions during both the study and test phases (e.g., Engelkamp, Zimmer, Mohr, & Sellen, 1994; Kormi-Nouri, Nyberg, & Nilsson, 1994; Mulligan & Hornstein, 2003; Saltz & Dixon, 1982), enactment can simultaneously serve as an encoding/event factor as well as a retrieval factor.

A final justification for treating task enactment as an independent factor has to do with the types of interactions that occur when enactment is manipulated in conjunction with other encoding and/or retrieval variables. As we will discuss, task enactment – for reasons that are still unknown – has been shown to eliminate, or in the very least greatly reduce, the mnemonic effects of manipulating levels-of-processing (Craik & Lockhart, 1972) and item generation (Jacoby, 1978; Slamecka & Graf, 1978). This seems counterintuitive, because a reasonable assumption is that a combination of recall-enhancing encoding tasks (e.g., generating plus performing) should yield positive (perhaps even additive) benefits to retention or, at the very least, should not harm performance. These counteractive effects, therefore, underscore the notion that task enactment can play an important independent role in memory experiments.

We turn now to consider the four prongs of Jenkins's (1979) model, with a focus on action memory experiments. As we shall see, no robust laws of action memory seem to be validated.

Subjects

The enactment effect, which has been primarily demonstrated in young adults, has been also observed in a variety of other subject populations. These include healthy groups of children (Cohen & Stewart, 1982), older adults (e.g., Bäckman & Nilsson, 1984, 1985; Freeman & Ellis, 2003; Rönnlund, Nyberg, Bäckman, & Nilsson, 2003), deaf (von Essen & Nilsson, 2003; Zimmer & Engelkamp, 2003), blind (Kormi-Nouri, 2000), and mentally retarded subjects (Cohen & Bean, 1983).

Since performance on tests of explicit memory (e.g., recall or recognition) for verbally encoded materials is typically impaired for children, older adults, and mentally retarded subjects compared to young adults, these data have been interpreted to reflect fundamental differences between action and verbal memory (Cohen, 1981, 1983; Nilsson, 2000). Nevertheless, there has been some discrepancy in the literature as to whether the memorial benefit of task enactment remains intact or changes with age.

For instance, whereas Cohen and Stewart (1982) reported no differences in recall performance for subject-performed tasks among 9-, 11-, and 13-year-old children, other researchers have observed significant improvements in recall with age (e.g., Foley & Johnson, 1985; Foley & Ratner, 2001). At the other end of the life cycle, Cohen, Sandler, and Schroeder (1987) as well as Brooks and Gardiner (1994) observed that, after subjects performed to-be-learned lists of action phrases, older adults recalled as much as younger adults when tested with short study lists but not with long lists. By contrast, several studies reported age-related declines in memory for performed actions using comparable shorter study lists and tests of free or cued recall (Dijkstra & Kaschak, 2006; Knopf, 1991; Rönnlund, Nyberg, Bäckman, & Nilsson, 2003). Knopf and Neidhardt (1989) observed age-related differences in free recall of subject-performed actions, but when given a recognition test, which typically minimizes self-initiated retrieval demands relative to tests of free or cued recall, performance was similar for young and older adults. These data provide support for the notion that verbal and task enactment encoding involve fundamentally similar cognitive processes (e.g., Bäckman & Nilsson, 1985; Kormi-Nouri & Nilsson, 2001). Consistent with Jenkins's (1979) model, these various and seemingly contradictory findings underscore the notion that the effects of aging on the enactment effect are themselves influenced by interactions with other factors such as types of materials (e.g., list length) or tests (e.g., recall vs. recognition).

More surprising demonstrations of generalization have been shown in patients suffering from amnestic mild cognitive impairment (aMCI; Karantzoulis, Rich, & Mangels, 2006), Alzheimer's disease (Karlsson et al., 1989), frontal-lobe dysfunction related to epileptic surgery (McAndrews & Milner, 1991), Korsakoff's syndrome (Mimura et al., 1998), and even Parkinson's disease (Knopf, Mack, Lenel, & Ferrante, 2005). Taken together, these findings demonstrate just how extensively the superiority of remembering previously performed actions over information that was verbally encoded generalizes across subject populations, especially among subject populations that exhibit marked deficits in episodic verbal memory tasks and motor functioning.

This statement must be qualified, however, by noting cases where task enactment does not appear to enhance memory performance. Gardiner, Brandt, Vargha-Khadem, Baddeley, and Mishkin (2006) recently reported a series of experiments conducted with a developmental amnesic patient that showed no benefit of task enactment at study on subsequent recognition memory performance relative to verbal encoding. This single study is particularly striking, because in separate experiments, the same patient did exhibit both levels-of-processing and bizarreness effects (enhanced memory for bizarre compared to ordinary items) in tests of recognition memory. The authors suggest, however, that the levels-of-processing and bizarreness effects were not pure, in that they most likely reflected contributions from semantic memory and not a clean dissociation between verbal episodic and action memory task performance.

In addition, some evidence indicates that schizophrenic patients show little or no benefit of task enactment (Daprati, Nico, Saimpont, Franck, & Sirigu, 2005). Similarly, patients suffering from frontal lobe syndrome, which primarily affects action-related planning processes, do not show an enactment effect (Knopf et al., 2005). Nyberg, Persson, and Nilsson (2002) analysed individual differences among participants in a longitudinal aging study and tentatively concluded that specific biological and neuropsychological factors related to motor system dysfunction, which are more prevalent in older adults, may impair one's ability to benefit from task enactment. Still, more research is necessary to specify what aspects of motor planning, encoding, and episodic integration contribute to the enactment effect, and which of these, in turn, may be differentially affected by developmental and age-related processes, brain damage, sensory impairments, or other neurological disorders.

In sum, when healthy subjects are tested in action memory experiments, virtually all groups reveal an enactment effect. However, some neurologically impaired groups do not show the effect, probably due to impairments affecting the motor system.

Events

The memorial benefit of task enactment has been demonstrated with a variety of study materials and types of actions. These include verbs, phrases, and sentences, actions performed or observed with real or imagined objects, and even the use of sign language (for reviews, see Engelkamp & Zimmer, 1994; Nilsson, 2000; Zimmer et al., 2001). Yet there is a great deal of debate in the literature as to whether these various types of materials and actions directly influence the magnitude of enactment effect.

For example, in the early studies of the enactment effect, researchers asked whether it is better to perform actions such as "to fill a glass", with the use of a real glass and liquid, or whether simply pretending to fill a glass yields a comparable enactment effect. Whereas some researchers tended to use real objects in their experiments, because the experience of engaging with the objects was presumed to play an important role during enactment encoding (e.g., Bäckman, Nilsson, & Chalom, 1986; Kormi-Nouri & Nilsson, 1999; Nilsson & Bäckman, 1989), others have argued that it was necessary to only use imagined objects, because only the bare motor component was critical to producing enactment effects (e.g., Engelkamp & Zimmer, 1983, 1996). Engelkamp and Zimmer (1983, 1996) demonstrated that both task enactment and the use of real objects to perform the to-be-learned actions enhance memory performance, but independently of one another. However, more recently, Kormi-Nouri (2000) reported two experiments that systematically varied task enactment encoding with verbal encoding; the use of real or imaginary objects; and the use of real or imagined actions. Furthermore, Kormi-Nouri (2000) compared performance for sighted subjects with groups of blindfolded and blind subjects. Across all groups and conditions, subject-performed tasks were better recalled than verbally encoded items. There were also no differences in recall performance between the subject groups, with the exception that blind subjects demonstrated worse recall for subject-performed tasks that were both imagined and, further, involved imaginary objects. Enhanced recall for subject-performed tasks occurred regardless of whether subjects actually performed or only imagined the to-be-learned actions, or whether they used real objects or simply imagined using the objects. Therefore, Kormi-Nouri (2000) argued that the enactment effect does not depend on either motor movements or the use of real objects, a striking conclusion.

Another question that dates back to the early days of action memory research is whether it is better to actually perform the to-be-learned action descriptions, or whether observing someone else (i.e., the experimenter) perform the to-be-learned actions produces comparable memory performance. For instance, Cohen (1981) in his pioneering study reported no difference between these two encoding conditions (performing vs. observing), and Steffens (2007) has more recently made the same observation. However, Engelkamp and Zimmer (1983, 1997) demonstrated superior memory for subject-performed actions relative to actions that subjects only observed. Although it is unclear what specific factors determine the relative memorial advantage of performing over observing actions, two factors appear to play decisive roles – list length and experimental design. For longer lists of to-be-learned actions (e.g., 24–48 items), or for randomly mixed lists of actions that are to be either performed or observed in a within-subjects design, performing is superior to observing the actions. However, when the lists are relatively short (e.g., 12 or fewer items) or the conditions are blocked within-subjects or distributed between-subjects, performing the actions results in memory test performance similar to observing the actions. Later, we will discuss in greater detail the influence of experimental design on the enactment effect.

Among the various types of study materials and actions that have been shown to elicit enactment effects, it also remains unclear whether the organization of the study items influences the magnitude of the effect. Numerous studies dating back to the early 1950s have examined the relationship between organization and learning by measuring the extent to which subjects recollect similar responses together, or in clusters, in tests of free recall. The similarity of the responses within each cluster may be based on semantics, temporal contiguity, or other psychological dimensions (e.g., Bousfield, 1953; Deese, 1959; Jenkins & Russell, 1952; Mandler, 1967; Miller, 1956; Tulving, 1962).

On the one hand, several studies conducted by Engelkamp and colleagues (e.g., Engelkamp & Zimmer, 1990; Engelkamp, Zimmer, & Mohr, 1990; Zimmer, 1991; Zimmer & Engelkamp, 1989) have demonstrated that organizational scores for recall protocols do not benefit from task enactment. By contrast, Bäckman and colleagues (Bäckman & Nilsson, 1984, 1985; Bäckman et al., 1986; Kormi-Nouri & Nilsson, 1999) have reported higher organizational scores for recall of actions that were performed during study. That is, task enactment may have enabled subjects to benefit more from the relational structure of the study list to aid recall. In a more recent study, Koriat and Pearlman-Avnion (2003) showed that task enactment influences the specific type of mental organization that occurs during encoding and retrieval. Specifically, they found that when subjects performed to-be-learned actions, they tended to cluster their recall responses based on motor movement similarities among list items. However, when subjects verbally encoded the described actions, they tended to cluster their responses based on inter-item semantic associations.

Aside from the organization of the study materials or subjects' recall protocols, do particular types of items tend to be remembered better than others following task enactment? The answer is yes. For instance, studies conducted by Kormi-Nouri (1995) and Kormi-Nouri and Nilsson (1998) have shown that pre-experimental semantic associations among verbs and nouns used to create individual action phrases modulated the memorial benefit of task enactment such that items with well-established pre-experimental semantic associations (e.g., "read the book") tend to benefit more from task enactment than items whose elements are weakly associated (e.g., "look at the stone"). Similarly, Engelkamp and Jahn (2003) observed that under task enactment study conditions, action phrases with highly associated objects and verbs were better recalled than phrases with weakly associated objects and verbs.

One type of study material that may not benefit from task enactment is the learning of paired associates. Engelkamp (1986) reported that paired-associate learning was surprisingly worse following enactment than following verbal encoding. Subjects studied unrelated pairs of verbs, either under standard verbal encoding conditions or by performing the described actions. Using a test of free recall, task enactment improved memory performance compared to verbal encoding. However, using a test of cued recall in which subjects were presented with one verb from each pair and asked to recall the verb-associate, recall after verbal encoding was superior to that after task enactment. This and related findings have been taken as evidence to support the notion that while performing to-be-learned actions enhances memory for the particular actions (item-specific processing), it does not enhance memory for relations among associated pairs of actions (relational processing), especially if the actions appear to be unrelated.

In order to fully address the question of whether the enactment effect generalizes across all types of study materials and actions, more research is needed to examine whether stimuli that do not directly lend themselves to active performance can benefit from some form of related enactment. Do all types of actions and activities benefit from task-enactment encoding? It is interesting to note that Cohen (1981) originally included a wide variety of tasks such as "fold your arms", "sharpen the pencil", "yawn", "read the

Xmas card", "spell COLD", and "add 2 + 3", some of which emphasized bodily movements, the use of objects, or distinct mental operations. Curiously, the performance of tasks such as the last three item examples probably involves the same sorts of perceptual and cognitive processing instructed of subjects when they perform verbal learning levels-of-processing and generation tasks, and yet, surprisingly, levels-of-processing and generation effects do not robustly occur under task enactment encoding conditions.

Another limit to the generalization of the enactment effect may be the complexity of the to-be-learned materials. The vast majority of studies that have examined the memorial consequences of task performance have employed lists of simple, discrete actions. Due to the simplicity of the actions, it remains unclear whether the memorial benefit of task enactment extends to more complex sequences of actions or goal-oriented activities that are more representative of everyday actions (for a detailed discussion of these issues, see Foley & Ratner, 2001).

In sum, although the enactment effect occurs with a wide variety of materials, there are clearly conditions in which the effect does not occur, such as with short lists of materials or in paired-associate recall.

Encoding

The memorial benefit of enactment has been demonstrated using several different encoding manipulations, including, but not limited to, instructing subjects to perform actions with either real or imaginary objects (e.g., Engelkamp & Zimmer, 1983, 1994); with intentional or incidental learning instructions (e.g., Zimmer & Engelkamp, 1984); by performing the target actions while blindfolded (Engelkamp, Zimmer, & Biegelmann, 1993; Kormi-Nouri, 2000); or in using sign language to enact the target actions (von Essen & Nilsson, 2003; Zimmer & Engelkamp, 2003).

However, a number of encoding variations that have been shown to greatly impact memory for verbally encoded stimuli do not appear to influence memory for actions. For instance, numerous studies have shown that the levels-of-processing effect (Craik & Lockhart, 1972; Craik & Tulving, 1975) does not occur, or at the very least is greatly reduced, when subjects were instructed to perform the study items (Cohen, 1981; Cohen & Bryant, 1991; Nilsson & Cohen, 1988; Nilsson & Craik, 1990; Zimmer & Engelkamp, 1999). The generation effect (Jacoby, 1978; Slamecka & Graf, 1978), in which there is a memorial advantage for information that is generated by subjects compared to information that is passively heard or read, was not obtained when items were encoded through enactment (Nilsson & Cohen, 1988).

Additional factors that are known to have significant influence on memory for verbally encoded stimuli, but little to no influence on subject-performed actions, include varying the study time interval (Cohen, 1985); the amount of item elaboration (Helstrup, 1987); whether the to-be-learned stimuli are bizarre or ordinary actions (Engelkamp et al., 1993; Knopf, 1991); and instructing subjects to study items under conditions of divided attention (e.g., Bäckman, Nilsson, Herlitz, Nyberg, & Stigsdotter, 1991; Bäckman, Nilsson, & Kormi-Nouri, 1993; Bäckman et al., 1986).

In sum, the strongest case to be made that action events differ systematically in memorability relative to verbal events comes from these different effects of encoding manipulations in the two domains.

Retrieval

The enactment effect has also been demonstrated in performance on different tests of memory, including free recall, cued recall, and recognition, with the effect generally being more pronounced on tests of recognition than in recall (e.g., Mohr, Engelkamp, & Zimmer, 1989). In addition, task enactment enhances the accessibility of items in priming on conceptual implicit memory tests. For instance, when subjects were instructed to generate category instances, previously enacted actions were generated more frequently than were actions previously studied with verbal encoding or non-studied actions (Zimmer, 1991). However, as noted above, the enactment effect does not occur in paired associate learning (Engelkamp, 1986).

The memorial benefit of task enactment has also been observed using the classic release from proactive interference (PI) paradigm (Wickens, 1970). In this paradigm, subjects typically study and attempt to recall individual triads of verbal stimuli (i.e., letters or words) on successive trials. Between study and test, subjects might be asked to perform a simple counting or arithmetic task to minimize rehearsal for a number of seconds (i.e., 20 s). The typical finding is that recall performance decreases sharply across trials, which can be described as a build-up of proactive interference. However, when there is a shift in the symbolic representation or taxonomic class of the triad on a later trial, there is a marked increase in recall performance, known as the release from PI. Nilsson and Bäckman (1991) applied the PI-release paradigm to studies of task enactment and demonstrated increased release from PI for previously performed actions relative to that for actions studied under verbal encoding.

Several studies have examined the effects of task enactment on hypermnesia, the improvement in recall across repeated tests (Erdelyi & Becker, 1974). In these experiments, subjects were given several successive recall tests after receiving lists of action descriptions that were either performed or verbally encoded during the study phase. Interestingly, these studies have shown that task enactment during study led both to more item gains (recall of additional study items that were not recalled on previous recall attempts) over repeated test trials as well as item losses (forgetting of items that were successfully recalled on previous recall attempts) relative to verbal events (Engelkamp & Seiler, 2003; Engelkamp, Seiler, & Zimmer, 2004).

Another line of research has investigated whether task enactment at retrieval in addition to study further enhances memory performance. Engelkamp and colleagues conducted a series of studies that demonstrated a benefit on recognition test performance when subjects enacted to-be-learned tasks during both study and test phases (e.g., Engelkamp & Zimmer, 1995; Engelkamp et al., 1994). Likewise, other recent studies have shown that having subjects perform to-be-learned actions during both encoding and retrieval increased the recall advantage of enactment relative to task enactment during study alone (Koriat & Pearlman-Anvion, 2003; Mulligan & Hornstein, 2003; Steffens, Buchner, & Wender, 2003). Indeed, these findings are consistent with theories such as the encoding specificity principle (Tulving & Thomson, 1973) and the transfer-appropriate processing framework (Bransford, Franks, Morris, & Stein, 1979), which posit that memory performance depends on the extent of overlap between recall and study conditions.

On the other hand, several types of memory tests and retrieval conditions do not appear to benefit from enactment. For instance, if subjects studied a list of items and were later instructed to recall the items in the correct order (serial recall) or to rearrange the items in their correct order, enactment encoding was no better than verbal encoding (Olofsson, 1996). Moreover, enactment does not appear to enhance retention of source information or one's ability to monitor learning. Several studies have showed no improvements in memory for the spatial or temporal context in which actions were originally studied compared to items that were verbally encoded (Cornoldi, Corti, & Helstrup, 1994; Koriat, Ben-Zur, & Cruch, 1991; Zimmer, 1994). Other researchers reported that subjects were worse in predicting their performance in a subsequent recall test following enactment encoding than they were following verbal encoding (Cohen, 1983, 1988, 1989; Cohen & Bryant, 1991; Engelkamp & Cohen, 1991).

In sum, although many retrieval tasks reveal an enactment effect, some popular tests, such as serial and paired-associate recall, do not. Free recall and recognition procedures do typically reveal the enactment effect.

Experimental design

In addition to the four sets of factors that Jenkins proposed in his model, experimental design is another factor that has been shown to directly influence a substantial number of mnemonic effects that are widely believed to be stable (for a review, see McDaniel & Bugg, 2008). Consider the generation effect. When list items that subjects are instructed to generate are randomly mixed with items that subjects are instructed to passively read, generated items are better remembered than are read items (e.g., Jacoby, 1978; Slamecka & Graf, 1978). However, when generated and read items are distributed between-subjects such that one group of subjects only generates study items and another group only reads study items, then recall performance is usually found to be equivalent in both conditions (Slamecka & Katsaiti, 1987). Comparable recall performance for generated and read items has also been reported in within-subjects designs when the two types of items are presented in homogeneous blocks (Begg & Snider, 1987; Hirshman & Bjork, 1988; Slamecka & Katsaiti, 1987).

The memorial advantage of performing to-be-learned actions over standard verbal encoding instructions does generalize across various experimental designs. However, as discussed above, if one compares recall for actions that were performed by subjects themselves versus actions that subjects observed others (such as the experimenter) perform, different patterns emerge, depending on the experimental design. Engelkamp and Zimmer (1997) reported that when subject-performed and experimenter-performed actions are randomly distributed within-subjects, subject-performed actions were recalled the best. However, this benefit of task enactment disappeared when the encoding conditions were distributed between-subjects (see also, Cohen, 1981, 1983).

To explain these discrepancies, Engelkamp and Zimmer (1997) suggested that whereas performing actions during encoding enhances processing of the features of the individual actions themselves (item-specific processing), observing the actions enhances processing of the temporal or semantic associations among actions in the study list (relational processing). Furthermore, when the encoding conditions are randomly distributed within-subjects, the enhanced item-specific processing for subject-enacted tasks detracts from the enhanced relational processing enjoyed by observing task enactment, thereby yielding superior recall performance in the subject-performance condition. By contrast, with the two conditions distributed between-subjects, recall should be equivalent because the enhanced item-specific processing of one condition will more or less match the enhanced relational processing of the other condition.

An alternative account of these findings is provided by the item-order theoretical framework, in which subjects make use of both item-specific and temporal-order information to guide retrieval (McDaniel & Bugg, 2008; Nairne, Riegler, & Serra, 1991; Serra & Nairne, 1993). The item-order account maintains that enhanced item-specific processing occurs at the expense of encoding temporal or order information about item presentation within the study list. In a within-subjects design, memory for order information is equivalent across all encoding conditions (performing vs. observing actions), because enactment would disrupt the encoding of order information throughout the list of described actions whereas item-specific processing of the individual actions would be enhanced in the subject-enactment condition. By contrast, in the between-subjects design, order memory would be enhanced for experimenter-enacted items at study, whereas order memory would remain diminished for subject-enacted items, thereby potentially reducing the difference between the two conditions (performed or observed).

McDaniel and Bugg (2008) recently reviewed studies of the generation effect, as well as the word-frequency effect (high-frequency words are recalled better than low-frequency words), the perceptual interference effect (perceptually masked words are recalled better than unmasked words), the bizarreness effect (items conceived in a bizarre scenario are better recalled than items conceived in an ordinary scenario), and the enactment effect (subject-performed tasks are better recalled than experimenter-performed tasks), in order to examine whether the puzzling influence of experimental design may be adequately explained in terms of a unifying theoretical framework. Indeed, they argued that the item-order theoretical framework can at present account for the collective findings related to each of these five effects (Nairne et al., 1991; Serra & Nairne, 1993).

For our purposes, McDaniel and Bugg (2008) cited data from studies conducted by Engelkamp and Dehn (2000) and Golly-Häring and Engelkamp (2003) that provide support for the predictions of the item-order theoretical framework. Engelkamp and Dehn observed that whereas free-recall performance varied with experimental design – that is, subject-performed actions were recalled better in within- but not in between-subjects designs – recognition of subject-performed actions was superior in both types of designs. The latter finding is consistent with the notion that item-specific processing enhances recognition test performance (and processing of order information is not particularly critical). Furthermore, when subjects attempted to reconstruct the presentation order of the study items, predictions of the item-order account were fulfilled. That is, order reconstruction scores were superior for experimenter-performed actions compared to subject-performed actions in the between-subjects design and were intermediate for actions studied in the within-subjects design. In a more recent study, Golly-Häring and Engelkamp (2003) provided further support for the item-order account by demonstrating that when the study lists are composed of categorically related items, subject-performed actions are better recalled than experimenter-performed actions, regardless of experimental design. They argued that this outcome occurred because subjects can effectively encode and make use of these inter-item associations to aid recall and compensate for deficits in order information encoding incurred through task enactment.

To conclude this section, action memory effects respond to design features of an experiment (within- or between-subjects designs) in a similar way to other well-known effects such as the generation effect and the word-frequency effect. In this case, action memory effects behave like other behavioural effects. However, it should be borne in mind that the effects due to changing designs discussed above refer to a comparison between subject-performed tasks and observing someone else perform the task. The advantage of subject-performed tasks to verbal tasks (hearing the instruction) survives design changes, similar to the picture superiority effect and the levels of processing effect. Why some study or encoding manipulations are affected by design changes and others are not remains an interesting target for future research.

Theory

The various ways that subject-performed tasks can be instantiated in memory experiments also highlights fundamental distinctions among the theories proposed to explain the benefit of task enactment. That is, each theory predicts that the manipulation of certain factors will be important in determining the presence and magnitude of enactment effects, while variations among other factors will have a negligible influence.

Cohen (e.g., 1981, 1983) proposed that, in contrast to standard verbal learning task conditions in which subjects may strategically rehearse, mentally organize, or form associations among to-be-learned items during study, subject performance of to-be-learned actions is a non-strategic form of encoding that is automatic and highly efficient. Task enactment represents an optimal form of encoding and, as such, is superior to verbal encoding. Therefore, experimental factors that either impair or minimize the use of "strategic" encoding and/or retrieval processes should lead to a memorial advantage for task enactment. As we will discuss later, some of these factors include subject factors such as age, intelligence, brain damage, and other neurological disorders.

Furthermore, the non-strategic encoding view does not specify the types of actions that may or may not benefit from subject performance. In fact, as already mentioned, Cohen (1981) originally included a wide variety of tasks such as "fold your arms", "sharpen the pencil", "yawn", "read the Xmas card", "spell COLD", and "add 2 + 3", some of which emphasize bodily movements, the use of objects, or distinct mental operations. It seems that a further prediction of the non-strategic encoding view is that the enactment effect should generalize across all types of subject-performed activities.

Bäckman and Nilsson (1984, 1985) argued that subject task performance involves both strategic and non-strategic forms of encoding (see also Bäckman et al., 1986). That is, when subjects perform to-be-learned actions, the action descriptions may be strategically encoded as verbal information, whereas the physical aspects of task enactment are encoded non-strategically (Bäckman et al., 1991, 1993). According to this dual encoding theory and in contrast to the non-strategic encoding view, factors that impair the use of strategic processes can reduce or eliminate the enactment effect. On the other hand, the inclusion of more physical components (e.g., real objects) to the study tasks should produce or increase the magnitude of the enactment effect.

An alternative proposal, by Engelkamp and Zimmer (e.g., 1983, 1984, 1985), was that the independent encoding of motor information during task performance produces the enactment effect. According to their theory, motor, verbal, and visual information are encoding independently in distinct mental codes or representations. More importantly, motor encoding is assumed to be more efficient than verbal and visual encoding. One methodological implication of these theoretical assumptions is that the enactment effect depends on the interaction between encoding activities and types of materials. Specifically, memory performance will be enhanced to the extent that either the encoding instructions or to-be-learned actions include a motor activation component (e.g., "raise your arm"). This requirement of a motor component suggests both extensions and limitations to the generalization of the enactment effect. In contrast to Cohen's (1981, 1983) approach, the enactment effect would depend on whether subjects are instructed to perform a physical activity. In contrast to the dual encoding account, Engelkamp and Zimmer further argued that the enactment effect does not depend on subjects' physical interactions with the environment (e.g., objects). An additional prediction is that task enactment during retrieval can either facilitate or interfere with memory performance depending on the similarity of the motor movements done at study and test.

In a radical departure from the above-mentioned accounts, Kormi-Nouri (1995) and Kormi-Nouri and Nilsson (2001) have argued that task enactment encoding is purely strategic and that there is little distinction between verbal and motor encoding. Rather, when subjects are asked to learn and perform lists of described actions, consistent with Tulving's (1983) conception of episodic memory, task enactment enhances subjects' experience and awareness of the learning episode as compared to standard verbal encoding conditions. Kormi-Nouri and Nilsson proposed that memory performance will be enhanced to the extent that task performance facilitates "episodic integration" of the to-be-learned information (e.g., verbs, objects) into a cohesive, distinct memory trace (Kormi-Nouri & Nilsson, 2001). This theoretical approach implies, for instance, that factors that impair episodic memory performance in general will likewise impair memory for previously performed actions.

The current status of theories of the enactment effect is one of ferment, with contending theories having both strengths and weaknesses in accounting for the huge body of empirical data. We have covered the action memory research somewhat selectively in this review, so a more thorough assessment would probably uncover even more problems for extant theories.

Conclusions

In the past 30 years, research on action memory (or the enactment effect or subject-performed tasks) has reached a state of scientific maturity in that a large body of research has been published on it. Cohen's (1981) proclamation that different laws of memory might underlie action memory relative to verbal memory seems, in its boldest form, to be wrong. There are no "laws of memory" using the criteria Teigen (2002) proposed, either in action memory or anywhere else in our field. On the other hand, if we soften the claim to one of "different principles" or "different patterns of effect", then we can see some evidence that Cohen (1981) was right. For example, the review of encoding effects above indicated that variables that commonly affect verbal memory tasks often have a different effect (or no effect) on action memory tasks. Nonetheless, surveying this body of literature and trying to reach firm conclusions about the effect of enactment as a variable usually leads us to such statements as "Self-performed tasks are better retained than watching another person perform a task, but this effect depends on the type of materials used, the method of measuring retention, the type of experimental design, using neurologically intact subjects in the experiment, and so on." As seemingly occurs with all memory phenomena, the answer to almost any question is "it depends" (Roediger, 2008). Our textbooks may tell pat stories for the instructors' and students' convenience, but scientists at the forefront of studying some phenomenon know that these are usually "just so" stories because the truth would demoralize students (and their instructors). "It depends" is just not a satisfying answer to questions, even though it usually represents the true state of affairs.

Interestingly, Lars-Göran Nilsson drew conclusions much like our own in an essay that appeared the year before the dawn of action memory research. In 1979 he published an edited volume of important essays to honour the 500th anniversary of Uppsala University. We think it is fitting to conclude our chapter in his honour with his prescient words from the introductory chapter he wrote 30 years ago:

> Apparently, there is no general theory in the making, and there are no single findings terminating any research pursuits. Certain discoveries may of course answer specific questions, but beyond those there are always still more challenging questions that require further study. Thus, as it now stands, there is no real hope for a final general theory in memory research. The general-theory view of science is of course more common among people in general than among scientists. However, even scientists often hope for a general theory that will be the salvation for a given field; and one might wonder how this view has become so popular. One very likely reason is the way undergraduate courses are usually taught. When we teach courses, we often seek to present the material in such a general and coherent form that it commonly violates scientific reality. If we would present the material in a way that more exactly reflects the diverging state of affairs in the memory area, it would probably leave the students in a state of bewilderment. Simplification and other pedagogical tricks may be necessary to avoid this state, but it is important to keep in mind that they are made for educational and not for scientific purposes.

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