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CHAPTER 6

Aging and Memory: Implications for Skilled Performance

Fergus I. M. Craik
University of Toronto

Larry L. Jacoby
McMaster University

This chapter concerns age-related changes in human memory and the implications that these changes have for the acquisition and maintenance of various types of skilled performance. After surveying what is currently known and understood about the differences in memory abilities at various ages, we focus primarily on the contrast between consciously controlled and automatic processes. The basic idea is that behavior reflects a combination of automatic influences and consciously controlled processes. In general, it seems that age differences are smallest when processes are driven automatically by the stimulus or supported by the environment, that is, in cases in which the stimulus is strongly linked to the appropriate response, either by "wired in" functions or because the response is habitual. Age differences are greatest, on the other hand, when processes must be self-initiated in a consciously controlled manner and when a different attentional set from that induced by habit, or by a specific environment, must be established. This account is somewhat similar to the proposal made by Hasher and Zacks (1979), that age differences are greatest with effortful processing and least with automatic processing. Also, it has similarities to Rabbitt's (1979, 1982) suggestion that data driven processes hold up well with age, whereas memory (or conceptually) driven processes are impaired.

We argue that to understand memory and learning fully, it is necessary to separate the contributions of automatic and controlled processes. This may be especially true for age-related differences, in which case there is reason to believe that consciously controlled processing becomes less effective with increasing age, necessitating a greater dependence on habitual modes of responding. We outline a method—the *process dissociation procedure* (Jacoby, 1991)—that was developed for the purposes of decomposing task performance into automatic and controlled components and showing how the method can be applied to problems of aging. In this chapter we use the terms *automatic influence* and *habit* somewhat interchangeably. In our view, a single experienced event can influence later behavior in an automatic and unconscious way. If a set of similar events or similar situations gives rise to the same response over time, then the response may become habitual, that is, typically given and somewhat stereotyped, yet specific to that set of stimuli, tasks, or contexts.

AGING AND MEMORY

There is general agreement that memory abilities do decline with the advancing years but also that the age-related differences are much greater in some tasks than in others. One major factor appears to be whether the task can be classified as implicit or explicit—that is, whether subjects simply demonstrate the effects of past experience in their present behavior or whether they are explicitly asked to recollect details of the original episode. In general, age differences are rather small in implicit tasks such as fragment completion, stem completion, and perceptual identification, but are typically much larger in explicit tasks such as recall and recognition (Light & LaVoie, 1993).

The implicit–explicit difference is not the only factor, however. Within implicit tasks, Light and LaVoie (1993) pointed out that associative priming tasks tend to show larger age differences than do item priming tasks. Item priming tasks appear to utilize mainly perceptual information, whereas associative priming tasks have a greater conceptual component (Craik, Moscovitch, & McDowd, 1994). In line with these findings, a study by Jelicic, Craik, and Moscovitch (in press) found no age differences in a perceptual implicit task (word fragment completion) and small but significant age differences in a conceptual implicit task (category generation). They also found large age differences in two explicit memory tasks, regardless of whether the task had substantial perceptual and conceptual components (stem-cued recall) or relied primarily on conceptual information (free recall). The data are shown in Table 6.1, and they suggest that older people may have some problems in encoding or utilizing conceptual information (Craik, 1983; Eysenck, 1974). That is, an age-related decrement

TABLE 6.1
Mean Proportions Correct (*M*) and Standard Deviations (*SD*) for Younger and Older Adults on Four Tests

	Younger Adults		*Older Adults*	
Task and Measure	*M*	*SD*	*M*	*SD*
Fragment completion				
Target	.47	.11	.39	.14
Baseline	.32	.12	.25	.11
Priming	.15	.09	.14	.08
Category generation				
Target	.39	.11	.32	.08
Baseline	.16	.06	.15	.13
Priming	.23	.11	.17	.11
Stem-cued recall				
Target	.47	.13	.29	.11
Baseline	.00		.00	
Free recall				
Target	.41	.11	.25	.13

Note: From "Effects of Aging on Different Explicit and Implicit Memory Tasks," by M. Jelicic, F. I. M. Craik, and M. Moscovitch, in press. Adapted by permission of the authors.

was found when conceptual processing was required, even when the task was an implicit one.

Within explicit memory tasks, the size of the age difference also varies, presumably again as a function of the underlying processes involved. One factor appears to be the extent to which the task requires effortful, self-initiated processing on the part of the participant, especially, perhaps, at retrieval (Craik, 1983, 1986). Thus, free recall requires more self-initiated processing than does recognition, and age-related differences are typically larger in the former task (Craik & McDowd, 1987).

In the original formulation of these ideas, it was suggested that less self-initiated processing is needed when more environmental support is present, that is, when the external context induces or supports the mental operations appropriate for successful completion of the task. In this sense, recognition tasks (in which the original stimuli are reprovided) involve more environmental support than recall tasks (in which the participant must generate the retrieval information in a self-initiated manner). If older people have more difficulty with self-initiated processing activities, because of their resource demanding and effortful nature, it follows that they should benefit especially from the provision of environmental support (Craik, 1983). Put another way, it may be that older people are more reliant on environmental support; they will perform relatively well when support is present and poorly when it is absent. Further, to the extent that older people require environmental support for processing operations that are carried out by younger people in the absence of such support, provision of support will improve performance in the old but not in the young (who can accomplish the processing in a self-initiated manner).

When the idea of environmental support is applied generally, it suggests that whenever encoding or retrieval conditions improve so that performance levels increase in younger participants, performance levels in older people should improve even more. That is, a pattern of compensation should be seen, with older people deriving more benefit from improved conditions. This pattern was observed in some early experiments reported by Craik and Byrd (1982); but in a later review article, Light (1991) pointed out that the great majority of studies showed that as encoding or retrieval conditions improved, older participants benefitted to the same extent as did their younger counterparts. Craik and Jennings (1992) agreed that many experiments showed equal benefit to young and old but cited cases in which compensation did occur and even cases in which young participants showed greater benefits. Craik and Jennings suggested that equal benefits may reflect situations in which the beneficial processing is achieved rather automatically (e.g., pictures rather than words, the generation effect); on the other hand, compensation occurs when the beneficial condition induces processing that is already carried out spontaneously by younger participants under the less effective encoding condition. Finally, greater benefits to younger participants may occur when processing possibilities are relatively open-ended—younger people carry out more self-initiated elaborate processing operations at encoding and/or retrieval.

This analysis is plausible but unsatisfactory as it stands. Any set of findings can be fitted post hoc to one or other of the theoretical patterns. If it is indeed the case that performance can be enhanced by self-initiated, consciously controlled processes, by automatic processes, or by some unknown mixture of the two, then it is clearly necessary to be able to measure the influence of the two types of processing separately. As described in a following section, this is precisely the purpose of the Process Dissociation Procedure, or PDP (Jacoby, 1991). Application of the PDP should yield a principled account of the circumstances under which various patterns of age-related encoding and retrieval benefits are observed.

NEGATIVE EFFECTS OF AUTOMATIC RESPONDING

After extended practice on real-life skills, many of the routine operations become automated and are thus no longer under conscious control. In general, this loss of control is beneficial, because it frees up working memory for other tasks. Occasionally, however, situations call for an override of habitual responding, with negative consequences if the automated responses are not inhibited. Everyday examples typically involve some unaccustomed deviation from a familiar routine, for example, the necessity to pick up a package from a store that is off our usual daily driving route to work; we are especially likely to forget to make the appropriate turn if our attention is on other matters. The tendency to be "absent-minded," and therefore vulnerable to such slips of action, appears to be greater when we are preoccupied with some problem; the tendency also appears to be greater in older people, at least anecdotally.

In the context of previous work distinguishing automatic and controlled processes in cognition (e.g., Posner & Snyder, 1975; Shiffrin & Schneider, 1977) Jacoby and his colleagues (Jacoby, 1991; Jacoby, Toth, & Yonelinas, 1993; Jennings & Jacoby, 1993) have proposed that there are two independent sources of influence on behavior—habit (automatic influence) and conscious control—of which the latter declines in effectiveness with increasing adult age whereas the former remains essentially constant. These ideas are similar to the framework proposed by Hasher and Zacks (1979) and later augmented by the same authors (Hasher & Zacks, 1988). They suggested that processing operations are either automatic or effortful and that only the latter decline in efficiency with increasing age. In the later paper, Hasher and Zacks proposed that inhibitory processes also decline with age, leading to heightened distractibility and to the continuation of off-track and irrelevant types of processing during memory encoding and retrieval. Jacoby's emphasis was on an age-related decline in conscious control rather than on a decline in inhibition. In turn, the decline in control leaves a relatively more dominant role for automatic and habitual responding. Importantly, the remedy is therefore not so much to inhibit habit as to enhance conscious control if we wish to restore cognitive functioning in older people.

In most cases, of course, we do follow familiar routines in our everyday activities, so automatic influences are perfectly adequate to provide general guidance for our actions, with conscious control serving to provide the fine tuning to deal with minor local perturbations. Similarly, conscious recollection of an intention or a command may often work in concert with preformed automatic influences, or automatic influences may be recruited to boost recollection, as when we put our keys and glasses in set locations or place a letter to be mailed by the door. In other cases automatic influences and conscious recollection work in opposition, with conscious control providing the appropriate guidance to behavior providing it is brought into play.

The notion of environmental support is relevant here in that we typically learn both automated routines and specific events in particular contexts; reinstatement of those environmental contexts is therefore likely to enhance automatic, habitual responding as well as recollection of some earlier event (Jacoby, 1994). In all of these cases, however, the environment supports recollection and induces automatic responding in unknown proportions. Craik's (1983, 1986) suggestions concerning environmental support were restricted to the beneficial effects of context on conscious recollection; he did not take into account the complicating factor of induced automatic influences, which may or may not support an appropriate response. Both conscious and unconscious influences must be considered for understanding age-related deficits, and also for relating these impairments to other patterns of performance such as those shown by patients with frontal lobe dysfunction. It has been suggested that these patients suffer from a reduction in consciously controlled processing and as a result are both dependent on environmental support to function effectively and, at the same time, are more at the mercy of inappropriate or maladaptive contextual stimulation (Lhermitte, 1983). These findings are relevant because of the evidence that supports the association between aging and the deterioration of frontal lobe functioning (Craik, Morris, Morris, & Loewen, 1990; Parkin & Walter, 1992) and that older people therefore function, in some respects at least, like patients with mild frontal lobe impairment (Stuss, Craik, Sayer, Franchi, & Alexander, in press).

Our main point is that many, if not all, cognitive operations in the realms of perception, attention, memory, and thinking can be characterized in terms of the balance between consciously controlled processes and unconscious, automatic influences. In many cases, these independent sources work together to influence the same outcome but their relative proportions are unknown. In other cases automatic processes and conscious control can be set in opposition to each other, leading to different responses. The PDP provides a technique by which the two sets of processing operations may be teased apart and quantified, thereby allowing their relative influence, and their changes with age, to be assessed.

THE ADVANTAGES OF OPPOSITION

Before turning to the PDP work we will describe some experiments in which automatic responses were set in opposition to processes of conscious recollection. As one example, Jacoby, Woloshyn, and Kelley (1989) explored the effect of recent presentation of a name on how famous the named person is judged to be in a later test. The idea is that recent presentation will increase the familiarity of the name in the subsequent fame judgment and that familiarity acts as an automatic cue to fame, even in the absence of any conscious recollection of who the person is or what he or she is famous for. In the fame paradigm, recollection and automatic influences are set in opposition by use of an exclusion test. People read a list of nonfamous names. Next, these old names are mixed with famous and new nonfamous names, and presented for fame judgments. Participants are correctly informed that all of the names they read in the first list are nonfamous, so if they recognize a name on the fame test as one from the first list they can be certain that the name is nonfamous. Thus conscious recollection of a name from the first list opposes any increase in familiarity the name might gain from being read in that list. A "false fame" effect for old nonfamous names will result if recollection fails and leaves automatic influences in the form of familiarity unopposed.

Using this paradigm, Dywan and Jacoby (1990) tested groups of young and elderly participants and obtained the results shown in Table 6.2. The fame judgment test contained names of genuinely famous people (e.g., Christopher Wren), mixed with made-up (nonfamous) names that had either been presented in the study list (old nonfamous) or were presented for the first time (new nonfamous). Table 6.2 shows that the elderly participants correctly identified more famous names than did the young—the elderly people were better informed. The

TABLE 6.2
Proportions of Names Classified as Famous by Young and Elderly Subjects in a Fame Judgment Test

	Young Adults		Elderly Adults	
Type of Name	*M*	*SD*	*M*	*SD*
Famous	.54	.16	.70	.14
New nonfamous	.25	.22	.14	.15
Old nonfamous	.14	.14	.20	.17

Note: From "Effects of Aging on Source Monitoring: Differences in Susceptibility to False Fame," by J. Dywan and L. L. Jacoby, 1990, *Psychology and Aging*, 5, p. 383. Adapted by permission.

results of interest emerge from the contrast between old and new nonfamous names. The young participants incorrectly classified 0.25 of new nonfamous names as "famous," but classified fewer old nonfamous names as "famous" (0.14); the implication is that these people remembered some of the old nonfamous names from the study list, and were therefore able to conclude that they were not famous names. The corresponding proportions of new and old nonfamous names incorrectly classified as "famous" by the elderly participants were .14 and .20, respectively, showing that for elderly people, prior presentation boosted the familiarity of old nonfamous names and that this enhanced familiarity was attributed to "fame" because it was largely unopposed by recollection that the names had been presented previously. We may therefore conclude that older people are less able to remember, or "monitor," the source of previously presented information (Hashtroudi, Johnson, & Chrosniak, 1989; McIntyre & Craik, 1987) and that they are thus more likely to make action slips in cases in which information comes to mind "automatically" and is poorly opposed by consciously controlled processes that would otherwise flag the action as inappropriate. It may be noted in passing that the fame judgment case (like the cases reported by Hashtroudi et al., 1989, and by McIntyre & Craik, 1987) is one in which older participants are less able than their younger counterparts to recollect details of the original episodic context; this age-related failure is contrasted in a later section with cases in which older people show a greater vulnerability to the misleading effects of prior context.

As a further illustration of the opposition logic, Jacoby and his colleagues conducted a study in which young people first studied a visually presented list in which words were presented either once, twice, or three times. They were then given a list of auditorily presented words, again with instructions to remember the words for a later test. Finally, they were given a recognition test list which contained words from both List 1 (visual) and List 2 (auditory) with instructions to respond "yes" only to List 2 words. The question of interest was whether participants would erroneously repond "old" to List 1 words and whether that tendency is affected by whether the List 1 word was presented once, twice, or three times. One final factor in the experiment was the imposition of a response deadline; participants had to decide whether a word was from the new or old list within either 700 msec or 1200 msec. The results showed that, with the shorter deadline, the probability of responding "old" to a List 1 word increased from 1 to 3 visual presentations, whereas with the longer deadline that probability decreased from 1 to 3 visual presentations. Jacoby accounts for this striking result by suggesting that within 700

msec, subjects can utilize only automatic information, that more visual presentations increase the accessibility of automatic information, thereby making the word appear very familiar and so leading to an "old" response. In contrast, at 1200 msec conscious recollection is available, and now further visual presentations increase the probability that the person will recognize that the word was on the visual list, thereby decreasing the likelihood that he or she will classify it as an auditory word.

So far this experiment has been carried out with young participants only, but some predictions may be made if it is repeated either with age or with divided attention as the crucial variable instead of response deadline. That is, whereas younger participants would continue to show a decrease in the number of false alarms as a function of visual repetitions, older participants should show an increase, indicating again that their less effective control processes fail to hold the automatic influences in check. Similarly, if the recognition test was conducted under divided attention conditions, false alarms should again increase with repetitions, showing that, with limited processing resources, the automatically available information was dominant.

PROCESS DISSOCIATION

The PDP measures cognitive control by contrasting results from a condition in which automatic and consciously controlled processes act in opposition with results from a condition in which the two types of process act in concert. In a situation in which the participant can exert no conscious control, these conditions will obviously yield the same levels of performance; by the same token, performance levels will differ between the conditions by an amount that reflects the degree of cognitive control. Jacoby et al. (1993) provided one illustration of how the method may be used in a memory context. In their experiment, words were presented for study and then tested by presentation of their first letters as a cue for recall (e.g., motel; mot _ _). The nature of the test was also varied; for an "inclusion" test, the word stem was accompanied by the message "old," and participants were instructed to use the stem as a cue for recall of a previously presented word or, if they could not do so, to complete the stem with the first word that came to mind. An inclusion test thus corresponds to a standard test of cued recall with instructions to guess when recollection fails. For an "exclusion" test, a word stem was accompanied by the message "new" and participants were instructed to complete the stem if possible but that they should not use a previously presented word as a completion for the stem. That is, participants were told to exclude old words and complete stems only with new words. Completing a stem with an old word for an exclusion test would correspond to an action slip. The two types of test were randomly intermixed.

For an inclusion test, participants could complete a stem with an old (previously presented) word either because they consciously recollected the old word, with a probability R, or because, even though recollection failed (1 − R), the old word came automatically to mind (A) as a completion; that is:

$$\text{Inclusion} = R + A(1 - R)$$

For an exclusion test, in contrast, a stem would be completed with an old word (contrary to instructions) only if recollection failed and the word came automatically to mind; that is:

$$\text{Exclusion} = A(1 - R)$$

Thus, the difference between the inclusion test (trying to use old words) and exclusion test (trying not to use old words) provides a measure of the probability of recollection. Given that estimate, the probability of an old word automatically coming to mind as a completion can be computed. One way of doing this is to divide the probability of responding with an old word in an exclusion test by (1 − R); that is:

$$R = \text{Inclusion} - \text{Exclusion}$$

$$A = \text{Exclusion} \div (1 - R)$$

An experiment conducted in Jacoby's lab extended these procedures to examine age-related differences in memory performance. When an inclusion or exclusion test immediately followed presentation of its completion word (0 spacing), performance of the elderly and of the young was close to ceiling. This finding is important in that it shows that the elderly were able to understand and follow instructions. In contrast, when a large number of items intervened between the presentation of a word and its inclusion or exclusion test (48 spacing), the elderly performed much more poorly than did the young. The data are shown in Table 6.3.

For the exclusion test, older participants were more likely to mistakenly complete a stem with an old word than were younger participants. Doing so amounts to an action slip, because for the exclusion test,

TABLE 6.3
Inclusion Scores, Exclusion Scores, and Estimates of Conscious Recollection (R) and Automatic Influences (A) for Younger and Older Adults

Measure	*Young Adults*	*Older Adults*
Inclusion	.70	.55
Exclusion	.26	.39
Recollection (R)	.44	.16
Automatic (A)	.46	.46

Note: From "Measuring Recollection: Strategic vs. Automatic Influences of Associative Context," by L. L. Jacoby, in C. Umilta and M. Moscovitch (Eds.), *Attention and Performance XV*, p. 670. Adapted by permission.

effects of automatic influences of memory for earlier reading a word should be opposed by recollection—a consciously controlled use of memory. The poorer performance of the older adults on the exclusion test can be explained as resulting from a deficit in recollection, as can their poorer performance on the inclusion test. Placing recollection and automatic influences in opposition, as was done by the exclusion test, can provide evidence of the existence of the two types of processes (Jacoby et al., 1993). However, it is necessary to combine results from the exclusion and inclusion tests to estimate the separate contributions of consciously controlled and automatic processes.

The estimates shown in Table 6.3 provide evidence that the older adults experienced a deficit in recollection as compared to younger participants but that automatic influences of memory were unchanged. The estimates of automatic influences were well above the baseline probability (.33) of completing a stem with a target word when that word had not been presented earlier. The difference between estimated automatic influences and baseline performance serves as a measure of automatic influences of memory —the effect of studying a word on the probability of the word later automatically coming to mind as a completion for a stem.

Results from this experiment showed age-related differences in memory to be very similar to effects produced by divided versus full attention to the study presentation of a word in an experiment by Jacoby et al. (Experiment 1b, 1993). That earlier experiment used the same materials but tested only young participants. Results showed that divided, as compared to full, attention during study reduced the probability of recollection (.00 vs. .25) but left automatic influences unchanged (.46 vs. .47). For the divided attention versus full attention experiment, study and test were in separate phases rather than intermixed, and, on average, the spacing between study of a word and its test was approximately 48 intervening items. The correspondence between age-related differences in memory and effects of full versus divided attention supports Craik's (1982) claim that dividing attention during study can mimic the effects of aging on memory.

To sum up this section, Jacoby (1991) suggested earlier that responses in memory retrieval tasks are driven by two distinct sets of processes: automatic processes, which give rise to feelings of familiarity, and controlled processes, which support conscious recollection of the original event, including details of the target item and its context. Typically these processes work together, but situations can be devised in which they are in opposition; the process-dissociation procedure utilizes the two types of situation to yield independent measures of automatic and controlled processes. We have focused on the applications of these ideas to memory, but they also apply to many other cognitive situations in which highly practiced habitual responses may or may not be in conflict with the appropriate response on one particular occasion. One well-researched example is the Stroop effect, in which easily read color names conflict with the discrepant names of the colors themselves; this effect has also been decomposed by means of the PDP technique into its constituent automatic and controlled aspects (Lindsay & Jacoby, 1994).

The PDP approach is not without its critics. For example, Curran and Hintzman (1995) argued that some items are both more familiar (reflecting automatic influences) and better recollected, and so the assumption of independence is violated. Their argument may be valid, but it also was shown that even if there is a high correlation at the item level, the bias in estimates of automatic influences is trivial (Jacoby, Begg, & Toth, in press). Another reservation is that a given task is likely to draw differentially on automatic and controlled processes at different times—for example, driving on an empty highway as opposed to driving on a busy city street. This point is also valid and provides an interesting topic for further research, although it should be remembered that the current laboratory versions of the PDP technique do measure aspects of performance on a given task at a given time and place.

With regard to aging, the results of the fame experiment (Dywan & Jacoby, 1990) and the results shown in Table 6.3 suggest strongly that the strength and effectiveness of habitual or automatic influences are unchanged across the lifespan, but that the effectiveness of conscious control declines with age, leaving habitual responding more dominant. The unchanging effectiveness of the automatic component with age is also supported by the absence of age-related effects on implicit memory tasks—at least of a perceptual variety (Table 6.1; Light & La Voie, 1993).

Why does conscious control (and associated processes such as recollection) decline with age? Presumably the answer lies in some set of changing biological processes—it is difficult to argue that the loss of control is adaptive in any sense. Hasher and Zacks (1988) proposed the influential idea that the effects of inhibitory control decrease with age and that this decrease results in a number of cognitive deficits. They suggested specifically that the capacity of working memory is apparently reduced in the elderly as a result of a failure to inhibit intrusive thoughts and to screen out irrelevant contextual stimulation. This is an appealing account in many ways; it ties in, for example, with the observation that older people have trouble "concentrating" and are more distractable (Hoyer, Rebok, & Sved, 1979; Park, Smith, Dudley, & Lafronza, 1989). However, rather than argue that working memory capacity is reduced as a secondary consequence of decreased inhibition, we prefer to argue that decreased effectiveness of executive control is the primary age-related dysfunction and that this reduction in control permits prepotent habitual responses to run off. Decreased executive control, which may be thought of as a reduction in the efficiency of the central executive component of working memory (Baddeley, 1986; Baddeley & Hitch, 1974), is very much a hallmark of the behavior of patients with prefrontal lesions (Lhermitte, 1983; Fuster, 1989; Shallice, 1988; Stuss & Benson, 1984). One possibility, therefore, is that normal aging is associated with a specific loss of efficiency of processes mediated by prefrontal structures and that the behavior of normal older people thus bears some resemblance to the behavior of patients with frontal dysfunction.

Roberts, Hager, and Heron (1994) have proposed an interactive model along these lines. In their version, the ability to inhibit a prepotent response (reflexive eye saccades, in their experiments) depends on the strength of the prepotency, the efficiency of the working memory system, and the working memory demands of a concurrent task. That is, if working memory is engaged with a demanding secondary task, as in conditions of divided attention, inappropriate prepotent responses will not be inhibited, and normal participants will behave somewhat like patients with prefrontal dysfunction. Clearly, this analysis is very much like the one argued for here and in previous publications (Jacoby, 1991; Jacoby et al., 1993). It is also in good agreement with the ideas that (a) working memory functions are less effective in older people (Baddeley, 1986; Craik, Morris, & Gick, 1990; Hasher & Zacks, 1988; Salthouse, 1990b); (b) the behavior of older people resembles that of patients with frontal disorders in some respects (Craik, Morris, Morris, & Loewen, 1990); (c) the division of attention in normal young adults makes them behave like older individuals (Craik, 1982); and (d) older people are particularly vulnerable to the disruptive effects of divided attention (Craik, 1977).

In summary, conscious control may decline in the elderly as a result of the less effective functioning of prefrontal structures (Albert & Kaplan, 1980; Craik, Morris, Morris, & Loewen, 1990; Whelihan & Lesher, 1985). In turn, this age-related loss of executive control will have the previously discussed consequences on memory, attention, and other cognitive functions. We now turn to the implications of this perspective for skilled performance in older people.

IMPLICATIONS FOR SKILLED PERFORMANCE IN THE ELDERLY

In this final section of the chapter we review the implications of the present set of ideas for the understanding of the acquisition, maintenance, and loss of skilled procedures in older people. Since the ideas are relatively novel, we concentrate on possible applications of the theoretical notions rather than on work already accomplished. In this way we hope that the chapter will serve a heuristic function with respect to new research. We also restrict our examples largely to the domain of cognition, rather than to that of perceptual–motor skill.

Context Reinstatement

Two sets of results that seem paradoxical at first sight can be explained very sensibly in light of the foregoing discussion. The first result is that older people have greater difficulty in remembering the source of acquired information (Hashtroudi et al., 1989; McIntyre & Craik, 1987), suggesting strongly that they are less able to recollect details of the episodic context. The second result is that older and impaired people's behavior sometimes appears to be more influenced by contextual reinstatement. For example, Nebes, Boller, and Holland (1986) asked patients with Alzheimer's disease (AD) and individuals in a control group to generate an appropriate last word for incomplete sentences that either were highly constrained (e.g., "Father carved the turkey with a ____ ") or had few semantic constraints (e.g., "They went to see the famous ____ "). With minimal guidance from the context the AD patients showed typical word finding difficulties and performed less well than the controls. With the highly constrained sentences, however, the patients performed fairly normally, both in terms of appropriateness of the ending and speed of response. The apparent

conflict between impaired memory for contextual detail on the one hand and greater reliance on contextual reinstatement on the other hand is resolved by the point that the first case represents an age-related decrease in controlled recollection, whereas the second case represents the continued effectiveness of the automatic influences of contextual reinstatement. These automatic influences may even appear to be greater for the older person if they are relatively unopposed by appropriate controlled processes. Thus, older skilled performers may be more reliant than their younger counterparts on the reinstatement of compatible contexts (between acquisition and utilization of the skill) but also more vulnerable to the disruptive effects of incompatible context reinstatement.

As discussed earlier, action slips can be described as the expression of automatic or habitual responses that emerge in the absence of conscious control. It seems likely that such slips are associated with particular contexts; they do not occur randomly but in response to certain environmental triggers. In the case of an elderly person's "telling the same story twice" (Koriat, Ben-Zur, & Sheffer, 1988), it is probable that specific individuals act as retrieval cues to increase the probability that a particular story will come to mind. Thus, an important question concerns the role of context in "activating" habits. Devising better methods for measuring the separate effects of recollection and habit is important for improving both the diagnosis and the management of such deficits. Knowledge of conditions that allow the establishment and maintenance of habits can be used to design special environments in which older people can better function.

A central question here concerns the qualitative type of contextual or environmental change that is most effective in activating specific automatic response tendencies. It is well established that implicit memory tasks such as perceptual identification, word fragment, and word stem completion are heavily dependent on the reinstatement of perceptual features for their successful performance. Is this reliance on perceptual reinstatement generally true of all habitual responses? That seems quite unlikely. Examples of conceptual factors interacting with habitual responses include being set to interpret written and spoken words in one of several languages that a person speaks, failing to see how objects can be used to solve a problem when they occur in a different functional context ("functional fixedness"), and the effectiveness of conceptually similar solutions in helping people solve analogical reasoning problems (Gick & Holyoak, 1980, 1983).

The problem for future work is therefore to determine which types of contextual reinstatement are maximally effective for various types of habitual response. The starting point for such research should presumably be the notions of encoding specificity (Tulving & Thomson, 1973) or transfer-appropriate processing (Morris, Bransford, & Franks, 1977; Roediger, Weldon, & Challis, 1989), which state in essence that the most effective retrieval cue for a learned item is some integral part of the item's functional encoding. In turn, this approach points to the need for a satisfactory analysis and classification of automatic responses, and their integration with environmental contexts.

Learning Automatic Responses

If we accept the idea that older people have less effective controlled processes, and that their performance is therefore dominated (relatively) by prepotent automatic responses, it becomes of immediate interest to ask about the acquisition, maintenance, and vulnerability to interference of these automatic responses. In particular, how easy is it for people of different ages to acquire new automatic responses, and how do such newly acquired habits differ from deeply ingrained habits of long standing?

New behavioral sets are quite easy to establish; the Wisconsin Card Sorting Test (WCST) is an obvious case in point. In this test, subjects discover a rule by which cards must be sorted, and then the rule is changed without the subject being informed. Normal controls discover the new rule and abandon the old one fairly quickly, but patients with frontal lesions perseverate with the now-inappropriate old rule for some time. Normal older people also show some tendency to persevere unadaptively with the original rule (Craik, Morris, Morris, & Loewen, 1990; Whelihan & Lesher, 1985). The question for research is therefore how rapidly older people can acquire new automatic responses, and how amenable these newly acquired habits are to change when change is indicated.

One paradigm that may prove useful here is one introduced by Jacoby and Hay (1993). In the first (training) phase of their experiments, word fragments were presented with a cue word (e.g., knee b _ n _), and participants were to predict which of two words would be used to complete the fragment. After they had made their prediction, participants were shown the "correct" completion. Probabilities were varied such that one completion (knee bone) was presented on 75% of the trials and another completion (knee bend) was presented on the remaining 25% of the trials. The training phase was designed to establish associations of varying strengths between the cue words and completions, much as would result from a behavior being performed a varying proportion of times in a particular context. Associations established in this first phase could either facilitate or interfere with

performance on a task required in the second phase of the experiment. In Phase 2, short lists of pairs to be remembered were followed by the presentation of cues and fragments. Participants were to complete fragments with words presented in the immediately preceding list. For some pairs, the completion presented in that list was the more common completion from Phase 1; thus, the effects of automatic responding were congruent with recollection and would facilitate performance. For other pairs, the less common completion from Phase 1 was presented so as to make automatic responding incongruent with recollection, thus producing interference. The incongruent pairs correspond to the action slip case—automatic influences would induce errors.

For the equations used to estimate recollection and automatic influences, performance on congruent pairs was treated as performance in an inclusion condition, and performance on incongruent pairs was treated as performance in an exclusion condition. Computing estimates in that way, Jacoby and Hay found that their estimates of automatic influences showed probability matching (e.g., Estes, 1976). That is, the estimated probability of giving a completion in Phase 2 due to automatic influences was very close to the objective probability of that completion in Phase 1. Effects on recollection and automatic influences were dissociated. Manipulating the objective probability of a completion in Phase 1 had an effect on estimates of automatic influences that produced probability matching across a range of probabilities, but had no effect on estimates of recollection. In contrast, requiring fast responding in Phase 2 reduced the probability of recollection but left estimated automatic influences invariant. A further experiment comparing the performance of young and elderly people showed a deficit in recollection for the elderly but no age-related difference in estimated automatic influences of memory. These dissociations are the same as those found with the inclusion–exclusion procedure, and provide converging evidence to support assumptions underlying the two ways of implementing the PDP.

The result with older participants suggests that older people acquire new automatic responses as readily as do their younger counterparts. This is a surprising result, although it is in accord with work by Howard and Howard (1992) showing that the learning of serial patterns is age invariant. Not all researchers have found age invariance in the development of new automatic procedures, however (Dulaney & Rogers, 1994; Fisk & Rogers, 1991; Rogers & Fisk, 1991), so an important further question concerns the characteristics of new automatic procedures that are either age invariant in their learning phase, or show age-associated differences. A related question for research is whether particular learning methods are particularly effective for older learners of new implicit knowledge; two candidates here are active versus passive learning procedures (cf. Reber, 1989) and techniques involving errorless learning (Baddeley & Wilson, 1994).

AUTOMATICITY, CONTROL, AND COGNITIVE FLEXIBILITY

Given that measures of recollection (R) and automatic influences (A) can be calculated for particular participants performing specific tasks, to what extent would we expect these measures to correlate across tasks for the same people, and across individuals for the same tasks? Put another way, are R and A characteristics of individuals, of tasks, or of their interactions? When we think of skilled tasks in everyday life—driving a car, playing a sport, riding a bicycle, speaking a second language—it becomes clear that the automated portions of these skills are very unlikely to share common elements. Rather, the automatic aspects are likely to be task specific (Jacoby et al., 1993; Ste. Marie & Jacoby, 1993). On the other hand, the consciously controlled R component of performance is likely to show more generality across tasks for the same individual. This is one of the main points made in this chapter—that younger and older adults differ in the amount of conscious control that they can exert. Even here, however, there is likely to be some degree of specificity in the R measure; that is, through natural aptitude and practice, tasks will vary in the amount of control that a particular person can bring to bear.

Some evidence on these questions can be gleaned from correlation studies. For example, Jennings and Hay (in an unpublished study) obtained preliminary evidence that memory complaints as measured by a cognitive failures questionnaire are correlated with contributions of R but not A to performance on laboratory tests of memory. Another source of evidence is the degree of correlation among tasks measuring working memory. If working memory (WM) is one fixed set of mechanisms or processes, as implied by the Baddeley and Hitch model (Baddeley, 1986; Baddeley & Hitch, 1974) then WM tasks should intercorrelate quite highly. Typically, this was not found, however (Daneman & Tardif, 1987; Roberts et al., 1994), suggesting at least some degree of task specificity in R or central executive control. This lack of correlation suggests that the concept of working memory might be better reformulated as an umbrella term for the computational aspects of a whole variety of types of knowledge and skilled procedures. Whereas there may well be some individual difference that dictates in general terms how well or how poorly an individual can

manipulate knowledge in a controlled manner (with some resemblance to Spearman's g perhaps), it is also likely that other aspects of R reflect specific person/task interactions. Further interesting research questions emerge from this analysis when it is applied to cognitive aging; are there age differences in the acquisition of control? Do such differences depend on the task, and on the individual's knowledge of similar tasks? How does maintenance of a previously learned skill (such as driving, word processing, or speaking a second language) interact with age, and with the R and A components of performance? Answers to at least some of these questions can probably be gleaned from the existing literature on skill and aging (see, e.g., Charness, 1985; Salthouse, 1990a).

A further question concerns the retraining of older workers and learners, and the extent to which cognitive flexibility can be built in to a training procedure. As discussed previously, new behavioral sets can be established fairly readily, even in an experimental setting. One example is the WCST in which patients with frontal lobe dysfunction discover the principle underlying the correct classification of multidimensional stimuli but then have great difficulty in abandoning that principle when it becomes irrelevant to a new rule that the tester has imposed. To the extent that normal older people behave like young patients with frontal disorders (Craik, Morris, Morris, & Loewen, 1990; Parkin & Walter, 1992), older learners should also have difficulty in switching to take changed conditions into account.

The WCST is one in which a newly aquired habit may continue to influence behavior if unopposed by conscious control processes. Patients with frontal lobe dysfunction, for example, apparently do not realize that their responses are now inappropriate, or, at least, they fail to initiate new responses. Two questions for research then, are first whether there are age differences in the development of awareness that current response patterns are inadequate, and second, whether age groups differ in the ability to inhibit inappropriate automatic responses and to establish a new set of appropriate responses. One of the most interesting findings from work on patients with frontal lobe disorders is that they show a deficit in controlled responding despite awareness of the information that would allow such control to operate. For example, on the WCST, these patients can often state the principles underlying the task, thus showing awareness, yet fail to utilize these principles in their actual performance—an example of the so-called *dysexecutive syndrome* (Stuss & Benson, 1984). Experiments should also check for the presence of this dissociation between awareness and performance in older people.

A final—and crucial—topic concerns age-related differences in cognitive control. To what extent do older people retain conscious control of highly practiced tasks? How flexible is cognitive control in the elderly, and how easy or difficult is it to train or retrain recollection and other forms of controlled processing?

We plan to examine these questions in a series of laboratory experiments. One specific question concerns age differences in the time taken to form a cognitive set. Previous work has suggested that older people are impaired in their ability to use prior information to set themselves for an upcoming stimulus (Byrd, 1981). A related question concerns the ease or difficulty with which people of different ages can override an existing set. The phenomenon of functional fixedness provides a paradigm case here. The uses of certain objects become fixed by experience, and participants in problem-solving situations have difficulty seeing alternative unusual uses for these objects. It seems likely that functional fixedness effects are greater in older people; can people be trained to think laterally in order to overcome such preexisting sets?

Once an appropriate set is established—a temporary goal or intention for example—how easily is it maintained by people of different ages? Older people complain that they are easily distracted and so, for example, tend to forget why they went into a particular room. The question of set maintenance, then, is similar to the maintenance of information in short term or working memory, which is a well researched topic in cognitive aging (Craik, 1977; Salthouse, 1990b). One difference is that we are now talking about maintaining an intention, as compared with a string of words or digits, and, to that extent, the topic also bears some resemblance to questions of prospective memory, for which age-related differences are also found (Cockburn & Smith, 1991; Dobbs & Rule, 1987).

On the question of training recollection in the elderly, Jennings and Jacoby (in an unpublished study) have obtained encouraging preliminary results using a technique in which participants learn a list of words (List 1) and are then given a second list made up of List 1 words plus new words, and a repetition of each new word at lags of 0, 3, or 12 intervening items. Participants are told that the second list is a recognition test, in which they say "yes" to List 1 words but "no" to new (List 2) words, both on a new word's first and second presentation. The second presentation of a new item is crucial, because its earlier presentation will increase its familiarity, thus increasing the likelihood that it will mistakenly be called a List 1 word. However, if participants recollect the first presentation of a List 2 word, they will correctly reject it; this recollection and rejection is very easy at a lag of 0, but gets increasingly difficult as the lag increases between the first and second

presentation of the List 2 word. In an initial study, Jennings and Jacoby found that older adults performed significantly worse than the younger adults when as few as 3 items intervened between first and second presentations—reflecting a time interval of less than 10 seconds! However, after extensive training involving positive feedback for correct responding and a gradual increase in the lag intervals, older people were able to perform at the level of young people with a lag of 28 intervening items. This result suggests that recollection (and perhaps other aspects of controlled processing) can be trained using this method of gradual shaping.

CONCLUSIONS

In summary, the present analysis of age differences in memory and related cognitive processes has some similarities and some dissimilarities to previous approaches. We agree with Hasher and Zacks (1979) that age differences are least with automatic processing and greatest with controlled processing. The present analysis is also in agreement with Craik's (1983, 1986) point that self-initiated processing is more difficult for the elderly. However, the present approach differs somewhat from the view expressed by Hasher and Zacks (1988) that an age-related loss in the efficiency of inhibitory processes underlies many cognitive deficits; we argue rather that an age-related reduction in the effectiveness of controlled processing is primary, resulting in a relative dominance of prepotent automatic responses. Crucially, the present set of suggestions relies on Jacoby's (1991) procedure for separating automatic influences from conscious control, and this separation opens up new perspectives on such issues as the effects of contextual support, learning and maintenance of new habitual responses, and the learning and maintenance of controlled procedures such as recollection and executive intentions.

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