Adult Age Differences in Visual Mental Imagery: Evidence for Differentially Age-Sensitive Components

by

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Abstract

A set of tasks developed in accordance with Kosslyn, Van Kleeck, & Kirby's (1990b) neurologically plausible model of visual mental imagery was used to explore effects of aging on specific component processes involved in image generation and maintenance. Contrary to the widely held belief that age differences in cognition are attributable to a single mechanism of global effect (e.g., a reduction in critical processing resources, Salthouse, 1988), results indicate that processes involved in visual mental imagery are differentially age-sensitive. More precisely, components required to actively maintain images are particularly sensitive to effects of aging, while those that access visual information from memory are not especially affected. Advantages of a componential approach to understanding age differences in cognitive processing are disscussed, as well as the potential for such age-related changes to be a readily exploitable source of information regarding the functional architecture of cognition.

Age Differences in Visual Mental Imagery

Research into effects of aging on visual mental imagery has focused primarily on the ability to "mentally rotate" disoriented objects (for a comprehensive review of such tasks see Shepard & Cooper, 1982). In general, results from these studies are consistent with age differences found on virtually all speeded cognitive tasks: That is, older adults perform more slowly than do their younger counterparts (Salthouse, 1985). In addition to this generalized, or task-independent, slowing, there is reason to believe that specific imagery processes differ in their sensitivity to effects of aging. An unpublished task analysis of the six most recent chronometric studies of aging and mental rotation (Berg, Hertzog & Hunt, 1982; Cerella, Poon & Fozard, 1981; Gaylord & Marsh, 1975; Jacewicz & Hartley, 1979; Puglisi & Morrell, 1986; Sharps & Gollin, 1987) suggested that observed age-related slowing may be primarily attributable to specific deficits in shifting visual attention. Furthermore, in the one mental rotation task reviewed where attentional demands were minimized (by presenting to-be-compared stimuli sequentially rather than simultaneously), older adults performed as quickly and accurately as the young adult group (Jacewicz & Hartley, 1979). Similarly, Dirkx and Craik (1989) found that older adults were impaired on certain tasks of mental image rotation (East-West Test) and image generation (Clock Test), yet demonstrated normal levels of performance on another version of the mental rotation task (Brook's Letter Test). Finally, in their neuropsychological study of various imagery abilities, Farah and Hammond (1988) reported age differences in the ability of healthy, older control subjects to perform judgements based on self-generated images in some, but not all tasks.

In sum, previous research suggests that some aspects of imagery are particularly sensitive to effects of aging, while others are not uniquely affected. The equivocal nature of these findings is not easily reconciled with the prevailing wisdom that age differences in performance are attributable to a single mechanism of global effect (e.g., a decline in the availability of critical processing resources (reviewed in Salthouse, 1988), slowed rate of neural conduction (Birren, 1974), or undifferentiated information-loss arising from increased 'neural-noise' (Myerson, Hale, Wagstaff, Poon, & Smith, 1990). If this is so, performance of all imagery tasks should be similarly affected by aging. Variability in effects of aging across imagery tasks is to be expected, however, if: (a) performance of visual imagery tasks demands contributions from numerous, relatively independent processing components (e.g., Kosslyn, 1987; Kosslyn, et al., 1984; Kosslyn, et al., 1990b); and, (b) such components are differentially sensitive to effects of aging (e.g., Johnson, 1990, Johnson & Kosslyn,1991; Johnson & Rybash, 1991). The present studies undertook to investigate these possibilities within the context of two basic imagery abilities -- image generation and image maintenence.

A Componential Approach

Kosslyn and his colleagues (Kosslyn,1988; Kosslyn, et al., 1988; Kosslyn et al., 1990a) have developed a set of tasks based on Podgorny and Shepard's (1978) paradigm that provide a means of examining the efficiency of particular component processes involved in generation and maintenance of visual mental images.

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Because these tasks allow one to study particular components in isolation, they are ideal for evaluating hypotheses regarding mechanisms responsible for age differences in imagery behavior. According to Kosslyn et al. (1990b), image generation and image maintenence do not depend entirely on the same set of processing components. Therefore, if components involved in imagery differ in their sensitivity to effects of aging, then image generation and image maintenance processes need not be similarly affected. If age differences in imagery arise from a generalized deficit that does not respect boundaries between component processes, however, image generation and image maintenance processes should be similarly affected.

Isolating Components

Eighteen older adults (ages 63 - 81) and 18 younger adults (ages 18 - 30), of comparable educational and intellectual status, were tested on three tasks -- Image Generation, Perceptual Control, and Image Maintenance. Tasks each consisted of 48 experimental trials preceded by 12 practice trials and were administered in an order counterbalanced within each age group.

Image Generation Task. Subjects studied a black, two-dimensional block pattern within a 4 x 5 cell grid displayed against a white field on a standard Macintosh SE20 CRT (Figures depicting similar displays can be found in Kosslyn, 1988; Podgorny & Shepard, 1978). When the figure was committed to memory, subjects depressed the space bar. One-hundred ms. later, a homogenous black mask appeared for 500 ms.; followed immediately by a blank 4 x 5 cell grid with an "X" probe in one of the cells. Subjects were required to decide, as quickly and accurately as possible, whether the probe would have fallen on or off the block pattern, were it still present in the grid. Reaction times (RT) were measured from onset of the probe until subjects responded by depressing either the "yes" or "no" key.

According to Kosslyn et al's. (1990b) neurologically-plausible model of visual mental imagery, image generation requires two subsets of processes: one to access stored visual information from memory, and a second to activate a pattern based on this retrieved information within a temporally-limited visual buffer.

In an elegant series of experiments employing tasks similar to those presently discussed, Kosslyn, et al. (1988) demonstrated that images are generated sequentially - - one segment at a time (see also Kosslyn, 1988). Concomitantly, stimulus complexity can be manipulated to affect varying degrees of processing load precisely on those component processes involved in generating images, and effects of these demands can be observed to determine the efficiency of these processes. To this end, an equal number of trials consisting of either one, two or three segment stimuli were presented.

In addition to imagery, response latencies on this Image Generation task reflect non-imagery processes used to encode the probe and execute a motor response. Because demands on these non-imagery processes do not vary with complexity of the stimulus, however, comparison of performance between trials with one, two, and three segment stimuli should reveal only rates of imagery processes (Kosslyn, et al., 1990a).

Perceptual Control Task. Differences in RT for stimuli of different complexity, however, reflect not only time to generate the image, but also time to search the image for probe location (Kosslyn, 1988; Kosslyn et al., 1988; Kosslyn et al., 1990a), and it is possible that rates of image search may covary with stimulus complexity. A Perceptual Control task was therefore included to control for rate of image search. This task was identical to the Image Generation task, except that both the probe and the stimulus pattern were visible simultaneously so as to obviate the need to generate an image: The subject merely had to determine whether the probe was on or off the pattern as quickly and accurately as possible while both were fully visible.

Given the preceding logic, effects of stimulus complexity on Image Generation and Perceptual Control tasks can then be compared, and any differences should reflect contributions of processes specific to image generation, apart from contributions of those involved in either non-imagery or image search processes. Likewise, age differences in efficiency of image generation components can be examined by comparing differences in effects of stimulus complexity on Image Generation and Perceptual Control tasks between younger and older adults.

Image Maintenance Task. Finally, an Image Maintenance task was used to evaluate age differences in the ability to actively maintain visual mental images for varying amounts of time. Procedurally speaking, the Image Maintenence task was identical to the Image Generation task except that: (a) no mask was used to disrupt subjects' maintenance of stimulus patterns over the delay, or interstimulus interval (ISI) interval; and, (b) probes on half on the trials were presented 500 ms. after the stimulus frame (the same ISI used in the Image Generation task), while the ISI on remaining trials was lengthened to 3000 ms.

According to Kosslyn et al. (1990b), image maintenence requires a subset of processes used to generate visual images from memory -- those that activate (or re-activate) patterns within a temporally-limited visual buffer. Since no mask was used during the ISI, it was reasoned that an image of the stimulus pattern would be actively maintained and, consequently, components used to access stored visual information would not be required. Manipulation of stimulus complexity and ISI should, therefore, place additional processing demands precisely on image maintenance components (Kosslyn et al., 1990a).

Results and Discussion

Image Generation. As intended, there was a significant two-way interaction between task (Image Generation vs. Perceptual Control) and stimulus complexity(one, two, or three segments) for both RT [F(2,64) = 21, p = .0001] and accuracy [F(2,64) = 4.8, p = .01] performance. This finding reflects the fact that as stimulus complexity increased performance on the Image Generation task decreased, while performance on the Perceptual Control task was unaffected (see Figure One). Manipulation of stimulus complexity was,therefore, successful in affecting additional processing demands precisely on those components involved in image generation apart from either perceptual-motor or image search processes.

There was also evidence for substantial age differences in performance: Older adults were slower than younger adults on both the Perceptual Control and Image Generation tasks, F(1,32) = 40.81, p<.0001). Older adults also committed significantly more errors than younger adults [(F(1, 32) = 9.52, p = .004], indicating that the main effect of age on RT was not attributable to speed/accuracy tradeoff (see Figure One).

Consonant with the observation that age differences tend to be more pronounced on tasks of greater difficulty (e.g., Cerella, Poon, & Williams, 1980), age differences were of greater magnitude on the Image Generation than the Perceptual Control task [F(1,32) = 7.46, p = .01]. Likewise, older adults were less accurate on the Image Generation than the Perceptual Control task [(F(1,32) = 6.31, p = .017)], again providing assurance that age differences in RT were not attributable to speed/accuracy tradeoff (see Figure One).

Contrary to what is expected if components involved in image generation are particularly sensitive to effects of aging, variations in stimulus complexity failed to exacerbate age differences in RT performance, F(2,64) = 2.0, p = .14. Age differences in accuracy did, however, show a tendency to increase with stimulus complexity, F(2,64) = 3.18, p = .05 (see Figure One). This raises the possibility that older adults may have sacrificed accuracy for speed. Since error rates were quite low (< 6% in all cells), it seems unlikely that speed-accuracy tradeoff alone was responsible for this finding.

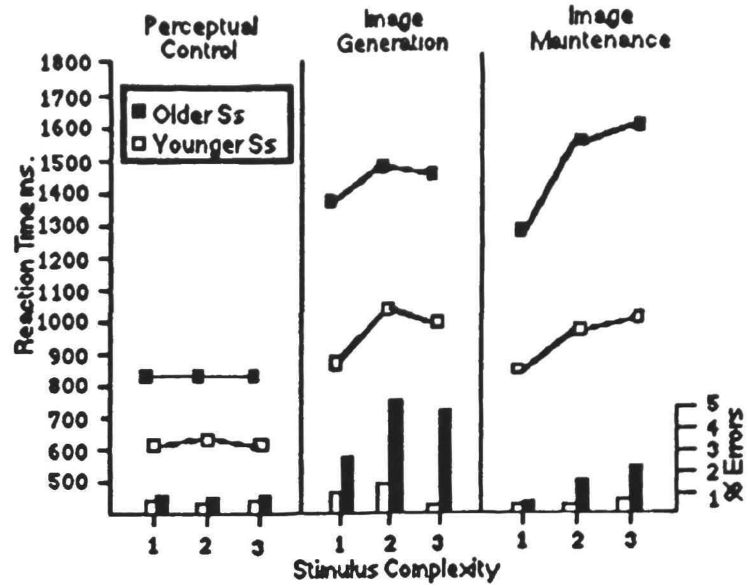

Figure One depicts effects of stimulus complexity on RT and accuracy performance of younger and older adults on the Perceptual Control, Image Generation, and Image Maintenance Tasks.

Image Maintenance. As expected, older subjects were also significantly slower [F(1,32) = 29.02, p = .0001)] and less accurate [F(1,32) = 8.69, p = .006)] than younger adults on the Image Maintenance task. In contrast to image generation, however, there was evidence that components involved in image maintenance are particularly age-sensitive. More precisely, age differences in RT [F(2,64) = 3.2, p = .047] and accuracy [F(2,64) = 5.48, p = .006] performance increased as a function of stimulus complexity (see Figure One). Age differences in RT or accuracy were not, however, affected by a six-fold increase in the interval over which images were maintained for RT or accuracy performance [F < 1 in both cases].

General Summary

Support was garnered for the hypothesis that aging has differential effects on specific components involved in visual mental imagery: More precisely, processes required to activate stored visual information during image generation are not particularly sensitive to effects of aging, while those needed to actively maintain patterns of visual information are uniquely affected.

The finding that imagery components are differentially age-sensitive is difficult to reconcile with the contemporary wisdom that attributes age differences to a single mechanism of global effect (e.g., Birren, 1974; Myerson et al., 1990; Salthouse, 1985).

These results instead suggest that age differences in information-processing may, in part, be attributable to highly selective mechanisms. Failure of previous attempts to identify such mechanisms may be due to employment of methodologies limited to examining cognitive performance at the relatively gross level of processing stages, rather than at the level of specific processing components of which such stages consist (for a comprehensive review of this issue see Johnson & Rybash, 1991).

The fact that age differences obtain for image maintenance but not image generation also provides additional support for the hypothesis that image generation and image maintenance do not recruit entirely the same set of processing components. That image maintenance processes are particularly age-sensitive, while image generation processes are not is, however, a somewhat curious finding. According to Kosslyn et al's. (1990b) model image generation requires one subset of processes to access visual information from memory and another to activate patterns based of this information in a temporally-limited visual buffer. In contrast, image maintenance requires only the latter subset. On one hand, processes that activate visual memories during image generation may somehow offset age differences in processes that activate patterns in the visual buffer, thereby minimizing age differences in performance on the Image Generation task. On the other hand, Image Generation and Image Maintenance may require entirely orthogonal sets of processing components, with only the latter set being particularly sensitive to effects of aging. Further experimentation will be required to discriminate between these alternatives.

To conclude, the present findings suggest that a componential approach may provide a better understanding of mechanisms responsible for age differences in behavior, and a potentially fertile avenue for exploring the functional architecture of cognition.

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