Effects of aging on perceptual closure

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Two research strategies were employed to investigate reasons for the poorer performance associated with increased age on perceptual closure tasks involving the integration and identification of incomplete pictures. One strategy consisted of examining age differences in measures designed to reflect the proficiency of processing components presumed to be involved in the closure task. The performance of older adults was significantly worse than that of young adults on each measure, suggesting that the age differences in the criterion task could not be localized in a single specific component. The second strategy involved determining whether young and old adults differed in the effects of practice or in the amount of specific and general transfer resulting from that practice. No age differences other than those in the overall level of performance were discovered, indicating that the age-associated problem may be independent of the processes contributing to the acquisition and transfer of new information. It was suggested that the age differences in perceptual closure tasks originate because of a general inefficiency in information processing due to a reduction in some type of general-purpose processing resource, and not because of a limitation in a single specific process.

Participants in perceptual closure tasks, when asked to identify pictures or drawings that have been degraded by removing various segments or elements, exhibit interesting patterns of individual differences for reasons still not understood. In particular, older adults have consistently been found to perform more poorly than young adults on a variety of perceptual closure measures (e.g., Basowitz & Korchin, 1957; Crook et al., 1958; Danziger & Salthouse, 1978; Dirken, 1972; Eisner, 1972; Glanzer, Glaser, & Richlin, 1958; Kinsbourne, 1974; Thomas & Charles, 1964; Verville & Cameron, 1946). There is even some reason to believe that measures of performance on tests of perceptual closure are among the behavioral measures with the greatest sensitivity to the effects of aging. To illustrate, Dirken (1972) reported that the correlation between age and closure score was larger than the correlations between age and a number of measures of

AMERICAN JOURNAL OF PSYCHOLOGY
Summer 1988, Vol. 101, No. 2, pp. 217–238

reaction time and memory. Furthermore, in two recent studies in our laboratory, we have found point-biserial correlations between age (ages 18 to 25 coded as 0, and ages 55 to 80 coded as 1) and score on a common test of perceptual closure, the Gestalt Completion Test (French, Ekstrom, & Price, 1963), of −.65 and −.68, compared with correlations with the Digit Symbol Substitution Test (Wechsler, 1958) of −.69 and −.62, respectively, in the same samples. These nearly identical values are particularly impressive because the digit symbol test is often considered to be one of the most age-sensitive measures available from psychometric tests (e.g., Botwinick, 1978; Salthouse, 1982, 1985a, 1985b).

The large effects of age on measures of perceptual closure are important because a reasonable strategy for attempting to investigate the cause of age-related differences in perceptual and cognitive functioning is to concentrate on abilities exhibiting the greatest sensitivity to the effects of age. Because those abilities can be presumed to reflect fundamental processes of aging, they might provide an important tool for understanding the psychological mechanisms affected by aging. Unfortunately, although the existence of a powerful effect of aging on perceptual closure measures is well documented, there is still little information available about the causes of these age-associated differences.

In light of the well-documented sensory changes across the adult years (e.g., see Corso, 1981; Fozard, Wolf, Bell, McFarland, & Podolosky, 1977; and Sekuler, Kline, & Dismukes, 1982, for reviews), it might be argued that peripheral processes are responsible for many of the age differences in perceptual closure. However, this seems unlikely because the stimuli are generally of high contrast and exposed for several seconds—conditions well beyond the threshold region for detection or discrimination even for older adults with mild visual impairments. Sekuler and Hutman (1980) did report that older adults had lower sensitivity than young adults to low spatial frequencies, and because closure seems to be based on the perception of low spatial-frequency information in that many of the higher frequencies are removed by the degradation process, it is conceivable that the age differences in closure performance are attributable to a loss of sensitivity to low spatial frequencies. However, the finding that age differences are most pronounced with low spatial frequencies has not proved reliable (e.g., Moscovitch, 1982), and subsequent research in the same laboratory (i.e., Sekuler & Owsley, 1982) reported exactly the opposite result—older adults were impaired more at high, rather than at low, spatial frequencies. Peripheral explanations cannot be completely ruled out, but there seems to be little evidence at present to indicate that age-related changes in sensory processes are important contributors to the age differences observed in perceptual closure performance.

One of the few analytical studies of the age differences in perceptual closure was reported by Danziger and Salthouse (1978). Three distinct hypotheses were examined across three experiments, but none received empirical support: (a) The possibility that the age differences were attributable to a greater reluctance on the part of the older adults to venture a potentially incorrect response was ruled out by the finding that the age differences still remained even when forced-choice response procedures were employed. (b) An unfamiliarity hypothesis was investigated by requiring subjects to match incomplete and complete figures, and by comparing the rank ordering of accuracy across stimulus figures in the young and older groups. Older adults still performed less accurately than young adults in the matching task, and both groups exhibited the same accuracy pattern across figures, thus suggesting that unfamiliarity with the stimuli was not responsible for the inferior performance of the older adults. (c) The third hypothesis was that older adults, relative to young adults, fail to distinguish between important and unimportant segments of the figure. This interpretation was rejected because the two age groups were very similar in their ratings of the informativeness of various picture segments, and the older adults were less accurate than young adults even when the information value of the segments was controlled. In the face of these negative results, Danziger and Salthouse (1978) suggested that the cause of the age differences was an age-related impairment in the efficiency of a "perceptual inference" process, but the precise nature of this process could not be specified.

The focus of the first study in the present project was to examine the effects of age on several hypothesized components in the closure task. An informal processing model that guided the design of the componential assessment consisted of the following steps. First, it is assumed that the impoverished input leads to the generation of a hypothesis about the identity of the object, sometimes supplemented by biases and preconceptions. After arriving at a hypothesis, it is expected that the individual will attempt to verify or falsify the hypothesis by deriving implications concerning the identity and location of expected components. For example, if the hypothesis is that the object is a dog, one would expect to find four legs in the bottom of the display, a tail at one end of the display, a head with ears, snout, etc., on the other end of the display, and so forth. Finally, the perceptual evidence might be evaluated to reach a decision to accept or reject the hypothesis under consideration.

This intuitive analysis of the processes involved in closure tasks is obviously only speculative at this time, but it has heuristic value for research on individual differences because the proposed components may be potential sources of variations in performance. For example, people could differ in accuracy of perceptual closure decisions because of differences in the effectiveness of deriving implications, of testing implications, of evaluating hypotheses, etc. Four tasks created to obtain measures assessing the effectiveness of several of these components were investigated in Experiment 1.

1. The task designed to appraise the *derive implications* component of the model required participants to locate regions of the stimulus display that would be helpful in identifying specific stimuli. That is, the participant was told to assume that the stimulus was X (some specific object) and to indicate the location in the display of the most informative region of that stimulus. This was postulated to be analogous to what the person actually does when attempting to verify a particular hypothesis. For example, if the participant's hypothesis is that the image is of a dog, then he or she is presumed to investigate whether it has expected features in the appropriate locations such as a head at one end of the display, a tail at the other end, legs at the bottom, etc.

Two separate measures were obtained in the task used to assess the derive implications component. One measure was based on the *absolute* location of the informative regions of the stimulus because no other information was available in the display, and the other was based on the location *relative* to a specified region of the display. It was assumed that the relative measure might reflect configurational knowledge (e.g., the position of the dog's tail *given* the position of the dog's head) not assessed in the absolute measure.

2. The task designed to measure effectiveness of the *test implications* component in the model consisted of the participant's attempting to determine whether a selected part was present in an adjacent display of an incomplete figure. For example, a stem and leaf might be displayed on the left panel, and an incomplete version of some stimulus displayed on the right panel. The participant was instructed to respond *yes* if the part was judged to have come from the complete picture from which the incomplete figure was derived, and to respond *no* otherwise. The parts in this task were intact (i.e., not degraded or incomplete), whereas the target stimuli were incomplete versions similar to those in the original criterion task. This was assumed to be analogous to the process of examining the incomplete figure to determine whether an expected part was in a specified location. The

presented parts were intended to correspond to the implications generated from a hypothesis, and thus accuracy of testing those implications could be estimated from the accuracy of making the *yes/no* judgments.

3. Effectiveness of the *evaluate hypothesis* component was assessed by presenting two discrete parts of a stimulus and asking the participant to identify the object from which they came. This task differed from the criterion incomplete figures test in that only two, intact, regions of the stimulus display were presented instead of the entire, but degraded, stimulus. The purpose of the task was to isolate the component concerned with integration and evaluation of discrete pieces of evidence about the stimulus. That is, the parts did not have to be abstracted from degraded images as in the criterion task, but instead the individual had to evaluate only whether those parts were consistent with a particular stimulus object.

4. A final *memory* task was designed to investigate the possibility that the individual had forgotten, or never had available, information about specific visual characteristics (e.g., size, orientation) of the stimuli. The most desirable method for determining the amount of visual detail about the stimulus available to the individual would be to administer tests with variations of orientation, size, detail, etc. However, a sensitive assessment of this type of information would have required too much additional time in an already lengthy experimental session. We therefore compromised by using a simple *old/new* recognition test for stimuli presented only once in the session. To the extent that an individual performed very poorly on the recognition test, performance on the closure tasks may have been impaired simply because the requisite information was no longer accessible.

It is sometimes suggested that the poor performance of older adults relative to young adults on a variety of perceptual and cognitive tasks may be due to an age-related difference in familiarity with activities of this type. If such an unfamiliarity interpretation applies to perceptual closure tasks, one might expect older adults to exhibit the same qualitative pattern, or profile, of differences from young adults as that distinguishing unpracticed from practiced individuals, although obviously in the opposite direction. This hypothesis was examined by giving a group of young adults considerable practice with a subset of the stimuli before they participated in the primary study. Only young adults received this additional practice because the total time required (a minimum of nearly 4 hr per participant) was considered unrealistic to request of the older volunteers.

EXPERIMENT 1

The initial study consisted of three groups of adults: a relatively large sample (n = 60) of young adults to provide standardization data, and samples of older adults (n = 20) and practiced young adults (n = 20). Because the participants receiving practice had additional experience with only one-half of the stimuli, it was possible to obtain separate estimates of specific transfer, involving the same stimuli experienced in practice, and general transfer, involving novel stimuli.

METHOD

Participants

Thirty young females and 30 young males (17 to 27 years of age, M = 18.6) served in the standardization sample; 8 young females and 12 young males (18 to 22 years of age, M = 18.3) served in the young practiced sample; and 10 older males and 10 older females (60 to 80 years of age, M = 71.3) served in the older sample. All participants reported themselves to be in good to excellent health, and arranged their own transportation to the laboratory. Education levels ranged from 12 to 16 years in the young samples (M = 12.4 for standardization, 12.2 for practiced), and from 8 to 20 years (M = 14.8) in the older sample. The mean scores on the Wechsler Adult Intelligence Scale Digit Symbol Substitution Test were 63.9 for the young standardization adults, 60.5 for the young practiced adults, and 37.1 for the older adults. Means on the Gestalt Completion Test (French, Ekstrom, & Price, 1963) were 16.6 for the young standardization adults, 17.2 for the young practiced adults, and 7.3 for the older adults. All of these results are consistent with earlier findings in the published literature, and thus suggest that the current samples are typical of those generally employed in previous studies of psychological aging.

Apparatus

All tasks were performed on an Apple II computer using the picture stimuli described by Prill (1984). These stimuli were constructed to have nearly equivalent sizes and locations, to the extent possible given the shape and orientation of the objects. An illustration of two incomplete stimuli, and the complete drawings from which they were derived, is presented in Figure 1.

Procedure

Eight tasks were performed, in the same fixed sequence by all participants, in a single session lasting between 1.5 and 3 hr. Two of the tasks, administered to assess the representativeness of the samples by reference to previous results (see above), were the *Gestalt Completion Test* and the *Digit Symbol Substitution Test.* The same 40 stimulus drawings were used in the *incomplete identification,* *part localization, part detection,* and *identification from parts* tasks, but these were supplemented by an additional 12 picture stimuli in the *familiarization* and *recognition* tasks. Each task except the last was preceded by a short demonstration/practice period involving four novel stimuli.

As part of the development of the tasks, 10 additional individuals (ages 18 to 36 years) identified three nonoverlapping cells, from a 10 × 10 matrix superimposed on each picture stimulus, according to their informativeness for establishing the identity of the object portrayed. (No systematic analysis was conducted on the contents of the regions selected as very informative, but most high-informative regions seemed to involve considerable contour change or dense concentration of details.) These regions were then rank-ordered for use in three of the tasks, as described below.

Familiarization. The initial experimental task simply involved the pre-

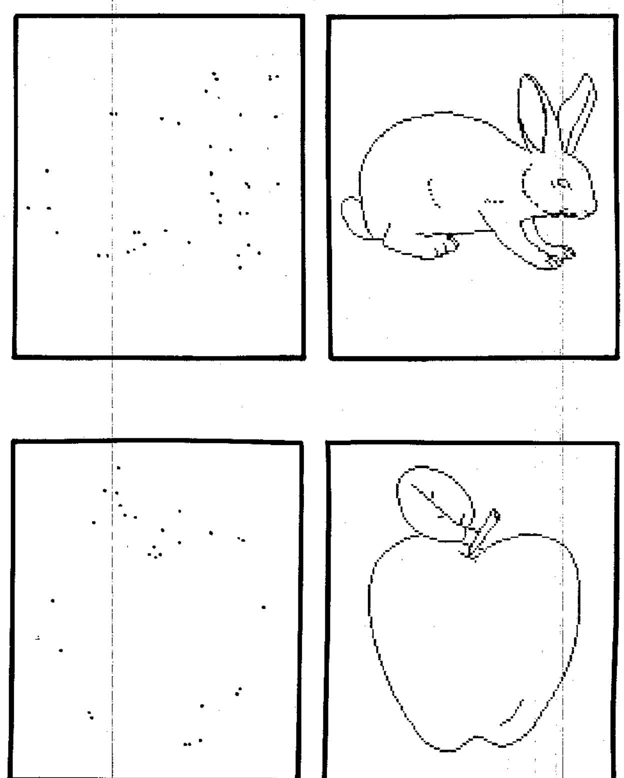

Figure 1. Illustration of the original and a 6%-completeness version of the rabbit and apple stimuli used in the current experiments (isolated dots in the degraded patterns enhanced in the drawing to maximize visibility)

sentation of complete versions of 52 stimulus drawings for 8 s each. The 52 stimuli were initially presented in an alphabetical order along with their names, after which the participants were given a page containing the name and code number of 40 of the 52 stimuli. At this time the participants could reexamine any of the 40 stimuli, although in practice very few individuals exercised this option. The additional 12 stimuli were used in the Old/New Recognition Test described below.

Incomplete identification. The second experimental task consisted of the participants attempting to identify incomplete versions of 40 of the drawings just inspected in the familiarization task. Incomplete versions were created by randomly removing 94% of the pixels (dots) comprising each drawing. Figure 1, containing incomplete versions of a rabbit and an apple, illustrates the appearance of the drawings with 94% of the pixels removed. The stimuli were displayed in the center of the screen for approximately 3 s; a message then appeared requesting that the individual enter the code number corresponding to the identity of the drawing. The alphabetized list of name-number pairings was continuously available to the participants in this task. Upon entering a number, the associated name appeared and the participant was given an opportunity to change the response before proceeding with the next trial. A response was therefore required for each stimulus, but an unlimited time was allowed after the display of the stimulus to produce the response. Two versions of each of the 40 stimulus figures were presented in a randomly arranged sequence to make a total of 80 trials in the incomplete identification task.

Part localization. In this task the participant was asked to move a box within an outlined border to indicate the most informative region for determining if the stimulus was a particular object. No actual stimulus was presented in this task, but instead the individual was given the name of a specific object from the set of stimuli in the familiarization set (e.g., *Apple*), and asked to position the box in a region that would be of the greatest value for confirming the identity of that particular object. A trial began with the presentation of the name of one of 40 objects, and then a (130 × 130-pixel) blank rectangle was displayed. In the upper-left corner of the rectangle was a (26 × 26-pixel) box which could be moved in steps of 13 pixels in the following manner: ← for left, → for right, *A* for up, and *Z* for down. After positioning the box in what was considered the most informative region of the display for verifying the identity of the object, the participant pressed a key to register the coordinates of the box.

The next phase of the trial immediately followed in which one box was fixed in a predetermined position and the participant was to move the location of a second box. The instructions indicated that the participant should move the second box to a region nonadjacent to the fixed box, which in conjunction with the region of the fixed box, would be most informative for verifying the identity of the object. Manipulation of the second box was the same as for the single box in the first phase of the task. The location of the fixed box was determined by the average ratings of the 10 rater participants—it was the second most frequently selected region in the 10 × 10 matrix of 13 × 13-pixel cells. This region was selected because it was of high enough salience to be recognizable by all individuals, and yet still allowed the possibility of choosing the first-ranked location.

Part detection. The stimulus display in this task consisted of a 3 s presentation of two horizontally adjacent boxes; the one on the left containing one complete 13 × 13-pixel cell from one of the complete drawings, and the one on the right containing an incomplete version (again, 94% of the original dots were removed) of one of the drawings. The participant was instructed to determine whether the part on the left could have been derived from the object represented on the right. Responses were communicated by a depression of the Z key for *yes* and a depression of the / key for *no*. One-half of the 80 trials consisted of the part matching the object on the left, and one-half consisted of a mismatch (i.e., a foil trial). Foil stimuli were selected on the basis of having a roughly comparable density of pixels in the relevant region as the stimulus picture. Correct (matching) parts were selected from the fourth- or fifth-ranked regions chosen by the 10 rater participants. Relatively low salience regions for the matching parts were selected to minimize the possibility that the individuals could identify the stimulus object from the part, and thus make their decisions on the basis of direct correspondence of objects rather than matching of parts to objects.

Identification from parts. In this task the participant attempted to identify the object represented by two spatially distinct, that is, nonadjacent, regions. A ceiling in identification accuracy was avoided by selecting regions from those not chosen as informative (when judged discretely rather than in combination) by any of the 10 rater participants. The two regions were presented for 3 s, and the individual then entered the code number corresponding to the identity of the drawing. As with the identification task, an alphabetized list of the number-name pairings was continuously available for consultation.

Recognition. The final task consisted of the presentation of 24 complete drawings for 3 s each, with the participant instructed to classify each according to whether it had been presented in the initial familiarization task. Twelve of the drawings had been presented earlier in the familiarization task (but not in any of the subsequent tasks), and 12 were new drawings not previously presented in any phase of the study. Decisions that the stimulus was *old* were communicated with a press of the Z key, and *new* decisions were communicated with a press of the / key.

The procedure with the practiced participants was identical except that these individuals received 200 trials of practice identifying incomplete versions of 20 of the 40 stimulus pictures 1 to 3 hr prior to the main experimental session. The 200 trials consisted of 10 versions of each of 20 pictures in a randomly arranged sequence. During the practice phase, one-half of the participants received one set of 20 stimuli, and the other half the remaining set of 20 stimuli. An identification response was required to each incomplete stimulus, and it was immediately followed by the presentation of the complete version of the stimulus for 3 s.

RESULTS AND DISCUSSION

The dependent variable for each task was the percentage of correct decisions, except in the part localization task. The dependent measure in that task was the average (across stimuli) number of rating participants who selected the designated region as an important part for the figure. In other words, the score in the localization task was based on the degree to which the rating participants judged the region chosen by the experimental participants as important in establishing the identity of that picture; higher scores therefore signify that the individual's choices had greater correspondence with the judges' ratings.

Before the nature of the age and practice effects are considered, several aspects of the data from the young standardization sample, summarized in Table 1, will be discussed. First, the absolute part localization task proved to be easier than the relative part localization task in that the participants selected more informative regions of the display when there was no other reference point available (i.e., 3.42

Table 1. Correlation matrix from young standardization subjects

	Variable					
Variable	1	2	3	4	5	6
1. Incomplete figure identification	(.770)	.465	.454	.529	.420	.322
2. Part localization, absolute		(.648)	.637	.198	.207	.230
3. Part localization, relative			(.548)	.229	.260	.255
4. Part detection				(.505)	.530	.465
5. Identification from parts					(.775)	.361
6. Recognition						—
M	50.98	3.42	2.83	70.95	38.62	82.12
SD	10.47	0.74	0.75	6.36	12.41	10.70

Note. Values in parentheses along the diagonal are estimated reliabilities derived from using the Spearman-Brown adjustment for the split-half correlation. The 95% confidence interval for a correlation with a sample of 60 is ±.250.

vs. 2.83 on a scale of 0 for completely uninformative to 10 for maximum informativeness). Moreover, this tendency is not simply due to a few unusual individuals, because 49 of the 60 participants exhibited the trend of having higher scores in absolute localization than in relative localization. One possible interpretation of this result is that the options for selecting a location were more restricted when one of the cells was presented, and that this response limitation overwhelmed any potential advantages of configurational knowledge about the stimuli.

Another interesting feature of the data is that the *old/new* recognition scores were substantially less than perfect (82.12%) even though there were only 24 stimuli to be discriminated. This is unusual in the context of studies of picture memory where recognition is generally found to be quite high, but it may be attributable to large amounts of interference created by nearly 2 hr of experience with very similar stimuli intervening between the initial presentation and the subsequent test.

The matrix of correlations among variables for the young standardization participants is displayed in Table 1. Values in parentheses along the diagonal represent estimated reliabilities based on the Spearman-Brown adjustment formula for split-half correlations. Although neither the reliabilities nor the intercorrelations of the test scores are extremely large, these values are consistent with earlier results. For example, reliabilities for closure tests of between .70 and .88 have been reported by several researchers (e.g., Botzum, 1951; Leeper, 1935; Mooney & Ferguson, 1951; Pemberton, 1952). The correlations between similar tests are also in line with previous results, as the correlation between pictorial (Gestalt Completion) and verbal (Mutilated Words) closure tests is generally between .33 and .52 (e.g., Botzum, 1951; Mooney, 1954; Pemberton, 1952; Roff, 1952; Thurstone, 1944). Although not portrayed in the table, the correlations between the experimental measures and scores on the Gestalt Completion Test were of the same magnitude (i.e., .269 to .588), except for correlations of only .09 and .06 for the part localization measures.

The major point to be noted from the data in Table 1 is that each of the measures presumed to reflect efficiency of component processes in the incomplete figure task is positively, and significantly, correlated with incomplete figure performance. Because each measure is correlated with performance on the criterion task, the various tasks can all be interpreted as assessing aspects involved in the activity of identifying incomplete figures.

Sex effects were also examined by means of point-biserial correlations (coding females as 1, and males as 0). Males performed slightly better than females on the Gestalt Completion Test ($r = -.214$, $p <$ .10), and performed significantly worse than females on the Digit Symbol Substitution Test ($r = .345$, $p < .01$). None of the correlations involving the sex variable with the experimental measures was statistically significant.

The older adults performed at significantly lower levels than the young standardization adults on all dependent measures ($ts > 3.91$), and the point-biserial correlations (coding young adults as 0 and older adults as 1) ranged from −.404 (for relative part localization) to −.759 (for identification from parts). As a basis for comparison with the earlier results, the point-biserial correlations for the digit symbol and Gestalt completion scores were −.723 and −.768, respectively.

Analyses were also conducted on the various measures after first partialling out performance on the recognition test to control for the possibility that an age difference in memory for the stimulus figures was responsible for the age differences in the other tasks. This memory control did not change the pattern of results, because all of the measures still exhibited significant ($p < .02$) age differences in favor of young adults.

In contrast to the very pervasive and general age effects, the effects of practice were quite specific. Not only were the benefits of practice limited to stimuli previously experienced, but they were also evident in only a few of the performance measures. Practiced participants performed significantly ($p < .01$) better than unpracticed subjects on the incomplete figure identification, absolute part localization, relative part localization, and part detection measures for the stimuli with which they had practiced ($ts > 1.99$), but not for the novel, unpracticed stimuli ($ts < 1.87$). One surprising result was that the performance of the practiced individuals was significantly worse than that of the unpracticed individuals on the part detection task with novel stimuli. It is conceivable that this was attributable to the practiced individuals always utilizing representations of familiar stimuli in attempting to interpret the stimuli, which could lead to erroneous decisions when the stimuli were actually novel. Performance on the recognition test was not separately analyzed for practiced and unpracticed stimuli, because there were too few *old* stimuli to allow a meaningful analysis.

The major results from the age and practice comparisons are summarized in Figure 2, which expresses performance in units of standard deviation of the distribution of young standardization adults. This figure clearly indicates that the pattern of aging effects is not identical to the pattern of practice effects, either for specific or general practice. If the differential familiarity interpretation of age differences on this task were valid, the age and practice effects should be vertical reflections of one another in this type of representation. That they obviously are not is evidence against the view that age differences are simply due to less familiarity on the part of older adults with the current tasks and materials.

The correlation matrices for the practiced young adults (above and to the right of the diagonal) and the older adults (below and to the left of the diagonal) are presented in Table 2. Correlations marked by an asterisk are significantly different from the corresponding value in Table 1 from the larger sample of young standardization adults. The higher correlations among the practiced participants for the

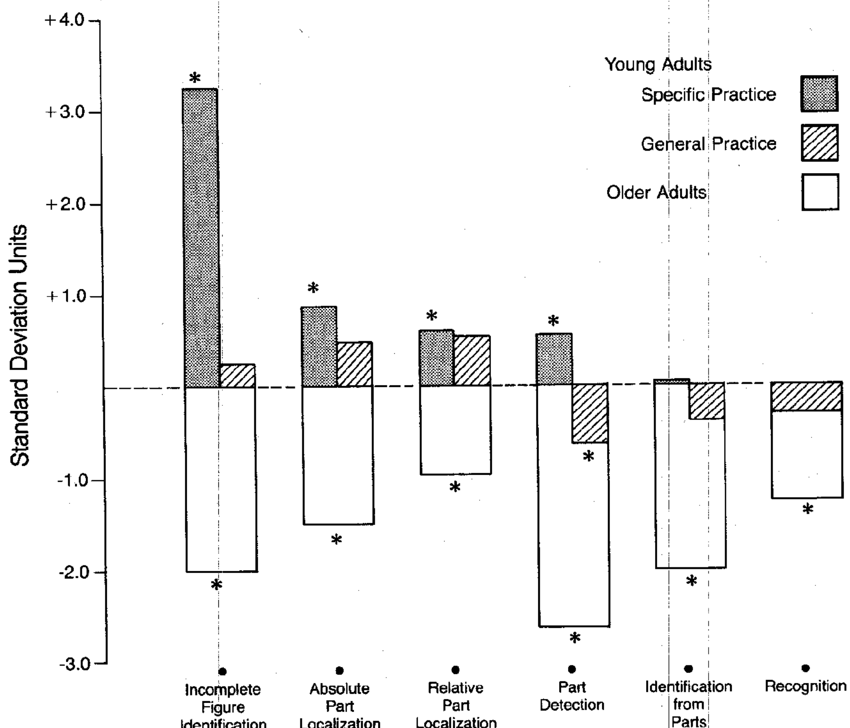

Figure 2. Summary of the age and practice effects of Experiment 1 expressed in standard deviation units from the mean of the 60 (young adult) standardization participants (bars indicated with an asterisk represent statistically significant, $p < .01$, differences from the young standardization adults; specific practice refers to stimuli experienced in the practice phase and general practice refers to novel, unpracticed, stimuli)

absolute part localization measure probably reflect the greater range of scores (i.e., standard deviations of 0.91 vs. 0.74) resulting from having practiced with half of the stimuli. When the corresponding values in Table 1 and the bottom of Table 2 differ significantly, the correlations among the older adults are generally lower than those found with the young standardization adults. This could be attributable either to less integration between component processes, or simply to restricted range due to rather low levels of performance (i.e., the standard deviations of the older adults were lower than those of the young standardization adults for all component measures except recognition). Despite these differences, the correlational patterns for the older adults in Table 2 and the young adults in Table 1 appear

Table 2. Correlation matrix for practiced young and unpracticed older subjects

Variable and group	Variable 1	2	3	4	5	6
1. Incomplete figure identification	—	.600	.411	.755	.536	.072
2. Part localization, absolute	.487	—	.687	.719*	.619*	.239
3. Part localization, relative	−.151*	.243*	—	.427	.534	.353
4. Part detection	.170*	.529	.088	—	.506	.124
5. Identification from parts	.446	.527	.442	.172*	—	.224
6. Recognition	.288	.178	.018*	.295	.423	—
Young practiced						
M	69.30	3.91	3.25	71.10	36.85	79.00
SD	8.84	0.91	0.88	5.78	11.33	10.88
Older						
M	30.10	2.30	2.10	54.30	13.80	68.80
SD	11.14	0.66	0.66	5.98	9.23	11.27

Note. Values above the diagonal are from the 20 practiced young subjects, and those below the diagonal are from the 20 older subjects. The 95% confidence interval for a correlation with a sample of 20 is ±.444. Correlations indicated with an asterisk are significantly different from the corresponding correlations in Table 1.

sufficiently similar to conclude that the hypothesized components were probably of comparable validity in both groups.

Three main results from this first experiment can be identified. One was the discovery that performance on each of the measures designed to reflect efficiency of different components of active processing was significantly correlated with accuracy of identifying incomplete figures, but not always correlated with each of the other measures (cf. Table 1). These findings can be interpreted as indicating that the component measures all reflect processes involved in the criterion task of identifying incomplete figures, but that they are not all measuring the same processes, because the correlations among measures are frequently lower than that allowed by the degree of reliability.

The second major result was that the older adults scored lower than the young adults on every measure examined. To the extent that the various components contribute to accuracy in identifying incomplete figures, the poor performance of the older adults in each of the components clearly makes the age differences in perceptual closure tasks understandable. If increased age is a disadvantage at each of the examined components involved in processing incomplete figures, it is only reasonable to expect deficiencies in the cumulative product of that processing. Therefore, although one could question the validity of the measures as reflections of the proposed processes, the data strongly indicate that regardless of exactly what is being measured in the various tasks, the tasks are assessing somewhat different processes, and the efficiency of each is lower among older adults than young adults.

Unfortunately, the absence of a clear differential pattern of impairment provides little clue as to exactly what the nature of the age-related difficulty might be. Figure 2 suggests that the magnitude of the age differences varies across component measures, but cross-task comparisons are inherently ambiguous because of possible measurement artifacts associated with floors and ceilings, and the likelihood of variations in complexity or difficulty across tasks (cf. Salthouse, 1985b, pp. 130–143). Of greater importance than the absolute magnitude of the differences is the fact that each is extremely unlikely to have occurred by chance. The most striking aspect of the age comparison results, therefore, is that virtually everything seems to be affected, and that the age differences cannot be localized in one or two processes.

The third major result from Experiment 1 was that unlike the situation with the age variable, the positive effects of practice were restricted to only some of the component measures, and even then were highly specific to the stimuli that one had experienced in the practice phase. As indicated in Figure 2, practice had a large effect on the accuracy of identifying new incomplete versions of the practiced stimuli, and it had smaller but still significant effects in absolute and relative part localization and in part detection. This pattern suggests that the additional experience results in the individuals' learning details of the practiced stimuli which help them in several of the component tasks. However, the absence of significant positive transfer to the unpracticed stimuli suggests that the participants have not improved in processes of generating and testing hypotheses independent of specific stimuli.

EXPERIMENT 2

One of the most surprising findings in the first study was that the effects of practice were so specific to the stimuli experienced during the practice phase. The absence of any general positive effects of experience leads to the inference that practice on these tasks merely improves knowledge of particular stimuli, and does not facilitate the general processes of reasoning about the identity of incomplete figures. This is a potentially important result, and it was considered desirable to attempt to replicate the principal finding before speculating further about its implications. The present study was therefore designed to investigate the effects of practice on the identification of incomplete versions of novel and familiar stimuli.

Older adults as well as young adults received the practice manipulation to determine whether similar trends were evident in both age groups, and to investigate the possibility that the magnitude of the age differences might be reduced with moderate practice. That is, if the processes facilitated by practice are also those responsible for the initial age differences in performance, then those differences may be reduced or even eliminated after moderate amounts of practice. Unlike the previous study, only the criterion incomplete figure identification task was presented after the practice to reduce the time commitments of the participants.

METHOD

Participants

Ten males and 10 females served in each of the samples of young (18 to 19 years of age, M = 18.1) and older (55 to 71 years of age M = 62.1) adults. None had participated in the previous experiment. All young participants had 12 years of education; the range for the older group was 12 to 22 years (M = 15.2). Because of a desire to keep the experimental session under 1.5 hr, neither the Digit Symbol nor the Gestalt Completion Test was administered to these individuals.

Apparatus and Procedure

The apparatus and procedure were identical to that of the practiced group in the previous study except that only the familiarization and identify incomplete figures tasks were presented after the practice phase.

RESULTS AND DISCUSSION

The principal results of this study are illustrated in Figure 3, which also contains relevant data from the previous experiment for comparison. The dashed horizontal lines represent accuracy in the incomplete figure identification task from Experiment 1 for the standardization sample of young adults and the sample of older adults.

Four measures representing different aspects of performance can be abstracted from the data summarized in Figure 3. One is simply the rate of learning, which, because everyone received the same amount

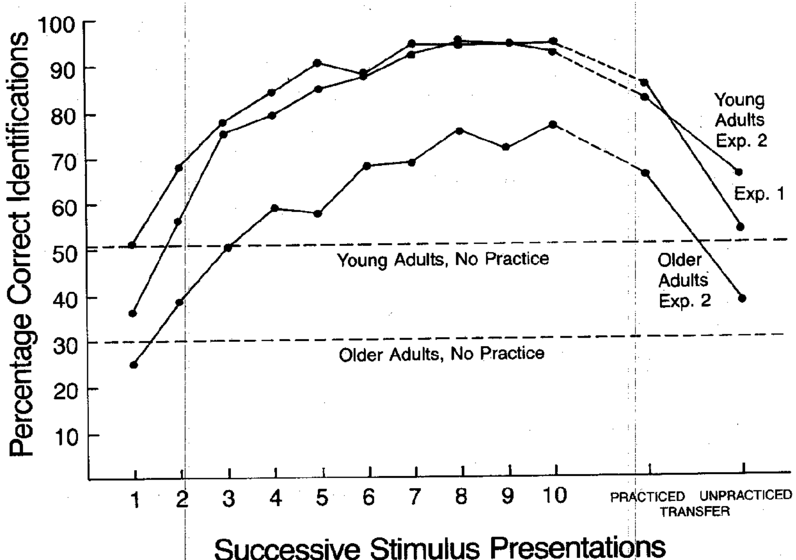

Figure 3. Mean performance of young and older adults across practice and during transfer in Experiments 1 and 2 (stimuli during transfer classified as practiced if familiar, and as unpracticed if novel)

of practice, can be expressed in terms of the difference between initial and final level of performance across the 10 exposures of the 20 practiced stimuli. A second measure is the difference in accuracy of identifying the practiced stimuli between the last practice exposure and the incomplete figure identification task. This will be termed *competitive interference* because it can be interpreted as reflecting the interference in performance resulting from the competition or confusion of novel stimuli. That is, accuracy decreases from the practice to the test phase, and this measure simply indicates the amount of decline. The third measure, specific transfer, corresponds to the difference in accuracy in the incomplete figure identification task between familiar (practiced) and novel (unpracticed) stimuli. The fourth measure, general transfer, corresponds to the difference between accuracy for novel (unpracticed) stimuli for participants receiving practice and accuracy for all stimuli for participants not receiving practice. The individuals without practice were those from Experiment 1, represented by the dashed lines in Figure 3. Notice that the specific transfer index represents the benefits of practice on particular stimuli and that the general transfer measure reflects the effects of practice on novel or unpracticed stimuli.

Summary statistics for these measures are presented in Table 3. In general, these results confirm the impressions conveyed from Figure 3. The amount of practice-related improvement was slightly less among the young adults in Experiment 1 than among the young adults in Experiment 2; an equivalent reduction in performance between practice and test occurred for all individuals; the difference between the familiar and novel stimuli was larger among the young adults of Experiment 1 and the older adults of Experiment 2 than among the young adults of Experiment 2; and finally, the young adults of Experiment 2 had significantly greater transfer to novel stimuli than the young adults of Experiment 1.

Two aspects of these data deserve special emphasis. The first is that unlike Experiment 1, significant positive transfer to novel stimuli did

Table 3. Summary of practice-related measures, Experiments 1 and 2

Experiment, group	Practice improvement	Competitive interference	Specific transfer	General transfer
1, Young	41.0_a	9.0_a	31.9_a	1.5_a
2, Young	56.5_b	10.3_a	17.2_b	14.1_b
2, Older	50.0_{ab}	10.5_a	27.2_a	7.6_{ab}

Note. Entries within a column with a common subscript are not significantly different from one another at $p < .01$.

occur in the young adults of Experiment 2. The reason for this discrepancy is not readily apparent, but it is important to note that the trends in Figure 3 are quite similar for the two groups and thus the difference is more quantitative than qualitative.

The second interesting feature of the data in Figure 3 and Table 3 is that the older adults exhibited trends very similar to those of the young adults, and for most measures were actually intermediate between the two young groups. This pattern suggests that the factors responsible for age differences in perceptual closure are not related to practice, and seem to be independent of the acquired knowledge of specific stimuli or of the amount of transfer or interference in subsequent tests. Together with the finding in Experiment 1 that different qualitative patterns were produced by age and practice, these results clearly make an explanation of the age differences in perceptual closure based on age-related differences in familiarity highly unlikely.

GENERAL DISCUSSION

The goal of Experiment 1 was to attempt to be more precise in characterizing age differences in perceptual closure performance in terms of specific information-processing components hypothesized to be concerned with deriving implications of a hypothesis, testing those implications, evaluating the viability of the hypothesis, and maintaining accurate knowledge about the relevant information. If older adults are impaired in perceptual closure tasks because of a deficiency in only one or two of these components, the measures of the effectiveness of the remaining components should not differ across groups of young and older adults. In fact, however, the young adults achieved superior scores on every available measure. Of course, the age difference might still be primarily determined by one of the components and its consequences manifested in reduced performance in all components because of the dependencies inherent in human information processing, but it is clear that the age effects are not simply restricted to one or two discrete processing components.

Experiment 2 employed a different research strategy in which young and old adults were given practice with the perceptual closure activity, and age differences were then examined in measures reflecting various aspects of learning and transfer. Because the participants practiced with only one set of stimuli and then were tested both with that set and with a new set of stimuli, the two groups could be compared with respect to (a) the amount of improvement during practice, (b) the degree of confusion or interference experienced when the same stimuli were to be identified in the presence of new stimuli, (c) the magnitude of specific transfer in terms of the advantage of practiced stimuli relative to unpracticed stimuli, and (d) the amount of general transfer to unpracticed stimuli relative to what would have been expected without any prior practice. If sizable age differences were evident in one or more of these measures, it would have been reasonable to argue that the age difficulty was specific to the processes contributing to that measure. For example, if older adults differed from young adults by exhibiting a greater reduction in accuracy when going from practice to test, it might be inferred that they were more susceptible to interference from similar stimuli, and thus were more likely to be confused when confronted with novel stimuli.

The results of the practice-related measures differed somewhat across two groups of young adults, but the older adults performed quite similarly to one or both young groups on each measure. Pronounced age differences were apparent in the overall level of performance, but they were slight to nonexistent in the measures reflecting amount of learning and transfer. The implication is that the age differences in the perceptual closure task are attributable to factors independent of, and presumably more pervasive than, those involved in the improvement and transfer of skills acquired through practice.

What are the factors contributing to age differences in simple perceptual and closure tasks? It is still too early to answer this question, but promising possibilities are age-related reductions in system-status characteristics such as working-memory capacity, attentional energy, or rate of performing elementary operations. Although the details have not been worked out for any of these types of processing resources (but see Salthouse, 1985b, in press, for relevant discussion), restrictions in any of them would likely impair the quality or quantity or nearly all aspects of processing. Whether because the data supplied to each information-processing operation is impoverished or because the efficiency of the operations is reduced, widespread performance consequences would be expected. This latter point is crucial because the results of the present experiments seem to indicate that, whatever the nature of the factors responsible for age-related reductions in closure performance, they appear to influence the effectiveness of almost all processing. In support of this inference is the finding in Experiment 1 that the age differences could not be localized in a single processing component, but instead were apparent in all of the measures examined. The second source of evidence for this inference is the finding in Experiment 2 that the older adults exhibited patterns of practice-related improvement and subsequent transfer comparable to those of the young adults. In this case it is the absence of a difference that leads to the inference that the factors responsible for the age differences in performance originate in a phase of processing independent of the influence of practice. General rather than specific factors therefore seem to be implicated in the age differences in perceptual closure tasks, and because the concept of processing resources possesses the requisite generality, age-related reductions in some type of processing resources may contribute to the observed performance differences in this, and possibly many other, perceptual and cognitive tasks.

Notes

This research was supported by National Institute of Aging Research Career Development Award 1K04 AG00146 and RO1 AG04226 to Timothy A. Salthouse. We would like to thank Kathy Berry for assistance in collecting data, and Reinhold Kliegl for valuable comments on an earlier draft.

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