Effects of Aging, Cue-to-Target Overlap, and Processing Resources on Intentional Cued Recall in Normal Human Adults

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Abstract

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Craik (1986) postulated that the advantage of young over older adults in memory decreases if more information is available at the time of retrieval. A first objective of this dissertation was to test the hypothesis that the mnemonic advantage of young adults decreases when the overlap between the cue at retrieval and the original target increases. A second objective was to verify whether increased cue-to-target overlap (CTTO) results in decreased requirements in processing resources. In Experiment 1, increases in CTTO co-occurred with a stability in the mnemonic advantage of young adults for both words and drawings. With words this stability could be explained by similar demands for processing resources across CTTO levels. However, with drawings this stability could not be attributed to similar demands for processing resources as the resources-recall correlation increased with increasing CTTO. In contrast to intentional processes, automatic

processes do not require processing resources. Therefore, findings of Experiment 1 with drawings can be explained if increasing CTTO increases both the contributions of automatic and intentional processing to recall, and if the increase in the contribution of automatic processing compensates for that in the contribution of intentional processing. In Experiment 2, the process-dissociation procedure (Jacoby, 1991) was further developed to permit testing of this hypothesis. Because the recall of the drawings failed to dissociate into intentional and automatic processes, this recall was analyzed the same way as in Experiment 1. The results with the drawings suggested that CTTO can be increased to a point where the demands for processing resources are reduced, but that this reduction will not necessarily be reflected in a decreased mnemonic advantage of young adults. The results with the words indicated that when CTTO was increased to a very large level, the mnemonic advantage of young adults increased. This result was caused by a marked decline in the recollection of older adults which co-occurred with an increased relevance of processing resources. Taken together, the results of Experiments 1 and 2 suggest that the relationships among age, CTTO, processing resources, and memory are more complex than Craik's hypothesis and other current theories would predict.

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Chapter 1

Introduction

Introduction

One of the most firmly established findings in the field of cognitive aging is the observation that older adults remember less than young adults on episodic memory tasks, that is, tasks that concern information about temporally dated episodes and events (Hultsch & Dixon, 1990; Poon, 1985).

According to Craik (1983, 1984, 1986, 1990; Craik & Jennings, 1992), age-related deficits (ARDs) on memory tasks are proportional to the extent to which these tasks require the use of self-initiated operations or "mental operations beyond those 'driven' by the environment or automatized by much previous practice" (Craik, 1983, p. 350). Craik hypothesizes that ARDs increase with the need for mental operations "initiated, organized and executed by subjects themselves" (1983, p. 350). Self-initiated operations are needed whenever the environment does not automatically trigger the operations that are required for the encoding and the retrieval of an event. In other words, the need for self-initiated operations increases whenever the amount of environmental support diminishes.

As shown in Table 1, conventional episodic memory tasks are thought of by Craik to vary in the amount of environmental support that is provided. Free recall is considered to provide a low level of support, cued recall a medium level of support, and recognition a high level of

Table 1

The Taxonomy of Episodic Memory Tasks Proposed by Craik

Task	Environmental support	Self-initiated activity	Age-related decrement
	Low	High ^	High ^
Free recall	|	|	|
Cued recall	|	|	|
Recognition	|	|	|
	V High	Low	Low

Note. From "Changes in Memory with Normal Aging" by F. I. M. Craik, 1990, In R. J. Wurtman et al. (Eds.) Advances in Neurology, Vol. 51: Alzheimer's Disease (p. 203). New York: Raven Press. Copyright 1990 by Raven Press.

support. Because of this variation of environmental support, ARDs should, according to Craik, be large in free recall, smaller in cued recall, and even smaller in recognition.

It appears logical to rank conventional episodic memory tasks in this order because the overlap of cue and target information, which is one way to define environmental support, varies between these tasks in the same order (see Barsalou, 1992). By definition, free recall implies that no cue is provided by the experimenter at the time of retrieval. Subjects are simply told to retrieve as many words as possible. Cue-to-target overlap (CTTO) is minimal and subjects must rely on their own efforts to recall the stimuli. The demand for self-initiated operations is therefore maximal.

In contrast, in recognition procedures the to-be-remembered stimuli themselves are presented again at the time of retrieval and the only activity required of subjects is to discriminate them from lures. Because in recognition the cue is the target itself, CTTO is maximal. According to Craik, the need for self-initiated operations is therefore minimal.

Finally, cued recall, like free recall, does not include the target itself as a cue for recall. However, similar to recognition, cued recall includes a cue. Whereas in recognition the cue is the target itself, in cued recall the cue may take many different forms such as a superordinate category label, a word learned as a paired associate, or even a fraction of the target's letters. The overlap of cue and target is therefore intermediate in cued recall, with the result that the demand for self-initiated operations is also intermediate.

The self-initiated operations hypothesis is embedded in the reduced processing resources framework, which in essence is the hypothesis that ARDs in cognitive performance are caused by an age-related reduction in the efficiency of a few general mechanisms such as the speed at which mental operations are executed. The self-initiated operations hypothesis may be thought of as defining a particular category of mental operations for which declines in speed of execution with advancing age are particularly marked. As Craik (1986) postulated: "A decline in processing resources may provide the underlying reason for the greater difficulty experienced by older people in carrying out such [self-initiated] operations" (p. 413).

The reduced processing resources framework proposes that at least a part of the effect of age on cognitive performance is mediated by an age-related reduction in mental resources (see Figure 1). Support for the reduced processing resources framework has come from studies using multiple regression where cognitive performance is the dependent variable and where both age and resources are the independent variables. Those studies have most often shown

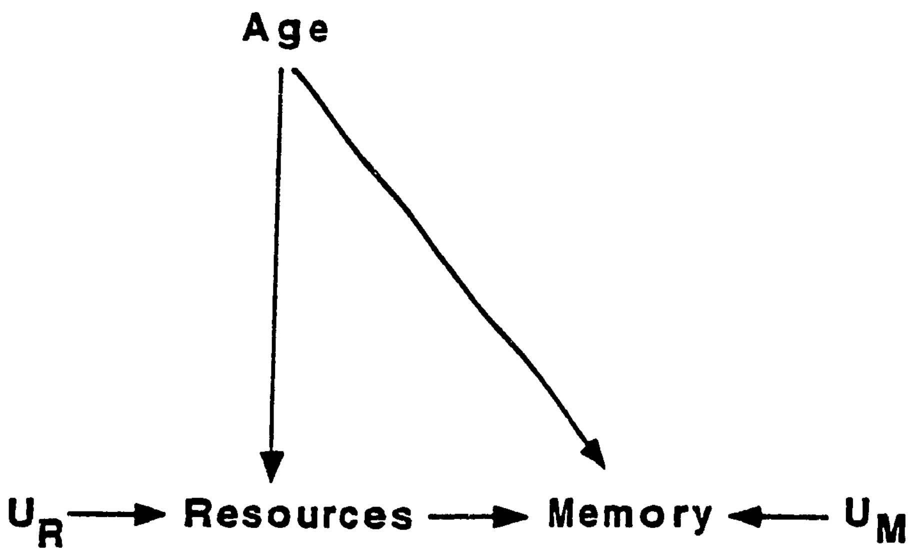

Figure 1. Model of the interrelations among age, processing resources, and memory performance proposed by Salthouse, Kausler, and Saults (1988a). Age is postulated to be an exogenous variable (i.e., outside the scope of the model), whereas processing resources and memory performance are assumed to be endogenous variables. The u_R and u_M terms represent unmeasured sources of variance in processing resources and memory performance, respectively.

that the percentage of variance explained by age decreases markedly when an index of resources is entered before age in the regression. For example, Salthouse (1993a) found that age alone explained 55% of the variance on a free recall task. However, when an index of resources was entered before age in the equation, this index explained 52% of the variance whereas age added only another 5% to it. This result suggests that the majority of the effect of age on free recall is mediated by an age-related reduction in processing resources. Actually, according to the review by Salthouse (1993b) on the latest nine studies on intellectual aging on average 78% of the age-related variance on cognitive tasks is associated with variations in processing resources linked to aging. Thus, one can find in the literature on cognitive aging strong support for the reduced processing resources framework.

Research on aging has mainly relied on tests on the difference between means as a way to explore ARDs in memory. A limitation with this approach is that it does not take into account the problem of differential sensitivity (Salthouse, 1985). This problem results from the fact that the capacity to detect ARDs depends on the difficulty level of the task. As shown in Figure 2, when a task is intermediate in difficulty, the mean of the dependent variable will be in the middle of the range of possible values. There is a maximum potential for variation, and ARDs

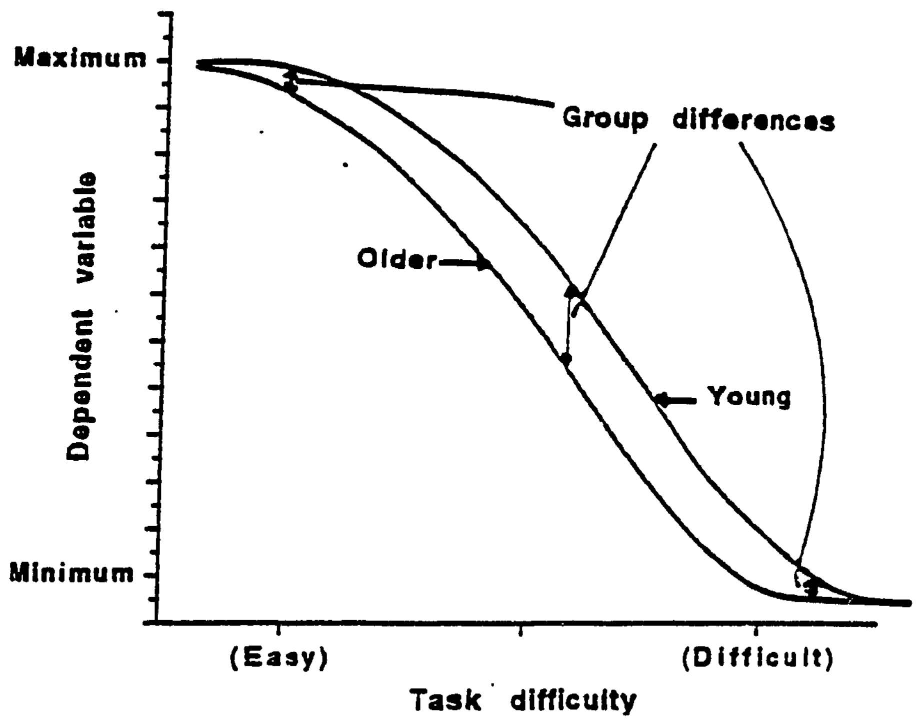

Figure 2. Abstract representation of the problem of differential sensitivity. The absolute magnitude of the age-related deficit is greater in the middle of the variable's range, and decreases at the extremes (near the common floor and ceiling). From "Memory Methodology in Maturity" by T. A. Salthouse and D. H. Kausler, 1985, In C. J. Brainerd and M. Pressley (Eds.) Basic Processes in Memory Development (p. 293). New York: Springer Publishing Company. Copyright 1985 by Springer Publishing Company.

will, therefore, be easily detected.

In contrast, as the mean performance approaches either a floor or a ceiling, the range of possible values is reduced because the scores are bounded by the floor or the ceiling. The potential for variation is then very low, and ARDs will, therefore, be difficult to detect. Because of the problem of differential sensitivity, artifactual variations of ARDs could be observed if conditions generating scores that are near to either a floor or a ceiling are compared with conditions generating scores in the mid-range.

Cohen's (1988) d, which is the standardized difference between the proportion of stimuli remembered by the younger group and those remembered by the older group, provides an estimate of effect size that is less affected than are group means by the problem of differential sensitivity. The use of Cohen's d is based upon the principle that the proximity of a floor or of a ceiling artificially restricts the range of possible scores. By taking the difference between the proportion of stimuli remembered by the two age groups and dividing that difference by the pooled within-group standard deviation, one can compensate for any artificial curtailment of scores that may occur.

When a measure of effect size such as Cohen's d is considered, the following steps can be used to assess whether the extant literature supports the notion that ARDs in conventional episodic memory tasks vary in the direction predicted by the self-initiated operation hypothesis. A first step consists of selecting only those studies where more than one episodic memory task was used with the same subjects under the same conditions. An advantage of such a selection is that relevant task variables such as study condition, list length, and type of material are all maintained constant. A secondary analysis is then conducted whereby the direction of each of the pairwise comparisons between tasks are determined.

Foisy (in press) conducted such a secondary analysis of the literature on intentional episodic memory for words. As shown in Table 2, 21 of 24 comparisons were in the direction predicted by the self-initiated operations hypothesis. Such a result, which greatly exceeds chance expectations ($p < .01$), provides evidence that ARDs in verbal episodic memory tasks do vary in the direction predicted by the self-initiated operation hypothesis.

Although the comparison of ARDs among conventional episodic memory tasks appears to support the view that the reduced processing resources framework may be generalizable to the study of episodic memory, there are several reasons to go beyond the comparison across tasks in evaluating the self-initiated operation hypothesis.

First, the problem of finding a metric common to all the conventional memory tasks seems insoluble. As long as free and cued recall are considered, defining performance as

Table 2

Results of Studies on Aging and Episodic Memory

Study	N	Age Span[b]	List Length	No. of Self-initiated operations ($\underline{d}^{a}$)	
				High	Low
Free recall vs. Recognition					
Craik & Rabinowitz (1985)	96	48	12	-1.18	-0.93
Erber (1974)	76	46	42	-1.19	-0.71
Erber, Herman, & Botwinick (1980)	120	46	28	-0.78	-0.40
Geffen, Moar, O'Hanlon, Clark, & Geffen (1990)	42	40	15	-1.40	-0.25
Light & Singh (1987, Exp. 1)	64	44	20	-0.69	0.00
Madden (1986)	48	48	72	-1.55	-1.44

(cont.)

Table 2 (continued)

Perlmutter (1978)	64	40	24	-0.66	-0.45
Phillips (1990)	48	54	20	-1.67	-0.62
Rabinowitz & Craik (1986, Exp. 1)	24	46	78	-1.32	-1.28
Spofford (1985)	48	45	20	-1.64	-1.07
Free recall vs. Cued recall					
Erber (1984)	44	48	35	-0.33	-0.25
Isingrini, Fontaine, Grellier, & Sauger (1990, Exp. 1)	60	39	40	-1.64	-0.75
Rabinowitz & Craik (1986, Exp. 1)	24	46	78	-1.32	-1.20
Rankin & Collins (1985, Exp. 1)	163	51	20	-0.86	-0.85
Rankin & Firnhaber (1986)	36	44	40	-0.69	-0.96
Rankin & Hinrichs (1983)	36	52	20	-1.50	-1.21
West & Cohen (1985)	160	40	40	-0.92	-0.96

(cont.)

Table 2 (continued)

	Cued recall vs. Recognition				
Luis (1985)	128	39	12	-0.81	-0.71
Rabinowitz (1984)	48	50	24	-1.20	-0.67
Rabinowitz (1986)	64	49	20	-2.00	-0.52
Rabinowitz & Craik (1986, Exp. 1)	24	46	78	-1.20	1.28
Shaps & Nilsson (1980, Exp. 1)	40	57	24	-1.23	-0.51
Shaps & Nilsson (1980, Exp. 2)	40	57	24	-0.68	-0.43
West & Boatwright (1983)	128	47	22	-0.65	-0.36

Note. [a]Negative values indicate superior performance of young subjects. Every *d* is adjusted for bias. [b]Mean age (in years) in the older group minus mean age (in years) in the young group.

the number of recalled stimuli appears reasonable. However, to operationalize recognition as the number of hits is problematic, as this number depends upon subjects' response criterion. For this reason, d' and other sensitivity indices have been developed (Kintsch, 1970). But as soon as an index other than number of hits is used, the comparability of recognition scores to those derived from cued or free recall is debatable.

A second difficulty is that the ranking of conventional episodic memory tasks in terms of environmental support can only be qualitative. Although some tasks (e.g., recognition) are considered to provide more support than others (e.g., free recall), it is not possible to determine the magnitude of that difference. The fact that the scale on which conventional episodic memory tasks may be placed in terms of environmental support can only be ordinal greatly limits the heuristic value of any comparisons among tasks.

Finally, the mental processes involved in conventional episodic memory tasks may be qualitatively different from one another. For example, according to the two-process theory of memory (see Watkins & Gardiner, 1979), free recall is postulated to involve two processes, search through memory and judgment of familiarity, whereas recognition involves only judgment of familiarity. It is still unclear whether the requirements in familiarity judgment could be increased to the point where recognition would reveal greater ARDs than both cued and free recall (although see Craik, 1986, for a reply to this argument).

Light (1991) suggested that a study relevant to the issue of self-initiated operations would be one where the amount of retrieval support would be varied within cued recall. Following Light's suggestion, suppose that CTTO is manipulated directly within a cued recall task, by varying the number of letters presented as cues in words of fixed length. Under this circumstance, CTTO can be operationally defined as the proportion of information in the target that is re-presented as a cue at test. If only one letter of a target word is provided as a cue, the test situation approaches that of free recall where CTTO is always equal to zero. In contrast, the greater the number of letters provided as cues at test, the greater the resemblance of cued recall task to recognition where CTTO is always equal to 1.

The reason for manipulating CTTO within a cued recall paradigm is that it resolves the three problems mentioned above. First, the same metric (i.e., proportion of words remembered) can be used for all levels of environmental support. Second, the ranking of the tasks in terms of environmental support is quantitative. Finally, at all levels of environmental support the task involves both a search through memory and a judgment of familiarity.

The primary objective of the present experiment was to verify whether ARDs in episodic memory increase when environmental support diminishes. Environmental support was operationalized as the overlap between the retrieval cue and the target within a cued recall paradigm. Both verbal and visual stimuli were used. The verbal stimuli were 6-letter common words, with CTTO defined as the proportion of the letters from these words presented again in the test phase. Visual stimuli were drawings of common objects, with CTTO defined as proportion of the target dots presented again in the test phase.

In the first experiment, three levels of CTTO were crossed with two different list length conditions to determine whether the effects of CTTO on memory for young and older subjects vary as a function of the number of to-be-remembered verbal or visual stimuli. According to the self-initiated operations hypothesis the effect of CTTO on memory should be the same across different list lengths. In order to maximize statistical power, all the manipulated variables in the study with the exception of age were within-subjects factors.

As pointed out by Botwinick (1984), a fundamental issue in research on memory is to disentangle answers that are produced by memory from those that result from guessing. In order to assess for each target its probability of being guessed, two versions of each verbal and spatial memory task were created, and the use of these versions was counterbalanced across subjects. Subjects who learned and tried to remember one version were also presented with the retrieval cues of the other version and were asked to guess the targets to which these cues corresponded.

Because the group of subjects used to generate norms were submitted to the same procedure as the group of subjects who were administered the memory tests, and because both groups were recruited from the same population, the relevance of the baseline completion rates thus created was maximal. The baseline completion rates were subtracted from the number of targets correctly remembered by each subject at each level of CTTO in order to produce an unbiased index of performance.

It should be noted that the hypothesis that increasing the number of letters presented as cues will reduce the magnitude of ARDs has also been tested by Park and Shaw (1992). Park and Shaw found no variation in ARDs across levels of support, thus failing to support the self-initiated operations hypothesis. However, rather than operationalizing environmental support as the proportion of presented letters, Park and Shaw manipulated the number of presented letters in words of various lengths. Such a manipulation neglects the fact that providing the same number of letters in words of different lengths does not control for the amount of effort required to retrieve the remaining letters.

Because in Park and Shaw's experiment CTTO was not constant within each environmental support condition, it is not surprising that an interaction involving age and environmental support was not obtained. Thus, Park and Shaw's results cannot be considered as necessarily negating the hypothesis that ARDs are reduced when environmental support increases.

Another limitation with Park and Shaw's experiment is that the problem of differential sensitivity was not controlled for. Interestingly, Cohen's d and a point-biserial correlation are two interchangeable ways to take into account the problem of differential sensitivity, as simple formulas permit to transform one into the other (Hunter & Schmidt, 1990). In the present study point-biserial correlations were preferred over Cohen's d because in order to test the difference between two dependent Cohen's d these effect sizes must first be transformed into point-biserial correlations. It is more advisable, therefore, to report point-biserial correlations rather than Cohen's d. A second objective of the present experiment was to test whether results are the same when the problem of differential sensitivity is controlled for by using point-biserial correlations.

Park and Shaw (1992) made the suggestion that it would be relevant to measure the amount of processing resources available to individual subjects and then to determine whether this amount accounts for the variance in the utilization of environmental support. If it is true that increasing environmental support decreases the demand for processing resources, then the performance of an individual should become less and less constrained by the amount of processing resources available to him or her as environmental support increases.

A simple way to test this hypothesis consists of comparing the correlations between processing resources and performance at different levels of environmental support partialling out the effect of age. The reason for partialling out the effect of age is the following. Because age is linked to the amount of processing resources that are available, a correlation between age and performance could create a spurious correlation of processing resources with performance. By partialling out the effect of age, the risk of seeing such a spurious correlation is eliminated. This method was used in the present experiment.

The index of processing resources used in the present experiment was the median latency on the computerized digit-symbol task (Salthouse, Kausler, & Saults, 1988b), a task which requires subjects to judge as rapidly as possible whether a pair that contains both a digit and a symbol corresponds to any of the pairs of a code table. Although digit-symbol latency is primarily a measure of processing speed, it was chosen because it is among the best single indices of processing resources, as shown in studies where digit-symbol latency is correlated not only with other measures of processing speed but also with measures of working memory (Salthouse, 1992; Salthouse, 1993b).

In summary, the present experiment was aimed at testing the hypothesis that ARDs are reduced when CTTO increases by examining both means and point-biserial correlations. Moreover, if such a reduction is due to the decreased relevance of processing resources, then the correlation between those resources and performance should decrease as CTTO increases.

Chapter 2

Experiment 1

Experiment 1

Method

Apparatus

An IBM compatible computer equipped with a VGA color monitor was used for most tasks. Stimulus items were presented in dark grey against a white background. Reading letter size for all texts was at least 1.5 cm in height and 1 cm in width. Picture stimuli were centered within a 12 cm x 12 cm white square, with the outer margins of the screen being left black. The "/" key was covered with a green tape on which was marked a Y for "yes" responses and the "z" key was covered with a red tape on which was marked a N for "no" responses. Moreover, a "Do not know" tape was placed on the space bar.

Background materials

The following questionnaires and tests were used to obtain demographic information about the subjects as well as information on various dimensions of intellectual and psychosocial functioning. They are presented here in the order in which they were administered to subjects.

Preliminary Questionnaire. This questionnaire asks for age, number of years of education, and first language. This questionnaire also includes a self-assessment of general health (from the OARS Multidimensional Functional Assessment Questionnaire, Duke University, 1978) where subjects rate their own health on a 4-point likert scale (from 0 for "poor" to 3 for "excellent"). Finally, the Preliminary Questionnaire inquires about autonomy through the following question: "Are you suffering from any permanent health troubles that prevent you from doing the things you normally need to do each day?"

Memorial University of Newfoundland Scale of Happiness (MUNSH). The MUNSH (Kozma & Stones, 1980) is a 24-item self-report computerized measure of happiness where subjects simply answer "yes" or "no" to each item. The first 10 items ask for happiness feelings in the past months whereas the next 14 items investigate for more general life experiences. By comparison to other mental health scales such as the Beck Depression Inventory (Beck, Rush, Shaw, & Emery, 1987), the main advantage of the MUNSH is that negative items are balanced with positive ones. The MUNSH has an internal consistency of .85 (Cronbach's alpha) and a test-retest reliability of .70 within one year.

Vocabulary subtest of the WAIS-R. The vocabulary subtest of the WAIS-R (Wechsler, 1981) is a list of 35 words that subjects define. By comparison to all of the other verbal subtests of the WAIS-R, the score on the vocabulary subtest is the most highly correlated with the total verbal score (.85). The measure was included here as a control for differences in verbal intelligence. The vocabulary subtest of the WAIS-R has an internal consistency of .96 (Spearman-

Brown formula) and a test-retest reliability of .91 within seven weeks.

Block design subtest of the WAIS-R. The Block design subtest of the WAIS-R is a series of 8 spatial designs presented in a booklet that subjects reproduce as quickly as possible using 9 cubes colored red on two sides, white on two sides, and half red half white on two sides. The Block design subtest of the WAIS-R has a test-retest reliability of .80 within seven weeks and a split-half consistency of .87 (Spearman-Brown formula). The Block design is the purest measure of spatial reasoning in the WAIS-R (Golden, 1979) and was included here as a control for differences in visual spatial ability. Block design has a correlation of .67 with the full scale score.

Experimental materials

Digit symbol task. The Digit symbol task, adapted from Salthouse et al. (1988b), is a computerized version of the Digit symbol Substitution subtest from the WAIS-R. In the present version, subjects were given 54 trials. On each trial, they saw the code table and a single digit-symbol pair. Subjects pressed the yes or no key depending on whether the pair presented to them matched a pair from the code table. Digit symbol time, defined as the median time per trial for correct responses, was used as a measure of processing resources. Before the statistical analyses the digit symbol time was multiplied by minus one to indicate that the slower the answer the poorer the resources. Test-retest reliability of Digit symbol time within two hours is .96.

Verbal memory lists. Two sets, A and B, of 10 lists each were created (see Appendix A). Each list contained two-syllable common nouns that were 6-letter long. Lists 1, 3, 5, 6, 8, and 10 contained 9 nouns each, whereas lists 2, 4, 7, and 9 contained 15 nouns each. In the test phase, one third of the nouns of each list were tested with 1-letter cued recall (small CTTO), one third with 2-letter cued recall (medium CTTO), and the last third with 3-letter cued recall (large CTTO). The number of letters to be filled in to complete the word was indicated by dashes. The nouns cued with 2- and 3-letter cues differed for Sets A and B. However, for one-letter cues, because the number of words required far exceeded the number of letters available for cues, the same nouns were used for both Sets A and B.

Each cue was chosen so that it could be filled with at least two words from the lexicon. To minimize age differences in familiarity with the words (see Erber, Galt, & Botwinick, 1985; Hanley-Dunn & McIntosh, 1984; Worden & Sherman-Brown, 1983), the mean of the frequency difference between Thorndike and Lorge's (1944) count and Kucera and Francis's (1967) count was no greater than ±5 within each level of CTTO.

Several steps were taken to minimize inter-list interference. First, the first two letters of a specific word could not be the same as those of any other word. Second, in the case of any word that was to be tested with 1-letter cued recall on a given list, no words of the preceding list could begin with the same letter. For example, if "crater" was to be cued by "c _ _ _ _ _" on List 5, no words of List 4 could start with "c". Third, a word tested with the same 1-letter cue as a word tested previously was separated from that word by at least two lists (e.g., if the cue "s _ _ _ _ _" was used on List 5, the cue "s _ _ _ _ _" could not be used again until List 8). The lists of cues were created in such a way that the average retention interval was constant across levels of CTTO.

Visual memory lists. Two sets, A and B, of 10 lists of drawings were constructed with the pictorial stimuli being taken from Snodgrass and Vanderwart's (1980) standardized set of 260 pictures (see Appendix C). Lists 1, 3, 5, 6, 8, and 10 contained 9 drawings each, whereas lists 2, 4, 7, and 9 contained 15 drawings each. When the present experiment was designed, eight levels of fragmentation existed for 150 pictures of that set (see Snodgrass, Smith, & Feenan, 1987).

The fragmentation algorithm used by Snodgrass et al. divided the 256 X 256 pixel square into 16 X 16 pixel blocks, counted the total number of blocks containing black pixels, and then randomly and cumulatively deleted those blocks from the picture. To ensure that guessing would be minimal, the first three levels of fragmentation were retained for this study, corresponding to 8% (small CTTO), 12% (medium CTTO), and 17% (large CTTO) of the total number of non blank squares of the stimuli.

Because this experiment required a total of 256 pictures (two sets of 128 pictures each), it was necessary to generate 106 new fragmented stimuli. Moreover, Snodgrass and Vanderwart's (1980) pictures were available only for the Apple Macintosh, whereas the present experiment was performed on an IBM compatible. The complete set of 150 pictures was therefore ordered from Snodgrass (personal communication, 1992). Each non fragmented picture plus one of its fragmentation level (randomly chosen among the three retained) were digitized with a ScanMan Plus digitizer (manufactured by LOGITECH). The remaining 106 non fragmented pictures were digitized from the original Snodgrass and Vanderwart's (1980) set. To obtain the corresponding fragmented pictures, a computer program that follows the same rules as that of Snodgrass's team was written and used. Examples of the visual stimuli used in the present experiment and the level of CTTO to which they were assigned appear in Figure 3.

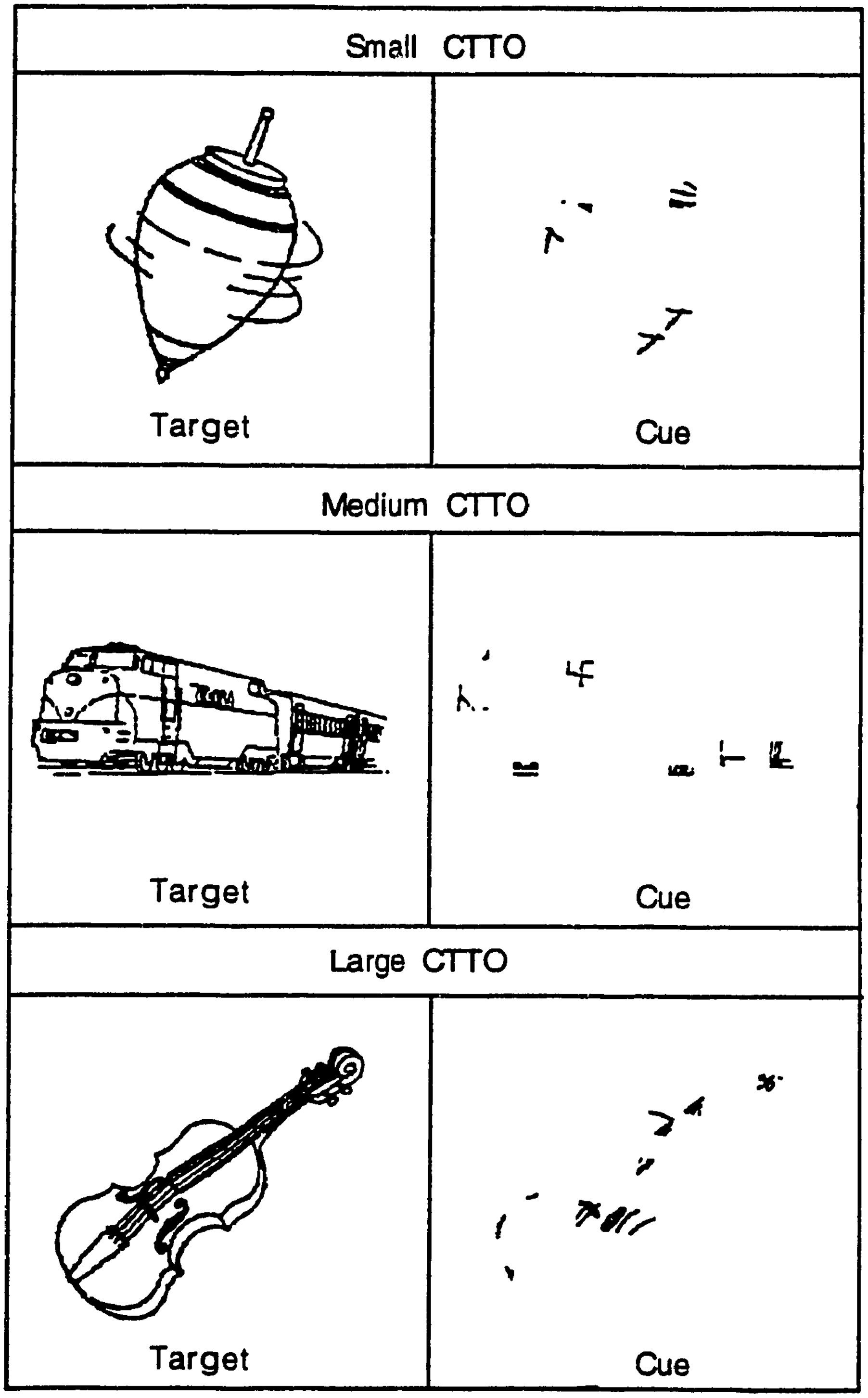

Figure 3. Examples of the visual stimuli used at each level of cue-to-target overlap (CTTO, Exp. 1).

Subjects

The criteria for participation included (a) living independently in the community, (b) English spoken as first language, (c) good or excellent self-assessed health, (d) a negative answer to the question "Are you suffering from any permanent health troubles that prevent you from doing the things you normally need to do each day?", and (e) current enrollment in university courses at Concordia University (to ensure that the general level of intellectual activity did not vary across age groups).

In order to control for recruitment bias (see Hertzog, 1990, March), it was originally planned to recruit all subjects from a booth on campus. Because only young students responded to that booth, the older subjects were contacted by telephone using a list of senior students provided by the University.

The final sample consisted of 48 young volunteers (19 males, 29 females), and 48 senior volunteers (18 males, 30 females). Mean age in the young group was 22.8 years (SD = 2.5), whereas mean age in the older group was 66.5 years (SD = 5.1). Subjects were offered $14 for their participation. In comparison to the young participants, older participants had more years of formal education, $t(94) = 2.48$ (young M = 14.3, older M = 15.0), were less depressed on the Memorial University of Newfoundland Scale of Happiness, $t(94) = 3.12$ (young M = 29.1, older M = 35.3), scored higher on the vocabulary scale from the WAIS-R, $\underline{t}(94) = 3.91$ (young $\underline{M}$ = 44.9, older $\underline{M}$ = 52.1), and scored lower on the block design from the WAIS-R, $\underline{t}(94) = 4.60$, (young $\underline{M}$ = 35.6, older $\underline{M}$ = 26.3). An additional 24 young adults (10 men, 14 women) and 24 older adults (9 men, 15 women) matched on educational background with the experimental subjects participated, as described below, in the generation of norms for the single letter verbal cues.

Design

Twelve conditions for each type of stimulus were created by crossing age (young or older) with list length (9 or 15 items) and CTTO (small, medium, or large). List length and CTTO were repeated measures variables. Order of administration of the verbal and visual tasks was systematically counterbalanced across subjects within age groups.

Procedure

Prior to the test session, subjects were administered the preliminary questionnaire. Subjects who met the criteria for participation were then tested individually in a single session of about two hours. After receiving general instructions and signing a consent form, subjects then were given the MUNSH and Digit symbol tasks followed by the memory tasks. The procedure was identical for the verbal and the visual tasks. The 10 lists of each task were presented, one target at a time, for a single study-test trial. Order of lists was constant for all subjects for each set. Each trial began with the message "X list(s) to come, are you ready?", where "X" corresponded to eleven minus the number of the trial.

The order of presentation of the targets within each list was randomized across subjects. Each target was displayed for 3 s and subjects were required to read it aloud and to try to memorize it. After the last target was presented, participants solved arithmetic problems for 20 s to control for recency effects. This buffer task involved subtracting 3 from three-digit numbers.

After the buffer task, the test phase specific to the just-presented list began. Recall order was the same across subjects. Each cue was presented until subjects made an oral response. If, after a delay of 20 s, no response had been made, the next cue was presented. If, before the end of the delay, subjects told the experimenter that they did not know the answer, they were prompted to say the first answer that came to mind. This answer was discarded if it was a plural or a proper name.

After all 10 lists of the first memory task, verbal or visual, had been presented and tested in this way, the vocabulary subtest of the WAIS-R was administered followed by the 10 lists of the second memory task. Upon completion of the second memory task, the norm generation task was given. Subjects were administered the alternate set of lists, A or B, to the set of lists used for the first memory task and were asked to respond with the first answer that came to mind within 20 s as long as that answer was not a plural or a proper name. The last task administered was the WAIS-R Block design test.

Although the experimental subjects generated norms for all CTTO levels with both types of stimuli, those generated for the single letter verbal stimuli (i.e., small CTTO) were not usable since the subject had seen a word beginning with that letter only a few minutes before. For that reason, a second sample, as described above, was recruited to generate norms for the small CTTO verbal cues, using the same instructions as had been used with the experimental subjects. These new norms replaced the small CTTO norms generated by the experimental subjects. The full sets of norms for verbal and visual stimuli are given in Appendices B, and C, respectively.

Results

Prior to analysis, the data were screened for outliers and for distributional anomalies that may violate the assumptions of statistical analyses. For both verbal and visual stimuli, subjects' memory scores for each Age X List Length X CTTO cell were obtained by subtracting the mean baseline completion rate across all words for that cell from the proportion of target items produced at test. The significance level for all tests was set at $p < .05$. Post hoc tests were Bonferroni-corrected t tests. The source table for the analysis of verbal memory is in Appendix E, and that for the analysis of visual memory is in Appendix G.

Analysis of means

Because results for Sets A and B did not differ for either the visual or the verbal tasks, the data were pooled across sets. In order to examine the effects of the experimental factors, several 2 (Age) X 2 (List Length) X 3 (CTTO) analyses of variance (ANOVAs) with age as the only between-subject factor were then computed.

Verbal memory. The Age X List Length X CTTO ANOVA on verbal memory scores showed main effects of age, List Length, and CTTO, all of which were modified by two-way interactions (Age X List Length, $F(1, 94) = 23.82$, $MS_e = .01$; Age X CTTO, $F(2, 188) = 3.70$, $MS_e = .01$; List Length X CTTO, $F(2, 188) = 6.37$, $MS_e = .01$). The Age X List Length interaction (see Figure 4) and follow-up post hoc tests showed that the performance of young subjects remained stable from 9-item to 15-item lists whereas the performance of older subjects significantly declined. The Age X CTTO interaction (see Figure 5) and follow-up post hoc tests suggested that although the young subjects significantly

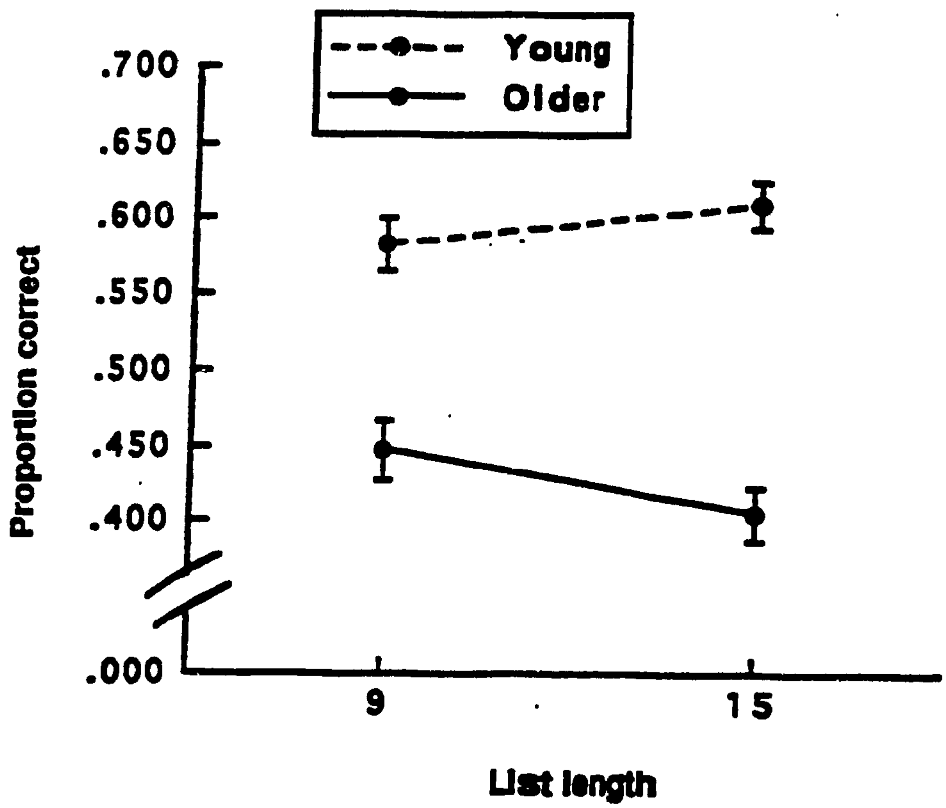

Figure 4. Proportion of remembered verbal stimuli as a function of age and list length (Exp. 1). Error bars indicate standard error of the mean.

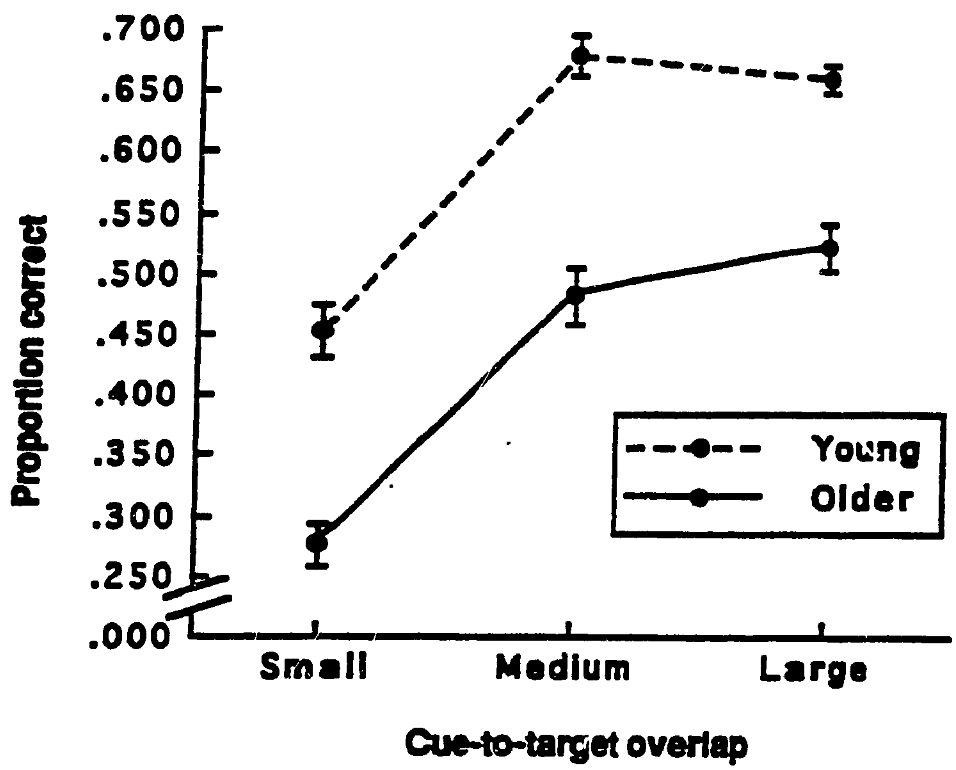

Figure 5. Proportion of remembered verbal stimuli as a function of cue-to-target overlap and age (Exp. 1). Error bars indicate standard error of the mean.

outperformed the older subjects at all CTTO levels, the magnitude of this superiority was greater with medium CTTO. Finally, the List Length X CTTO interaction (see Figure 6) and follow-up post hoc tests showed that when CTTO was low, subjects had significantly better memory for 9-item than for 15-item lists whereas when CTTO was medium or large subjects' performance was not affected by list length.

Visual memory. The Age X List Length X CTTO ANOVA on visual memory scores yielded a main effect of Age, $F(1, 94) = 43.30$, $MS_e = .09$, which indicated that the memory performance of young subjects (.406) was superior to that of older subjects (.242). There were also main effects of List Length and CTTO, but these effects were qualified by a List Length X CTTO interaction, $F(2, 188) = 10.23$, $MS_e = .01$. As shown in Figure 7, although performance increased with CTTO for both list lengths, the amount of increase was larger with 9-item lists than with 15-item lists. Post hoc tests revealed that the superiority of 9-item over 15-item lists was reliable with medium and large CTTO only. No other effects reached significance.

Clearly the analysis of means did not support the self-initiated operation hypothesis. Although the effect of age was significant for both types of stimuli, the expected Age X CTTO interaction was not found. For visual stimuli, there was no Age X CTTO interaction at all. For verbal stimuli, there was such an interaction, but it showed the magnitude

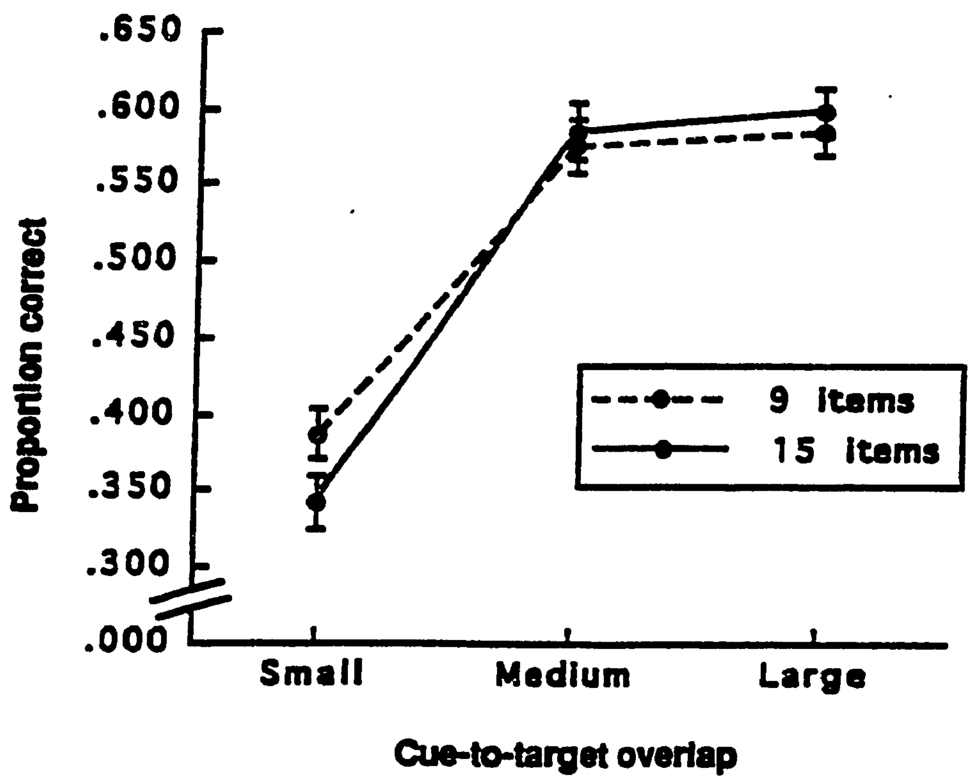

Figure 6. Proportion of remembered verbal stimuli as a function of cue-to-target overlap and list length (Exp. 1). Error bars indicate standard error of the mean.

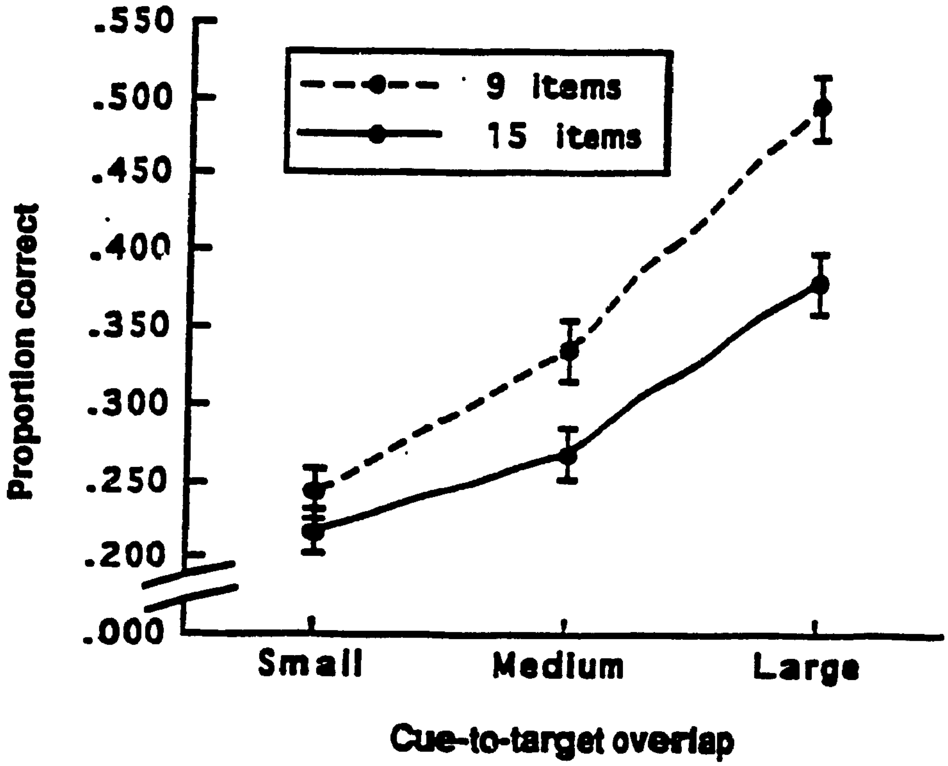

Figure 7. Proportion of remembered visual stimuli as a function of cue-to-target overlap and list length (Exp. 1). Error bars indicate standard error of the mean.

of ARDs to be greater for medium CTTO by comparison with the two other CTTO levels.

Analysis of correlations

As explained previously, analyses of means do not take the problem of differential sensitivity into account, whereas analyses of correlations do. It is therefore relevant to examine whether the conclusions to be drawn from the data remain the same once this problem is taken into account. As can be seen from Table 3, all the correlations between age group and performance were highly significant ($p < .001$), indicating that ARDs were found in every condition. Table 3 also shows that three comparisons (i.e., small-medium, small-large, medium-large) between point-biserial correlations involving age group and memory performance were available for each type of stimulus and for each list length, for a total of 12 comparisons. Of this total, only two of the nine comparisons that were in the expected direction of decreased negative correlation with increasing CTTO were significant. These two significant differences were found with visual stimuli: the correlation of age group with performance with the 9-item lists was significantly more negative, indicating a larger ARD, with small CTTO (-.59) than with either medium CTTO (-.44), or large CTTO (-.39) (ts(93) = 1.64, and 2.66, for medium, and large CTTO, respectively).

A second issue concerning correlations is that of

Table 3

Point-Biserial Correlation Between Age Group and Proportion of Remembered Items as a Function of Cue-to-Target Overlap, List Length, and Stimulus (Exp. 1)

	Cue-to-target overlap		
List length	Small	Medium	Large
	Verbal		
9	$-.40_a^{***}$	$-.46_a^{***}$	$-.38_a^{***}$
15	$-.61_a^{***}$	$-.63_a^{***}$	$-.55_a^{***}$
	Visual		
9	$-.59_a^{***}$	$-.44_b^{***}$	$-.39_b^{***}$
15	$-.49_a^{***}$	$-.51_a^{***}$	$-.46_a^{***}$

Note. A negative sign indicates the superiority of young over older subjects. Correlations that do not share a common subscript within a given row differ at $p < .05$.

$^{***}p < .001$

determining whether the constraint of processing resource limitations on memory performance decreases when CTTO increases as the self-initiated operations hypothesis would predict. The shorter latencies of young adults on the digit symbol task (M = 1.27 sec) as compared with older adults (M = 1.73 sec), $t(94) = 7.05$, $p < .001$, supports the hypothesis that there is an age-related decrement in response speed, one of the indices of processing resources (Salthouse, 1992). The correlations between processing resources and proportion of remembered items as a function of CTTO, list length, stimulus, and age group are displayed in Table 4. In that Table, a positive sign indicates that the greater the resources the better the memory performance, and a negative sign indicates that the greater the resources the poorer the memory performance.

As shown in Table 4, for young subjects with both verbal and visual stimuli the correlation between processing resources and performance tended not to be significantly greater than zero, whereas with older subjects the correlation between processing resources and performance tended to be highly significant. The meaning of this result will be discussed below.

The partial correlation between processing resources and performance with age group partialled out was significantly superior to zero in every condition for both verbal and visual stimuli. Of greater importance for the

Table 4

Correlation Between Processing Resources and Proportion of Remembered Items as a Function of Cue-to-Target Overlap, List Length, Stimulus, and Age Group (Exp. 1)

	9 items			15 items		
Group	Small	Medium	Large	Small	Medium	Large
			Verbal			
Young (n = 48)	$.11_a$	$.07_a$	$.22_a$	$.05_a$	$.22_a$	$.06_a$
Older (n = 48)	$.34_a^{*}$	$.50_a^{***}$	$.40_a^{**}$	$.45_a^{***}$	$.44_a^{**}$	$.39_a^{**}$
Age adjusted	$.22_a^{*}$	$.36_a^{***}$	$.36_a^{***}$	$.28_a^{**}$	$.37_a^{***}$	$.29_a^{**}$
			Visual			
Young (n = 48)	$.35_a^{*}$	$.20_a$	$.35_a^{*}$	$.25_a$	$.30_a^{*}$	$.25_a$
Older (n = 48)	$.32_a^{*}$	$.56_{ab}^{***}$	$.64_b^{***}$	$.43_a^{**}$	$.58_{ab}^{***}$	$.61_b^{***}$
Age adjusted	$.32_a^{***}$	$.43_{ab}^{***}$	$.55_b^{***}$	$.34_a^{***}$	$.46_{ab}^{***}$	$.51_b^{***}$

Note. A positive sign indicates that the greater the resources the better the memory performance, and a negative sign indicates that the greater the resources the poorer the memory performance. Correlations within the same list length condition that do not share a common subscript within a given row differ at $p < .05$.

$^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$

present study, however, were the comparisons of the partial correlations across CTTO levels. With verbal stimuli the correlation between processing resources and performance did not vary with increasing CTTO for both 9-item and 15-item lists. Although this result is at odds with the self-initiated operations hypothesis, it is in line with the prediction from the reduced processing resources framework in that when no variations in ARDs are found (as it was the case here with verbal stimuli, see Table 3) the correlation between processing resources and performance should be invariant.

With the visual stimuli the results are not in line with either hypotheses. Contrary to the self-initiated operations hypothesis the partial correlation between processing resources and performance was significantly more positive, suggesting greater resources demands, with large CTTO than with small CTTO, for both 9-item lists (pr large = .55, pr small = .32), $t(90) = 2.62$, and 15-item lists (pr large = .51, pr small = .34), $t(90) = 1.83$ (see Table 4). According to the reduced processing resources framework, the greater demands for resources with increased CTTO should have resulted in increased ARDs. However, as it was shown in Table 3, with 9-item lists ARDs decreased from small to large CTTO, and with 15-item lists they remained stable.

Discussion

Results of the present experiment with both verbal and visual stimuli suggest that ARDs in episodic memory do not decrease with increased CTTO even when the problem of differential sensitivity is controlled for. The only exception to this rule was with the 9-item lists of the visual stimuli where the correlation between age group and performance was significantly larger with small CTTO than with large CTTO. It is too soon to decide whether this exception is of any theoretical importance as the other results of the present experiment suggest that it may well be a Type I error.

Processing resources appeared to be more relevant to the performance of older adults than to that of young adults. It could be argued that processing resources are sufficiently available that their performance is not constrained by restrictions of speed or capacity. However, it may simply be that the within-group correlations for the young group were restricted by the smaller age range of that group. In the present experiment the variance in age was approximately one fourth for the young group ($\underline{S}^2 = 6.3$) than for the older group ($\underline{S}^2 = 26.0$). It is then not surprising that the standard deviation of the processing resources index was smaller for the young group (0.25 sec) than for the older group (0.37 sec) resulting in resources-performance correlations much smaller for the former than the latter.

Although the results of the present experiment are at odds with the self-initiated operations hypothesis, they are in line with the study conducted by Park and Shaw (1992). It thus does not seem to matter whether environmental support is defined as the number of first letters presented as cues in words of different lengths as Park and Shaw (1992) did or as CTTO as in the present experiment: invariance of ARDs in intentional cued recall tasks, at least with verbal stimuli, appears to be the rule rather than the exception.

Taken together, the results of the present experiment and those of Park and Shaw (1992) indicate that the variation in ARDs typically found among conventional episodic memory tasks (free recall, cued recall, and recognition) cannot be reproduced by varying environmental support within cued recall. It is possible, though, that in both Park and Shaw's (1992) study ard the present experiment the contrast between CTTO levels was not large enough by comparison to that in conventional episodic memory tasks to reveal variations in ARDs. Thus, a relevant study would be one that extended the range of CTTO levels beyond those used in the present experiment.

With verbal stimuli the stability in ARDs across different levels of CTTO can be attributed to the fact that the requirements in processing resources do not change when CTTO increases. In contrast, with visual stimuli the lack of variation in ARDs across CTTO levels (and even the decrease in ARDs over CTTO levels with the 9-item lists) co-occurred with an increased correlation of performance with processing resources, as CTTO increased. This result is indeed inconsistent with the reduced processing resources framework because according to this framework ARDs should be maximal under conditions where demands on processing resources are greatest.

The process dissociation framework proposed by Jacoby (1991; Jacoby & Kelley, 1992; Jacoby, Lindsay, & Toth, 1992; Jacoby, Ste-Marie, & Toth, 1993) can be used as an alternative perspective to understanding the present findings with both the verbal and visual stimuli. According to this framework, there is not a one-to-one mapping between episodic memory tasks and intentional processing. Instead, performance on memory tasks is thought of as depending on both intentional and automatic processes.

If Jacoby's hypothesis is correct, then the decrease in ARDs that has often been observed with environmental support could be due either to decreased requirements for self-initiated operations, which are presumably intentional, effortful, and sensitive to age (Craik, 1983), or to increased dependency on automatic operations, which are presumably unintentional, effortless, and insensitive to age (Hasher & Zacks, 1979).

Using the process dissociation framework CTTO effects on ARDs and on processing resource demands would be predicted to vary depending on the particular mix of intentional and automatic processes that were involved in the learning and memory performance of each age group with each type of stimulus under each CTTO condition.

The set of results found here with the verbal stimuli could be explained by assuming that, with these stimuli, the increase in CTTO was accompanied by stable demands for intentional processes that maintained constant the extent to which performance was constrained by processing resources, but at the same time was accompanied by a stability in automatic processes so that these processes did not interfere on the impact of intentional processes on ARDs.

Moreover, the puzzling set of results (from a resource model standpoint) found here with the visual stimuli could be explained by assuming that, with these stimuli, the increase in CTTO was accompanied by an increase in demands for intentional processes that increased the extent to which performance was constrained by processing resources, but at the same time was accompanied by an increase in automatic processes that offset the impact of greater processing demands on ARDs. This assumption makes intuitive sense since more informative cues are likely to elicit both more instances where a response spontaneously comes to mind and more extensive search processes when the response does not come to mind.

In summary, the results of the present experiment do not support the notion that manipulations of environmental support may reduce the magnitude of ARDs in episodic memory tasks. Moreover, the results of the present experiment are not consistent with the view that stability in ARDs across task conditions always reflects similar requirements in intentional processing.

The process dissociation procedure could be used to test an alternative approach that examines the impact of environmental support separately for automatic and intentional processes. However, before the process dissociation procedure can be used, it requires some explanation and also a further development of the technique to permit standard statistical analyses. Thus, the process dissociation procedure will next be described. This description will include some of the findings that are relevant for the study of the role of environmental support in aging. Jacoby's procedure will then be developed so that it can generate measures for individuals as well as for the group. Finally, it will be shown that such a hybrid model permits a test of the significance of any differences in automaticity and recollection (i.e., the result of effortful processing) at different levels of environmental support.

Chapter 3

Process dissociation procedure: An alternative methodology

Process dissociation procedure: An alternative methodology

According to Jacoby (1991), in a stem-completion task like that used in Experiment 1 there are three reasons for subjects to produce at test an item from the previously studied list. First, subjects may intentionally recall a list item. The probability of intentionally recalling a list item is called recollection by Jacoby. Second, some automatic processes may have been triggered while subjects were studying the list items. The probability that those processes produce at test an item from the studied list will be labeled priming in this dissertation. Third, even if no list of items had been studied there would be a probability of producing one of these items by chance. This probability is called base rate by Jacoby. Moreover, Jacoby labels automaticity the sum of base rate and priming. Therefore, when Jacoby discusses automatic processes, he means all the processes which are not intentional.

In order to measure the respective magnitudes of both intentional and automatic processes, Jacoby (1991) has developed the process dissociation procedure, which assumes that those processes are statistically independent. The process dissociation procedure involves both an inclusion condition and an exclusion condition. In a stem-completion task like that used in Experiment 1, the inclusion condition has the same instructions as those typically used in studies on intentional cued recall. Thus, subjects must try to complete stems with the words from the studied list or, if that cannot be done, to complete them with the first word that comes to mind. Performance on this condition is the probability of intentionally recalling a list item, that is, recollection, plus the probability of the list item automatically coming to mind when there is a failure of recollection (1 - Recollection):

$$Inclusion = Recollection + [Automaticity * (1 - Recollection)]. \quad (1)$$

In the exclusion condition, subjects are asked to try to complete stems with any words that are not from the list. A list item will therefore be produced only when it "automatically" comes to mind due to either guessing or priming, and the individual fails to recollect that it was from the list:

$$Exclusion = Automaticity * (1 - Recollection). \quad (2)$$

From looking at both Equations 1 and 2, one can see that recollection can be estimated as the probability of responding with a list item in the inclusion condition minus the probability of responding with a list item in the exclusion condition:

$$Recollection = Inclusion - Exclusion. \quad (3)$$

Once the magnitude of recollection is estimated, that of automaticity can be calculated with the following equation:

$$Automaticity = \frac{Exclusion}{1 - Recollection}. \tag{4}$$

Finally, to know how much the automaticity component has been specifically induced by prior exposure of the list items during study, one obtains a measure of priming by subtracting the baseline completion rate component from the result of Equation 4:

$$Priming = Automaticity - Base\ rate. \tag{5}$$

An example will illustrate the process dissociation procedure. Suppose that a particular subject obtained a score of .80 in the inclusion condition, and a score of .30 in the exclusion condition. From Equation 3, one is able to tell that the recollection component for the subject was .50 (i.e., .80 - .30). In other words, the probability that the subject intentionally remembered any word from the list was .50. From Equation 4, one also knows that the automaticity component of the subject was .60 (i.e., .30 ÷ (1 - .50)). That is, the probability that automatic processes made the subject produce any word from the list was .60. Now, suppose that the baseline completion rate was .40. This means that, even without prior exposure to the list, any word from the list has a probability of .40 to be mentioned. But because the subject participated in the study phase, some automatic processes were then triggered so that his or her total automaticity score is now greater than baseline completion rate. Specifically, the proportion of words from the list produced by priming would be .20 (i.e., .60 - .40).

Three experiments that Jacoby and his team have conducted are particularly relevant for the present purpose. Jennings and Jacoby (1993) examined the effects of dividing attention and of aging on the recognition of proper names. In the exclusion condition, subjects were told that all the earlier-read names were nonfamous, whereas in the inclusion condition, they were told that all the earlier-read names were famous. During the test phase participants were shown a list of both previous seen names and new names, and were asked to say whether the names were famous. Jennings and Jacoby found that, relative to young subjects whose attention was not divided, the intentional component was greatly reduced both in young subjects whose attention was divided and in older subjects. In contrast, the automatic component remained basically the same across all conditions.

In a series of two studies, Jacoby, Toth, & Yonelinas (1993, Exp. 1a & 1b), investigated again the possible independence of the intentional and the automatic components. Thirty-six undergraduate students were assigned to either a full or a divided-attention condition and their task was to try to remember a list of 5-letter common words. At test, participants were presented 3-letter stems. In the inclusion condition, those stems had to be completed with a word seen earlier, whereas in the exclusion condition they had to be completed with a word not seen earlier. In both studies, dividing attention completely eliminated the intentional component, whereas the automatic component remained stable.

The findings of Jacoby and his colleagues suggest that both divided attention and aging diminish the ability to execute intentional operations, whereas the ability to execute automatic operations remains intact. Moreover, the fact that the automatic component was well above zero in all conditions of those studies support the view that performance on episodic memory tasks is not based only on intentional operations.

Now that the process dissociation procedure has been described, it is possible to become more specific in explaining the results with visual stimuli of Experiment 1. One aspect of that experiment was that baseline completion rate was subtracted from the proportion of list items subjects produced in an inclusion condition. To understand the impact of subtracting baserate, one needs first to substitute automaticity by the sum of priming and baserate in Equation 1:

$$Inclusion = Recollection + [Automaticity * (1 - Recollection)]$$

$$= Recollection + (Priming + Baserate)(1 - Recollection)$$

$$= Recollection + Priming - (Priming * Recollection)$$

$$+ Baserate - (Baserate * Recollection).$$

Thus, if one subtracts baserate from the proportion of list items produced in an inclusion condition as required by the conventional measure of memory used in Experiment 1, one obtains:

$$Inclusion - Baserate = Recollection + Priming - (Priming * Recollection) - (Baserate * Recollection). \quad (6)$$

Equation 6 illustrates that subtracting baserate from the proportion of list items produced in an inclusion condition does not completely eliminate its effect on performance. However, because it is subtracted from the total score, the residual effect of baserate, as represented in the product of baserate by recollection, will tend to decrease estimates of memory, not increase them as it is the case normally with baserates. Moreover, given that in Experiment 1 baserate was a constant within age for each List Length X CTTO condition, the stability in the correlation between age and performance cannot be attributed to age differences in baserates because in an extreme group design as that used in Experiment 1, the point-biserial correlation between age and performance is identical to that between baserate and performance.

Equation 6 also illustrates a possible explanation for the stability in the correlation of age with performance observed with visual stimuli when CTTO increased in Experiment 1. This stability, which occurred despite the increasing demands for processing resources as indicated by the increasing correlation with performance as CTTO increased, could have been due to an increased priming component.

Even when baserate is subtracted from the proportion of list items produced in an inclusion condition (as it was the case with the conventional measure of memory used in Experiment 1), priming still inflates this proportion. This situation occurs because even if the product of priming and recollection is subtracted from the proportion of list items produced, this product will always be inferior to the priming component alone (the product of two proportions that are both inferior to one is always inferior to either of them).

Thus, the results of Experiment 1 can be explained by assuming that with visual stimuli environmental support increases both the priming component (which is independent of processing resources) and the recollection component (which is dependent on processing resources), at least over the range measured here, and that the increase in the recollection component is compensated for by an increase in the priming component.

In order to apply Jacoby's method for use in the present study, it is necessary to be able to measure the magnitude of both the recollection and the priming components at several levels of environmental support. There are two different approaches that can be used to derive sample means for the three memory components (i.e., recollection, automaticity, and priming) provided by the process dissociation procedure. A first approach, which is used by Jacoby and his colleagues (L. L. Jacoby, personal communication, February 4, 1994), consists of calculating recollection, automaticity, and priming scores for each subject separately, and then averaging these scores. It will be labelled the idiographic approach to process dissociation. A second approach involves averaging the performance of subjects in both the inclusion and exclusion conditions and then using these means to estimate recollection, automaticity, and priming. Because it gives the three memory estimates for the sample as a whole but not for individual subjects, the second approach will be labelled the nomothetic approach to process dissociation.

In the following pages, the idiographic and the nomothetic approaches will be compared and contrasted. It will be argued that because both approaches are limited in terms of the kinds of statistical analyses that can be performed, a hybrid approach to process dissociation is required, and that, with such a hybrid approach, the question of interest in this thesis can be addressed.

The idiographic approach to process dissociation

If one names the recollection score of a particular subject "recollection_i", then the proportion of list items this subject produced in the inclusion condition is called "inclusion_i", and the proportion of list items he or she produced in the exclusion condition is labelled "exclusion_i". The formula for calculating the recollection score of that subject is the following:

$$Recollection_i = Inclusion_i - Exclusion_i. \tag{7}$$

Equation 7 means that the recollection score of a particular subject is obtained by subtracting the proportion of list items he or she produced in the exclusion condition from the proportion of list items he or she produced in the inclusion condition.

Once the size of the recollection component for a particular subject has been calculated, two steps are required to find the size of his or her automaticity component (i.e., automaticity_i). The first step consists of subtracting the recollection component of the subject from one. The second step involves dividing the exclusion score of the subject from the result of the subtraction executed in the first step. Thus, one can write:

$$Automaticity_i = \frac{Exclusion_i}{1 - Recollection_i}. \tag{8}$$

The size of the priming component for a given subject (i.e., priming_i) under a given condition can be obtained by subtracting from the automaticity component of that subject the mean baseline completion rate for the particular combination of age group and retrieval task condition:

$$Priming_i = Automaticity_i - Base\ rate. \tag{9}$$

To obtain the mean recollection of the sample, one averages the recollection scores of individual subjects:

$$Mean\ recollection = \frac{\sum_{i=1}^{n} Recollection_i}{n}. \tag{10}$$

where n is the sample size. The same procedure is then applied with the automaticity scores:

$$Mean\ automaticity = \frac{\sum_{i=1}^{n} Automaticity_i}{n}, \tag{11}$$

and with the priming scores:

$$Mean\ priming = \frac{\sum_{i=1}^{n} Priming_i}{n}. \tag{12}$$

The nomothetic approach to process dissociation

As mentioned above, a second approach to process dissociation involves averaging the performance of subjects in both the inclusion and exclusion conditions and then using these means to estimate recollection, automaticity, and priming. In this nomothetic approach, the mean recollection is obtained by subtracting the mean score in the exclusion condition from that in the inclusion condition:

$$\textit{Mean recollection} = \frac{\sum_{i=1}^{n} \textit{Inclusion}_i}{n} - \frac{\sum_{i=1}^{n} \textit{Exclusion}_i}{n}. \tag{13}$$

Once the mean recollection has been calculated, two steps are required to find the mean automaticity score. The first step consists of subtracting the mean recollection from one. The second step involves dividing the mean exclusion score from the result of the subtraction executed in the first step. Thus, one can write:

$$\textit{Mean automaticity} = \frac{\frac{\sum_{i=1}^{n} \textit{Exclusion}_i}{n}}{1 - \textit{Mean recollection}}. \tag{14}$$

Finally, the mean priming score is obtained by subtracting the mean baseline completion rate of the sample from the mean automaticity score:

$$\textit{Mean priming} = \textit{Mean automaticity} - \textit{Base rate}. \tag{15}$$

Are the idiographic and nomothetic approaches equivalent?

An example will illustrate the observation that the nomothetic and idiographic approaches to process di sociation result in the same means for recollection but for divergent means for automaticity. Because the calculations used to derive the priming measure involves the subtraction of a constant (i.e., baseline completion rate) from automaticity, the nomothetic and idiographic approaches will also result in discrepant means for priming. In the following example, only recollection and automaticity scores will therefore be discussed as the conclusion drawn for automaticity scores also apply to priming scores.

Suppose that two subjects participated in both an inclusion and exclusion condition. Subject "A" obtained a score of .60 in the inclusion condition, and a score of .40 in the exclusion condition. As shown in Table 5, the recollection component for this subject is .20 (i.e., .60 - .40), whereas his or her automaticity component is .50 (i.e., .40 ÷ (1 - .20)). Subject "B" obtained a score of .40 in both the inclusion and the exclusion conditions, yielding a recollection componentof .00 and an automaticity component of .40. If the idiographic approach is used, the recollection components of the two subjects are averaged, and .10 is obtained. The automaticity components of the two subjects are then averaged, and .45 is obtained. Thus, according to the idiographic approach, the average recollection is .10, whereas the average automaticity is .45 (see Table 5). If the nomothetic approach is used, the inclusion and exclusion scores of the two subjects are averaged, yielding measures of .50 for inclusion and .40 for exclusion. The mean recollection is then computed by subtracting the mean exclusion score from the mean inclusion score and .10 is obtained. The mean automaticity is finally calculated. As shown in Table 5, it is .44.

Table 5

First Example of The Discrepancy Between The Idiographic Approach and The Nomothetic Approach in Mean Automaticity.

	Inclusion	Exclusion	Recollection	Automaticity
Subject "A"	.60	.40	.20	.50
Subject "B"	.40	.40	.00	.40
Idiographic mean			.10	.45
Nomothetic mean	.50	.40	.10	.44

Note. Recollection is obtained by subtracting Exclusion from Inclusion. Automaticity is obtained by dividing Exclusion by 1 - Recollection.

In the preceding example, both the idiographic and the nomothetic approaches lead to the conclusion that the mean recollection is .10. Results of the two approaches converge in the example because their respective formulas are algebraically equivalent:

$$\frac{\sum_{i=1}^{n} Recollection_i}{n} = \frac{\sum_{i=1}^{n} Inclusion_i}{n} - \frac{\sum_{i=1}^{n} Exclusion_i}{n}. \tag{16}$$

In contrast, the two approaches lead to different conclusions with respect to automaticity. According to the idiographic approach the mean automaticity is .45, whereas according to the nomothetic approach the mean automaticity is .44. Results of the two approaches diverge in the example because the formula used by the idiographic approach is not algebraically equivalent to that used by the nomothetic approach:

$$\frac{\sum_{i=1}^{n} Automaticity_i}{n} <> \frac{\frac{\sum_{i=1}^{n} Exclusion_i}{n}}{1 - Mean\ recollection}. \tag{17}$$

A relevant question then becomes: Which of the two approaches should be used to calculate the mean automaticity? A limitation with the idiographic approach comes from the fact that because sampling error is maximal in individual subjects, for some of them the exclusion score will be greater than the inclusion score, leading to a negative estimate of recollection. That the recollection score of some subjects will be negative is not a problem as far as the means for recollection are considered, since those means will be the same whether the idiographic or the nomothetic approach is used.

In contrast, that the recollection score of some subjects will be negative creates problem when estimating the mean automaticity with the idiographic approach. This problem occurs because, as shown in Equation 13, the automaticity score is obtained by dividing an individual's inclusion score by one minus his or her recollection score. When recollection is negative, the denominator of Equation 13 becomes greater than one, so that the automaticity score of the subject becomes smaller than his or her score in the exclusion condition. This phenomenon will result in an underestimation of the mean automaticity of the sample. The nomothetic approach avoids this problem because it averages exclusion scores before subtracting the mean thus obtained from the mean inclusion score. Since sampling error decreases as sample size increases, the probability that the mean exclusion score will be larger than the mean inclusion score will also decrease as sample size increases, so that a negative mean for recollection is never likely to occur.

An example will illustrate this point. Suppose that subjects "C" and "D" participated in a memory task using the process dissociation procedure and received the inclusion and exclusion scores shown in Table 6. As shown in that table, the recollection component for "C" is -.20 and the automaticity component is .50. For subject "D", the recollection component is .40 and the automaticity component is .33.

If the idiographic approach is used, the recollection components of the two subjects are averaged, and .10 is obtained. The automaticity components of the two subjects are then averaged, and .42 is obtained. Thus, according to the idiographic approach, the average recollection is .10, whereas the average automaticity is .42 (see Table 6). If the nomothetic approach is used, the inclusion and exclusion scores of the two subjects are averaged, yielding means of .50 for inclusion and .40 for exclusion. The mean recollection is then computed by subtracting the mean exclusion score from the mean inclusion score and .10 is obtained. The mean automaticity is finally calculated. As shown in Table 6, it is .44.

Thus, as it was the case with the example that involved subjects "A" and "B", the example that involves subjects "C" and "D" demonstrates that both the idiographic and the nomothetic approaches lead to the same mean for recollection. In contrast, only the example that involves subjects "C" and "D" shows that when at least one subject has a negative recollection score, the idiographic approach will tend to lead to an automaticity mean that is smaller than that provided by the nomothetic approach.

The two examples also illustrate a further problem with

Table 6

Second Example of The Discrepancy Between The Idiographic Approach and The Nomothetic Approach in Mean Automaticity.

	Inclusion	Exclusion	Recollection	Automaticity
Subject "C"	.40	.60	-.20	.50
Subject "D"	.60	.20	.40	.33
Idiographic mean			.10	.42
Nomothetic mean	.50	.40	.10	.44

Note. Recollection is obtained by subtracting Exclusion from Inclusion. Automaticity is obtained by dividing Exclusion by 1 - Recollection.

the idiographic approach to process dissociation. As shown in Tables 5 and 6, the mean for the inclusion condition is .50 in both examples. The mean for the exclusion condition is also the same in both examples, that is, .40. Thus, as long as those means are considered, there is no reason for the recollection and automaticity means to differ from the first to the second examples. Because it uses the inclusion and exclusion means as raw data, this regularity was picked up by nomothetic approach, which concluded that the mean automaticity component was .44 in the two examples.

In contrast, because it does not use the inclusion and exclusion means as raw data, the idiographic approach leads to the conclusion that the mean automaticity component is .45 in the first example, but .42 in the second example. Thus, the idiographic approach failed to capture the invariance of inclusion and exclusion means from the first to the second example. This situation is problematic because only the inclusion and exclusion scores of individual subjects are directly measured. In contrast, their recollection and automaticity scores are not measured: they are obtained from transformations of the inclusion and exclusion scores. Although these transformations lead to estimates of the real recollection and automaticity scores of subjects, the observation that the recollection scores obtained this way may be inferior to zero clearly illustrates that both the recollection and automaticity scores of particular subjects obtained from the process dissociation procedure are not error free. When the respective means for inclusion and exclusion are the same across studies, so should be the respective means for recollection and automaticity. Therefore, the idiographic approach has to be refined further.

Description of the hybrid approach to process dissociation

If the objective is only to obtain accurate means for automaticity and priming, the nomothetic approach appears to be better than the idiographic approach. A limitation with this approach, however, particularly for the present study is that because recollection, automaticity, and priming scores are not created for individual subjects, it is not possible to conduct statistical analyses. Hence, in the present case, one could not use the process dissociation procedure to test whether level of CTTO is significantly related to the recollection or automatic components of memory. In contrast, because it uses recollection and automaticity scores of individual subjects, the idiographic approach makes it possible to conduct statistical analyses. Unfortunately, as it was discussed previously, this approach does not guarantee strictly accurate means for automaticity and priming.

A more appropriate alternative than either the nomothetic or the idiographic approaches would be one that would use the mean for automaticity provided by the nomothetic approach but that would also keep the capacity of the idiographic approach to permit statistical analyses. Such a <u>hybrid</u> approach requires the following steps:

1) Individual recollection and automaticity scores are computed.

2) The mean for automaticity is calculated using the nomothetic approach.

3) The mean for automaticity is calculated using the idiographic approach.

4) The mean for automaticity provided by the idiographic approach is subtracted from that provided by the nomothetic approach to yield a correction factor.

5) The correction factor obtained in the previous step is added to the individual automaticity scores.

6) The new automaticity scores replace those obtained in Step 1 in computing the priming scores of individual subjects.

An example will illustrate the hybrid approach. Suppose that subjects "E" and "F" participated in both an inclusion and exclusion condition. Subject "E" obtained a score of .80 in the inclusion condition, and a score of .30 in the exclusion condition. As shown in Table 7, the recollection component subject "E" is .50 and the automaticity component is .60. Subject "F" obtained a score of .60 in the inclusion condition, and a score of .40 in the exclusion condition. As

Table 7

Example of The Scores Produced by The Hybrid Approach to Process Dissociation.

	Inclusion	Exclusion	Recollection	Automaticity	Corrected Automaticity
Subject "E"	.80	.30	.50	.60	.59
Subject "F"	.60	.40	.20	.50	.49
Nomothetic mean	.70	.35	.35	.54	
Idiographic mean			.35	.55	
Correction factor				-.01	
Hybrid mean			.35		.54

Note. Recollection is obtained by subtracting Exclusion from Inclusion. Automaticity is obtained by dividing Exclusion by 1 - Recollection. The correction factor is obtained by subtracting the idiographic mean from the nomothetic mean.

shown in Table 7, the recollection component subject "F" is .20 and his or her automaticity component is .50.

The nomothetic approach being first used, the inclusion and exclusion scores of the two subjects are averaged, yielding .70 for inclusion and .35 for exclusion. The mean recollection is then computed by subtracting the mean exclusion score from the mean inclusion score and .35 is obtained. The mean automaticity is finally calculated. As shown in Table 7, it is .54.

The idiographic approach is next used in that the automaticity components of the two subjects are averaged, and .55 is obtained. Thus, according to the idiographic approach, the average automaticity is .55 (see Table 7). The mean automaticity given by the idiographic approach is subtracted from the mean automaticity given by the nomothetic approach. The correction factor is thus -.01. The automaticity score of subject "E" is .60; the corrected automaticity score of this subject is therefore .59. The automaticity score of subject "F" is .50; the corrected automaticity score of that subject is therefore .49. The respective priming scores of subjects "E" and "F" would next be calculated by subtracting their respective baseline completion rates from their corrected automaticity scores.

Chapter 4

Experiment 2

Experiment 2

Results of Experiment 1 suggested that, whereas with verbal stimuli a stability in the magnitude of ARDs with increasing CTTO co-existed with stable demands for processing resources, with visual stimuli a stability in the magnitude of ARDs with increasing CTTO co-existed with increasing demands for processing resources. If these results are replicable, then one way of attempting to find out why the pattern of results differs for the two types of stimuli is to analyse performance into recollection and priming components. If, with visual stimuli, increasing levels of environmental support result in an increase in recollection that is compensated for by an increase in priming, the increase in recollection would explain why the correlation between processing resources and performance increased with CTTO, and the increase in priming would explain why ARDs remained stable with increasing CTTO. The first objective of Experiment 2 was therefore to examine the replicability of the pattern of results found in Experiment 1 under conditions where it was possible to analyse performance into recollection and priming components.

The second objective of Experiment 2 was to determine whether processing resources predict performance on the following three measures: the conventional measure of memory, recollection, and, finally priming. If, as originally suggested by Hasher and Zacks (1979), automatic processes are not constrained by the amount of processing resources one possesses, then there should be a zero correlation between processing resources and the size of the priming component. Moreover, if, as hypothesized by Jacoby (1991), recollection represents a pure measure of the role of intentional processes whereas the conventional measure of memory is contaminated by automatic processes, then the correlation between processing resources and recollection should be greater than that between processing resources and the conventional memory measure.

There is a large body of literature suggesting a lack of age differences in priming (see Salthouse, 1992, for a review). A limitation with this literature is that the evaluation of the priming component may have been inflated by the intrusion of intentional processes. Because the process dissociation procedure permits the calculation of a priming component that is free from intrusions of intentional processes, the third objective of Experiment 2 was to test the hypothesis of age invariance of automatic processes using the purer estimate of priming provided by the process dissociation procedure.

The fourth objective of Experiment 2 was to verify whether the lack of variation in ARDs observed in Experiment 1 was caused by not having a large enough CTTO level. In order to fulfill this objective, the smallest of the three CTTO levels of Experiment 1 was replaced by a CTTO level in

Experiment 2 that was larger than any used in Experiment 1. An advantage of this change was that it avoided the problem of requiring a separate norm generation sample for single-letter verbal cues.

The design of Experiment 2 was changed in two other respects from that of Experiment 1. First, in order to make it possible to dissociate the recollection and priming components, both an inclusion and an exclusion conditions were used. The inclusion condition corresponded to the standard procedure used in Experiment 1. Second, in Experiment 2 only one list length was used for each type of stimulus. This change was made to simplify the experimental design, and also because a pretest showed that with lists as short as those used in Experiment 1, young subjects did not produce list items as intrusions in the exclusion condition.

Pretests also showed that when the stimuli were words, both age groups were able to work with a list of 72 items. A list length of 72 items was selected so that there would be 12 items in each combination of inclusion-exclusion and level of CTTO. In contrast, when the stimuli were drawings, the proportion of list items produced by older adults in the inclusion condition of a 72-item list approached chance. Further pretesting showed that 18-item lists were the longest that could be used with older adults. It was therefore decided to divide the list of 72 drawings into four lists of 18 drawings each.

Experiment 2 also introduced a refinement into the Jacoby procedure in order to take into account a recent criticism by Komatsu, Graf, and Uttl (in press). They pointed out that a critical assumption of the process dissociation procedure is that the size of the automaticity component in the inclusion condition is the same as in the exclusion condition. To evaluate this assumption they introduced at test non-studied familiar words, that is, words that have large baserates. If the size of the automaticity component in the inclusion condition is the same as in the exclusion condition, the false alarm probability, that is, the probability of mistakenly declaring that the non-studied familiar words were members of the studied list should be the same for both the inclusion condition and the exclusion condition. Komatsu et al. (in press) found that false alarm rates were significantly higher in the inclusion condition than in the exclusion condition. These results suggest that subjects are less conservative in the inclusion condition than in the exclusion condition so that the assumption that automaticity is invariant for inclusion and exclusion would not be valid.

Komatsu et al.'s critique applies also to the evaluation of the recollection component in that if subjects are less conservative in the inclusion condition than in the exclusion condition their recollection score will be artificially high. One way to take the results of Komatsu et al. (in press) into account requires first to calculate, for each Age X CTTO X Retrieval Task (i.e., inclusion or exclusion) cell, the proportion of cues completed with an acceptable answer. With verbal stimuli an acceptable answer is defined as any word that fits the cue and that is neither a plural nor a proper noun, whereas with visual stimuli it is defined as any drawing that fits the cue. The conservatism scores thus produced are then used to adjust both the recollection and the priming components.

For example, suppose the extreme case whereby a group of subjects would have produced twice as many acceptable answers in the exclusion condition than in the inclusion condition. According to the proposed correction method, an unbiased measure of recollection would be computed by dividing the proportion of list items produced in the exclusion condition by two before subtracted it from the proportion of list items produced in the inclusion condition. An unbiased measure of priming would then be calculated by subtracting baserate from the quotient of the corrected exclusion score divided by the corrected recollection score already computed. A fifth objective of Experiment 2 was to use this new correction method in order to examine whether it gives the same pattern of results as when no correction method is used.

To summarize, Experiment 2 had five objectives: (a) to use the process dissociation procedure to examine the replicability of the pattern of results found in Experiment 1 and the relationship of that pattern to recollection and priming, (b) to determine the extent to which processing resources predict performance on the conventional measure of memory, recollection, and priming, (c) to test the hypothesis of age invariance of automatic processes, (d) to verify whether the lack of variation in ARDs observed in Experiment 1 was caused by not having a large enough CTTO level, and (e) to examine whether conservatism varies as a function of age, CTTO, and retrieval task (i.e., inclusion or exclusion), and if so, whether correcting for this factor changes the pattern of results.

Method

Stimulus materials

Verbal memory lists. Two lists, A and B, of 72 words each were created (see Appendix M). Each list contained two-syllable common words that were 6-letter long. In the test phase, one third of the words of each list were tested with 2-letter cued recall (medium CTTO), one third with 3-letter cued recall (large CTTO), and the last third with 4-letter cued recall (very large CTTO). The number of letters to be filled in to complete the word was indicated by dashes. Each cue was chosen so that it could be filled with at least two words from the lexicon and so that it would fit only one list item. To minimize cohort differences in familiarity with the words, the average difference between Thorndike and Lorge's (1944) count and Kucera and Francis's (1967) count was no greater than ±7 within each level of CTTO.

Visual memory lists. Eight lists of 18 drawings each were created, four in each of the sets A and B (see Appendix H). As in Experiment 1, all the drawings came from Snodgrass and Vanderwart's (1980) standardized set of 260 pictures. The three levels of fragmentation retained for this study were the second, third, and fourth levels used by Snodgrass et al. (1987). That is, these levels corresponded to 12% (medium CTTO), 17% (large CTTO), and 24% (very large CTTO) of the total number of non blank squares of the drawings. The stimuli used for medium and large CTTO levels were a subset of those used in Experiment 1. The stimuli used for very large CTTO levels were a subset of those used in the small CTTO level of Experiment 1.

Other materials. The control measures and the digit symbol substitution measure of processing resources were the same as those used in Experiment 1.

Subjects

The criteria for participation were the same as those for Experiment 1, except that older subjects did not have to be currently studying at a university. Subjects who participated in Experiment 1 were excluded. Young subjects were recruited through ads put on the various bulletin boards of Concordia University. Older subjects were recruited from the Senior Students Association of Concordia University, and from a booth at a conference for senior citizens.

The final sample consisted of 48 young adults (24 males, 24 females) and 48 older adults (24 males, 24 females), except for the visual memory task where the sample of older adults was reduced to 40 due to a problem with the software used. Subjects were offered $14 for their participation. Mean age in the young group was 22.6 years (SD = 2.6), whereas mean age in the older group was 66.0 years (SD = 4.9). There was no difference between the age groups in the number of years of formal education (young M = 14.5, older M = 14.8).

In comparison to the young participants, older participants were less depressed on the Memorial University of Newfoundland Scale of Happiness, $t(94) = 2.08$ (young M = 30.3, older M = 33.8), scored higher on the vocabulary scale from the WAIS-R, $t(94) = 1.99$ (young M = 46.1, older M = 49.0), and scored lower on the block design from the WAIS-R, $t(94) = 5.81$ (young M = 36.0, older M = 23.3).

Thus, the only difference between the participants of the two experiments was that in Experiment 1 the older subjects had more years of education than the young subjects, whereas in Experiment 2 the two age groups did not differ in years of education.

Design

Six conditions were created for each type of stimulus (verbal or visual) and each measurement condition (inclusion or exclusion) by crossing age (young or older) with CTTO (medium, large, or very large). Age was the only between-subject factor.

Procedure

Subjects were tested individually in a single session of about two hours. The general sequence of tasks was the same for all subjects and was the same as that used in Experiment 1. The specific sequence of visual and verbal tasks was counterbalanced so that half the subjects in each age group did the visual memory task before the verbal memory task and likewise the visual memory norm before the verbal memory norm, and the other half did them in the reverse order.

As in Experiment 1, the order of presentation of the targets within each study list was randomized across subjects. Targets were displayed for 3 s each, and subjects were asked to say the name of the target aloud before trying to memorize it. After the last target of a list was presented, the buffer task described in Experiment 1 was administered followed by the test phase specific to the just-studied list. Just before starting the test phase, subjects were reminded about the instructions specific to inclusion and exclusion.

As in Experiment 1, order of items at test was constant across subjects. The lists of cues for both verbal and visual stimuli were presented in such a way that the average retention interval was constant across levels of CTTO as well as across the inclusion and exclusion conditions. Both level of CTTO and retrieval task (inclusion or exclusion) were varied within lists rather than across lists so that, at time of study, subjects would not know which level of CTTO and retrieval task a specific item would belong to at testing. Moreover, conditions were counterbalanced across targets and subjects so that every target was tested equally often in the inclusion and exclusion conditions. The message "THE ANSWER FROM THE LIST" appeared on top of the computer screen for both verbal and visual stimuli during testing in the inclusion condition. In contrast, the message "NOT THE ANSWER FROM THE LIST" was used for both types of stimuli during testing in the exclusion condition. These messages also were spoken out loud by the experimenter as soon as they appeared on the screen. The message appeared at the same time as the cue and remained visible as long as the cue remained visible.

Each cue was presented until subjects made a response, which was typed by the experimenter. If, after a delay of 30 s, no response had been made, the next cue was presented. Subjects who, prior to the end of the delay period, stated that they did not know the target (inclusion condition) or that they could not think of an alternate word to the target (exclusion condition) were encouraged to continue trying to come up with an appropriate response before the time expired.

The colors of stimuli in the study phase of the two memory tasks and also in the norm tasks were the same as in Experiment 1. In contrast, the colors used in the test phase depended upon whether the condition was inclusion or exclusion, and whether the stimuli were verbal or visual. For verbal stimuli, both the message "THE ANSWER FROM THE LIST" and the retrieval cue were presented in green in the inclusion condition, whereas both the message "NOT THE ANSWER FROM THE LIST" and the retrieval cue were presented in red in the exclusion condition. For visual stimuli in the inclusion condition, the message "THE ANSWER FROM THE LIST" was presented in white letters and the retrieval cue was presented in the same colors as in the study phase while the remainder of the screen was colored green. In the exclusion condition, the message "NOT THE ANSWER FROM THE LIST" and the retrieval cue were presented in the same colors as in the inclusion condition while the rest of the screen was colored red.

General results of Experiment 2

Because results for Sets A and B did not differ for either the visual or the verbal tasks, the data were pooled across sets. Only effects that were significant at $p < .05$ are reported and post hoc tests were all Bonferroni-corrected t tests. In contrast to Experiment 1, the results were such that the same method of analysis could not be used for both verbal and visual stimuli. The results for visual stimuli will be presented first and they will also be discussed before the results for verbal stimuli are reported. The source tables for the various analyses for visual stimuli are in Appendices I to L, and those for the various analyses for verbal stimuli are in Appendices O to U.

Results and Discussion: Visual Stimuli

Analysis of means

Baseline rates. A 2 (Age) X 3 (CTTO) ANOVA was conducted on the norm generation data for visual stimuli. The main effects of Age and CTTO were qualified by an Age X CTTO interaction, $F(2, 188) = 7.39$, $MS_e = .01$. As shown in Figure 8, young subjects produced more targets on the norm generation task than older subjects at all CTTO levels, and the magnitude of this advantage increased with increasing CTTO. Post hoc tests revealed that the baseline guessing rates of young subjects were significantly greater than

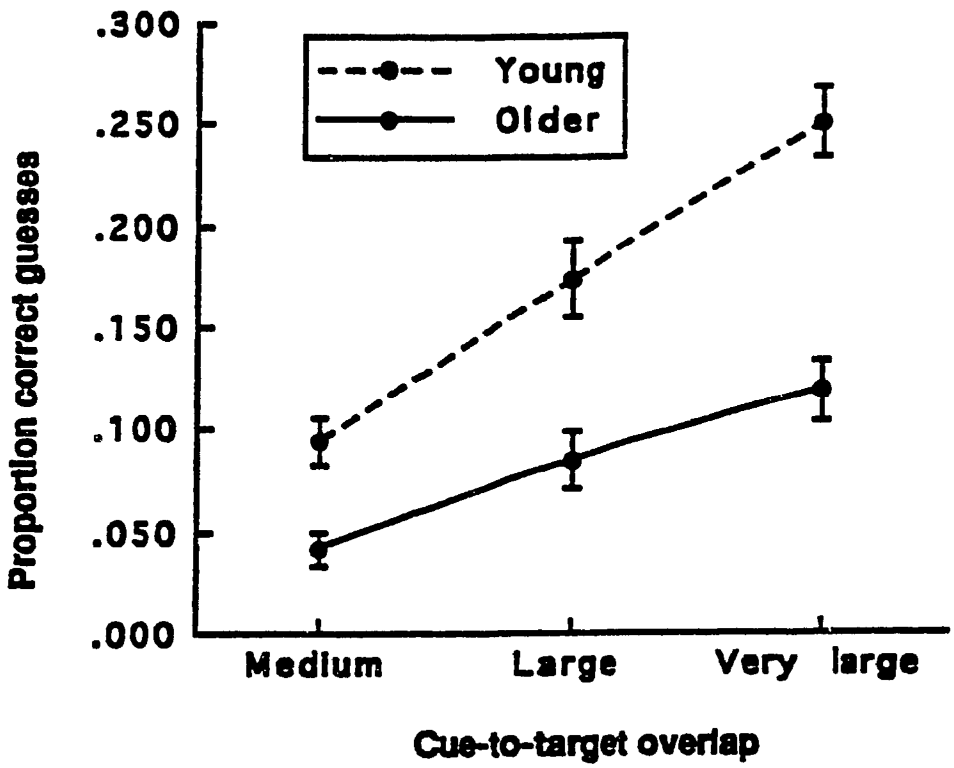

Figure 8. Baseline rates of visual stimuli as a function of cue-to-target overlap and age (Exp. 2). Error bars indicate standard error of the mean.

those of older subjects at all CTTO levels.

Thus, the baseline rates showed the same trends as in Experiment 1 in that they increased with CTTO for both young and older subjects, and that young subjects benefitted disproportionately from increasing CTTO.

Conventional episodic memory analysis. A 2 (Age) X 3 (CTTO) ANOVA was performed on the proportion of visual cues completed with a list item in the inclusion condition, proportion from which baserate specific to each Age X CTTO cell was subtracted. Only the main effects were significant. Young subjects (.447) recalled more than older subjects (.231), $F(1, 86) = 58.02$, $MS_e = .05$, and recall steadily increased with CTTO, $F(2, 172) = 23.11$, $MS_e = .02$. Means were .286, .344, and .416, for medium, large, and very large CTTO, respectively. Post hoc tests revealed that these three means were all significantly different from one another.

Proportion of cues completed with a list item. A 2 (Age) X 2 (Retrieval Task: inclusion/exclusion) X 3 (CTTO) ANOVA was performed on the proportion of cues completed with a list item. Completions with list items correspond to correct responses (uncorrected for guessing) in the inclusion condition and incorrect intrusions in the exclusion condition. The main effects of Age, Retrieval Task, and CTTO were qualified by two-way interactions. The Age X Retrieval Task interaction (see Figure 9) and follow-up post hoc tests, $F(1, 86) = 113.90$, $MS_e = .03$, showed that

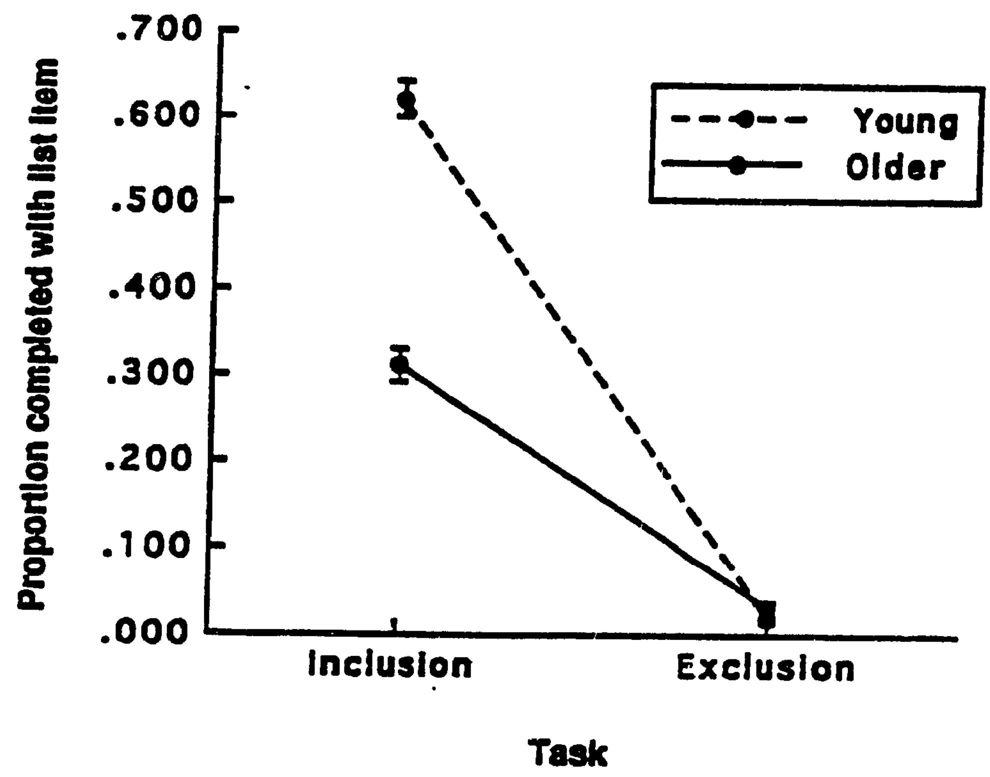

Figure 9. Proportion of visual cues completed with a list item as a function of retrieval task and age (Exp. 2). Error bars indicate standard error of the mean.

young adults had a greater proportion of cues correctly completed with a list item than older adults in the inclusion condition whereas the two groups did not differ in the proportion of cues erroneously completed with a list item in the exclusion condition. The Retrieval Task X CTTO (see Figure 10) and follow-up post hoc tests, $\underline{F}(2, 172) = 67.64$, $\underline{MS}_e = .01$, indicated that the proportion of cues correctly completed with a list item in the inclusion condition increased with CTTO, whereas the proportion of cues incorrectly completed with a list item in the exclusion condition was unrelated to CTTO. Further, the proportion of cues correctly completed with a list item in the inclusion condition was superior to the proportion of cues incorrectly completed with a list item in the exclusion condition at all CTTO levels.

Because the proportion of cues erroneously completed with list items in the exclusion condition was near zero and well below the mean proportion of list items produced in the baseline task, one must assume that subjects either had perfect memory, a hypothesis not supported by performance in the inclusion condition, or that they were able to use some strategy to enhance exclusion performance. In any event, it is obvious that, given an observed intrusion rate that is much smaller than baserate, one cannot use Jacoby's formulas to calculate recollection, automaticity, and priming.

When the scores from the exclusion condition cannot be

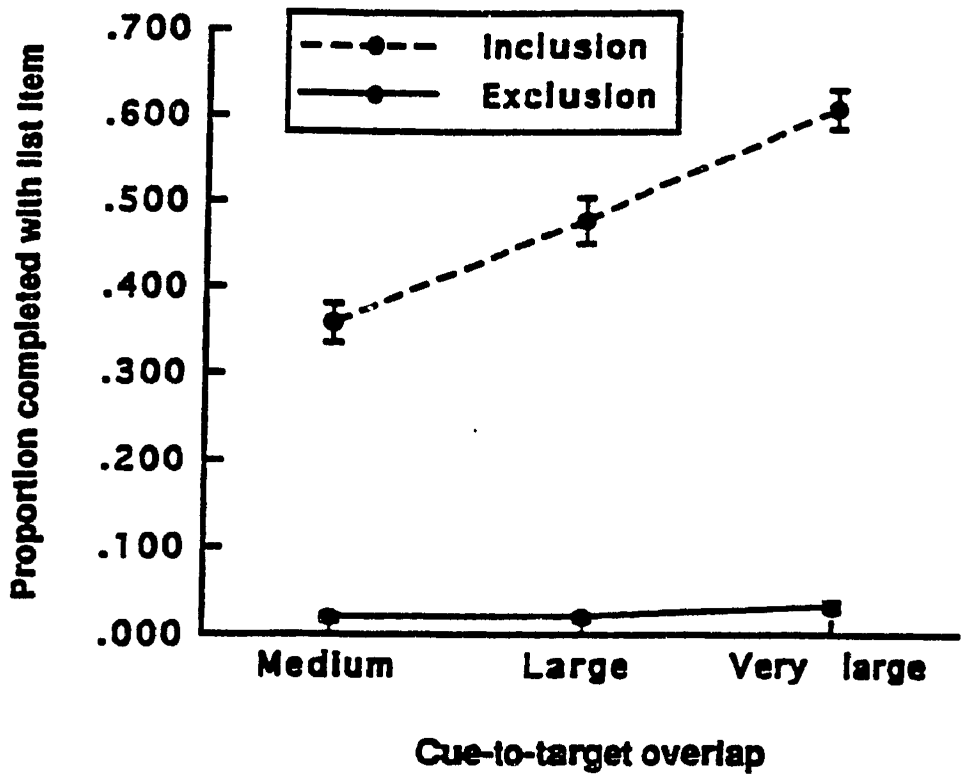

Figure 10. Proportion of visual cues completed with a list item as a function of retrieval task and cue-to-target overlap (Exp. 2). Error bars indicate standard error of the mean.

used, the best estimate of the proportion of list items produced by intentional processes is to subtract baseline completion rate from the proportion of list items produced in the inclusion condition, or, in other words, to do the "conventional episodic memory analysis" reported above. Thus, only the conventional scores, in addition to the directly measured inclusion and exclusion scores, were considered in further analyses.

<u>Analysis of correlations</u>

The point-biserial correlations between age group and the different measures involving visual stimuli for the conventional memory measure and for the inclusion and exclusion measure are displayed in Table 8. A positive sign indicates the superiority of older over young subjects, and a negative sign indicates the superiority of older over young subjects, and a negative sign indicates the superiority of young over older subjects. Young subjects were significantly superior to older subjects on the inclusion and conventional memory measures, but neither age group was superior to the other on the exclusion measure. For none of these measures did the magnitude of the correlations change significantly with increasing CTTO.

The question of whether processing resources become less relevant when CTTO increases, as the self-

Table 8

Point-Biserial Correlation Between Age Group and Proportion of List Items Produced as a Function of Cue-to-Target Overlap, and Sccre: Visual Stimuli (Exp. 2)

	Cue-to-target overlap		
Score	Medium	Large	Very large
Inclusion	$-.65_a^{***}$	$-.67_a^{***}$	$-.71_a^{***}$
Exclusion	$.19_a$	$.08_a$	$.13_a$
Conventional measure[a]	$-.58_a^{***}$	$-.54_a^{***}$	$-.50_a^{***}$
Recollection[b]	NA	NA	NA
Priming[c]	NA	NA	NA

Note. NA = Not available. A positive sign indicates the superiority of older over young subjects, and a negative sign indicates the superiority of young over older subjects. Correlations that do not share a common subscript on a given row differ at $p < .05$.

[a]Inclusion - Baserate. [b]Inclusion - Exclusion. [c](Exclusion ÷ (1 - Recollection)) - Baserate.

$^{***}p < .001$

initiated operations hypothesis would predict, was also examined. Young adults (M = 1.23 sec) had significantly more processing resources, as reflected in shorter Digit symbol latencies, than older adults (M = 1.75 sec), $t(94) = 8.13$, $p < .001$. The correlations between processing resources and the conventional measure of episodic memory as a function of CTTO and age group are displayed in Table 9. The superiority of young over older subjects. Young subjects were significantly superior to older subjects on the inclusion and conventional memory measures, but neither age correlations have been calculated so that a positive sign indicates that the greater the resources the better the memory performance, and a negative sign indicates that the greater the resources the poorer the memory performance.

As shown in Table 9, with young subjects processing resources were a significant predictor of performance at each CTTO level. In contrast, with older subjects processing resources were a significant predictor of performance only with very large CTTO. Moreover, for the older subjects the correlation between processing resources and performance was negative (-.41), suggesting the counter-intuitive conclusionthat the greater the processing resources the poorer the performance.

When age group was partialled out, the correlation between processing resources and performance was significantly different from zero with both medium CTTO

Table 9

Correlation Between Processing Resources and The Conventional Measure of Episodic Memory as a Function of Cue-to-Target Overlap, and Age Group: Visual Stimuli (Exp. 2)

	Cue-to-target overlap		
Group	Medium	Large	Very large
Young (n = 48)	$.43_a^{**}$	$.57_a^{***}$	$.32_a^{*}$
Older (n = 40)	$-.05_a$	$-.03_a$	$-.41_b^{**}$
Age adjusted	$.19_a^{*}$	$.27_a^{**}$	$-.12_b$

Note. A positive sign indicates that the greater the resources the better the memory performance, and a negative sign indicates that the greater the resources the poorer the memory performance. Correlations that do not share a common subscript on a given row differ at $p < .05$.

$^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$

(*pr*(85) = -.19), and large CTTO (*pr*(85) = -.27), but not with very large CTTO (*pr*(85) = .12). A more important question was whether the partial correlations differed significantly across CTTO levels. As Table 9 shows, the correlation between processing resources and performance was significantly smaller with very large CTTO than with either medium CTTO, $t(82) = -2.73$, or large CTTO, $t(82) = -3.48$.

Discussion of results with visual stimuli

When targets were visual stimuli in Experiment 2, ARDs in memory performance corrected for the problem of differential sensitivity remained stable with increasing CTTO. This finding is in line with most of the results of Experiment 1 and supports the suggestion that the one exception, the finding with the 9-item visual lists of a larger ARD in the small CTTO condition compared with the medium and large CTTO conditions, was probably a Type I error.

In both Experiments 1 and 2, the correlation between processing resources and memory performance when age group was partialled out remained stable from medium to large CTTO. This result is in line with the reduced processing resources approach which predicts that stability in ARDs should co-occur with stability in the relevance of processing resources. With very large CTTO the correlation between processing resources and the proportion of remembered stimuli was significantly lower than with medium or large CTTO, a result consistent with the self-initiated operations hypothesis in that a greater level of environmental support (more CTTO) should reduce demands on processing resources.

However, inconsistent with both the self-initiated operations hypothesis and the reduced processing resources framework, the magnitude of ARDs remained constant with very large CTTO despite the decline in the correlation of processing resources and performance. Even more puzzling for the reduced processing resources framework is the picture with the two age groups considered separately. The young subjects showed no change across CTTO levels but at least better performance was consistently and significantly associated with greater processing resources. For older subjects, in contrast to the results of the older subjects of Experiment 1, the correlation between processing resources and performance was not significant with either medium or large CTTO, and with very large CTTO it was significant in the unpredicted direction, better performance being associated with less demands on processing resources. One possibility is that for the older subjects the task was so difficult that the true recollection was near zero, making processing resource limitations essentially irrelevant to performance. With very large CTTO there is sufficient information in the cue that subjects who rely on guessing, rather than attempting to recollect, have greater probability of success, leading to the negative correlation between processing resources and performance.

Another surprising result of Experiment 2, and the one that made it impossible to test the hypothesis concerning changes in priming and recollection with increasing CTTO, was the observation that the proportion of cues erroneously completed with list items in the exclusion condition was below the mean proportion of list items produced as correct guesses in the baseline task. As already suggested there are at least two possible reasons for this outcome. First, if recollection is near perfect, subjects will identify the list items most of the time, and therefore not report them in the exclusion condition. Second, subjects may opt to use any one of a number of strategies that would affect the probability of giving a list item in the exclusion condition but would be essentially unrelated to recollection. They may not produce an answer either so as to be sure not to mention a list item or because they cannot find an item other than the list item to fit the cue. Alternatively, they may develop a strategy to mention items that they are sure are not from the list.

The results observed with visual stimuli were probably caused by a mixture of the above reasons. Although the proportion of list items found in the inclusion condition was inferior to .5 at all CTTO levels for older subjects, this proportion was superior to .5 at both large and very large CTTO levels for young subjects (see Table 10). This result means that whereas the older subjects could not find the list item for the majority of the cues, the young subjects could. Thus, as far as young subjects are concerned, it is possible that the task was too easy when CTTO was large or very large. It is also possible that both young and older subjects were less willing to provide answers in the exclusion condition in comparison with the inclusion condition or were simply unable to find an alternate to the list item. If either of these occurred, fewer answers would be given in the exclusion condition than in the inclusion condition, as was indeed the case (see Table 10). Finally, with visual stimuli, much more than with verbal stimuli, subjects could develop a strategy of naming items that they were sure were not from the list. This situation was due to a basic difference between verbal and visual stimuli. When targets are words, there is only a small set of easily identifiable answers that fit the cue provided at test phase. In contrast, when targets are drawings, the number of drawings that are reasonably compatible with a specific pattern of dots is large. For this reason, in the exclusion condition, subjects simply had to come up with a name that did not correspond to any drawing they had seen in the study phase and then to say it aloud, hoping that the experimenter would accept their

Table 10

Proportion of Visual Cues Completed With a List Item as a Function of Age, Retrieval Task, and Cue-to-Target Overlap (Exp. 2)

	Inclusion			Exclusion		
	Medium	Large	Very Large	Medium	Large	Very Large
			Young (n = 48)			
M	.486	.625	.750	.012	.016	.024
SD	.187	.206	.139	.034	.044	.048
			Older (n = 40)			
M	.200	.300	.435	.029	.023	.040
SD	.138	.152	.178	.052	.046	.071

Note. Means are proportions.

answer as a plausible one.

The observation that the number of drawings compatible with a specific pattern of dots is large may also have produced a very different phenomenological experience than that with verbal items. With visual cues subjects may have started thinking, "If I see what these dots represent, then it means that the thing I am seeing was in the to-be-remembered list. So, since I am in the exclusion condition, I better not mention what I think the dots represent, but something else". If this was the phenomenological experience of subjects, then it would not be surprising that the number of list items produced in the exclusion condition was so low.

One impetus for conducting this experiment was the finding with visual stimuli of a stability in ARDs that could not be explained by the reduced processing resources framework in the first experiment. The reason offered then as a explanation for this finding was that an age-related increase in the use of automatic operations can, in some situations such as when environment support is provided, compensate for deficits linked to age in the utilization of intentional operations. Unfortunately, this hypothesis cannot be tested with the visual stimuli because of an inability to apply the process dissociation procedure. One way future research could apply the process dissociation procedure to visual stimuli would be to limit the number of alternatives by using stimuli that are members of the same class (e.g., common zoo animals).

Results and Discussion: Verbal Stimuli

Analysis of means

Baseline rates. A 2 (Age) X 3 (CTTO) ANOVA was conducted on the baseline data. The only significant effect was an increase in baseline rates with CTTO, $F(2, 188) = 80.56$, $MS_e = .005$. Means for medium, large, and very large CTTO items were .066, .133, and .190, respectively. Post hoc tests revealed that these three means were all significantly different from one another.

Conventional episodic memory analysis. A 2 (Age) X 3 (CTTO) ANOVA was performed on the conventional memory measure (proportion correct in the inclusion condition minus baserate specific to each Age X CTTO cell). Main effects of both Age and CTTO were qualified by an Age X CTTO interaction, $F(2, 188) = 3.05$, $MS_e = .02$. As shown in Figure 11, the superiority of young subjects over older subjects on the conventional measure of memory remained stable from medium to large CTTO, but increased from large to very large CTTO. Post hoc tests showed that the age difference was significant at every CTTO level.

Proportion of cues completed with a list item. A 2 (Age) X 2 (Retrieval Task: inclusion/exclusion) X 3 (CTTO) ANOVA was performed on the proportion of verbal cues

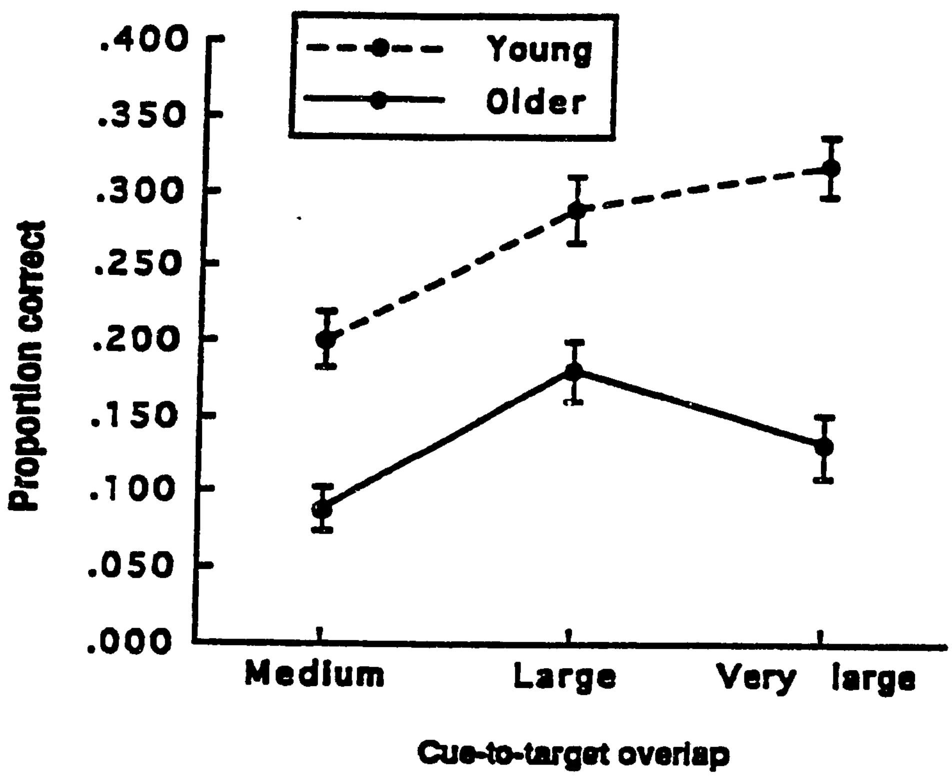

Figure 11. Proportion of verbal items correctly recalled in the inclusion condition minus baserate as a function of cue-to-target overlap and age (Exp. 2). Error bars indicate standard error of the mean.

completed with a list item. There were main effects of Age, Retrieval Task, and CTTO, all of which were qualified by interactions. As shown in Figure 12, the highest order interaction was Age X Retrieval Task X CTTO, $\underline{F}(2, 188) = 3.75$, $\underline{MS}_e = .01$. Post hoc tests on simple effects showed that the superiority in correctly completing cues with list items of young subjects over older subjects observed in the inclusion condition decreased when changing from medium to large CTTO, and then increased when changing from large to very large CTTO. In contrast, in the exclusion condition the higher rate of erroneously completing cues with list items of older subjects over young subjects increased disproportionately with increasing CTTO.

Because the proportion of list items produced in each Age X Retrieval Task X CTTO cell was superior to the corresponding baserates, one can calculate both the recollection component and the priming component. But before doing this, the proportion of cues completed with acceptable answers must be analysed, because, as Komatsu et al. (in press) have pointed out, variations in answer rates across conditions can invalidate the assumptions underlying the dissociation of performance into recollection and priming component. For the present purpose, variations in answer rates will be termed variations in conservatism.

Proportion of cues completed with acceptable answers. A 2 (Age) X 2 (Retrieval Task: inclusion/exclusion) X 3 (CTTO)

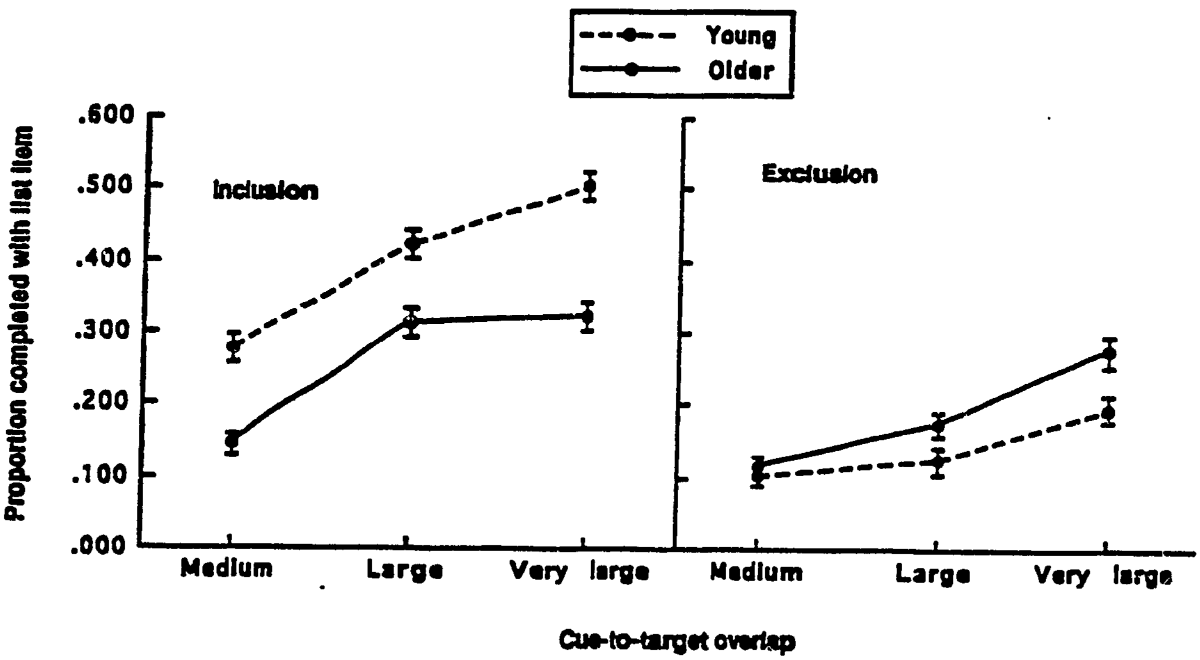

Figure 12. Proportion of verbal cues completed with a list item as a function of cue-to-target overlap, age, and retrieval task (Exp. 2). Error bars indicate standard error of the mean.

ANOVA was performed on the proportion of cues completed with acceptable answers (i.e., all stem completions that are neither plurals or proper names, regardless of whether the words are list or new items) to verify whether conservatism varies as a function of these three factors. The effects of Age, Retrieval Task, and CTTO were all significant, but all were qualified by two-way interactions. The Age X Retrieval Task interaction (see Figure 13) and follow-up post hoc tests, $\underline{F}(1, 94) = 7.41$, $\underline{MS}_e = .01$, indicated that young subjects produced the same number of completions as older subjects in the inclusion condition but significantly fewer completions than older subjects in the exclusion condition.

The Age X CTTO interaction (see Figure 14) and follow-up post hoc tests, $\underline{F}(2, 188) = 5.83$, $\underline{MS}_e = .01$, showed that young subjects produced significantly fewer completions than older subjects with both medium and large CTTO whereas the two age groups produced the same number of completions with very large CTTO. Finally, the Retrieval Task X CTTO interaction (see Figure 15) and follow-up post hoc tests, $\underline{F}(2, 188) = 24.08$, $\underline{MS}_e = .01$, showed that with medium CTTO subjects produced significantly more completions in the exclusion condition than in the inclusion condition, with large CTTO the same number of completions in the inclusion condition as in the exclusion condition, and with very large CTTO significantly more completions in the inclusion condition than in the exclusion condition.

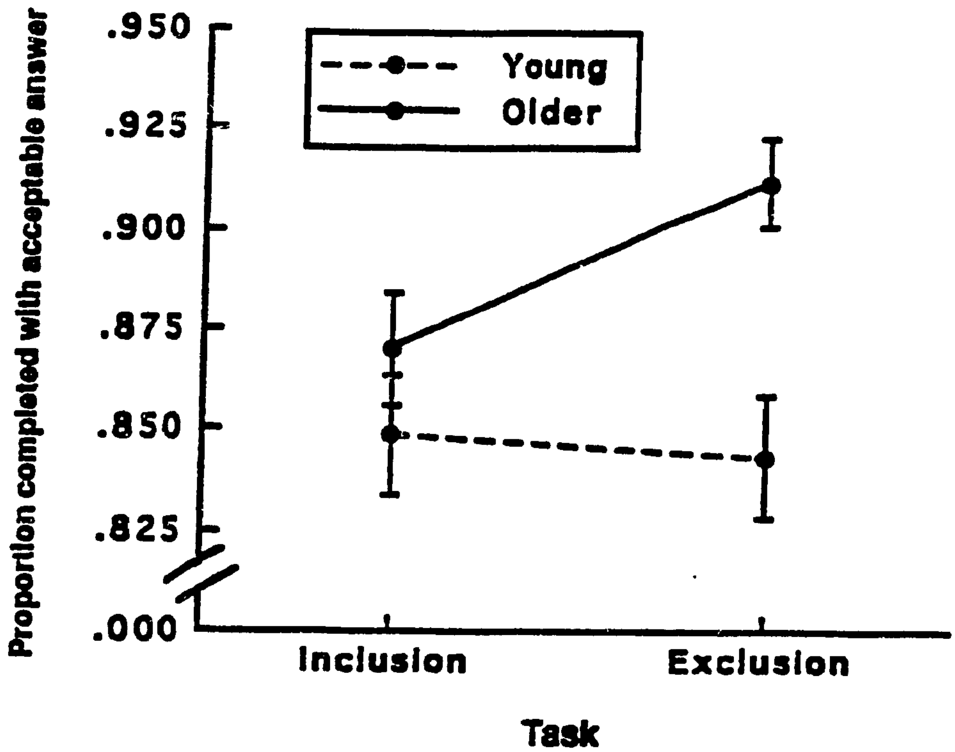

Figure 13. Proportion of verbal cues completed with acceptable answers as a function of retrieval task and age (Exp. 2). Error bars indicate standard error of the mean.

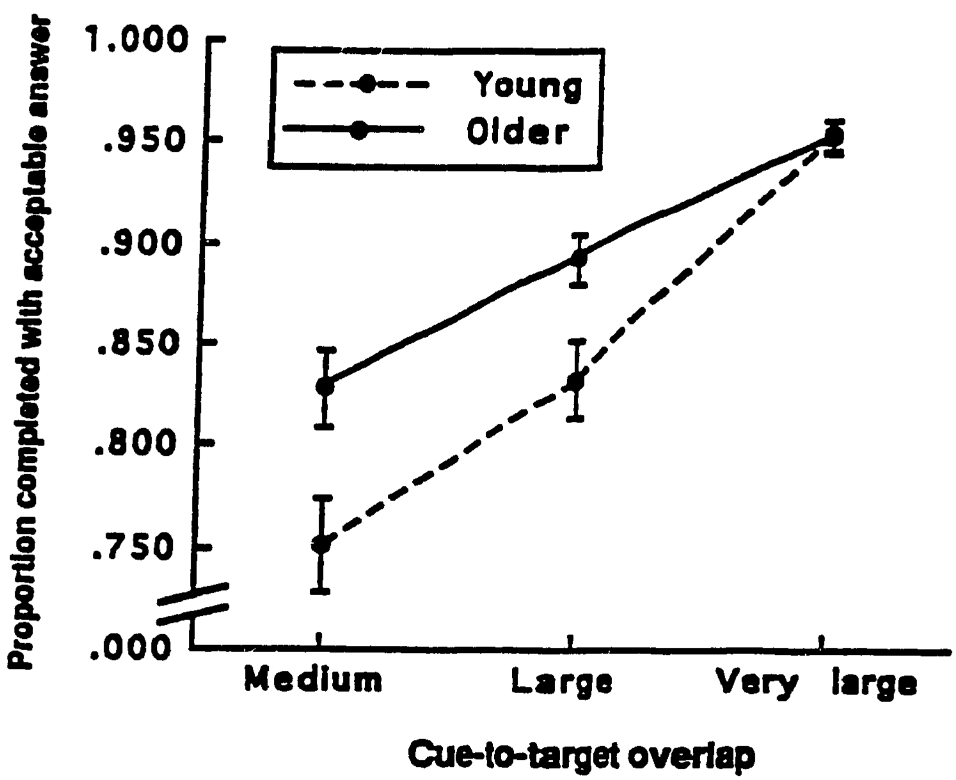

Figure 14. Proportion of verbal cues completed with acceptable answers as a function of cue-to-target overlap and age (Exp. 2).

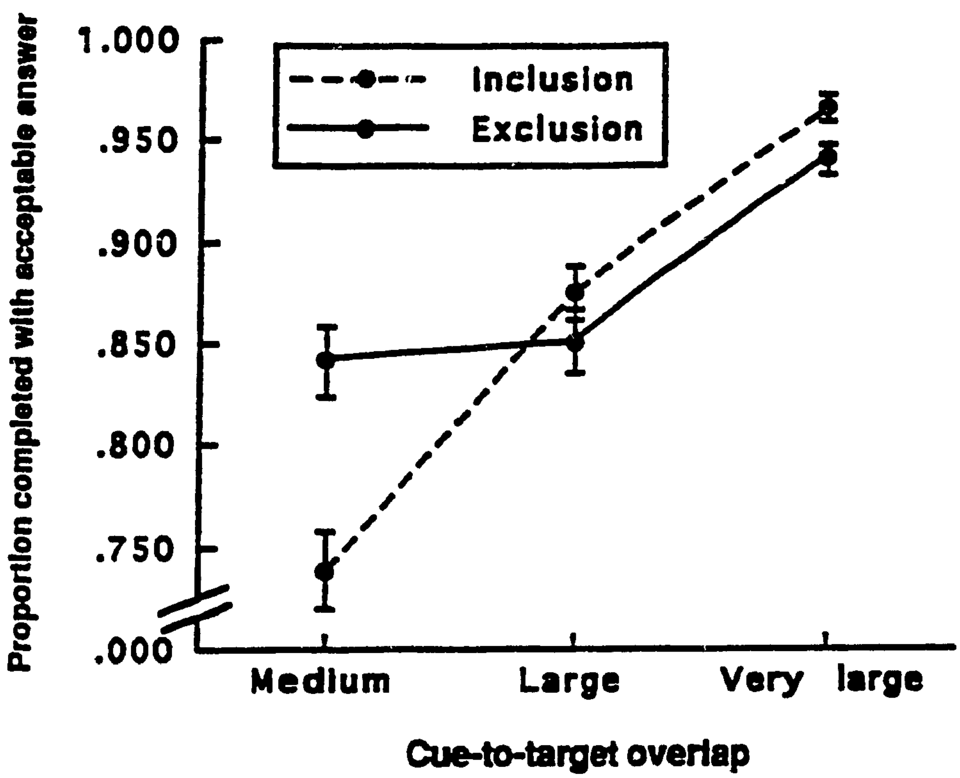

Figure 15. Proportion of verbal cues completed with acceptable answers as a function of cue-to-target overlap and retrieval task (Exp. 2). Error bars indicate standard error of the mean.

From these analyses it appears that, in general, young subjects are more reluctant than older subjects to provide responses, particularly in the exclusion condition or when CTTO is medium or large. Also, for both age groups, the difference in conservatism between inclusion and exclusion depends on CTTO.

Thus, the present results support Komatsu et al.'s (in press) critique that conservatism may vary as a function of whether the retrieval task is inclusion or exclusion. Moreover, these results extend those of Komatsu et al. (in press) by showing that conservatism varies as a function of age and CTTO as well as retrieval task and, in addition, is subject to interactions among the three variables. The implication of these findings is that one should correct recollection and priming scores for variations in conservatism.

The next section presents recollection, first using the hybrid approach to process dissociation and second, correcting those results for variations in conservatism. The following section does the same for priming.

Recollection. The hybrid approach to process dissociation was used to calculate individual scores for recollection of verbal stimuli. A 2 (Age) X 3 (CTTO) ANOVA was performed on recollection scores. The main effects of Age and CTTO were qualified by an Age X CTTO interaction, $F(2, 188) = 3.75$, $MS_e = .03$. As displayed in Figure 16, the

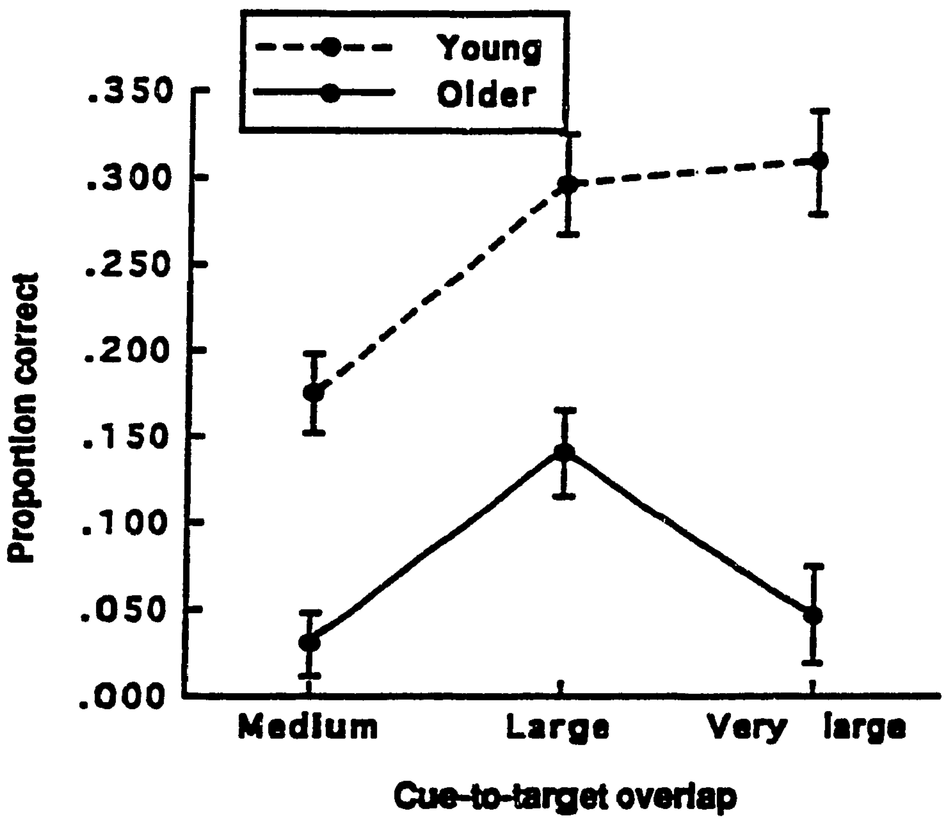

Figure 16. Size of the recollection component for the verbal stimuli as a function of cue-to-target overlap and age (Exp. 2). Error bars indicate standard error of the mean.

pattern resembled that found with the conventional memory measure. Post hoc tests showed a significant increase in recollection from medium to large CTTO that was about the same in both age groups. The performance of young subjects then plateaued, whereas that of older subjects declined significantly to a point that was not significantly greater than zero nor significantly different from their performance with medium CTTO. Post hoc tests also revealed that the superiority of young over older subjects was significant at all CTTO levels.

The data were then reanalysed to take account of how observed variations in conservatism might have affected the results. The first possibility examined was that the main effect of age on recollection was caused by the older subjects providing a significantly greater number of answers than the young subjects in the exclusion condition (see Figure 13), thereby lowering their recollection scores.

This possibility was evaluated by calculating a correction factor for the exclusion scores of elderly subjects at each CTTO level. The correction factor was the quotient of the proportion of cues completed by any acceptable answer (i.e., list or new items) by the young subjects in the exclusion condition divided by the proportion of cues completed by any acceptable answer by the older subjects in the same condition. For example, the correction factor for the medium CTTO level was .901

(.797/.885, see Table 11). A corrected mean probability of responding with list items in the exclusion condition was then calculated for the older subjects at each CTTO level by multiplying the mean that already existed by the correction factor. For example, the new mean for the older subjects at the medium CTTO level was .104, that is, the product of their old mean (.115 from Figure 16) by the correction factor (.901). The difference between the old mean and the corrected mean was then added to the recollection score of every elderly subject and these corrected scores were analysed. Reanalysis of the data using the hypothesis that the ARD in recollection was caused by not using corrected recollection scores also produced a main effect of age on recollection. Thus, one can reject the hypothesis that this effect was caused by the older subjects being less conservative than the young subjects in the exclusion condition.

A second possibility was that the unexpected decrease in the recollection component observed in the elderly subjects from large to very large CTTO (see Figure 16) was an artifact of either an increased conservatism in the inclusion condition, or a decreased conservatism in the exclusion condition. This possibility was evaluated by calculating the quotient of the probability of providing an answer in the inclusion condition divided by that of providing an answer in the exclusion condition for both

Table 11

Proportion of Verbal Cues Completed With Acceptable Answers as a Function of Age, Retrieval Task, and Cue-to-Target Overlap (Exp. 2)

	Inclusion			Exclusion		
	Medium	Large	Very Large	Medium	Large	Very Large
			Young (n = 48)			
M	.707	.863	.976	.797	.802	.931
SD	.194	.136	.048	.176	.168	.074
			Older (n = 48)			
M	.771	.885	.955	.885	.899	.950
SD	.177	.117	.066	.137	.102	.066

Note. Means are proportions.

large and very large CTTO. As can be seen from the data from Table 11, this quotient was about the same in both the large (.885/.899 = 0.98) and very large CTTO (.955/.950 = 1.01) levels, suggesting that a change in conservatism cannot explain why recollection decreased so much from large to very large CTTO in the older subjects.

A third possibility was that the poor recollection of both age groups in the medium CTTO condition was an artifact of subjects producing a greater number of answers in the exclusion condition than in the inclusion condition (see Figure 15). Again, the analysis using the corrected means reaffirmed the pattern found with the original scores.

Thus, although the analysis of the proportion of cues completed with acceptable answers supported Komatsu et al.'s (in press) claim that conservatism may vary as a function of whether the retrieval task is inclusion or exclusion, the effects observed were not large enough to modify substantially the pattern of recollection scores, and hence the original, uncorrected scores were used in further analyses.

Priming. The hybrid approach revealed that priming of verbal stimuli[1] was significantly greater than zero in all conditions. An Age X CTTO Anova showed that the only

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[1]The correction factors generated by the hybrid approach for young subjects were .008, .019, and .016, for medium, large, and very large CTTO, respectively. The corresponding correction factors for older subjects were .005, .008, and .010, respectively.

significant effect was of CTTO, $\underline{F}(2, 188) = 4.61$, $\underline{MS}_e = .01$. Means were .055, .056, and .097, for medium, large, and very large CTTO, respectively. Post hoc tests showed that the difference between medium and large CTTO was not significant, but that the difference between these two conditions pooled together and very large CTTO was significant. Again, the computation of means corrected for possible changes in conservatism across age groups and CTTO levels produced the same results as the uncorrected scores.

Analysis of correlations

As shown in Table 12, the measure of inclusion, the conventional measure of memory, and Jacoby's measure of recollection gave essentially the same results in terms of the point-biserial correlations between age and memory at each level of CTTO. For all three measures, the superiority of young over older subjects was highly significant at each level of CTTO. This superiority decreased slightly from medium to large CTTO and then increased significantly from large to very large CTTO ($\underline{t}$s(93) = 1.83, 2.01, and 1.75, for inclusion, conventional measure, and recollection, respectively).

The tendency of older adults to make more list items errors than young adults in the exclusion condition increased with increasing CTTO, and was significantly greater with very large CTTO ($\underline{r} = .28$) than with medium CTTO

Table 12

Point-Biserial Correlation Between Age Group and Proportion of List Items Produced as a Function of Cue-to-Target Overlap, and Score: Verbal Stimuli (Exp. 2)

	Cue-to-target overlap		
Score	Medium	Large	Very large
Inclusion	$-.49_{ab}^{***}$	$-.36_{a}^{***}$	$-.55_{b}^{***}$
Exclusion	$.07_{a}$	$.20_{ab}$	$.28_{b}^{*}$
Conventional measure[a]	$-.43_{ab}^{***}$	$-.35_{a}^{***}$	$-.56_{b}^{***}$
Recollection[b]	$-.45_{ab}^{***}$	$-.39_{a}^{***}$	$-.55_{b}^{***}$
Priming[c]	$.08_{a}$	$.10_{a}$	$.01_{a}$

Note. A negative sign indicates the superiority of young over older subjects, and a positive sign indicates the superiority of older over young subjects. Correlations that do not share a common subscript on a given row differ at $p < .05$.

[a]Inclusion - Baserate. [b]Inclusion - Exclusion. [c](Exclusion ÷ (1 - Recollection)) - Baserate.

$^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$

(r = .07), $t(93) = 1.74$. Finally, the correlation between age group and priming did not vary significantly across CTTO levels.

A second issue pertaining to correlations was whether processing resources predict performance on the three measures of memory (the conventional measure, recollection, and, priming) and whether changes in the correlations between resources and those measures predict the variations in ARDs in memory. When the three CTTO levels were averaged, the correlation adjusted for age between processing resources and recollection (pr = .14) was significantly larger than that between processing resources and the conventional memory measure (pr = .02), $t(90) = 2.12$, $p < .05$, suggesting that recollection may be a purer measure of the role of intentional processes than the conventional measure of memory, although neither of these two correlations were significantly greater than zero. Also, the correlation between processing resources and priming was significantly inferior to zero (pr = −.23, $p < .05$), indicating that the greater the processing resources the poorer the priming.

The correlations between processing resources and the three memory measures as a function of CTTO and age group appear in Table 13. In contrast to the results with verbal stimuli in Experiment 1 and to the results with visual stimuli in both experiments, processing resources did not

Table 13

Correlation Between Processing Resources and Proportion of List Items Produced as a Function of Cue-to-Target Overlap, Score, and Age Group: Verbal Stimuli (Exp. 2)

	Cue-to-target overlap		
Group	Medium	Large	Very large
	Conventional measure[a]		
Young (n = 48)	$.07_a$	$-.17_a$	$.11_a$
Older (n = 48)	$.02_a$	$-.11_a$	$.04_a$
Age adjusted	$.05_a$	$-.14_a$	$.06_a$
	Recollection[b]		
Young (n = 48)	$.20_a$	$-.10_a$	$.17_a$
Older (n = 48)	$.01_a$	$-.01_a$	$.30_a^*$
Age adjusted	$.09_{ab}$	$-.05_a$	$.24_b^*$
	Priming[c]		
Young (n = 48)	$-.20_a$	$-.19_a$	$-.16_a$
Older (n = 48)	$.03_a$	$-.11_{ab}$	$-.30_b^*$
Age adjusted	$-.08_a$	$-.14_a$	$-.23_a^*$

Note. A positive sign indicates that the greater the resources the better the performance, and a negative sign indicates that the greater the resources the poorer the performance. Correlations that do not share a common subscript on a given row differ at $p < .05$.

[a]Inclusion - Baserate. [b]Inclusion - Exclusion. [c](Exclusion ÷ (1 - Recollection)) - Baserate.

$^*p < .05$

appear to be constraining the performance of either older subjects or younger subjects under medium and large CTTO as none of the correlations between processing resources and any of the conventional measure, recollection, or priming reached significance. With very large CTTO, greater processing resources were associated, for the older subjects only, with both significantly better recollection and significantly worse priming. Partial correlations, controlling for age groups, did not change this picture greatly. Processing resources were unrelated to the conventional measure of memory across CTTO levels, and, with very large CTTO, greater processing resources were associated with both significantly better recollection and significantly worse priming.

Discussion of results with verbal stimuli

A first issue addressed by Experiment 2 relative to verbal stimuli was whether ARDs corrected for the problem of differential sensitivity varied as a function of CTTO. The results of Experiment 2 replicated and extended those of Experiment 1 in that no variations were observed in ARDs in the conventional measure of memory or in recollection when medium CTTO was compared with large CTTO.

When CTTO was increased to very large, then, contrary to the prediction from the self-initiated operations hypothesis, ARDs in both the conventional measure of memory and recollection increased. This counter-intuitive result will be addressed in more detail below.

A second issue investigated with the verbal stimuli was the relationship between processing resources and performance on the conventional measure of memory, recollection, and, priming. A first result was the observation that processing resources did not predict performance, as defined by the conventional measure of episodic memory, for either age groups. This result, which is consistent with the results for young adults with the verbal stimuli of Experiment 1 but which is at odds with those for older adults, may be related to the fact that in the verbal condition of Experiment 2 a list of 72 stimuli had to be remembered. With that list length it could be argued that the memory of all subjects was so overloaded that the amount of processing resources they possessed became irrelevant.

One problem with this argument is that, when the conventional measure was broken into recollection and priming, the partial correlations, adjusted for age, between processing resources and each of these two components was significant with very large CTTO. Given that recollection was better with more processing resources, it could be argued that at least with very large CTTO, subjects' memory was not overloaded to the point where the amount of processing resources they possessed was irrelevant.

The significant link between processing resources and priming found with the very large CTTO level is intriguing, particularly since it goes in the unexpected direction of more priming with less resource. According to the literature, ARDs are not found with priming, a finding replicated by the present experiment. Therefore, the amount of priming should not depend upon the amount of processing resources an individual possesses. However, the present experiment indicates that with very large CTTO and with the effect of age group partialled out, the more the processing resources, the less episodic memory performance depends upon automatic influences and the more it depends on intentional influences. This result makes intuitive sense because the more the processing resources the more performance can depend upon intentional efforts, leaving less and less place to automatic processes.

The significant relationship found at very large CTTO between processing resources and both recollection and priming co-occurred with the significant increase in ARDs from large to very large CTTO in the three measure of episodic memory (inclusion, conventional measure, and recollection). Put together, these two results suggest that some processes required by the very large CTTO condition may be qualitatively different from those required by the smaller CTTO levels so that the amount of processing resources a subject possesses would become specially relevant. Again, this issue will be discussed in more detail below.

A third issue investigated with the verbal stimuli was to examine whether conservatism varies as a function of age, CTTO, and retrieval task (i.e., inclusion or exclusion). The results of the present experiment suggest that conservatism does vary as a function of age, CTTO, and retrieval task. However, this variation does not seem to be large enough to modify any of the pattern of results obtained with uncorrected recollection and priming scores. Thus, at least with the issues of age and CTTO, the results of the present experiment indicate that variations in conservatism are not a problem when the process dissociation procedure is used.

A last issue investigated with the verbal stimuli was to verify whether the lack of variation in ARDs observed in Experiment 1 was caused by not having a large enough CTTO level. The results of the present experiment suggest that when CTTO is increased to very large, ARDs in recollection magnify, an effect opposite to that predicted by the self-initiated operations hypothesis. Thus, clearly the lack of decrease in ARDs with increasing CTTO found in Experiment 1 cannot be attributed to not having a large enough CTTO level.

If increasing CTTO does not lead to decreased ARDs, then a question that remains is why. As was shown in Table 2, ARDs corrected for the problem of differential sensitivity decreased from free recall to recognition in most of the studies available in the literature. It could be, to the extent that Watkins and Gardiner's (1979) two-process theory of memory is valid, that the reason for recognition to reveal smaller ARDs than free recall is the absence in the former of a search through memory caused by a total (100%) overlap between the cue and the target. When CTTO is less than 100% and more than one word fits the cue, a search through memory is still needed, explaining why large ARDs may still be found. Paradoxically, the results from the present experiment suggest the new possibility that increasing CTTO to very large may increase the difficulty of the memory search, resulting in magnified rather than decreased ARDs.

The significant increase in the ARDs in the conventional memory measure and recollection that occurred for verbal stimuli from large to very large CTTO, is a particularly problematic result for the self-initiated operations hypothesis. To understand this result, which was mainly attributable to the decrease in recollection of older adults with very large CTTO, as well as to understand why recollection in general was so low for older adults, it is necessary first to consider the different processing steps required by the process dissociation procedure.

A model of the different processing stages required by the process dissociation procedure when targets are verbal stimuli. In light of the present results and of the critique by Graf and Komatsu (1994) that the instructions required by the process dissociation procedure may be too complex for older adults, it is crucial at this point in time to try to understand the different processing stages required by the process dissociation procedure and whether age differences exist in the way those stages are performed.

A model of the different processing stages required by the process dissociation procedure when targets are verbal stimuli is presented in Figure 17. As shown that Figure, the first stage involves registering the reminder of the instructions specific to the trial (i.e., "THE ANSWER FROM THE LIST" or "NOT THE ANSWER FROM THE LIST"). The second stage requires paying attention to the cue. The operations involved in looking at the cue may or may not make a potential answer "pop" to mind. If paying attention to the cue does not trigger the emergence of a potential answer, subjects need to engage in a memory search until such an answer is found.

Each potential answer that is generated must be compared with any potential answers that have been previously considered and rejected. If the potential answer is the first one to be considered, or if it has not been rejected before, subjects have to check whether it contains

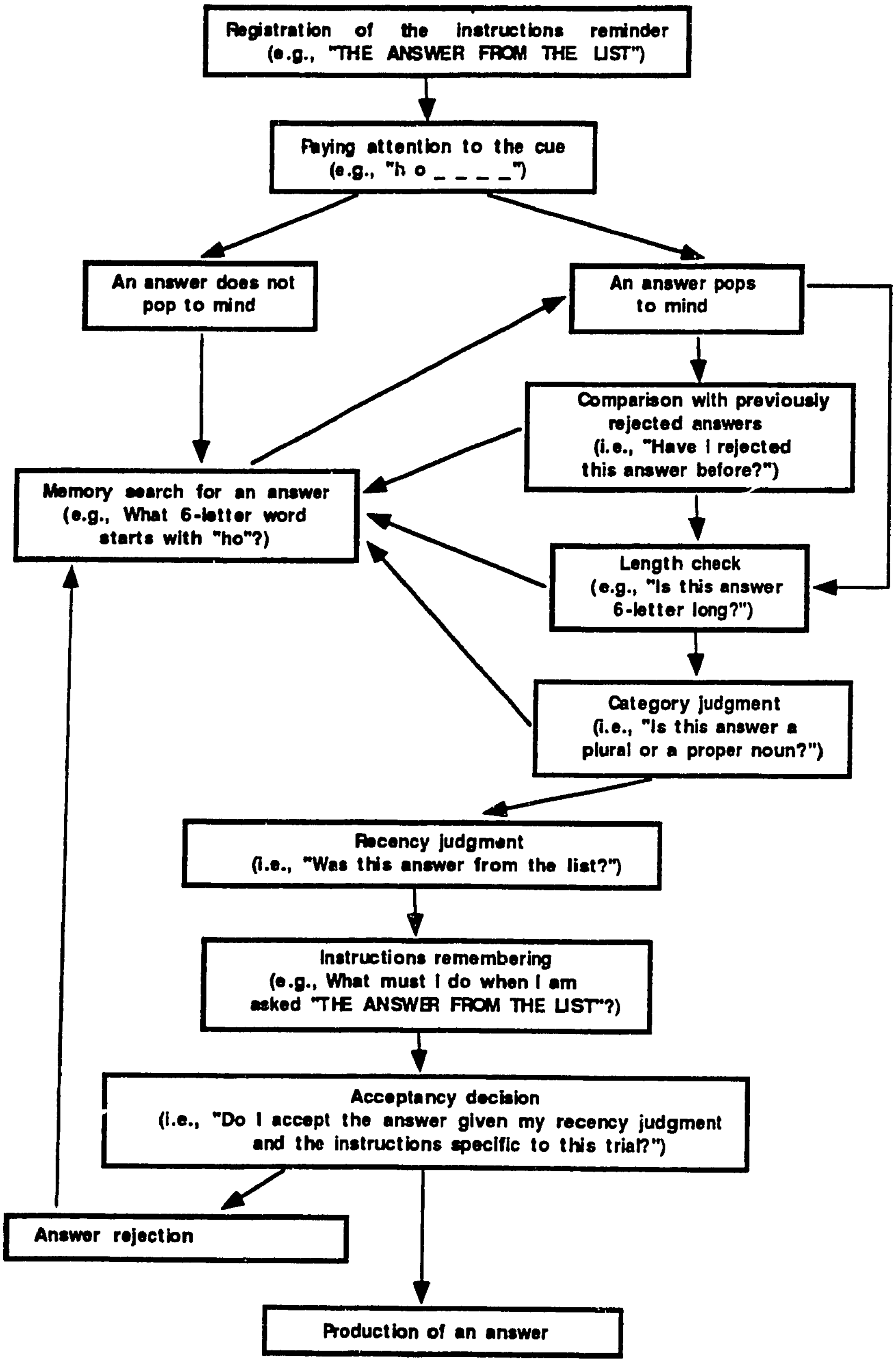

Figure 17. Model of the processing stages required by both the inclusion and exclusion conditions when targets are verbal stimuli.

the proper number of letters. If it does then a category judgment must be made as words that are plurals or proper nouns are not allowed.

Once a potential answer has successfully passed through the category judgment stage, a recency judgment must then be made about it. Subjects must decide whether the potential answer they are thinking of is one that they saw in the just presented list. When the recency judgment is made, subjects have then to remember whether they are in inclusion or exclusion as well as the instructions specific to these two conditions.

Based on both the recency judgment and the instructions specific to the condition they are in, subjects must decide whether to accept the potential answer as valid. If the decision is not to accept the potential answer as valid, a new memory search has to be performed. In contrast, if the decision is to accept the potential answer, the potential answer becomes the actual answer and no further stages are executed.

In examining the processing stages required by the process dissociation procedure, it is important to note that some stages do not need to be performed in the same order as that illustrated in Figure 17. For example, the category judgment can be executed before the length check without creating problems. However, the general order of stages must be that of Figure 17. Otherwise, inappropriate answers will be produced.

Why was the recollection of older adults for verbal stimuli in general so low in Experiment 2? Although recollection scores showed the same general pattern as did conventional memory scores, there was one striking difference. When the recollection component alone was considered, performance of the older adults did not differ significantly from zero for two of the three CTTO levels. Only with large CTTO was older adults' mean recollection score significantly greater than zero. As can be seen in Figure 17, several processing stages must be executed in both the inclusion and exclusion conditions in order to produce adequate answers. An age-related difference in the way one or several of these stages are performed could lead to the ARD in recollection observed in Experiment 2.

Hypothesis 1: Giving the first answer that comes to mind. Because of the operations executed during the study phase, targets have an increased likelihood of being the first answer thought of by subjects at test phase (Merikle & Reingold, 1991; Schacter, 1987, 1989). Suppose that age disrupts the integrity of the series of stages presented in Figure 17 in such a way that older adults show a greater tendency than young adults to give this first answer. What would the consequences of such a tendency be when the process dissociation procedure is used?

In the inclusion condition the performance of older adults would be helped by the fact that the first answer available will often be the target. However, to the extent that sometimes the first item that comes to mind is not the target, the more limited processing resources of older adults (found in both Experiments 1 and 2) will restrict their ability to put the first answer aside and search for the target.

In the exclusion condition, because the first answer that comes to mind is likely to be the target, a good strategy is not to give this answer but rather to try to think of a second answer that would sound less familiar, adding additional steps to the amount of processing done before producing an answer. If older adults, because of their more limited processing resources, showed a greater tendency than young adults to produce the first answer that comes to mind, they would erroneously produce a greater number of list items than the young adults which is exactly what happened with the verbal stimuli at large and very large CTTO.

The hypothesis that older adults are more likely than young adults to produce the first item that comes to mind is consistent not only with the reduced processing resources framework but also with the theoretical position of Hasher and her colleagues (Hamm & Hasher, 1992; Hartman & Hasher, 1991; Hasher & Zacks, 1988). According to these authors elderly adults have a greater difficulty than young adults in discarding from working memory answers that are no longer relevant. According to Hasher and Zacks (1988), the reason for this phenomenon is an age-related impairment in the inhibitory mechanisms that prevent irrelevant information from entering working memory.

Placed in the context of the model presented in Figure 17, Hasher and Zacks's theory would imply that elderly adults find the operations of the "comparison with previously rejected answers" stage particularly difficult to execute. For them the distinction between answers that have been discarded and those that are currently being considered would be much less clear than for young subjects. Hasher and Zacks's theory would also imply that, even when a potential answer has been discarded, elderly subjects would find it difficult not to think of this same answer again at the "recency judgment" stage or even at the "acceptancy decision" stage.

As far as the inclusion condition is concerned, the observation that the target has an increased probability to be the first answer to enter working memory, is not problematic. If this answer is given, it will often increase the recollection score. In contrast, the observation that the target has an increased probability to be the first answer to enter working memory poses a distinct problem for the exclusion condition. Once the target has entered working memory, older adults will be less able than young adults not to think of it, even when it is rejected as a potential answer. Thinking again of the target would increase its probability of being given.

Thus, from both a reduced processing resource perspective and an impaired inhibitory mechanisms perspective, older adults should have a greater tendency than young adults to produce targets in the exclusion condition.

Hypothesis 2: Registering the instructions. The instructions used in the process dissociation procedure are complex, and they require subjects to switch repeatedly during retrieval between the inclusion and exclusion retrieval tasks. Because in both the inclusion and exclusion conditions the task is to find a word that fits the cue, subjects may be tempted to ignore the instructions reminder and to try right away to find a word that fits the cue. Moreover, because the cue appears on the computer screen at the same time as the instructions reminder, subjects' attention may be attracted by the cue, and they may forget to register the instructions reminder.

If the subject actually produces the answer that came to mind at the sight of the cue, then since it is likely to be the target, the result will be to increase the proportion of targets produced in both the inclusion and exclusion conditions. Thus, when there are failures to register the instructions reminder, a target produced in the inclusion condition will be balanced by one produced in the exclusion condition, pushing the recollection scores toward zero.

Suppose that there is an age-related increase in failures to register the instructions reminder due to the mental flexibility that is required in order to alternate frequently between inclusion and exclusion conditions. The magnitude of the vector that pushes the recollection scores towards zero would be bigger for the older adults than for the young adults, explaining why their performance was in general so low in Experiment 2.

Why did the recollection of older adults for verbal stimuli decrease from large to very large CTTO in Experiment 2? The most puzzling result with the verbal stimuli was the finding that a very high level of environmental support was associated with decreased recollection for older adults. One possible explanation is that this decrease was due to a magnification with very large CTTO of the processes described in the previous section. Suppose that when CTTO is very large, there is a large increase in the probability that the first answer that comes to mind is the target. If older adults show an increased tendency to give the first answer that comes to mind, a large increase in the probability that the first answer is the target will be enough to explain why the proportion of targets produced by older adults increased from .174 (large CTTO) to .276 (very large CTTO) in the exclusion condition of verbal stimuli of

Experiment 2. However, a large increase in the probability that the first answer is the target should also have led to a large increase in the number of targets produced in the inclusion condition. Actually, the increase in the proportion of targets produced by older adults from large to very large CTTO was only .009, suggesting that the probability that the first answer that comes to mind was the target did not increase significantly from large to very large CTTO.

Another possible explanation is that because the number of answers that fit the cue decreases with increasing CTTO, it becomes increasingly difficult to find an alternate to the first answer that comes to mind. When CTTO is very large, the probability that the first answer that comes to mind is the target may be only a little bit higher than when CTTO is large, but finding an acceptable alternate to it, that is, another 6-letter word that has the same first four letters as the cue, would appear to represent a significant increase in difficulty.

Proponents of the reduced processing resources framework could argue that when CTTO increases, finding an alternate to an answer that is already available (i.e., the target) will require an increasing amount of processing resources, so that the probability of producing this answer rather than an alternate increases disproportionately in older adults. Defenders of the reduced inhibition framework could claim that when CTTO increases, the alternates become increasingly similar to the target because they share an increasing number of letters. It would, therefore, become more difficult not to confound the target with alternates, resulting in an increased probability of producing the traget as an answer. Again, because of impaired inhibitory mechanisms, this effect would be particularly evident in older adults.

How could the proposed explanations be tested? As one can see, several competing hypotheses would need to be considered before providing a complete explanation for why the recollection of older adults was in general very low in Experiment 2, and why the recollection of older adults for verbal stimuli decreased from large to very large CTTO.

The notion that older adults are more likely than young adults to produce the first answer that comes to mind in both the inclusion and exclusion conditions could be tested simply by asking subjects to report all potential answers that come to mind as soon as they think of them and to notify the experimenter when one of these answers is retained as their choice. The present argument would be supported if older adults are more likely than young ones to select as their answer the first item they come up with. Moreover, varying CTTO would permit assessment about whether CTTO level interacts with age differences in the probability of choosing the first answer that comes to mind.

In terms of processing resources, it could be argued that if, to avoid giving the target as an answer, the exclusion condition requires on average a greater number of steps than the inclusion condition, then the time spent from the presentation of the cue to the production of an answer will be longer in the exclusion condition than in the inclusion condition. Moreover, if the number of steps increases with CTTO, then the time spent from the presentation of the cue to the production of an answer should increase accordingly.

If inhibition mechanisms are more important in the exclusion than in the inclusion condition, then the correlation between a measure of the ability to inhibit responses and the number of targets produced will be higher for the exclusion than for the inclusion condition. If inhibition mechanisms become more relevant in the exclusion condition when CTTO increases, then the correlation between an inhibition index and the number of targets produced in that condition should also be expected to increase.

In order to control the risk of failure to register the instructions reminder, the following procedure could be used. The reminder would be presented before the cue and would stay on the screen until subjects read it. After subjects have read it, the reminder would stay on the screen during the cue presentation and would stay in view until subjects decide which answer they select. Finally, to make sure that the remembering of instructions is not an issue, these instructions should be overlearned before test phase.

An ability required by the exclusion condition is that of generating a second answer when the first one to come to mind is the target and is recognized as such. The assumption that both young and older adults possess this ability to an equal degree has never been tested. One way this assumption could be tested involves two conditions. In the first condition, a word would be presented on top of the computer screen (e.g., "holder"), whereas a stem starting with the same first letters as that word (e.g., "h o l _ _ _") would be presented at the bottom of the screen. Both the word and the stem would remain on the screen so that subjects would simply have to find a word that is different from the one provided that also fits the stem. Thus, this first condition would test whether both young and older adults are equally able to generate a second word when a first one is already available.

The second condition would be identical to the first except that the word would be presented before the stem for a period of time just long enough to be named, and then it would disappear. Only then would the stem appear and the task would be the same as in the first condition. The finding that older adults are impaired only in the second condition would suggest that the memory component inherent in the exclusion task creates problems for them. In contrast, finding an age-related impairment in both the first and the second condition would suggest that both the word generation and the memory components deteriorate with age. Finally, varying CTTO in the two conditions just mentioned would also allow investigation of whether it becomes more difficult to find an alternate to the first answer that comes to mind when CTTO increases.

What about conservatism? For the purpose of clarity, assume that recency judgments (see Figure 17) are of the following three types: (a) "yes, the answer was from the list", (b) "no, the answer was not from the list", and (c) "not sure whether the answer was from the list". When subjects are in the inclusion condition, they must remember to produce the answer only when the recency judgment is either "yes" or "not sure". In contrast, when subjects are in the exclusion condition, the best strategy is to produce the answer only when the recency judgment is "no". When the judgment is "not sure", it is better to inhibit answering in order to be sure not to produce a target.

Suppose that in the exclusion condition elderly subjects are more ready than young subjects to give an answer that they are not sure of, that is, not sure about whether it comes from the list. Such a change in conservatism with age would increase the number of targets produced in the exclusion condition, contributing to the age-related decline in recollection scores observed in

Experiment 2.

Moreover, the existence of an interaction involving age and CTTO as independent variables and conservatism as the dependent variable could also account for the finding that the recollection of older adults for verbal stimuli decreased from large to very large CTTO. That is, suppose that older adults, but not young adults, become less conservative when CTTO is very large than when it is large in that they will show an increased tendency to give an answer when the recency judgment is "I am not sure whether the answer was from the list".

From the results obtained to date, an age-related change in conservatism appears to exist, because the total number of answers produced in the exclusion condition (i.e., targets plus non-targets) of Experiment 2 increased with age (see Table 11). However, correcting the number of produced targets for this increase did not change the outcomes of the statistical analyses performed in Experiment 2. Thus, the results of Experiment 2 do not support the view that an age-related change in conservatism can explain either why recollection of older subjects was so low or why it decreased from large to very large CTTO for them.

In any case, future research should take into account the possible effects of an age-related change in conservatism. One way to test the existence of that change in a more direct way than that used in Experiment 2 would be to ask the following question once an answer is produced: "To what extent are you sure that X (subject's answer) was/was not from the list?".

Chapter 5

General Discussion and Conclusions

General Discussion and Conclusions

There are two main issues to be discussed with respect to the research reported in this dissertation. The first concerns the implications of the present findings for current hypotheses on the role of processing resources and environmental support in determining ARDs in memory. The second concerns the process dissociation procedure, and what the present study reveals as to its utility as a tool for separating intentional and automatic processes in memory. Each of these issues will be addressed in turn.

Processing resources, environmental support, and ARDs in memory

Taken together, the results of Experiments 1 and 2 suggest that the relationships among age, CTTO, processing resources, and episodic memory are more complex than current theories would predict. In contrast to the prediction from the self-initiated operations hypothesis, once corrected for the problem of differential sensitivity ARDs with both verbal and visual stimuli were found to be generally stable across three CTTO levels in Experiment 1. Consistent with the reduced processing resources framework, with verbal stimuli this stability was reflected in lack of variations across CTTO levels in the correlation between processing resources and performance. However, inconsistent with the reduced processing resources framework, with visual stimuli this stability co-occurred with an increased relevance of processing resources as CTTO level increased.

The results with visual stimuli raised the possibility that increased CTTO increases both the contribution of intentional and automatic processes to performance, and that the increase in the contribution of intentional processes is compensated for by an increase in the contribution of automatic processes. One objective of Experiment 2 was to test this explanation using Jacoby's (1991) process dissociation procedure. Unfortunately, this objective could not be met due to a failure in the proportion of remembered visual stimuli to dissociate into recollection and automaticity. As discussed earlier, a likely cause of this failure was the fact that, with visual stimuli, the number of acceptable answers was not constrained so that in the exclusion condition subjects simply had to think of a plausible answer that sounded unfamiliar. This strategy made them produce so few list items in the exclusion condition that applying the formulas from the process dissociation procedure would have led to nonsensical results.

Experiment 2 also showed, as in Experiment 1, that the correlation between age and the proportion of visual stimuli remembered remained stable as CTTO increased. However, in contrast to Experiment 1, the correlation between processing resources and recall was smaller with the largest CTTO level than with the other CTTO levels, suggesting that CTTO can be increased to a point where the demands for processing resources are reduced. This finding is indeed problematic for the reduced processing resources framework because according to this framework decreased requirements for resources should result in decreased ARDs. However, because this finding was observed in only one condition the amount of attention that it should be given is unclear at this point: it could well be a Type I error.

In Experiment 2, the results with the verbal stimuli indicated that when CTTO was increased from large to very large, the magnitude of the ARD increased. This result, which was at odds with the prediction from the self-initiated operations hypothesis, was due to a marked decline in the recollection of older adults which co-occurred with an increased relevance of processing resources. It appears that three premises concerning test phase are required to explain why the recollection of older adults declined from large to very large CTTO:

1) Because of their decreased processing resources by comparison with young adults, older adults show an increased tendency to give the first answer that comes to mind;

2) The probability that the first answer that comes to mind is the target increases with CTTO;

3) Because the number of answers that fit the cue decreases with CTTO, more processing resources are needed to find an alternate to the first answer that comes to mind.

The observation that processing resources became a better predictor of recollection with very large than with large CTTO in Experiment 2 is in line with the notion that the bottom-line source of the increase in the ARDs in the conventional measure of memory that occurred from large to very large CTTO is an ARD in processing resources.

Thus, the results of the present dissertation do not support the prediction from the self-initiated operations hypothesis that when CTTO increases ARDs in intentional cued recall decrease. With the visual stimuli of both Experiments 1 and 2 and with the verbal stimuli of Experiment 1 ARDs corrected for the problem of differential sensitivity remained stable with increased CTTO. Moreover, with the verbal stimuli of Experiment 2, when CTTO was increased from large to very large ARDs actually increased with CTTO.

The results of the present dissertation are less clear with respect to the reduced processing resources framework. Some of the results with the verbal stimuli tended to support this framework. In Experiment 1 the stability of ARDs in recall observed was mirrored by invariant correlations between processing resources and performance. In Experiment 2 the increased ARDs in recollection from large to very large CTTO co-occurred with a similar increase in the correlation between resources and recollection, indicating that performance was increasingly constrained by available processing resources. However, the increased ARDs with the conventional verbal memory measure from large to very large CTTO were not associated with an increased correlation between processing resources and the conventional verbal memory measure.

With visual stimuli the results were in general at odds with the reduced processing resources framework: ARDs were stable despite an increased correlation between processing resources and performance with increased CTTO in Experiment 1, and ARDs were also stable in Experiment 2 despite a decreased correlation between resources and performance with increasing CTTO. Unfortunately, the impossibility to dissociate recall of visual stimuli into recollection and automaticity did not permit identification of the mechanisms that led to those results.

Utility of the Process Dissociation Procedure

The conclusions from the present dissertation with regard to the verbal stimuli of Experiment 2 are limited by the assumptions of the process dissociation procedure. Recently, Joordens and Merikle (1993) have challenged Jacoby's (1991) assumption that intentional and automatic processes are stochastically independent. Instead, Joordens and Merikle suggest that intentional and automatic processes may be redundant in that, whereas some automatic processes may occur without a correlated intentional process, it would be impossible for an intentional process to occur without a correlated automatic process.

Venn diagrams may help to clarify the difference between the independence and the redundancy assumption. The independence assumption is represented in the top panel of Figure 18. As one can see, this assumption permits three situations: (a) the occurrence of intentional processes without the co-occurrence of automatic processes, (b) the occurrence of automatic processes without the co-occurrence of intentional processes, and (c) the co-occurrence of automatic and intentional processes. In contrast, as shown in the bottom panel of Figure 18, the redundancy assumption admits only two situations: (a) the occurrence of automatic processes without the co-occurrence of intentional processes, and (b) the co-occurrence of automatic and intentional processes.

The redundancy assumption leads to a different interpretation of the processes involved in both the inclusion and exclusion conditions. To understand this, one must first multiply automaticity by the failure to recollect (i.e., 1 minus recollection) in both the inclusion equation:

$$Inclusion = Recollection + [Automaticity * (1 - Recollection)] \tag{18}$$

$$= Recollection + Automaticity - (Automaticity * Recollection),$$

and the exclusion equation:

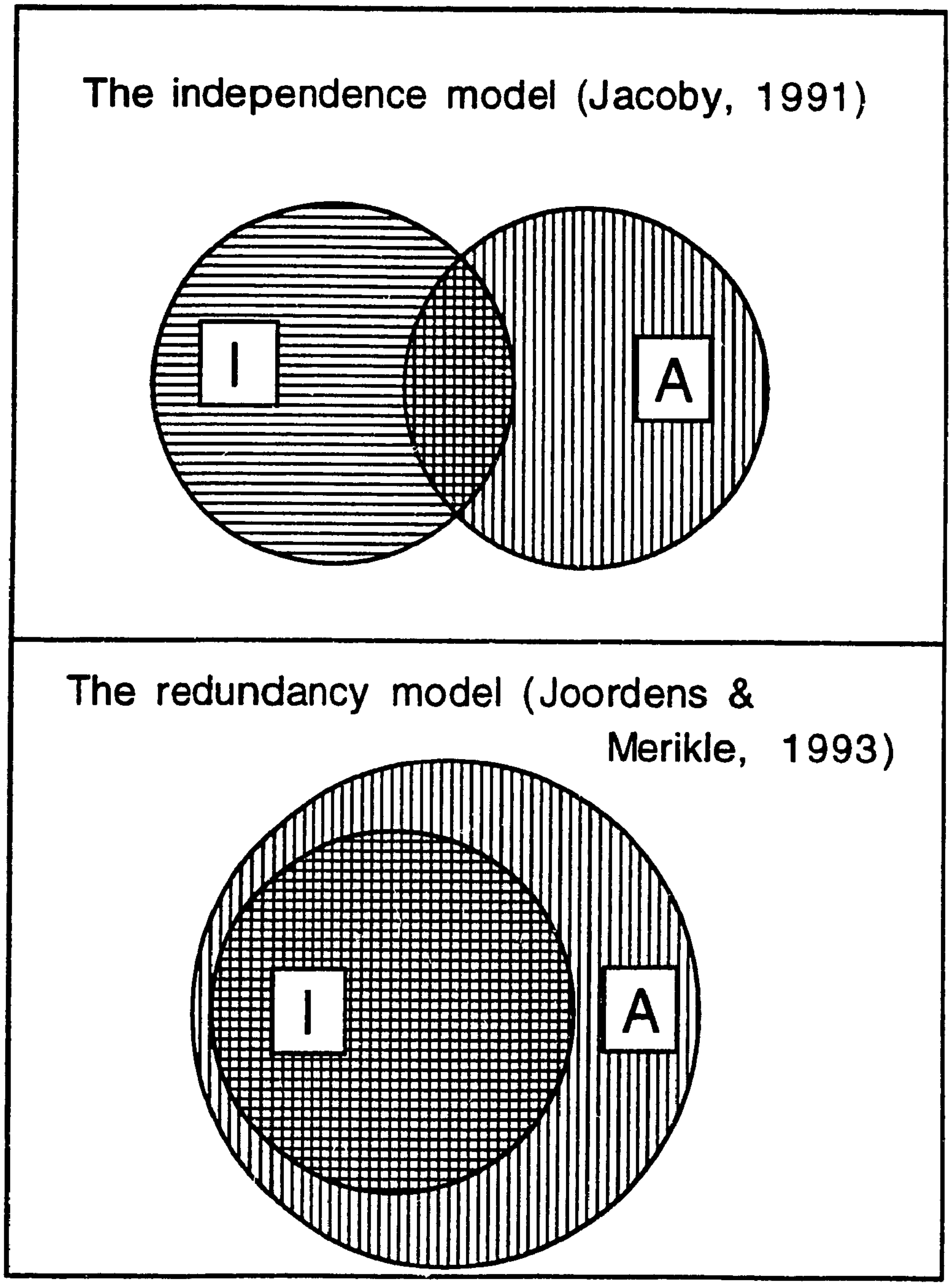

Figure 18. Venn diagrams of independence relation (top panel) and of the redundancy relation (bottom panel) between intentional (I) and automatic (A) processes.

$$Exclusion = Automaticity * (1 - Recollection) \tag{19}$$

$$= Automaticity - (Automaticity * Recollection).$$

According to the redundancy model, the only situation where both automatic and intentional processes co-occur, which is represented by the product of automaticity and recollection in Equations 18 and 19, is also the only situation where intentional processes do occur. One can therefore replace the product of automaticity and recollection by recollection in both Equations 18:

$$Inclusion = Recollection + Automaticity - Recollection \tag{20}$$

$$= Automaticity,$$

and 19:

$$Exclusion = Automaticity - Recollection. \tag{21}$$

One can see from looking at both Equations 20 and 21 that the redundancy model leads to a reinterpretation of the processes involved in the inclusion condition. According to this model, the inclusion condition reflects the probability that automatic processes alone produced the item from the studied list, that is, the automaticity component (see Equation 20). In contrast, the exclusion condition reflects the subtraction of the probability that intentional processes produced the item from the studied list (i.e., recollection) from the probability that automatic processes produced that item (i.e., automaticity, see Equation 21).

One can also see from looking at both Equations 20 and 21 that the procedure used to evaluate the recollection component is the same for both the independence and redundancy models. That is, one subtracts the proportion of list items produced in the exclusion condition from the proportion of list items produced in the inclusion condition. Thus, the conclusions drawn for the recollection component extracted from the verbal stimuli of the second experiment of this dissertation will be the same whichever of the independence or the redundancy model is correct. As the data presented in Figure 16 suggested, the recollection component appears to be greater for young than older subjects. Second, both young and older adults seem to be displaying the same increase in performance from medium to large CTTO. Third, whereas the performance of young adults appears to be the same for large and very large CTTO, the performance of older adults seems to be significantly poorer with very large than with large CTTO.

In contrast, the procedure used to evaluate the priming component will be very different whether the independence or redundancy model is chosen. As discussed earlier, the independence model requires first to divide the proportion of list items produced in the exclusion condition over one minus recollection, and then to subtract base rate from the quotient thus obtained. With the redundancy model, however, because all the items produced in the inclusion condition will be equal to the automaticity component, one simply has to subtract base rate from the proportion of list items produced in the inclusion condition to obtain the priming estimate.

As it was previously shown, in the second experiment of this dissertation the independence model led to the conclusion that the priming component of verbal stimuli was the same for both age groups, and that it increased from large to very large CTTO. If the redundancy model had been chosen, would the conclusions be the same?

In order to answer to this question, a 2 (Age) X 3 (CTTO) ANOVA was performed on the priming component as calculated with the method proposed by the redundancy model (the source table for this analysis is in Appendix V). Both the effects of Age and CTTO were significant, but these were qualified by an Age X CTTO interaction (see Figure 19), $\underline{F}(2, 188) = 3.05$, $\underline{MS}_e = .02$. Post hoc tests revealed that the superiority of young over older subjects was significant with all CTTO levels. Thus, if the redundancy rather than the independence model is correct, it would mean that young subjects would display greater priming than older subjects. That is, in contrast to the results suggested by the independence model, the redundancy model suggests that the number of automatic processes induced by the study phase was greater for the young than for the older subjects. Actually, because the measure for automaticity used by

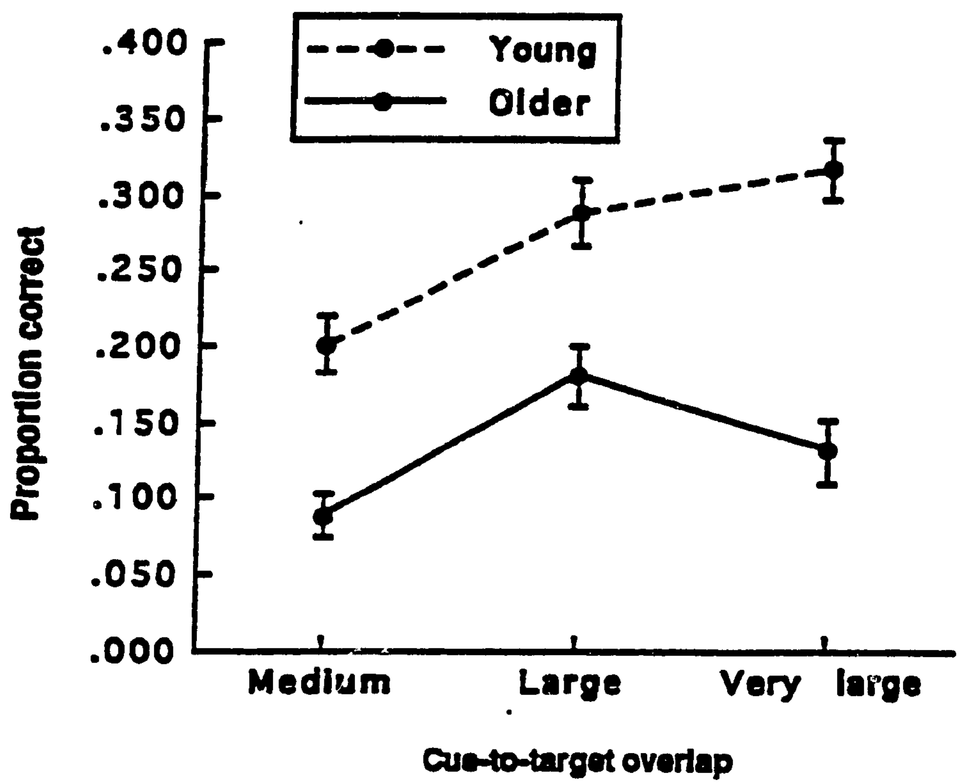

Figure 19. Size of the priming component for the verbal stimuli as a function of cue-to-target overlap and age according to the redundancy model (Exp. 2). Error bars indicate standard error of the mean.

the redundancy model is the subtraction of base rate from the proportion of list items produced in the inclusion condition, one is almost sure to find a main effect of age. The reason for being almost sure to detect a main effect for age is that the procedure used by the redundancy model to calculate automaticity is paradoxically the same as that what has been termed here the conventional measure of memory. Thus, if the redundancy model is correct, explicit tasks, which were considered until recently pure measures of intentional processes (see Jacoby, 1991), would in fact be pure measures of automatic processes!

The possibility that the redundancy model rather than the independence model may be correct means that one cannot reject the hypothesis that older adults are impaired in the execution of automatic, as well as intentional processes. What is clear from the debate between the independence and redundancy models is that without the a priori adoption of a model that mathematically defines the relation between intentional and automatic processes, it is impossible to derive automaticity scores. Because the relationship between intentional and automatic processes is unknown, researchers must arbitrarily assume a particular mathematical definition of this relationship before deriving automaticity scores. In fact, the independence and redundancy models are only two of many possible models relating intentional to automatic processes. As Joordens and Merikle (1993) argue: "The degree of overlap between processes may be other than described by either the redundancy or the independence models" (p. 466).

The lack of understanding of the relation between intentional and automatic processes limits attempts, such as that made in this dissertation, to explain variations of ARDs in episodic memory tasks by age-related changes in the utilization of automatic processes. If the model relating intentional to automatic processes a priori adopted is inaccurate, so will be the conclusions based on it. Thus, if the independence model is false, so would perhaps the results pertaining to the priming component from the second experiment of this dissertation.

As acknowledged by Joordens and Merikle (1993), the joint use of inclusion and exclusion conditions permits the derivation of a measure of the contribution of intentional processes that is independent of the type of relation that exists between them and the processes that are automatic. In other words, the recollection scores produced by Jacoby's process dissociation procedure will be the same whatever the relation between intentional and automatic processes is independence or redundancy.

That recollection scores are not linked to a specific model means that a potentially fruitful avenue of research would be to focus exclusively on the relation between CTTO and ARDs in recollection rather than on both this relation and that between CTTO and automaticity. For example, as discussed earlier, the decline in recollection that was observed from large to very large CTTO in the older subjects of Experiment 2 may have co-occurred with an increased relevance of inhibition mechanisms. That is, if the integrity of inhibition mechanisms is more important with very large than with large CTTO, it would explain why the performance of older subjects was poorer in the former than in the latter condition. Thus, the correlation between an index of inhibition and recollection should be greater with very large than with large CTTO.

It is becoming increasingly clear that a dual-process approach is required to explain the variety of phenomena that are occurring in intentional cued recall. First, the results of Experiment 1 were at odds with a mono-process view in that ARDs in the proportion of visual items remembered remained stable with CTTO despite processing resources became increasingly relevant. Such results can be explained only if one assumes the existence of two different types of processes that would both increase with CTTO. An increase in the execution of intentional processes, for example more extensive memory searches, would explain why the correlation between processing resources and performance increased with CTTO. An increase in automatic target production in response to cues would explain why the correlation between age and performance did not change with CTTO.

Second, the results with the verbal stimuli of Experiment 2 are in line with those from Jacoby, Toth, and Yonelinas (1993). That is, it seems that on cued recall tasks both dividing attention and aging decrease recollection but leave automaticity intact. Such an Age by Type of memory interaction is consistent with the view that researchers need to postulate the existence of two types of memory processes: those that are intentional, and those that are automatic.

It could be argued, however, that finding a dissociation between recollection and automaticity scores is not sufficient evidence for the existence of intentional and automatic processes. The reason for such an argument is that in order to derive both recollection and automaticity scores, one must have previously made two assumptions: (a) that intentional and automatic processes do exist, and (b) that intentional and automatic processes display a specific relation (i.e., independence, redundancy, etc.). Because the existence of both intentional and automatic processes is embedded in the assumptions of the process-dissociation framework defined by Jacoby, this framework will always produce results consistent with the view that two types of memory processes do exist. Thus, evidence for a dual-process approach to intentional cued recall must come outside from the process-dissociation framework.

Perhaps the most stringent test of the need to adopt dual-process approaches is the finding of reversed associations, which are defined as any nonmonotonic relation between two tasks of interest (see Dunn and Kirsner, 1988). To test for a reversed association, a minimum of two tasks and three experimental conditions are required. The verbal stimuli of Experiment 2 meet this requirement in that there are two tasks (inclusion and exclusion) and six experimental conditions (medium, large, and very large CTTO, for each of the two age groups). If more than one process is used by either of the two age groups under the different CTTO levels in either the inclusion condition or the exclusion condition, then, when the means for each age group at each CTTO level for exclusion are plotted against the corresponding means for inclusion, exclusion scores will be a nonmonotonic function of inclusion scores. In contrast, if only one process is used by both age groups under the different CTTO levels in both the inclusion and exclusion conditions, then exclusion scores will be a monotonic function of inclusion scores.

As shown in Figure 20, the results of Experiment 2 suggest the existence of a nonmonotonic relation between the proportion of list items produced in the exclusion condition and the proportion of list items produced in the inclusion condition. This finding is due to the observation that the relation between the list items produced in the exclusion condition and those produced in the inclusion condition is

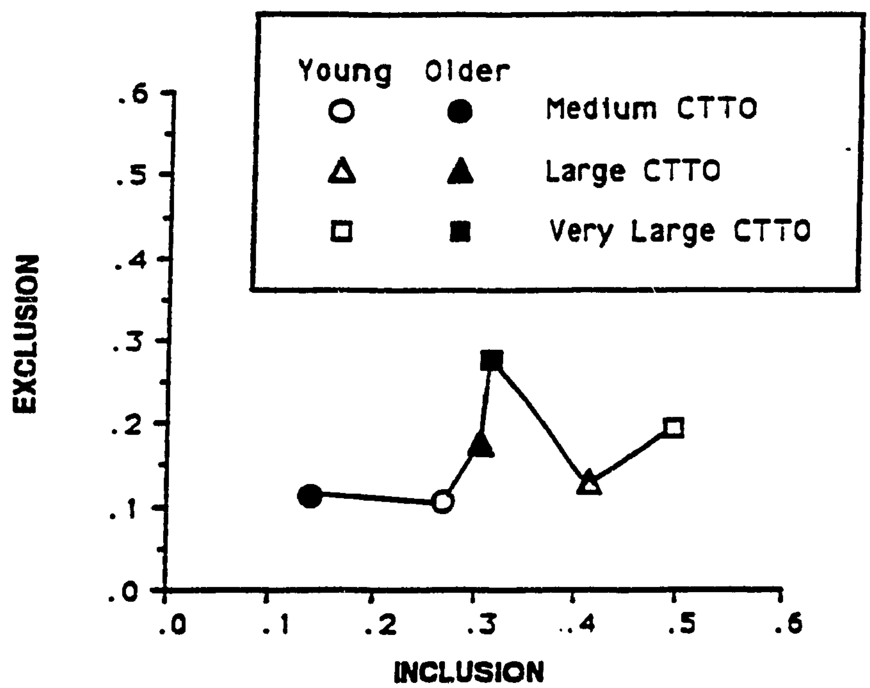

Figure 20. Reversed association between the proportion of verbal list items produced in the exclusion condition and the proportion of verbal list items produced in the inclusion condition (Exp. 2).

not the same for both age groups. For young subjects, the proportion of list items produced in the exclusion condition appears to increase slowly with the proportion of list items produced in the inclusion condition. In contrast, for older subjects, the proportion of list items produced in the exclusion condition appears to increase markedly with the proportion of list items produced in the inclusion condition. But more importantly the function that relates the number of list items produced in the exclusion condition to those produced in the inclusion condition for the older subjects overlaps the similar function for the young subjects in such a way that a reversed association is created.

Because it is impossible in Figure 20 to find a monotonic function that would show the proportion of list items produced in the exclusion condition to always either increase or decrease with the proportion of list items produced in the inclusion condition, one can reject the hypothesis that a mono-process approach is sufficient. More precisely, the reversed association observed in Figure 20 suggests that a dual-process approach is required and sufficient to explain the pattern of results observed in Experiment 2. Future research will tell whether Jacoby's independence model, Joordens and Merikle's redundancy model, or another model relating intentional to automatic processes is the appropriate dual-process approach required to explain the array of phenomena observed in cued recall.

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Appendix A

Frequencies per Million

of the Verbal Stimuli

Experiment 1

	Version A			Version B		
		Frequency			Frequency	
CTTO	Target	Kucera & Francis (1967)	Thorndike & Lorge (1944)	Target	Kucera & Francis (1967)	Thorndike & Lorge (1944)
			List no. 1			
Small	option	5	2	option	5	2
	slogan	7	5	slogan	7	5
	zenith	6	4	zenith	6	4
Medium	accent	9	16	advent	5	6
	hurdle	3	2	holdup	2	2
	ladder	19	19	legend	26	22
Large	barrow	1	3	batter	2	15
	bureau	42	44	bustle	2	10
	canter	1	2	carver	1	2
			List no. 2			
Small	eighty	11	22	eighty	11	22
	gypsum	2	2	gypsum	2	2
	jockey	5	2	jockey	5	2
	psyche	7	4	psyche	7	4
	writer	72	75	writer	72	75
Medium	fungus	2	5	spiral	8	6
	kernel	3	4	kidney	6	5
	ordeal	3	5	nugget	1	2
	socket	3	6	syntax	6	1
	vassal	1	9	volley	6	6
Large	dealer	25	26	coupon	1	1
	insert	13	14	intern	2	1
	madman	2	6	matron	3	9
	murder	74	75	musket	6	8
	revolt	8	22	ticker	1	2
			List no. 3			
Small	appeal	61	75	appeal	61	75
	blazon	1	1	blazon	1	1
	hybrid	1	5	hybrid	1	5
Medium	escort	9	13	duster	0	1
	mystic	3	4	import	17	31
	riddle	1	12	rodent	3	2
Large	garlic	4	3	gallon	6	12
	mettle	2	2	memoir	2	5
	pillar	2	16	rabble	2	3

CTTO	Version A Target	Frequency Kucera & Francis (1967)	Frequency Thorndike & Lorge (1944)	Version B Target	Frequency Kucera & Francis (1967)	Frequency Thorndike & Lorge (1944)
			List no. 4			
Small	cinder	2	6	cinder	2	6
	oyster	6	23	oyster	6	23
	saddle	25	41	saddle	25	41
	twenty	70	150	twenty	70	150
	yeller	2	26	yeller	2	26
Medium	allure	1	4	ambush	7	5
	domain	9	9	driver	48	40
	jasper	1	2	jumper	1	3
	liquor	42	34	locust	6	7
	peanut	6	7	puppet	6	6
Large	ballot	12	14	bandit	3	5
	hamper	5	8	harper	2	2
	morass	1	2	mutton	8	10
	parish	11	11	picker	1	1
	wallet	6	6	winner	8	10
			List no. 5			
Small	feline	2	2	feline	2	2
	glance	39	75	glance	39	75
	rhythm	22	7	rhythm	22	7
Medium	beacon	5	4	bomber	8	1
	saloon	12	12	sizzle	1	1
	tussle	4	1	thesis	10	3
Large	castor	2	2	camper	3	2
	porter	17	19	pollen	11	6
	tinsel	2	2	trophy	8	8
			List no. 6			
Small	eyelid	1	9	eyelid	1	9
	jersey	25	21	jersey	25	21
	zipper	1	0	zipper	1	0
Medium	assist	26	44	autumn	22	49
	chorus	18	17	cutter	4	9
	vellum	1	1	upland	2	6
Large	hearer	2	6	gunman	3	2
	poster	4	5	victim	27	36
	resist	22	29	retail	20	9

	Version A			Version B		
		Frequency			Frequency	
CTTO	Target	Kucera & Francis (1967)	Thorndike & Lorge (1944)	Target	Kucera & Francis (1967)	Thorndike & Lorge (1944)
			List no. 7			
Small	bypass	3	0	bypass	3	0
	island	165	150	island	165	150
	lumber	35	34	lumber	35	34
	object	64	150	object	64	150
	swivel	5	1	swivel	5	1
Medium	census	11	7	crater	2	4
	filler	1	1	folder	1	2
	gospel	13	13	gender	2	1
	novice	3	4	nickle	7	11
	wobble	3	11	weasel	1	9
Large	corner	113	150	collar	17	44
	defect	3	14	demise	4	1
	motive	22	26	merger	21	3
	ration	10	8	ranger	2	3
	treble	2	5	truant	1	4
			List no. 8			
Small	attack	104	75	attack	104	75
	hijack	0	0	hijack	0	0
	python	14	1	python	14	1
Medium	broker	1	7	binder	1	2
	nectar	3	2	nausea	3	2
	offset	9	5	outset	13	4
Large	mentor	1	1	marrow	5	5
	regret	9	33	repair	20	47
	tenant	5	16	temper	12	39

	Version A			Version B		
		Frequency			Frequency	
CTTO	Target	Kucera & Francis (1967)	Thorndike & Lorge (1944)	Target	Kucera & Francis (1967)	Thorndike & Lorge (1944)
			List no. 9			
Small	excise	4	2	excise	4	2
	ghetto	11	0	ghetto	11	0
	jigger	1	4	jigger	1	4
	umpire	1	3	umpire	1	3
	whisky	23	9	whisky	23	9
Medium	antler	3	5	arcade	3	1
	dipper	6	4	damage	33	32
	prison	41	75	planet	21	34
	runway	4	2	staple	1	8
	toilet	13	11	typhus	3	1
Large	closet	16	20	clinic	3	6
	despot	2	4	deceit	2	6
	misuse	5	4	midway	8	7
	pallet	1	2	pastel	3	2
	tangle	8	11	tallow	1	4
			List no. 10			
Small	fallow	1	3	fallow	1	3
	omelet	3	2	omelet	3	2
	zodiac	0	3	zodiac	0	3
Medium	effort	143	150	ending	31	14
	gibbet	1	2	grower	1	3
	subway	7	6	shaker	2	2
Large	buffet	6	12	bundle	20	25
	recoil	5	6	reform	30	31
	trifle	9	24	trader	8	16
Small	Mean	21.2	26.2		21.2	26.2
	SD	34.2	42.7		34.2	42.7
Medium	Mean	11.7	14.1		8.4	9.1
	SD	23.7	26.2		10.7	12.0
Large	Mean	12.5	17.2		7.3	10.6
	SD	21.3	26.1		7.8	12.4

Appendix B

Baseline Completion Rates

of the Verbal Stimuli

Experiment 1

	Version A				Version B		
		Baseline Completion Rate				Baseline Completion Rate	
Target	Cue	Young	Older	Target	Cue	Young	Older
			List no. 1				
zenith	z_____	.08	.04	zenith	z_____	.08	.04
ladder	la____	.17	.08	legend	le____	.00	.00
barrow	bar___	.00	.17	batter	bat___	.33	.42
accent	ac____	.08	.17	advent	ad____	.08	.08
bureau	bur___	.08	.00	bustle	bus___	.58	.00
slogan	s_____	.00	.00	slogan	s_____	.00	.00
canter	can___	.00	.00	carver	car___	.00	.00
option	o_____	.00	.00	option	o_____	.00	.00
hurdle	hu____	.17	.00	holdup	ho____	.00	.00
			List no. 2				
eighty	e_____	.00	.00	eighty	e_____	.00	.00
fungus	fu____	.00	.00	spiral	sp____	.00	.00
murder	mur___	.50	.67	musket	mus___	.00	.08
ordeal	or____	.00	.08	nugget	nu____	.08	.08
madman	mad___	.08	.08	matron	mat___	.00	.00
jockey	j_____	.00	.00	jockey	j_____	.00	.00
revolt	rev___	.08	.17	ticker	tic___	.00	.08
gypsum	g_____	.00	.00	gypsum	g_____	.00	.00
vassal	va____	.00	.08	volley	vo____	.00	.00
psyche	p_____	.00	.00	psyche	p_____	.00	.00
socket	so____	.00	.00	syntax	sy____	.00	.00
dealer	dea___	.42	.33	coupon	cou___	.00	.00
insert	ins___	.08	.33	intern	int___	.42	.25
kernel	ke____	.00	.08	kidney	ki____	.00	.00
writer	w_____	.00	.00	writer	w_____	.00	.00
			List no. 3				
mystic	my____	.25	.25	import	im____	.42	.25
pillar	pil___	.17	.08	rabble	rab___	.08	.08
blazon	b_____	.00	.00	blazon	b_____	.00	.00
garlic	gar___	.00	.00	gallon	gal___	.33	.33
appeal	a_____	.00	.00	appeal	a_____	.00	.00
escort	es____	.08	.00	duster	du____	.00	.00
hybrid	h_____	.00	.00	hybrid	h_____	.00	.00
riddle	ri____	.25	.42	rodent	ro____	.00	.00
mettle	met___	.50	.33	memoir	mem___	.00	.00

Version A				Version B			
		Baseline Completion Rate				Baseline Completion Rate	
Target	Cue	Young	Older	Target	Cue	Young	Older

List no. 4

Target	Cue	Young	Older	Target	Cue	Young	Older
peanut	pe____	.08	.00	puppet	pu____	.00	.00
parish	par___	.08	.00	picker	pic___	.00	.08
yeller	y_____	.00	.04	yeller	y_____	.00	.04
hamper	ham___	.17	.08	harper	har___	.00	.00
cinder	c_____	.00	.04	cinder	c_____	.00	.04
domain	do____	.00	.08	driver	dr____	.08	.00
twenty	t_____	.00	.00	twenty	t_____	.00	.00
allure	al____	.00	.00	ambush	am____	.25	.25
ballot	bal___	.00	.17	bandit	ban___	.00	.00
jasper	ja____	.08	.00	jumper	ju____	.00	.08
morass	mor___	.00	.00	mutton	mut___	.00	.17
saddle	s_____	.00	.04	saddle	s_____	.00	.04
oyster	o_____	.04	.04	oyster	o_____	.04	.04
wallet	wal___	.42	.25	winner	win___	.67	.92
liquor	li____	.00	.08	locust	lo____	.08	.08

List no. 5

Target	Cue	Young	Older	Target	Cue	Young	Older
tinsel	tin___	.08	.17	trophy	tro___	.17	.00
rhythm	r_____	.00	.00	rhythm	r_____	.00	.00
tussle	tu____	.00	.00	thesis	th____	.17	.08
feline	f_____	.00	.00	feline	f_____	.00	.00
saloon	sa____	.00	.00	sizzle	si____	.00	.00
porter	por___	.25	.33	pollen	pol___	.08	.17
beacon	be____	.00	.00	bomber	bo____	.00	.00
castor	cas___	.00	.08	camper	cam___	.67	.42
glance	g_____	.00	.00	glance	g_____	.00	.00

List no. 6

Target	Cue	Young	Older	Target	Cue	Young	Older
jersey	j_____	.00	.00	jersey	j_____	.00	.00
chorus	ch____	.00	.00	cutter	cu____	.08	.08
poster	pos___	.33	.50	victim	vic___	.17	.00
assist	as____	.08	.00	autumn	au____	.17	.00
hearer	hea___	.00	.00	gunman	gun___	.17	.08
zipper	z_____	.00	.00	zipper	z_____	.00	.00
resist	res___	.17	.00	retail	ret___	.08	.00
eyelid	e_____	.00	.00	eyelid	e_____	.00	.00
vellum	ve____	.00	.00	upland	up____	.00	.00

	Version A				Version B		
		Baseline Completion Rate				Baseline Completion Rate	
Target	Cue	Young	Older	Target	Cue	Young	Older
			List no. 7				
ration	rat___	.08	.08	ranger	ran___	.17	.00
object	o_____	.00	.00	object	o_____	.00	.00
census	ce____	.00	.00	crater	cr____	.00	.00
island	i_____	.17	.13	island	i_____	.17	.13
gospel	go____	.00	.00	gender	ge____	.08	.08
treble	tre___	.17	.17	truant	tru___	.08	.08
wobble	wo____	.00	.00	weasel	we____	.25	.08
defect	def___	.00	.00	demise	dem___	.25	.25
bypass	b_____	.00	.00	bypass	b_____	.00	.00
corner	cor___	.17	.50	collar	col___	.42	.00
lumber	l_____	.04	.00	lumber	l_____	.04	.00
novice	no____	.08	.00	nickle	ni____	.33	.17
filler	fi____	.00	.00	folder	fo____	.00	.00
swivel	s_____	.00	.00	swivel	s_____	.00	.00
motive	mot___	.08	.08	merger	mer___	.08	.17
			List no. 8				
nectar	ne____	.00	.00	nausea	na____	.00	.00
regret	reg___	.00	.17	repair	rep___	.08	.08
attack	a_____	.00	.00	attack	a_____	.00	.00
mentor	men___	.25	.33	marrow	mar___	.08	.00
python	p_____	.00	.00	python	p_____	.00	.00
broker	br____	.00	.08	binder	bi____	.00	.00
hijack	h_____	.00	.00	hijack	h_____	.00	.00
offset	of____	.00	.00	outset	ou____	.25	.00
tenant	ten___	.08	.00	temper	tem___	.75	.92

Version A				Version B			
		Baseline Completion Rate				Baseline Completion Rate	
Target	Cue	Young	Older	Target	Cue	Young	Older
			List no. 9				
ghetto	g_____	.00	.04	ghetto	g_____	.00	.04
runway	ru____	.00	.00	staple	st____	.00	.00
despot	des___	.08	.00	deceit	dec___	.00	.00
dipper	di____	.00	.00	damage	da____	.00	.08
pallet	pal___	.25	.00	pastel	pas___	.17	.00
umpire	u_____	.00	.04	umpire	u_____	.00	.04
misuse	mis___	.25	.08	midway	mid___	.17	.17
excise	e_____	.00	.00	excise	e_____	.00	.00
antler	an____	.08	.08	arcade	ar____	.00	.00
whisky	w_____	.00	.00	whisky	w_____	.00	.00
toilet	to____	.08	.08	typhus	ty____	.00	.00
closet	clo___	.00	.33	clinic	cli___	.00	.17
tangle	tan___	.17	.42	tallow	tal___	.25	.17
prison	pr____	.08	.08	planet	pl____	.00	.00
jigger	j_____	.00	.00	jigger	j_____	.00	.00
			List no. 10				
trifle	tri___	.00	.00	trader	tra___	.00	.00
zodiac	z_____	.00	.00	zodiac	z_____	.00	.00
gibbet	gi____	.00	.00	grower	gr____	.00	.00
omelet	o_____	.00	.00	omelet	o_____	.00	.00
effort	ef____	.17	.67	ending	en____	.00	.00
buffet	buf___	.42	.42	bundle	bun___	.83	.42
subway	su____	.00	.00	shaker	sh____	.08	.00
recoil	rec___	.00	.00	reform	ref___	.00	.08
fallow	f_____	.00	.00	fallow	f_____	.00	.00

Appendix C

Baseline Completion Rates

of the Visual Stimuli

Experiment 1

	Version A				Version B		
		Baseline Completion Rate				Baseline Completion Rate	
Target	Cue	Young	Older	Target	Cue	Young	Older
			List no. 1				
foot	8%	.00	.00	belt	8%	.00	.00
mushroom	12%	.50	.08	sun	12%	.33	.17
bee	17%	.00	.00	french horn	17%	.00	.00
motorcycle	12%	.50	.08	kite	12%	.33	.08
tree	17%	.33	.08	clock	17%	.67	.08
hand	8%	.08	.00	dresser	8%	.00	.00
roller skate	17%	.08	.00	swan	17%	.08	.08
truck	8%	.08	.00	pot	8%	.00	.00
penguin	12%	.00	.00	cup	12%	.08	.00
			List no. 2				
barn	8%	.00	.00	sweater	8%	.00	.00
drum	12%	.00	.00	pencil	12%	.42	.33
frog	17%	.00	.00	saw	17%	.17	.33
mitten	12%	.00	.00	bottle	12%	.33	.17
sled	17%	.25	.08	monkey	17%	.00	.00
airplane	8%	.08	.00	car	8%	.33	.00
bus	17%	.17	.08	bird	17%	.33	.00
lock	8%	.08	.00	eagle	8%	.00	.00
lion	12%	.08	.00	owl	12%	.00	.00
snake	8%	.00	.00	glasses	8%	.00	.00
snowman	12%	.00	.00	sandwich	12%	.00	.00
umbrella	17%	.25	.17	cat	17%	.42	.33
hammer	17%	.08	.08	dress	17%	.08	.00
hanger	12%	.00	.00	camel	12%	.08	.08
bread	8%	.00	.00	scissors	8%	.25	.00
			List no. 3				
pig	12%	.00	.08	bicycle	12%	.00	.08
house	17%	.67	.50	star	17%	.08	.00
pitcher	8%	.00	.00	shoe	8%	.00	.00
strawberry	17%	.00	.00	guitar	17%	.08	.00
eye	8%	.00	.00	book	8%	.00	.00
train	12%	.00	.00	doll	12%	.33	.50
lemon	8%	.00	.00	mouse	8%	.00	.00
skirt	12%	.00	.00	ear	12%	.08	.00
duck	17%	.17	.25	leaf	17%	.00	.00

	Version A				Version B		
		Baseline Completion Rate				Baseline Completion Rate	
Target	Cue	Young	Older	Target	Cue	Young	Older
			List no. 4				
lettuce	12%	.00	.00	refrigerator	12%	.00	.00
paintbrush	17%	.00	.00	knife	17%	.00	.00
button	8%	.00	.00	dog	8%	.00	.00
heart	17%	.92	.58	pants	17%	.17	.00
skunk	8%	.00	.00	suitcase	8%	.00	.00
rooster	12%	.17	.00	carrot	12%	.33	.00
thimble	8%	.00	.00	cow	8%	.00	.00
jacket	12%	.75	.42	broom	12%	.00	.00
bell	17%	.08	.00	baby carr.	17%	.00	.00
traffic lig.	12%	.08	.00	swing	12%	.00	.00
frying pan	17%	.25	.25	shirt	17%	.25	.17
clown	8%	.00	.00	moon	8%	.00	.00
foot. helmet	8%	.00	.00	chain	8%	.00	.00
nail	17%	.00	.00	candle	17%	.25	.00
potato	12%	.00	.00	hair	12%	.00	.00
			List no. 5				
glass	17%	.25	.08	nose	17%	.25	.17
pineapple	8%	.00	.00	ladder	8%	.00	.00
peanut	12%	.00	.00	screwdriver	12%	.00	.00
pepper	8%	.00	.00	pear	8%	.08	.00
artichoke	12%	.08	.00	television	12%	.17	.08
tennis rack.	17%	.25	.17	toaster	17%	.00	.00
necklace	12%	.17	.08	football	12%	.00	.00
toothbrush	17%	.00	.00	elephant	17%	.08	.00
wheel	8%	.08	.00	vase	8%	.00	.00
			List no. 6				
lightbulb	8%	.50	.42	telephone	8%	.00	.00
pen	12%	.00	.00	trumpet	12%	.00	.00
cannon	17%	.00	.00	flower	17%	.58	.08
spider	12%	.00	.00	vest	12%	.00	.00
cap	17%	.00	.00	sailboat	17%	.00	.00
chisel	8%	.00	.00	gorilla	8%	.00	.00
donkey	17%	.08	.00	lips	17%	.25	.00
asparagus	8%	.00	.00	gun	8%	.00	.CO
raccoon	12%	.00	.00	pumpkin	12%	.17	.00

	Version A				Version B		
		Baseline Completion Rate				Baseline Completion Rate	
Target	Cue	Young	Older	Target	Cue	Young	Older
			List no. 7				
giraff	17%	.67	.25	violin	17%	.00	.08
cherry	8%	.00	.00	rolling pin	8%	.00	.00
flag	12%	.08	.00	horse	12%	.17	.00
buetle	8%	.00	.00	watch	8%	.00	.00
ostrich	12%	.42	.25	comb	12%	.25	.00
bed	17%	.08	.08	arm	17%	.17	.08
seahorse	12%	.00	.00	fish	12%	.08	.00
watering can	17%	.58	.25	rabbit	17%	.08	.00
box	8%	.50	.25	piano	8%	.00	.00
corn	17%	.42	.00	mountain	17%	.17	.17
barp	8%	.00	.00	ball	8%	.08	.00
spool	12%	.00	.00	kangaroo	12%	.33	.08
leopard	12%	.33	.08	balloon	12%	.00	.00
peach	8%	.00	.00	tie	8%	.42	.00
screw	17%	.33	.00	banana	17%	.67	.17
			List no. 8				
deer	12%	.00	.00	bear	12%	.08	.00
wrench	17%	.08	.00	pipe	17%	.00	.00
wineglass	8%	.00	.00	record play.	8%	.00	.00
envelop	17%	.17	.00	goat	17%	.08	.00
spin. wheel	8%	.08	.00	spoon	8%	.08	.00
anchor	12%	.00	.00	apple	12%	.00	.00
blouse	8%	.00	.00	saltshaker	8%	.00	.00
zebra	12%	.25	.00	axe	12%	.00	.00
brush	17%	.25	.08	table	17%	.50	.00

	Version A				Version B		
		Baseline Completion Rate				Baseline Completion Rate	
Target	Cue	Young	Older	Target	Cue	Young	Older
			List no. 9				
alligator	8%	.00	.00	helicopter	8%	.00	.00
arrow	12%	.00	.00	lamp	12%	.00	.00
lobster	17%	.00	.00	thumb	17%	.00	.00
watermelon	12%	.00	.00	grapes	12%	.00	.00
bow	17%	.25	.08	sock	17%	.08	.08
window	8%	.08	.00	top	8%	.17	.00
pliers	17%	.42	.25	bowl	17%	.50	.08
windmill	8%	.00	.00	key	8%	.00	.00
toe	12%	.00	.00	stove	12%	.17	.08
door	8%	.25	.00	coat	8%	.17	.00
cloud	12%	.00	.00	whistle	12%	.00	.00
fork	17%	.17	.08	pocket book	17%	.00	.00
leg	17%	.08	.00	hat	17%	.25	.00
celery	12%	.00	.00	ruler	12%	.00	.00
snail	8%	.00	.00	onion	8%	.00	.00
			List no. 10				
grasshopper	17%	.00	.00	couch	17%	.83	.75
orange	8%	.00	.08	stool	8%	.00	.00
well	12%	.00	.00	tiger	12%	.00	.00
fly	8%	.00	.00	cake	8%	.00	.00
doorknob	12%	.00	.00	squirrel	12%	.00	.00
ironing brd.	17%	.17	.00	desk	17%	.17	.00
turtle	12%	.00	.00	chair	12%	.00	.00
butter	17%	.08	.00	kettle	17%	.08	.00
cigare	8%	.00	.00	iron	8%	.00	.00

Appendix D

Instructions for the Verbal Memory Task

Experiment 1

For the next task, you will see 6-letter words on the computer screen that you have not seen before in this experiment. None of these words will be proper names or plurals. Your task is to try to remember these words so that you are able to identify them at a later time when only their first letters are presented to you. Now, we will do a practice session **(Press "Y")**. Before each list, you will see the following message: "Press Y when ready for the next list". I'll press "Y" and now you can see the first word. What is it?. Each time you see a word, I want you to tell me what it is. Let me show you another word. After the you have seen all the words, you will be asked to solve simple additions problems. For instance, (**press the Y key**), now you see... (addition appears). (**Wait before pressing enter.**) When the additions problems are over, you will be shown the first letters of each of the words that were shown in the preceding list. (**Press enter**) When you are ready to tell me what the word is, I will type the answer for you. I want you to tell me the answer by spelling it. This way, I am sure not to make any typing errors. What is your answer?

Some words will probably be easy for you to remember, whereas other words will probably be difficult for you to remember. That's okay. What is important is that you do your best. Are you ready for a new practice list?. Please don't forget to tell me the name of the words that you see and to try to learn them.

(**When the second test phase starts**): If you don't give me an answer within 20 seconds, the computer will skip to the next item. If you think you know the answer, please spell it. If you don't know the answer, please say the first answer that comes to mind as long as this answer is not a proper noun or a plural. When you don't remember the answer, it is very important that you try to guess it. There will be a total of 12 lists of words. Some of the lists contain 9 words each, and some other lists contain 15 words each. Do you have any questions? Are you ready to begin?

Appendix E

Means and Standard Deviations

for Proportion of Verbal Items Remembered

as a Function of Age, List Length, and CTTO

Experiment 1

List Length	CTTO	Age		Mean
		Young	Older	
		(n = 48)	(n = 48)	
9	Small	.456 (.178)	.319 (.134)	.387
	Medium	.657 (.140)	.493 (.178)	.575
	Large	.636 (.096)	.530 (.155)	.583
	Mean	.583	.447	.515
15	Small	.451 (.153)	.233 (.132)	.342
	Medium	.700 (.120)	.470 (.163)	.585
	Large	.681 (.111)	.513 (.147)	.597
	Mean	.611	.405	.508
	Mean	.597	.426	.512

<u>Source</u>	<u>DF</u>	<u>MS</u>	<u>F</u>
Test of Between-Subjects Effects			
Age	1	4.18	53.82***
Error	94	.08	
Tests Involving "List Length" Within-Subject Effect			
List Length	1	.01	1.08
Age x List Length	1	.17	23.82***
Error	94	.01	
Tests Involving "CTTO" Within-Subject Effect			
CTTO	2	3.12	259.16***
Age x CTTO	2	.04	3.70*
Error	188	.01	
Tests Involving "List Length x CTTO" Within-Subject Effect			
List Length x CTTO	2	.05	6.37**
Age x List Length x CTTO	2	.002	.15
Error	188	.01	

$^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$

Appendix F

Instructions for the Visual Memory Task

Experiment 1

For the next task, you will see pictures of common objects on the computer screen that you have not seen before in this experiment. Your task is to try to remember these objects so that you are able to identify them at a later time when only a part of each object is presented to you. Now, we will do a practice session **(Press "Y")**. Before each list, you will see the following message: "Press Y when ready for the next list". I'll press "Y" and now you can see the first object. What is it? (**barrel**). Each time you see an object, I want you to tell me what it is. Let me show you another object (**hen**). After the you have seen all the objects, you will be asked to solve simple additions problems. For instance, (**press the Y key**), now you see... (addition appears). (**Wait before pressing enter.**) When the additions problems are over, you will be shown a part of each of the objects that were shown in the preceding list. (**Press enter**) When you are ready to tell me what the object is, I will type the answer for you. I want you to tell me the answer by spelling it. This way, I am sure not to make any typing errors. What is your answer?

Some objects will probably be easy for you to remember, whereas other objects will probably be difficult for you to remember. That's okay. What is important is that you do your best. Are you ready for a new practice list? (2 drawings will be presented). Please don't forget to tell me the name of the objects that you see and to try to learn them.

(**When the second test phase starts**): If you don't give me an answer within 20 seconds, the computer will skip to the next item. If you think you know the answer, please spell it. If you don't know the answer, please say the first answer that comes to mind. When you don't remember the answer, it is very important that you try to guess it. There will be a total of 12 lists of objects. Some of the lists contain 9 objects each, and some other lists contain 15 objects each. Do you have any questions? Are you ready to begin?

Appendix G

Means and Standard Deviations

for Proportion of Visual Items Remembered

as a Function of Age, List Length, and CTTO

Experiment 1

List Length	CTTO	Age		Mean
		Young	Older	
		(n = 48)	(n = 48)	
9	Small	.339 (.140)	.145 (.131)	.242
	Medium	.426 (.155)	.264 (.180)	.345
	Large	.573 (.162)	.415 (.212)	.494
	Mean	.446	.275	.360
15	Small	.283 (.123)	.150 (.115)	.216
	Medium	.353 (.150)	.182 (.143)	.268
	Large	.463 (.133)	.295 (.192)	.379
	Mean	.366	.209	.288
	Mean	.406	.242	.324

Source	DF	MS	F
Test of Between-Subjects Effects			
Age	1	3.89	43.30***
Error	94	.09	
Tests Involving "List Length" Within-Subject Effect			
List Length	1	.76	91.61***
Age x List Length	1	.01	.83
Error	94	.01	
Tests Involving "CTTO" Within-Subject Effect			
CTTO	2	2.11	153.31***
Age x CTTO	2	.0001	.01
Error	188	.01	
Tests Involving "List Length x CTTO" Within-Subject Effect			
List Length x CTTO	2	.10	10.23***
Age x List Length x CTTO	2	.02	2.17
Error	188	.01	

***$p < .001$

Appendix H

Baseline Completion Rates

of the Visual Stimuli

Experiment 2

	Version A				Version B		
		Baseline Completion Rate				Baseline Completion Rate	
Target	Cue	Young	Older	Target	Cue	Young	Older
			List no. 1				
french horn	17%	.00	.00	dresser	17%	.29	.21
leaf	17%	.00	.04	kettle	17%	.38	.21
wineglass	12%	.21	.08	window	12%	.13	.08
television	24%	.13	.04	thimble	24%	.04	.04
peanut	12%	.00	.00	lettuce	12%	.04	.00
ashtray	24%	.25	.17	babycarriage	24%	.25	.17
flag	12%	.13	.08	cup	12%	.13	.04
grapes	24%	.25	.13	hammer	24%	.21	.08
cloud	12%	.00	.00	celery	12%	.00	.00
pants	24%	.21	.08	pencil	24%	.08	.04
saw	17%	.38	.21	saltshaker	17%	.29	.13
tree	17%	.29	.13	toothbrush	17%	.00	.04
screw	24%	.13	.08	screwdriver	24%	.29	.13
suitcase	24%	.13	.08	sweater	24%	.38	.21
bread	17%	.08	.00	bow	17%	.17	.08
pineapple	12%	.33	.13	piano	12%	.08	.00
cake	17%	.04	.04	butter	17%	.08	.04
snowman	12%	.08	.04	sandwich	12%	.04	.00
			List no. 2				
hat	17%	.17	.04	gun	17%	.50	.17
well	12%	.00	.00	watermelon	12%	.00	.00
mountain	17%	.00	.08	moon	17%	.17	.08
key	12%	.00	.00	helicopter	12%	.08	.00
vest	24%	.08	.04	watch	24%	.00	.00
chair	24%	.08	.00	doorknob	24%	.00	.08
arrow	12%	.00	.04	apple	12%	.00	.00
bottle	12%	.42	.25	bicycle	12%	.04	.04
football he.	24%	.25	.08	frying pan	24%	.13	.08
strawberry	17%	.04	.00	stool	17%	.29	.21
knife	24%	.38	.13	lights	24%	.08	.00
wrench	17%	.00	.00	violin	17%	.21	.08
record play.	24%	.54	.25	refrigerator	24%	.25	.17
bell	17%	.00	.00	bed	17%	.42	.21
chain	17%	.00	.04	cap	17%	.04	.04
skirt	24%	.04	.00	sled	24%	.25	.21
potato	12%	.00	.00	pot	12%	.04	.04
top	12%	.17	.04	stove	12%	.58	.21

	Version A				Version B		
		Baseline Completion Rate				Baseline Completion Rate	
Target	Cue	Young	Older	Target	Cue	Young	Older
			List no. 3				
train	24%	.08	.04	telephone	24%	.13	.04
balloon	24%	.50	.21	accordeon	24%	.13	.13
dress	17%	.00	.04	desk	17%	.29	.08
windmill	12%	.13	.04	wheel	12%	.08	.04
ironing brd	17%	.42	.21	iron	17%	.00	.00
lamp	12%	.21	.08	ladder	12%	.17	.08
sailboat	17%	.00	.04	onion	17%	.00	.04
comb	12%	.29	.13	coat	12%	.46	.17
toaster	17%	.08	.00	tennis	17%	.42	.21
carrot	12%	.04	.08	broom	12%	.17	.13
harp	24%	.21	.08	glasses	24%	.25	.17
pliers	24%	.00	.04	paintbrush	24%	.08	.00
pepper	12%	.00	.00	pen	12%	.00	.04
ruler	12%	.00	.00	pumpkin	12%	.04	.00
shirt	24%	.50	.21	rolling pin	24%	.33	.21
book	17%	.00	.00	belt	17%	.50	.13
swing	24%	.00	.00	spoon	24%	.71	.25
bus	17%	.08	.17	brush	17%	.21	.17
			List no. 4				
whistle	24%	.08	.00	vase	24%	.13	.08
guitar	17%	.13	.04	glass	17%	.58	.17
drum	24%	.25	.13	button	24%	.00	.00
lock	17%	.08	.08	lemon	17%	.13	.00
trumpet	12%	.00	.00	traffic lite	12%	.00	.00
hanger	12%	.13	.00	football	12%	.08	.00
star	17%	.25	.13	scissors	17%	.83	.21
umbrella	17%	.04	.04	truck	17%	.08	.08
garbage can	24%	.42	.21	envelop	24%	.79	.29
anchor	12%	.04	.04	airplane	12%	.00	.00
axe	12%	.04	.00	artichoke	12%	.00	.00
mitten	24%	.08	.08	kite	24%	.71	.29
pitcher	12%	.13	.04	pipe	12%	.00	.00
rollerskate	24%	.29	.13	pocketbook	24%	.67	.21
spool	12%	.00	.00	spinning whe	12%	.00	.00
sock	24%	.58	.33	shoe	24%	.71	.25
barn	17%	.00	.00	ball	17%	.04	.00
cannon	17%	.04	.08	candle	17%	.29	.04

Appendix I

Means and Standard Deviations

for Baseline Completion Rate of Visual Stimuli

as a Function of Age and CTTO

Experiment 2

CTTO	Age		Mean
	Young (n = 48)	Older (n = 48)	
Medium	.094 (.084)	.041 (.059)	.067
Large	.174 (.130)	.084 (.097)	.129
Very large	.251 (.120)	.118 (.104)	.184
Mean	.173	.081	.127

Source	DF	MS	F
Between-Subjects Effects			
Age	1	.61	29.40***
Error	94	.02	
Within-Subject Effects			
CTTO	2	.33	63.59***
Age x CTTO	2	.04	7.39***
Error	188	.01	

***$p < .001$

Appendix J

Instructions for the Visual Memory Task

Experiment 2

For the next task, you will be presented with lists of words, and your task will be to try to remember these words. The words will be presented one at a time on the computer screen. All the words will be 6-letter long, and none of them will be either proper names or plurals. For instance, you could see the following two words: JAGUAR, QUARTZ.

Once all the words have been shown to you, you will be presented with the first letters from each word plus a message above those letters. For some of these word stems, the message above the letters will be "FROM THE LIST". If you see this message, your task will be to remember which word from the list completes the wordstem shown. For instance, the wordstem "JAG___" is completed by the word "JAGUAR". Fine. It may occur that you don't remember the word from the list that completes the wordstem shown. In this case, you will should attempt to guess what that word was. If ever you don't remember which word from the list completes the wordstem, it is very important that you try to guess what that word was when the instructions are "FROM THE LIST". Please note that plurals and proper names are not allowed. If you don't provide an answer within a period of 30 seconds, the machine will beep and the first letters corresponding to a new word will appear on the screen. Thus, "QU____" belongs to ... QUARTZ. Fine.

Let's practice with another list, which will once again have 2 words. From this moment, whenever you see a new word appearing on the screen, you will first read it aloud, and you will then try to remember it. Are you ready? KEEPER, ICEBOX, IC____, KEE___. Fine.

For some of the words, the message above the letters will not be "FROM THE LIST". It will be "<u>NOT</u> FROM THE LIST" instead. If you see the message "<u>NOT</u> FROM THE LIST", your task will be to think of a word that was <u>not</u> from the list and completes the wordstem shown. In order to do so, you must first try to find a word that starts with the same letters as those that are shown to you. When you find such a word, you should ask yourself whether this word was from the list. If you think that this particular word was <u>not</u> from the list, you should then say aloud this word. In contrast, if you think that the word that comes to your mind is the word from the list, you should then try to think of another word that starts with the same letters. Let's practice the "<u>NOT</u> FROM THE LIST" instruction. We will use a list that has 2 words in it. SKIING, IODIDE. Fine. SKI___, IODI__. As you can see, it may occur that the word that comes to your mind is that from the list. In this case, you will try to think of another word which begins with the same first letters as the word from the list. It may occur that only one word comes to mind and you think that this word is from the list. In this case, you should not say aloud this word. When the instructions are "NOT FROM THE LIST", it is better to leave the cue blank than to respond with the word from the list. If you don't provide an answer within a period of 30 seconds, the machine will beep and the first letters corresponding to a new word will appear on the screen. Let's practice with another list, which will have again 2 words. Are you ready? SWINGY, ZEROED. SWI___, ZE____. Fine.

Thus, as you can see, whether your task is "FROM THE LIST" or "NOT FROM THE LIST", it is very important that you try to remember the word from the list. When the task is "FROM THE LIST", you should try to remember the word from the list in order to say it aloud. In contrast, when the task is "NOT FROM THE LIST", you should try to remember whether the word that comes to your mind is that from the list. If you think that this particular word was not from the list, you say aloud this word. If you think that the word that comes to your mind is the word from the list, you try to find another word that starts with the same letters.

Let's practice again with a last list, just to make sure that you are comfortable with the procedure. This list will contain 6 words. Do you have any question? IRONED, OCTAVE, KNOTTY, EITHER, IGNITE, EQUINE. IRON__, OC____, KNO___, EI____, IGN___, EQUI__.

AFTER THE PRACTICE SESSION IS OVER: We are now ready for the experiment per se. You will see one list of 72 words. Please continue naming aloud the words as they appear and then trying to learn them. Thus far, nobody has been able to remember all of the words. What is important is that you do your best. Are you ready?

Appendix K

Means and Standard Deviations

for the Conventional Measure of Memory with

Visual Stimuli

as a Function of Age and CTTO

Experiment 2

CTTO	Age		Mean
	Young (n = 48)	Older (n = 40)	
Medium	.392 (.187)	.159 (.138)	.286
Large	.451 (.206)	.216 (.152)	.344
Very large	.499 (.139)	.317 (.178)	.416
Mean	.447	.231	.349

Source	DF	MS	F
	Between-Subjects Effects		
Age	1	3.07	58.02***
Error	86	.05	
	Within-Subject Effects		
CTTO	2	.39	23.11***
Age x CTTO	2	.02	1.20
Error	172	.02	

***$p < .001$

Appendix L

Means and Standard Deviations

for Proportion of Visual Cues

Completed With List Items

as a Function of Age, Task (inclusion/exclusion), and

CTTO

Experiment 2

Task	CTTO	Age		Mean
		Young	Older	
		(n = 48)	(n = 40)	
Inclusion	Medium	.486 (.187)	.200 (.138)	.356
	Large	.625 (.206)	.300 (.152)	.477
	Very large	.750 (.139)	.435 (.178)	.607
	Mean	.620	.312	.480
Exclusion	Medium	.012 (.034)	.029 (.052)	.020
	Large	.016 (.044)	.023 (.046)	.019
	Very large	.024 (.048)	.040 (.071)	.031
	Mean	.017	.031	.023
	Mean	.319	.171	.252

Source	DF	MS	*F*
Test of Between-Subjects Effects			
Age	1	2.86	107.87***
Error	86	.03	
Tests Involving "Task" Within-Subject Effect			
Task	1	25.59	860.26***
Age x Task	1	3.39	113.90***
Error	86	.03	
Tests Involving "CTTO" Within-Subject Effect			
CTTO	2	.75	77.55***
Age x CTTO	2	.01	.68
Error	172	.01	
Tests Involving "Task x CTTO" Within-Subject Effect			
Task x CTTO	2	.62	67.64***
Age x Task x CTTO	2	.00	.31
Error	172	.01	

***$p < .001$

Appendix M

Frequencies per million

of the Verbal Stimuli

Experiment 2

Version A			Version B		
	Frequency			Frequency	
Target	Kucera & Francis (1967)	Thorndike & Lorge (1944)	Target	Kucera & Francis (1967)	Thorndike & Lorge (1944)
		Medium CTTO			
absent	28	31	allied	29	17
advice	51	75	amount	172	100
anchor	15	26	bother	20	30
argued	29	33	broker	1	7
beyond	175	100	census	11	7
bigger	34	100	cubist	7	0
chisel	4	9	dugout	7	2
damage	33	32	emerge	18	21
driven	44	20	engine	50	75
estate	51	44	factor	71	35
evoked	7	2	flying	43	100
feline	2	2	giving	96	100
gossip	13	16	glided	1	2
grimly	11	12	humble	18	36
middle	118	100	likely	151	75
mostly	44	32	nickel	7	11
propel	4	4	obeyed	7	75
pursue	20	49	sedate	2	1
richer	5	9	spider	2	24
syntax	6	1	typing	7	1
tanker	1	19	unjust	3	13
tenant	5	16	uptake	5	0
viewer	4	6	vanish	5	39
voting	30	17	woolen	4	11
Mean	30.6	31.5	Mean	30.7	32.6
SD	39.3	30.9	SD	46.0	34.3

	Version A			Version B	
	Frequency			Frequency	
Target	Kucera & Francis (1967)	Thorndike & Lorge (1944)	Target	Kucera & Francis (1967)	Thorndike & Lorge (1944)
			Large CTTO		
asthma	1	1	barley	6	12
banish	4	16	bureau	43	44
basing	4	0	causal	6	100
catsup	1	0	clergy	12	9
client	13	15	coldly	8	12
cortex	7	1	coming	174	100
cowboy	16	6	cookie	1	7
depart	7	50	deadly	19	25
design	114	100	demure	3	2
folded	15	2	detail	72	75
helmet	1	21	gasket	4	0
induce	9	21	hamper	5	8
infant	11	22	inject	6	4
leader	74	100	laying	12	6
loudly	17	22	legion	7	15
reader	43	50	mantle	48	19
reduce	62	75	outfit	16	17
regard	89	100	ransom	5	10
socket	3	6	rental	15	2
steady	41	75	silent	49	75
sturdy	16	16	submit	18	40
tribal	6	2	sundae	0	0
waited	70	100	timing	11	5
waning	2	7	wisely	8	14
Mean	26.1	33.7	Mean	22.8	25.0
SD	31.6	36.4	SD	36.2	30.3

	Version A			Version B	
	Frequency			Frequency	
Target	Kucera & Francis (1967)	Thorndike & Lorge (1944)	Target	Kucera & Francis (1967)	Thorndike & Lorge (1944)
		Very Large CTTO			
acting	61	16	attain	20	30
appeal	62	75	ballad	8	10
buckle	5	8	button	10	39
campus	33	7	closer	61	100
candid	3	3	convoy	3	0
easing	3	0	expend	1	8
galley	4	8	extern	1	0
handed	38	0	forgot	18	75
harden	1	19	freest	2	28
insect	14	40	hereby	8	5
intern	2	1	impart	4	11
lessen	5	15	invest	3	75
nearby	44	12	latent	9	5
picker	1	20	market	155	100
pillar	2	16	notion	40	33
rabble	2	3	pistil	0	5
rating	10	1	posted	11	10
relief	66	75	recent	179	75
resign	2	26	refund	22	2
reveal	30	75	remake	2	0
slowly	115	75	rubble	1	1
stated	85	100	single	172	100
summit	12	17	wallow	2	4
warmly	8	9	weakly	3	11
Mean	25.3	25.9	Mean	30.6	30.3
SD	30.9	29.5	SD	54.1	35.2

Appendix N

Baseline Completion Rates

of the Verbal Stimuli

Experiment 2

Version A		Baseline Completion Rate		Version B		Baseline Completion Rate	
Target	Cue	Young	Older	Target	Cue	Young	Older
tribal	tri___	.08	.08	submit	sub___	.21	.29
banish	ban___	.17	.17	bureau	bur___	.00	.08
voting	vo___	.00	.00	woolen	wo___	.42	.08
buckle	buck___	.33	.29	ballad	ball___	.04	.08
argued	ar___	.04	.08	broker	br___	.00	.00
campus	camp___	.04	.04	closer	clos___	.25	.13
evoked	ev___	.04	.08	emerge	em___	.08	.04
nearby	near___	.54	.17	impart	impa___	.04	.25
gossip	go___	.04	.00	giving	gi___	.00	.08
rating	rati___	.17	.21	notion	noti___	.17	.17
depart	dep___	.21	.42	cookie	coo___	.04	.08
helmet	hel___	.42	.17	demure	dem___	.00	.08
resign	resi___	.08	.00	recent	rece___	.25	.29
summit	summ___	.08	.25	extern	exte___	.00	.29
leader	lea___	.21	.33	hamper	ham___	.25	.25
mostly	mo___	.04	.00	humble	hu___	.38	.08
steady	ste___	.08	.17	ransom	ran___	.17	.04
tanker	ta___	.00	.00	vanish	va___	.21	.08
waited	wai___	.08	.04	sundae	sun___	.33	.29
beyond	be___	.04	.00	cubist	cu___	.00	.04
catsup	cat___	.08	.04	causal	cau___	.13	.04
anchor	an___	.04	.04	amount	am___	.00	.08
appeal	appe___	.46	.21	attach	atta___	.17	.17
harden	hard___	.38	.04	refund	refu___	.00	.08
driven	dr___	.08	.08	dugout	du___	.04	.00
feline	fe___	.08	.17	flying	fl___	.25	.00
insect	inse___	.83	.54	forgot	forg___	.08	.08
cortex	cor___	.00	.00	coldly	col___	.00	.00
picker	pick___	.00	.17	latent	late___	.33	.29
infant	inf___	.17	.13	detail	det___	.04	.00
relief	reli___	.04	.08	posted	post___	.25	.42
reader	rea___	.00	.21	inject	inj___	.17	.08
warmly	warm___	.08	.17	weakly	weak___	.13	.17
socket	soc___	.00	.00	legion	leg___	.13	.00
propel	pr___	.00	.00	sedate	se___	.00	.04
richer	ri___	.13	.00	unjust	un___	.04	.00
slowly	slow___	.29	.13	single	sing___	.04	.04
acting	acti___	.04	.04	button	butt___	.38	.38
waning	wan___	.00	.00	wisely	wis___	.17	.08
advice	ad___	.25	.21	bother	bo___	.08	.04
basing	bas___	.00	.00	clergy	cle___	.17	.04
bigger	bi___	.04	.04	glided	gl___	.04	.04
design	des___	.08	.17	gasket	gas___	.17	.08
estate	es___	.04	.08	census	ce___	.00	.00
induce	ind___	.13	.17	mantle	man___	.00	.08
middle	mi___	.21	.08	obeyed	ob___	.00	.00
galley	gall___	.08	.17	freest	free___	.04	.00

Version A				Version B			
		Baseline Completion Rate				Baseline Completion Rate	
Target	Cue	Young	Older	Target	Cue	Young	Older
handed	hand__	.17	.17	hereby	here__	.50	.38
syntax	sy____	.21	.00	spider	sp____	.04	.00
tenant	te____	.08	.04	typing	ty____	.13	.13
lessen	less__	.13	.13	market	mark__	.17	.17
loudly	lou___	.25	.17	outfit	out___	.00	.08
reveal	reve__	.38	.25	rubble	rubb__	.13	.17
sturdy	stu___	.08	.08	timing	tim___	.17	.04
stated	stat__	.38	.13	wallow	wall__	.08	.04
client	cli___	.38	.25	coming	com___	.25	.17
candid	cand__	.33	.29	expend	expe__	.13	.13
asthma	ast___	.08	.04	barley	bar___	.00	.08
absent	ab____	.29	.42	allied	al____	.00	.00
chisel	ch____	.00	.00	engine	en____	.00	.04
reduce	red___	.00	.00	deadly	dea___	.21	.13
folded	fol___	.13	.00	laying	lay___	.08	.13
damage	da____	.08	.13	factor	fa____	.00	.00
easing	easi__	.00	.00	convoy	conv__	.04	.25
grimly	gr____	.04	.00	likely	li____	.04	.00
intern	inte__	.25	.38	remake	rema__	.08	.25
pursue	pu____	.04	.04	nickel	ni____	.17	.04
pillar	pill__	.08	.08	pistil	pist__	.00	.00
viewer	vi____	.04	.00	uptake	up____	.00	.00
rabble	rabb__	.17	.21	invest	inve__	.04	.21
cowboy	cow___	.42	.04	rental	ren___	.08	.04
regard	reg___	.08	.13	silent	sil___	.33	.25

Appendix O

Means and Standard Deviations

for Baseline Completion Rate of Verbal Stimuli

as a Function of Age and CTTO

Experiment 2

CTTO	Age		Mean
	Young (n = 48)	Older (n = 48)	
Medium	.077 (.044)	.055 (.046)	.066
Large	.134 (.077)	.133 (.067)	.133
Very large	.188 (.084)	.192 (.081)	.190
Mean	.133	.127	.130

Source	DF	MS	F
	Between-Subjects Effects		
Age	1	.005	.59
Error	94	.003	
	Within-Subject Effects		
CTTO	2	.370	80.56***
Age x CTTO	2	.005	1.07
Error	188	.005	

***p < .001

Appendix P

Instructions for the Verbal Memory Task

Experiment 2

For the next task, you will be presented with lists of words, and your task will be to try to remember these words. The words will be presented one at a time on the computer screen. All the words will be 6-letter long, and none of them will be either proper names or plurals. For instance, you could see the following two words: JAGUAR, QUARTZ.

Once all the words have been shown to you, you will be presented with the first letters from each word plus a message above those letters. For some of these word stems, the message above the letters will be "FROM THE LIST". If you see this message, your task will be to remember which word from the list completes the wordstem shown. For instance, the wordstem "JAG___" is completed by the word "JAGUAR". Fine. It may occur that you don't remember the word from the list that completes the wordstem shown. In this case, you will should attempt to guess what that word was. If ever you don't remember which word from the list completes the wordstem, it is very important that you try to guess what that word was when the instructions are "FROM THE LIST". Please note that plurals and proper names are not allowed. If you don't provide an answer within a period of 30 seconds, the machine will beep and the first letters corresponding to a new word will appear on the screen. Thus, "QU____" belongs to ... QUARTZ. Fine.

Let's practice with another list, which will once again have 2 words. From this moment, whenever you see a new word appearing on the screen, you will first read it aloud, and you will then try to remember it. Are you ready? KEEPER, ICEBOX, IC____, KEE___. Fine.

For some of the words, the message above the letters will not be "FROM THE LIST". It will be "<u>NOT</u> FROM THE LIST" instead. If you see the message "<u>NOT</u> FROM THE LIST", your task will be to think of a word that was <u>not</u> from the list and completes the wordstem shown. In order to do so, you must first try to find a word that starts with the same letters as those that are shown to you. When you find such a word, you should ask yourself whether this word was from the list. If you think that this particular word was <u>not</u> from the list, you should then say aloud this word. In contrast, if you think that the word that comes to your mind is the word from the list, you should then try to think of another word that starts with the same letters. Let's practice the "<u>NOT</u> FROM THE LIST" instruction. We will use a list that has 2 words in it. SKIING, IODIDE. Fine. SKI___, IODI__. As you can see, it may occur that the word that comes to your mind is that from the list. In this case, you will try to think of another word which begins with the same first letters as the word from the list. It may occur that only one word comes to mind and you think that this word is from the list. In this case, you should <u>not</u> say aloud this word. When the instructions are "<u>NOT</u> FROM THE LIST", it is better to leave the cue blank than to respond with the word from the list. If you don't provide an answer within a period of 30 seconds, the machine will beep and the first letters corresponding to a new word will appear on the screen. Let's practice with another list, which will have again 2 words. Are you ready? SWINGY, ZEROED. SWI___, ZE____. Fine.

Thus, as you can see, whether your task is "FROM THE LIST" or "<u>NOT</u> FROM THE LIST", it is very important that you try to remember the word from the list. When the task is "FROM THE LIST", you should try to remember the word from the list in order to say it aloud. In contrast, when the task is "<u>NOT</u> FROM THE LIST", you should try to remember whether the word that comes to your mind is that from the list. If you think that this particular word was <u>not</u> from the list, you say aloud this word. If you think that the word that comes to your mind is the word from the list, you try to find another word that starts with the same letters.

Let's practice again with a last list, just to make sure that you are comfortable with the procedure. This list will contain 6 words. Do you have any question? IRONED, OCTAVE, KNOTTY, EITHER, IGNITE, EQUINE. IRON__, OC____, KNO___, EI____, IGN___, EQUI__.

AFTER THE PRACTICE SESSION IS OVER: We are now ready for the experiment per se. You will see one list of 72 words. Please continue naming aloud the words as they appear and then trying to learn them. Thus far, nobody has been able to remember all of the words. What is important is that you do your best. Are you ready?

Appendix Q

Means and Standard Deviations

for the Conventional Measure of Memory with

Verbal Stimuli

as a Function of Age and CTTO

Experiment 2

CTTO	Age		Mean
	Young	Older	
	(n = 48)	(n = 48)	
Medium	.201 (.136)	.089 (.100)	.145
Large	.288 (.148)	.181 (.136)	.235
Very large	.317 (.141)	.131 (.140)	.224
Mean	.269	.134	.201

Source	DF	MS	F
	Between-Subjects Effects		
Age	1	1.31	57.24***
Error	94	.02	
	Within-Subject Effects		
CTTO	2	.23	14.72***
Age x CTTO	2	.05	3.05*
Error	188	.02	

*$p < .05$ ***$p < .001$

Appendix R

Means and Standard Deviations

for Proportion of Verbal Cues

Completed With List Items

as a Function of Age, Task (inclusion/exclusion), and

CTTO

Experiment 2

Task	CTTO	Age		Mean
		Young (n = 48)	Older (n = 48)	
Inclusion	Medium	.278 (.136)	.144 (.100)	.211
	Large	.422 (.148)	.314 (.136)	.368
	Very large	.505 (.141)	.323 (.140)	.414
	Mean	.402	.260	.331
Exclusion	Medium	.102 (.099)	.115 (.087)	.109
	Large	.125 (.126)	.174 (.114)	.149
	Very large	.196 (.125)	.276 (.151)	.236
	Mean	.141	.188	.165
	Mean	.272	.224	.248

Source	DF	MS	F
Test of Between-Subjects Effects			
Age	1	.32	14.34***
Error	94	.02	
Tests Involving "Task" Within-Subject Effect			
Task	1	3.99	185.13***
Age x Task	1	1.27	59.14***
Error	94	.02	
Tests Involving "CTTO" Within-Subject Effect			
CTTO	2	1.33	101.90***
Age x CTTO	2	.01	.94
Error	188	.01	
Tests Involving "Task x CTTO" Within-Subject Effect			
Task x CTTO	2	.17	12.60***
Age x Task x CTTO	2	.05	3.75*
Error	188	.01	

*$p < .05$ ***$p < .001$

Appendix S

Means and Standard Deviations

for Proportion of Verbal Cues

Completed With Acceptable Answers

as a Function of Age, Retrieval Task

(inclusion/exclusion), and CTTO

Experiment 2

Task	CTTO	Age		Mean
		Young (n = 48)	Older (n = 48)	
Inclusion	Medium	.707 (.194)	.771 (.177)	.739
	Large	.863 (.136)	.885 (.117)	.874
	Very large	.976 (.048)	.955 (.066)	.965
	Mean	.849	.870	.859
Exclusion	Medium	.797 (.176)	.885 (.137)	.841
	Large	.802 (.168)	.899 (.102)	.851
	Very large	.931 (.074)	.950 (.066)	.940
	Mean	.843	.911	.877
	Mean	.846	.891	.868

Source	DF	MS	F
Test of Between-Subjects Effects			
Age	1	.29	6.68*
Error	94	.04	
Tests Involving "Task" Within-Subject Effect			
Task	1	.05	4.45*
Age x Task	1	.08	7.41**
Error	94	.01	
Tests Involving "CTTO" Within-Subject Effect			
CTTO	2	1.28	93.72***
Age x CTTO	2	.08	5.83**
Error	188	.01	
Tests Involving "Task x CTTO" Within-Subject Effect			
Task x CTTO	2	.26	24.08***
Age x Task x CTTO	2	.01	.75
Error	188	.01	

*$p < .05$ **$p < .01$ ***$p < .001$

Appendix T

Means and Standard Deviations

for Recollection of Verbal Stimuli

as a Function of Age and CTTO

Experiment 2

CTTO	Age		Mean
	Young (n = 48)	Older (n = 48)	
Medium	.175 (.163)	.030 (.126)	.102
Large	.297 (.202)	.141 (.173)	.219
Very large	.309 (.206)	.047 (.191)	.178
Mean	.260	.073	.166

Source	DF	MS	F
	Between-Subjects Effects		
Age	1	2.55	59.14***
Error	94	.04	
	Within-Subject Effects		
CTTO	2	.33	12.60***
Age x CTTO	2	.10	3.75*
Error	188	.03	

*$p < .05$ ***$p < .001$

Appendix U

Means and Standard Deviations

for Priming of Verbal Stimuli

as a Function of Age and CTTO

when independence

between intentional and automatic processes is assumed

Experiment 2

CTTO	Age		Mean
	Young (n = 48)	Older (n = 48)	
Medium	.047 (.110)	.063 (.082)	.055
Large	.044 (.145)	.069 (.113)	.056
Very large	.096 (.140)	.098 (.127)	.097
Mean	.062	.077	.069

Source	DF	MS	F
	Between-Subjects Effects		
Age	1	.02	.73
Error	94	.02	
	Within-Subject Effects		
CTTO	2	.05	4.61*
Age x CTTO	2	.003	.25
Error	188	.01	

*$p < .05$

Appendix V

Means and Standard Deviations

for Priming of Verbal Stimuli

as a Function of Age and CTTO

when redundancy

between intentional and automatic processes is assumed

Experiment 2

CTTO	Age		Mean
	Young	Older	
	(n = 48)	(n = 48)	
Medium	.201 (.136)	.089 (.100)	.145
Large	.288 (.148)	.181 (.136)	.235
Very large	.317 (.141)	.131 (.140)	.224
Mean	.269	.134	.201

Source	DF	MS	F
	Between-Subjects Effects		
Age	1	1.31	57.24***
Error	94	.02	
	Within-Subject Effects		
CTTO	2	.23	14.72***
Age x CTTO	2	.05	3.05*
Error	188	.02	

*$p < .05$ ***$p < .001$